Long-Term Operation – Biological Assessment

Chapter 7 – Steelhead

Central Valley Project, California

Interior Region 10 – California-Great Basin

U.S. Department of the Interior

November 2023

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Contents

Tables

Figures

Chapter 7 Steelhead

The federally listed Evolutionarily Significant Unit (ESU) of California Central Valley (CV) steelhead distinct population segment (DPS) (*Oncorhynchus mykiss*) and designated critical habitat occurs in the action area and may be affected by the seasonal operations of the State Water Project (SWP) and Central Valley Project (CVP). Steelhead exhibit the most complex suite of life history traits of any species of Pacific salmonid. *O. mykiss* may migrate to the ocean as listed anadromous steelhead or remain a freshwater resident as non-listed rainbow trout. Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death; however, iteroparity in California steelhead populations is considered relatively rare (Moyle 2002), and it is rare for steelhead to spawn more than twice before dying. Anadromous adults migrating downstream after spawning are termed “kelts.” Steelhead and rainbow trout are present in nearly every Central Valley tributary.

7.1 Status of Species and Critical Habitat

The California CV steelhead DPS was originally listed as threatened under the Endangered Species Act on March 19, 1998 (63 FR 13347). The listing was reaffirmed on January 5, 2006 (71 FR 834) and updated April 14, 2014 (79 FR 20802). The updates did not change the status or add or revise critical habitat designation.

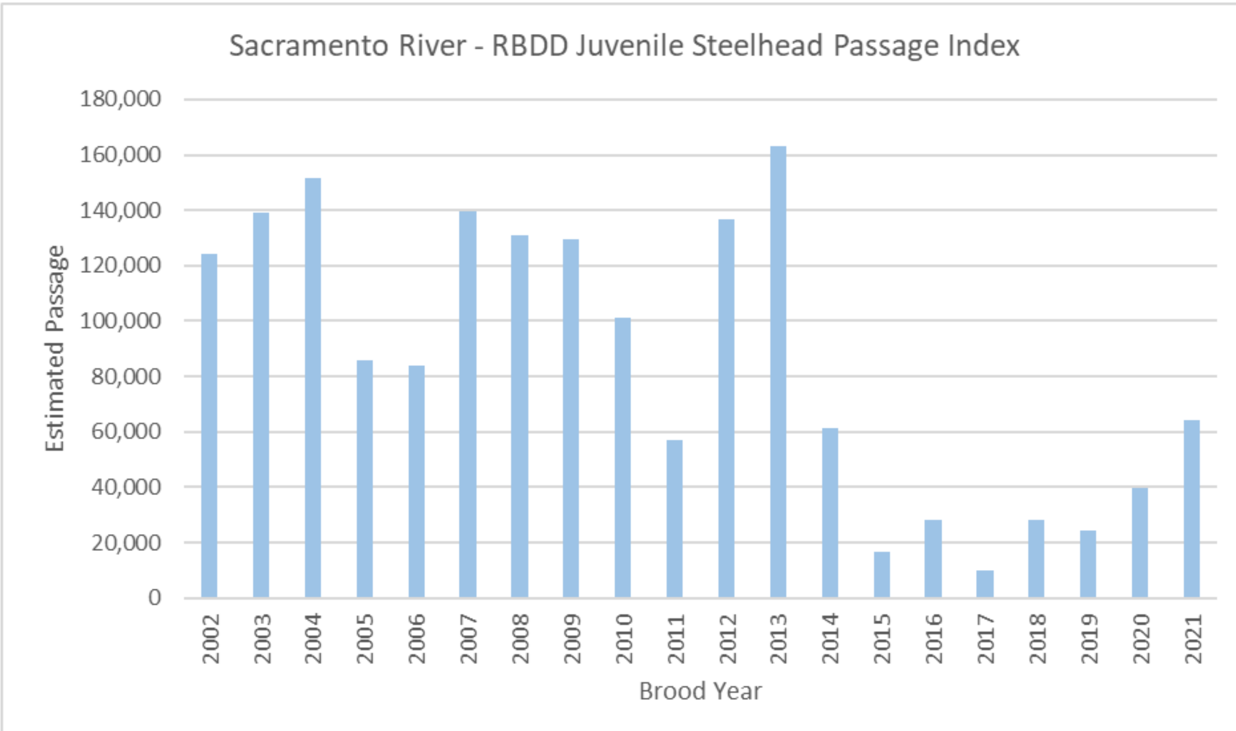
Critical Habitat was designated on September 2, 2005 (70 FR 52629).

7.1.1 Distribution and Abundance

CV steelhead were distributed from the upper Sacramento and Pit River systems (upper Sacramento, McCloud, Pit and Fall rivers) south to the Kings River (and possibly Kern River systems in wet years) and in both east- and west- side tributaries of the Sacramento River and east-side tributaries of the San Joaquin River (McEwan 2001). Currently, Central Valley steelhead are found in the Sacramento River downstream of Keswick Dam and in the major tributary rivers and creeks in the Sacramento River watershed. Steelhead are present in three tributaries to the San Joaquin River (Stanislaus, Tuolumne, and Merced rivers) as well as in the Calaveras Rivers, and a hatchery supporting steelhead population occurs in the Mokelumne River (Zimmerman et al, 2009).

Abundance estimates of steelhead in the Sacramento River were scarce until recently. Average estimated spawner abundance upstream of the Feather River confluence in the 1950s was 20,564 individuals but was fewer than 10,000 individuals in 1991-1992 (McEwan and Jackson 1996). Steelhead escapement surveys occurred from 1967-1993 at the former location of the Red Bluff Diversion Dam. The estimated number of individuals passing this location was between 470 and 19,615 (California Hatchery Scientific Review Group 2012).

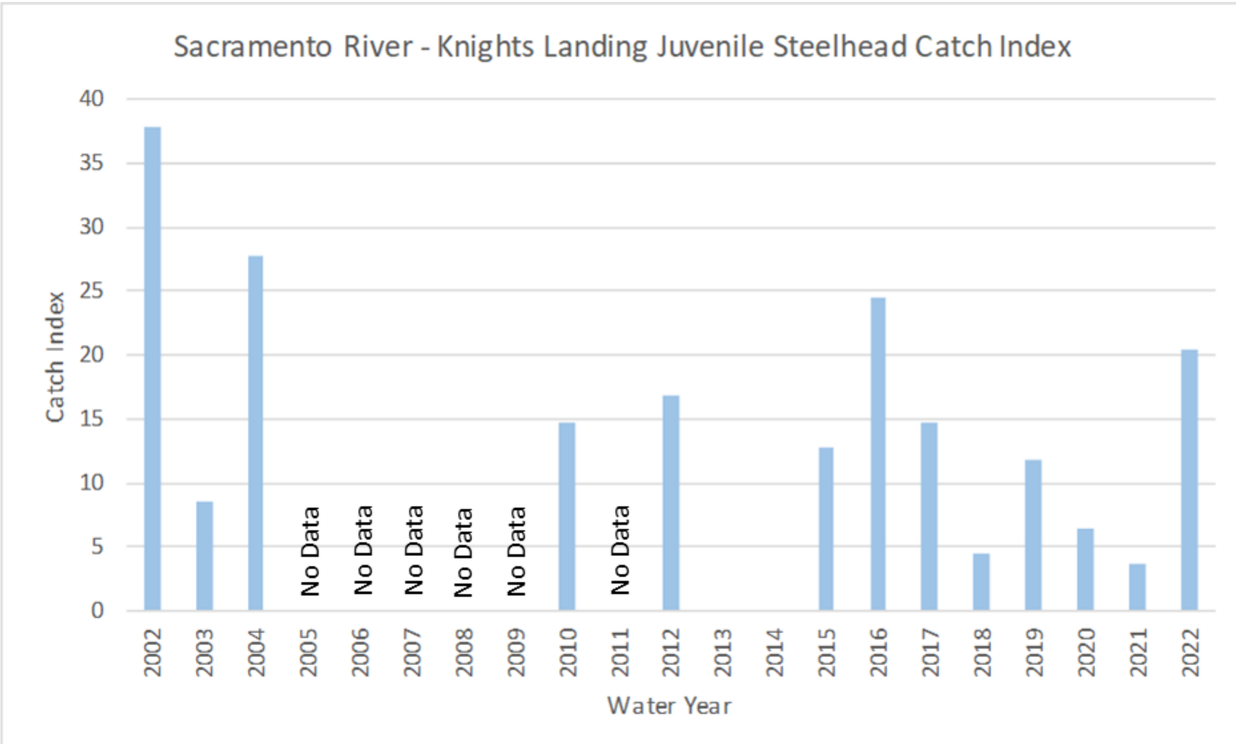
Steelhead abundance is now monitored at multiple locations throughout the Central Valley. Estimated juvenile passage in the Sacramento River at the former location of the Red Bluff Diversion Dam ranged from ~60,000 to 160,000 individuals from 2002 to 2014 but dropped substantially and ranged from ~10,000 to 30,000 in 2015-2019 (Figure 7-1). Environmental conditions (e.g., flow and turbidity) influence rotary screw trap efficiency (RST), therefore observed differences in juvenile steelhead abundance across years is likely due to a combination of differences in population productivity and trap efficiency.



Source: Annual reports by the U.S. Fish and Wildlife Service.
Efficiency trials for the RSTs were performed with Chinook salmon, and not with steelhead.

Figure 7-1. Steelhead Juvenile Passage Index, Sacramento River at Red Bluff Diversion Dam Rotary Screw Traps, 2002–2021.

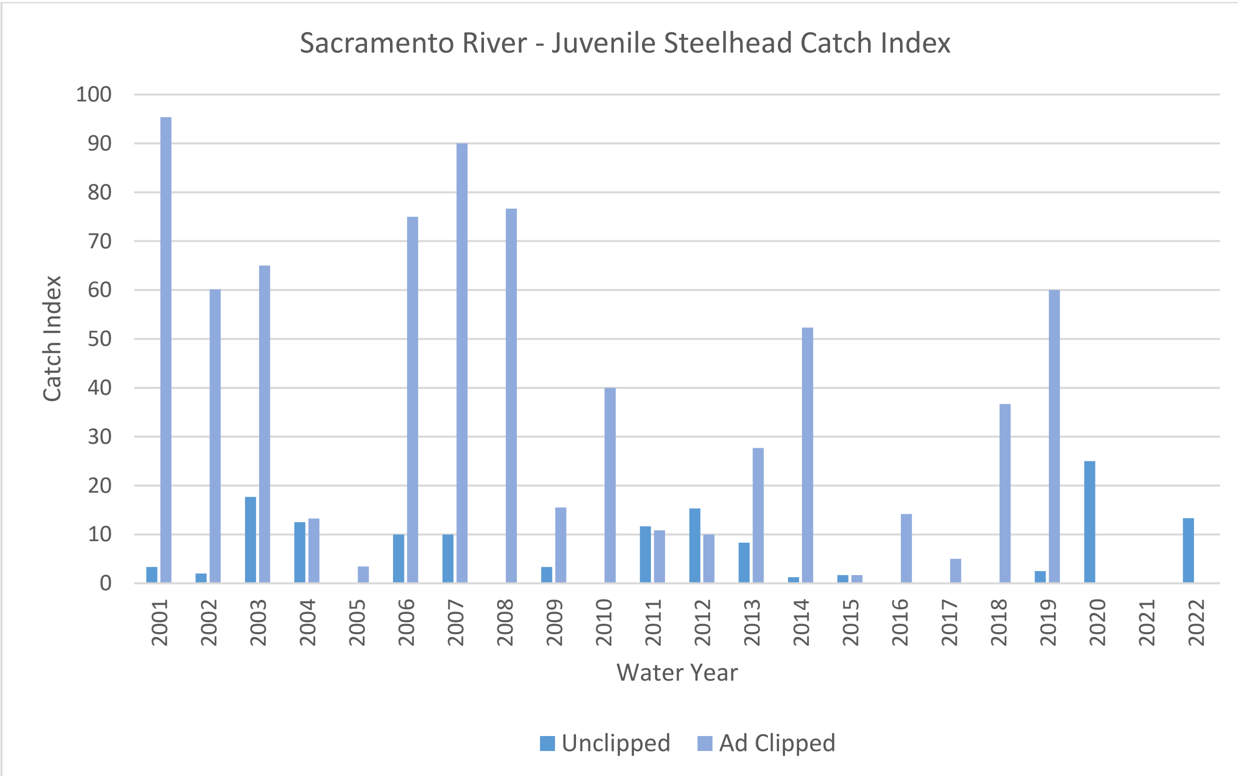
Due to COVID-19 restrictions sampling during BY-2020 resulted in missed sampling periods; therefore, interannual comparison of 2020 with other years is not advised. Recorded catch of juvenile *O. mykiss* at the RSTs does not distinguish between life stages or life history type. Juvenile adjusted catch index in the California Department of Fish and Wildlife (CDFW) RSTs at Knights Landing from Water Year 2002 through Water Year 2022 was highly variable with the highest two index values occurring in Water Year 2002 and Water Year 2004 (Figure 7-2).



Note: Some data were missing from Water Years 2005-2009 and Water Year 2011, precluding index calculations. Adjusted Catch Index was standardized using catch per unit effort. Source: California Department of Fish and Wildlife Knights Landing Annual Reports and workbooks from Phillips (2022).

Figure 7-2. Juvenile Steelhead Adjusted Catch Index, Sacramento River at Knights Landing, Water Years 2002–2022.

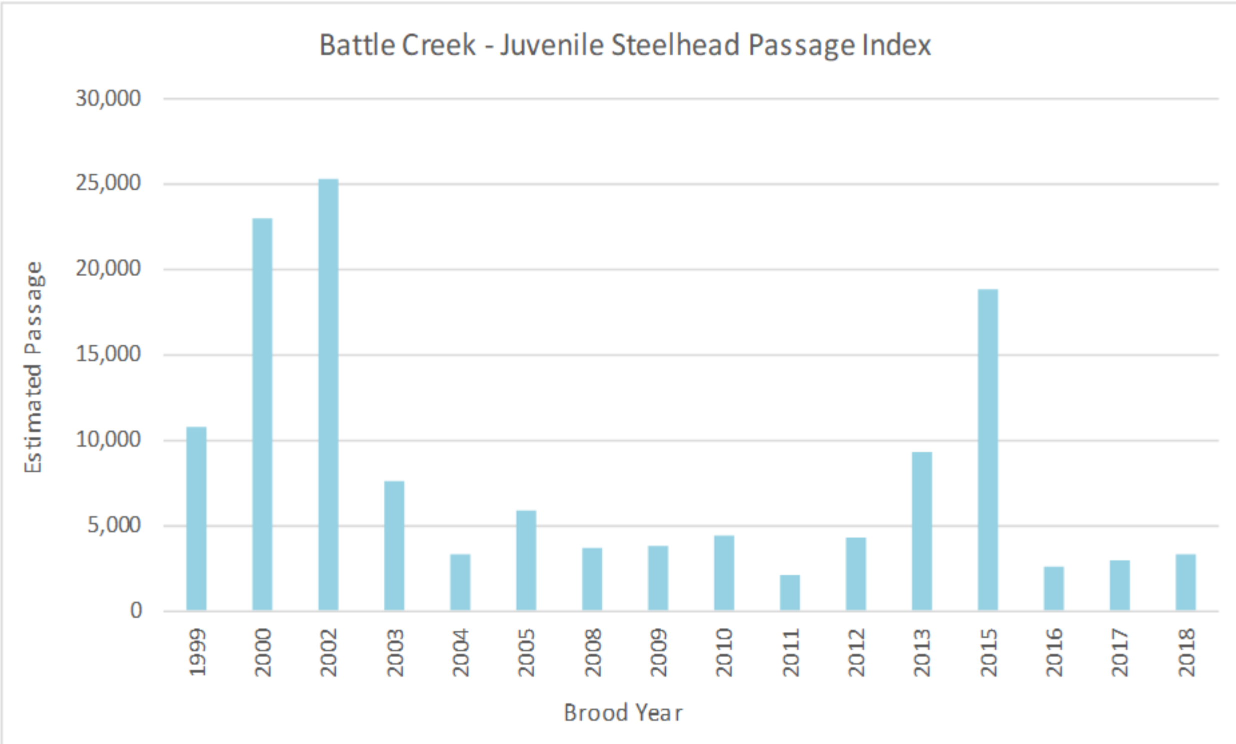
The juvenile catch index for the U.S. Fish and Wildlife Service (USFWS) Sacramento area beach seines was also variable between Water Years 2001 and 2021 (Figure 7-3). The highest index value was in Water Year 2001 for ad-clipped individuals and in Water Year 2020 for unclipped individuals.



Source: U.S. Fish and Wildlife Service Delta Juvenile Fish Monitoring Program, Interagency Ecological Program (2022).
Notes: Catch values were standardized for catch per unit effort for eight sites: Verona, Elkhorn, Sand Cove, Miller Park, Sherwood Harbor, Discovery Park, American River, and Garcia Bend.

Figure 7-3. Steelhead Juvenile Adjusted Catch Index, Sacramento Area Beach Seines, Sacramento River, Water Years 2001–2022.

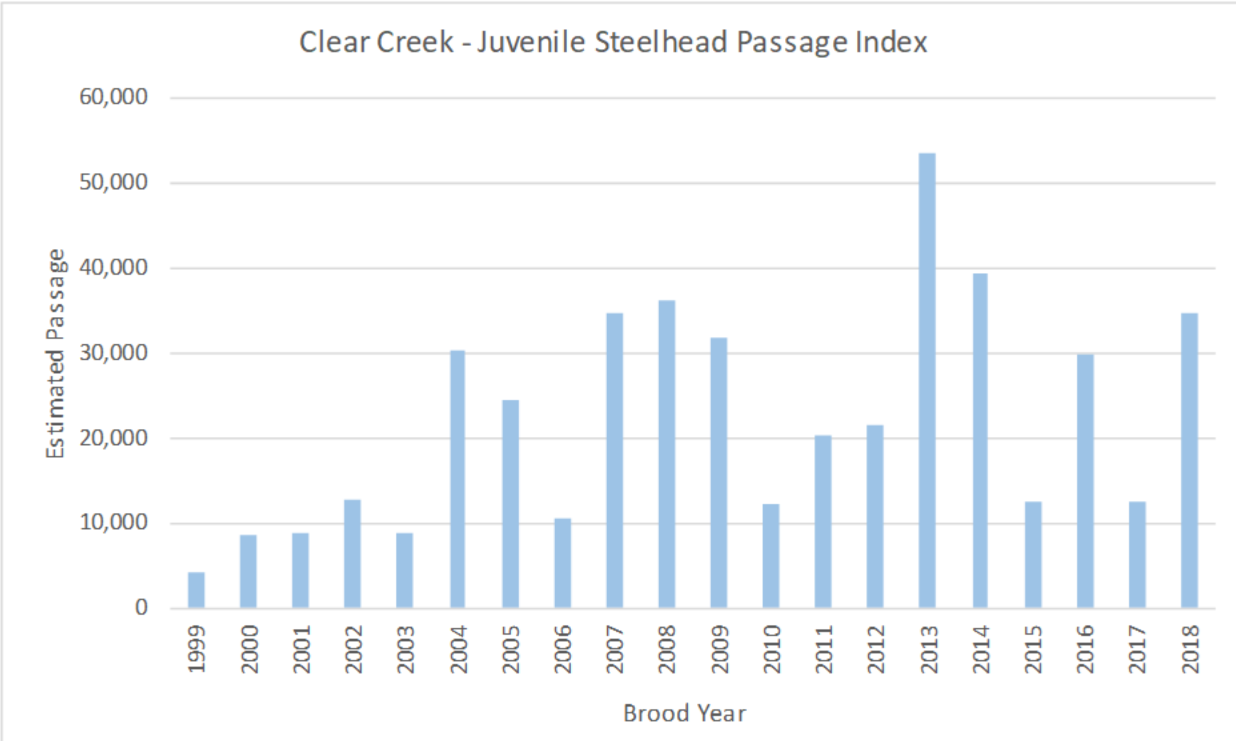
In Battle Creek, estimated juvenile passage between Brood Years 1999 and 2018 has ranged from a low of 2,071 individuals in Brood Year 2011 to 25,302 individuals in Brood Year 2002 (Figure 7-4).



Source: Table A1 in Schraml and Earley (2021).
Passage index was calculated using weekly catch totals and either the weekly trap efficiency or season average trap efficiency.

Figure 7-4. Juvenile Steelhead Passage Index, Battle Creek Rotary Screw Trap, Brood Years 1999–2018.

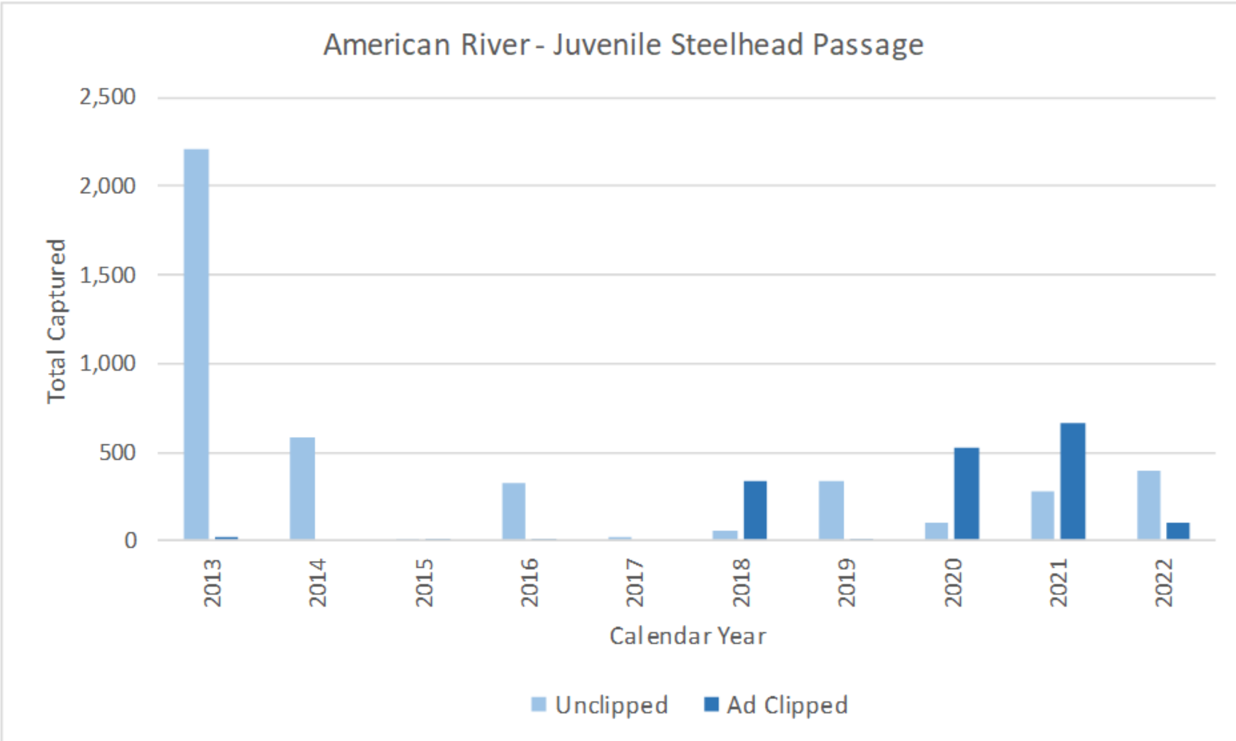
In Clear Creek, estimated juvenile passage between Brood Years 1999 and 2018 has fluctuated from 4,229 individuals in Brood Year 1999 to 53,371 individuals in Brood Year 2013 (Figure 7-5).



Source: Table A1 in Schraml and Chamberlain (2021), see report for details on passage index calculations
Note: Index is calculated for calendar year only for 1999-2002.

Figure 7-5. Juvenile Steelhead Passage Index, Clear Creek Rotary Screw Trap, River Mile 1.7, Brood Years 1999–2018.

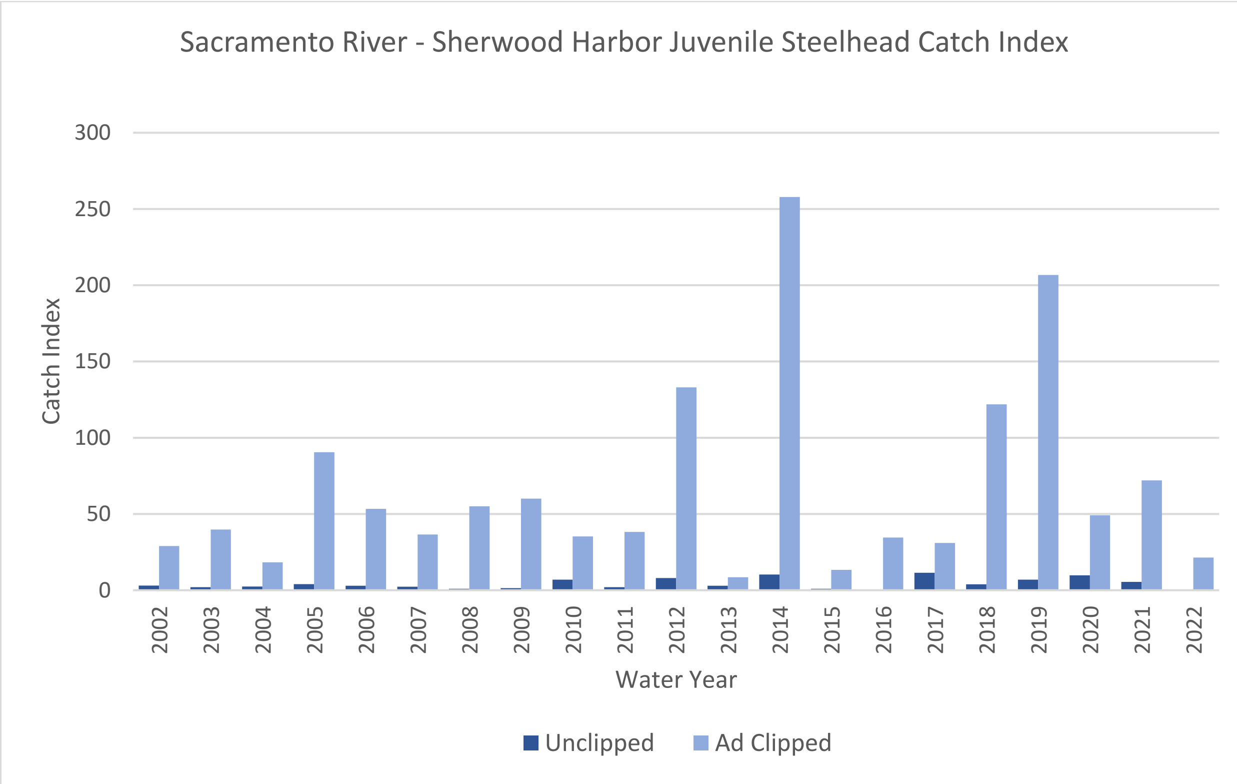
In the American River, estimated juvenile steelhead passage between 2013 and 2022 based on rotary screw trapping for both ad-clipped and unclipped individuals has remained near or below 500 individuals except for unclipped fish in 2013 (Figure 7-6).



Source: Workbooks from Day (2022).
Effort was not provided so passage has not been standardized.

Figure 7-6. Juvenile Steelhead Passage, American River Rotary Screw Trap at Watt Ave, 2013–2022.

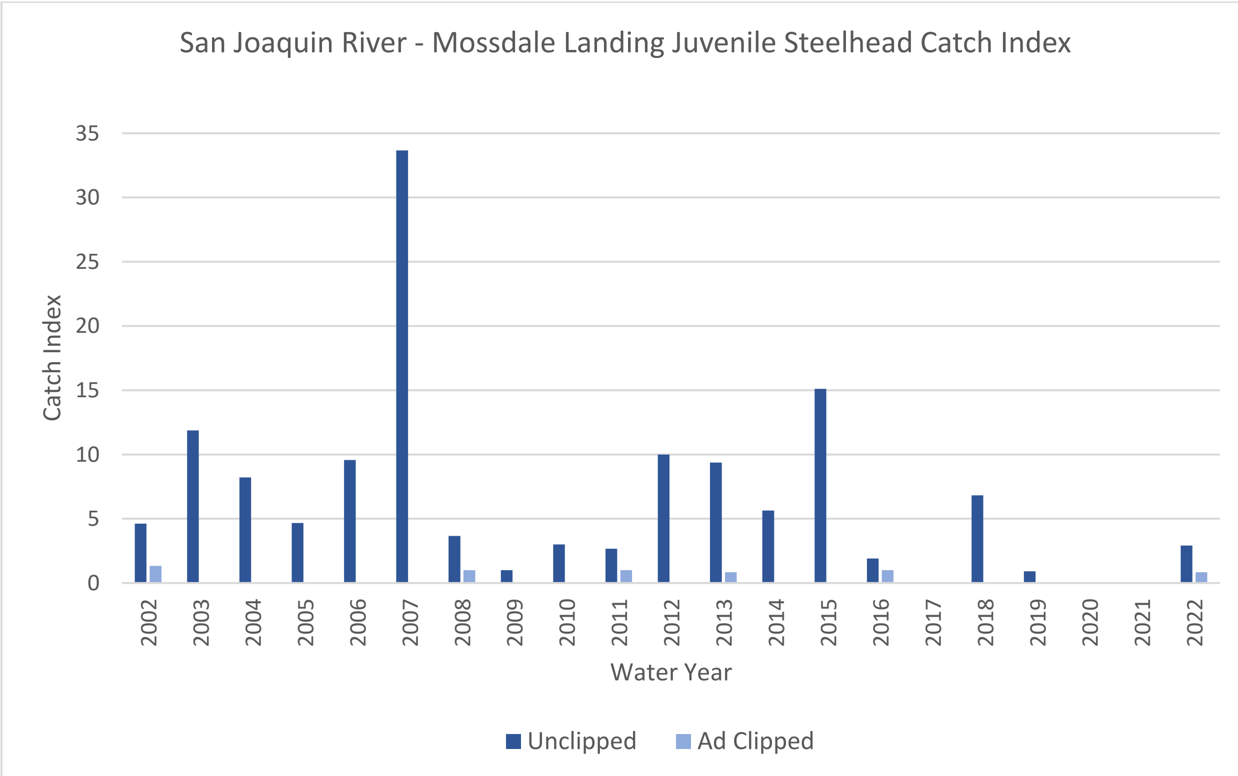
Adjusted juvenile catch index at the upstream margin of the Delta on the Sacramento River at Sherwood Harbor between Water Years 2002-2021 peaked in Water Year 2014 for ad-clipped fish at 258 individuals and in Water Year 2017 for unclipped fish at 11.5 individuals (Figure 7-7).



Source: U.S. Fish and Wildlife Service Delta Juvenile Fish Monitoring Program, Interagency Ecological Program (2022).
Adjusted Catch Index was standardized using catch per unit effort.

Figure 7-7. Steelhead Juvenile Adjusted Catch Index in Kodiak and Midwater Trawls, Sacramento River at Sherwood Harbor, 2002–2022.

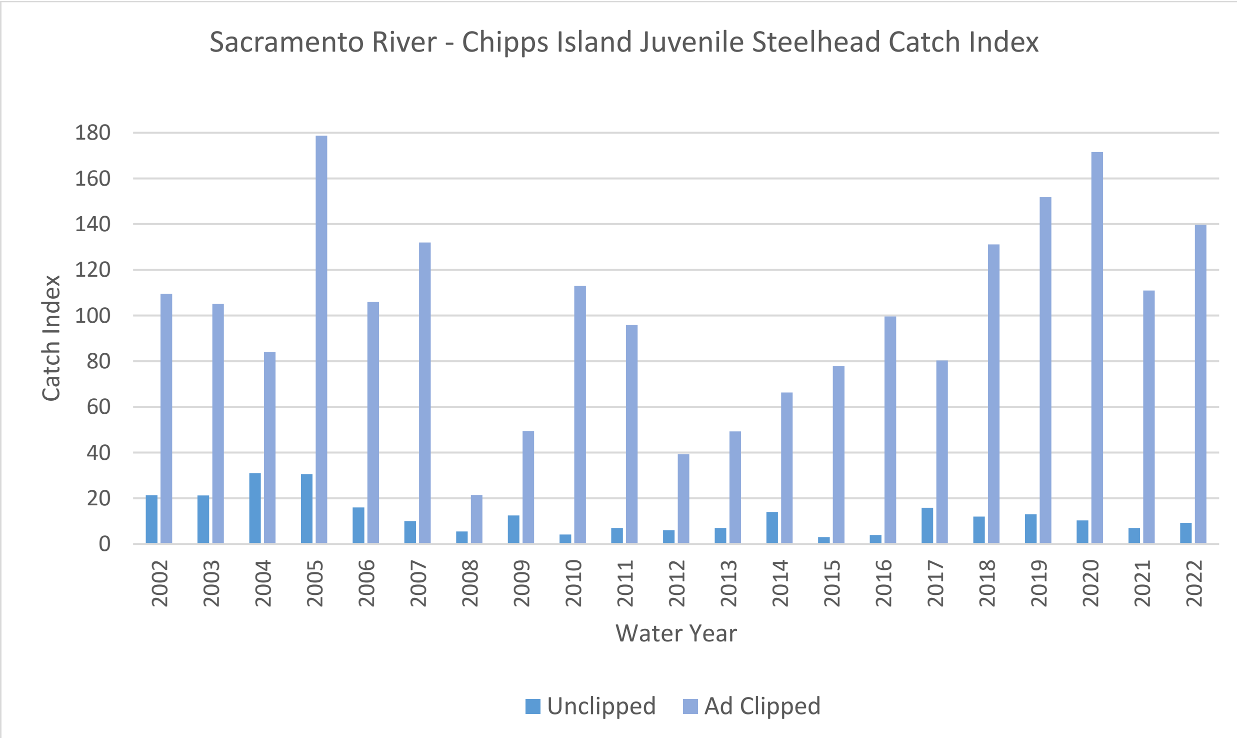
Adjusted juvenile catch index at the upstream margin of the Delta on the San Joaquin River at Mossdale between Water Year 2002-2021 peaked in Water Year 2002 at 1.3 individuals for ad-clipped fish and in Water Year 2007 at 33.7 individuals for unclipped fish (Figure 7-8).



Source: U.S. Fish and Wildlife Service Delta Juvenile Fish Monitoring Program, Interagency Ecological Program (2022).
Adjusted Catch Index was standardized using catch per unit effort.

Figure 7-8. Steelhead Juvenile Adjusted Catch Index in Midwater Trawls, San Joaquin River at Mossdale, Water Years 2002–2022.

Adjusted juvenile catch index at the seaward margin of the Delta at Chipps Island between Water Years 2002-2021 peaked for both ad-clipped and unclipped individuals in Water Year 2005 (Figure 7-9). The ad-clipped index steadily increased in most years between Water Years 2012 and 2020.

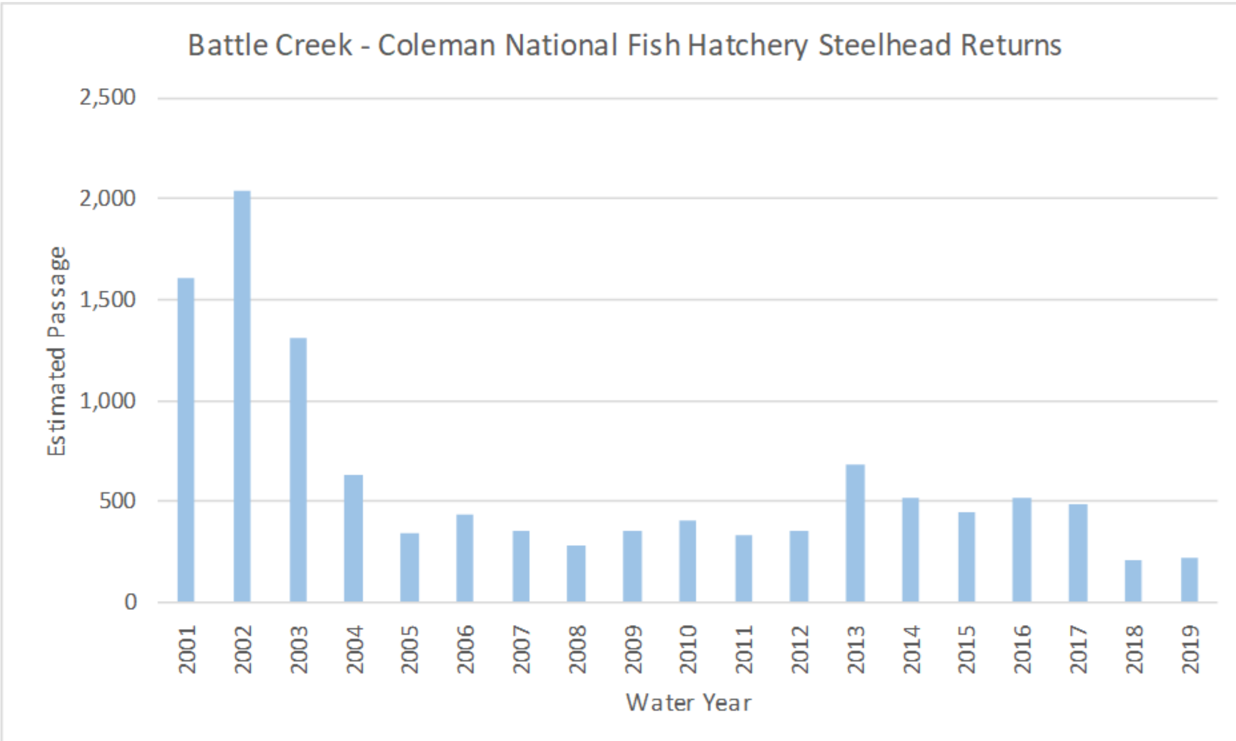


Source: U.S. Fish and Wildlife Service Delta Juvenile Fish Monitoring Program, Interagency Ecological Program (2022)
Adjusted Catch Index was standardized using catch per unit effort.

Figure 7-9. Steelhead Juvenile Adjusted Catch Index, Chipps Island Midwater Trawl, Water Years 2002–2022.

Adult escapement and redd monitoring have occurred in the following waterways: Battle Creek, Clear Creek, American River, and Stanislaus River.

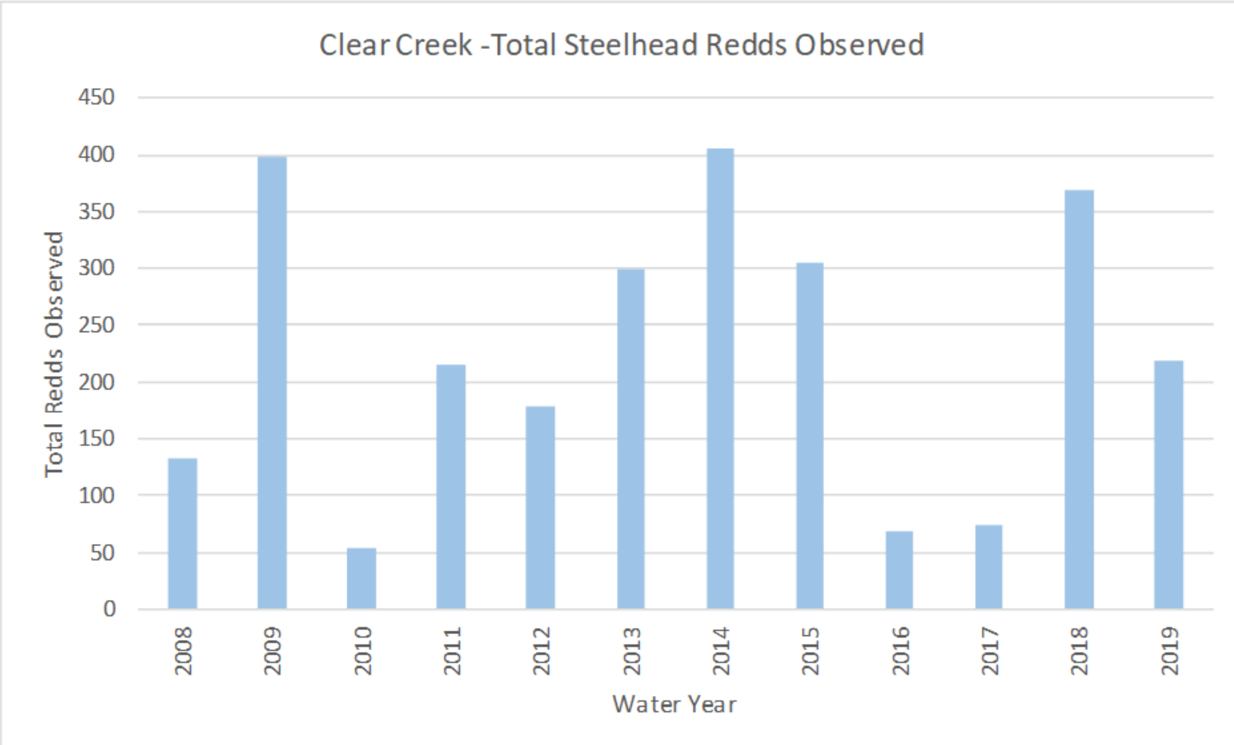
In Battle Creek, steelhead returns to the Coleman National Fish Hatchery were between 1,306 and 2,035 individuals between Water Years 2001 and 2003, but were <700 individuals from Water Year 2004 to Water Year 2019. The lowest returns have been observed in recent years (Figure 7-10).



Source: Table 3 in Stanley et al. (2020).

Figure 7-10. Adult Steelhead Returns in Video and Trap Monitoring, Combined Ad-clipped and Unclipped, Coleman National Fish Hatchery, Battle Creek, Water Years 2001-2019

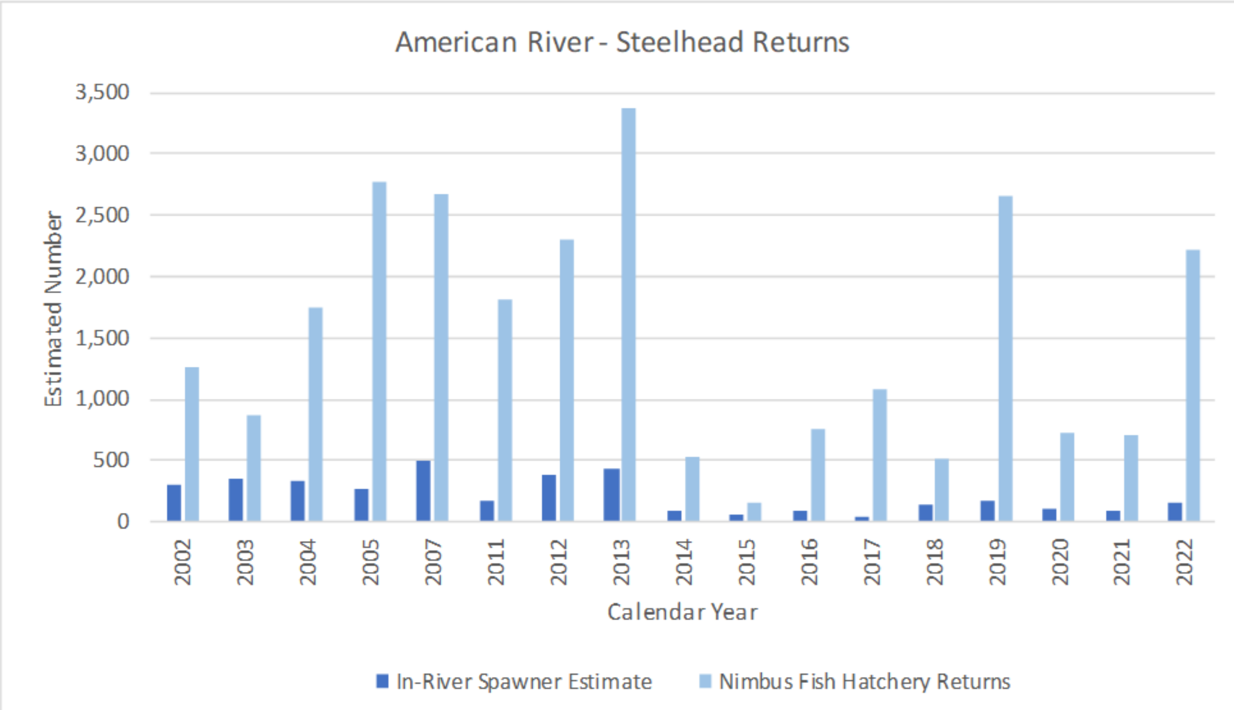
In Clear Creek between Water Years 2008 and 2019, the number of steelhead redds observed in kayak-based surveys has ranged from 54 individuals in Water Year 2010 to 406 individuals in Water Year 2014 (Figure 7-11).



Source: U.S. Fish and Wildlife Service Annual Reports 2008 - 2019.

Figure 7-11. Steelhead Redds Observed in Kayak-Based Surveys, Coleman National Fish Hatchery, Battle Creek, Water Years 2008-2019.

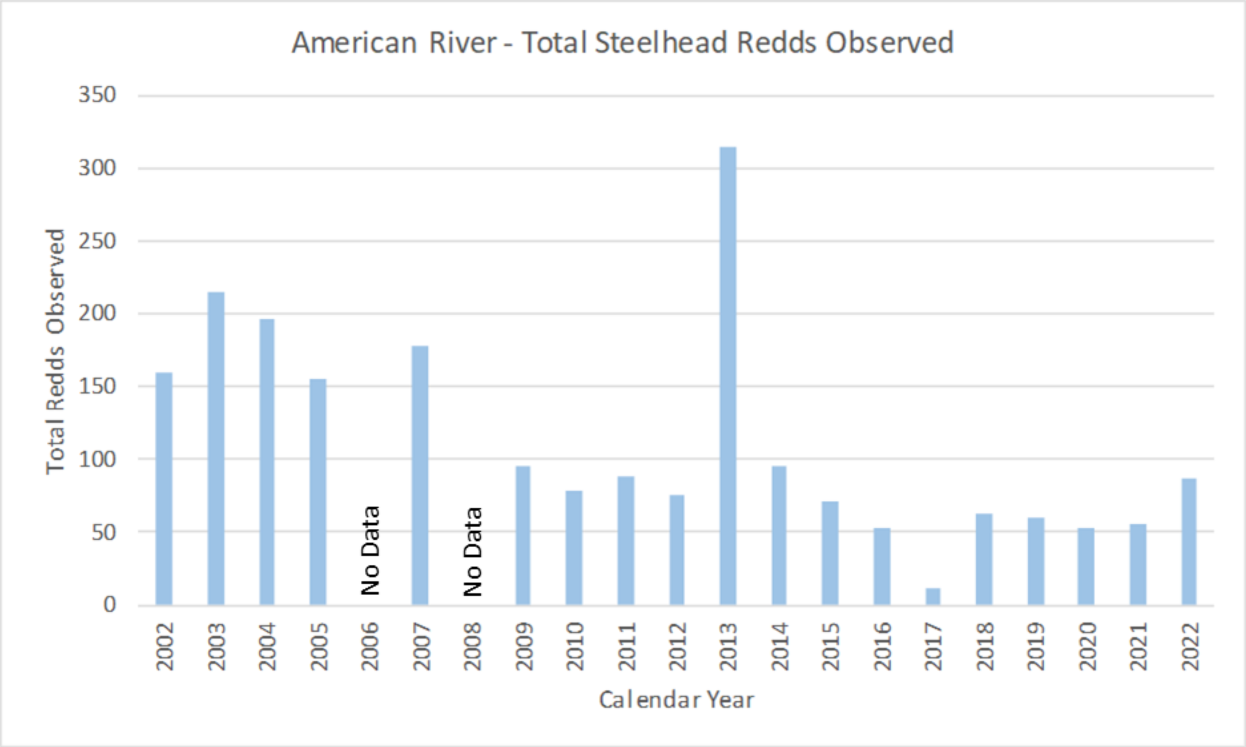
In the American River, Nimbus Hatchery adult returns have ranged from <200 fish in 2015 to ~3,400 fish in 2013 (Figure 7-12). In-river spawners have ranged from <50 fish in 2015 to nearly 500 fish in 2007.



Source: Cramer Fish Sciences (2022).

Figure 7-12. Steelhead Nimbus Hatchery Returns and In-River Spawner Estimates, American River, 2002-2022

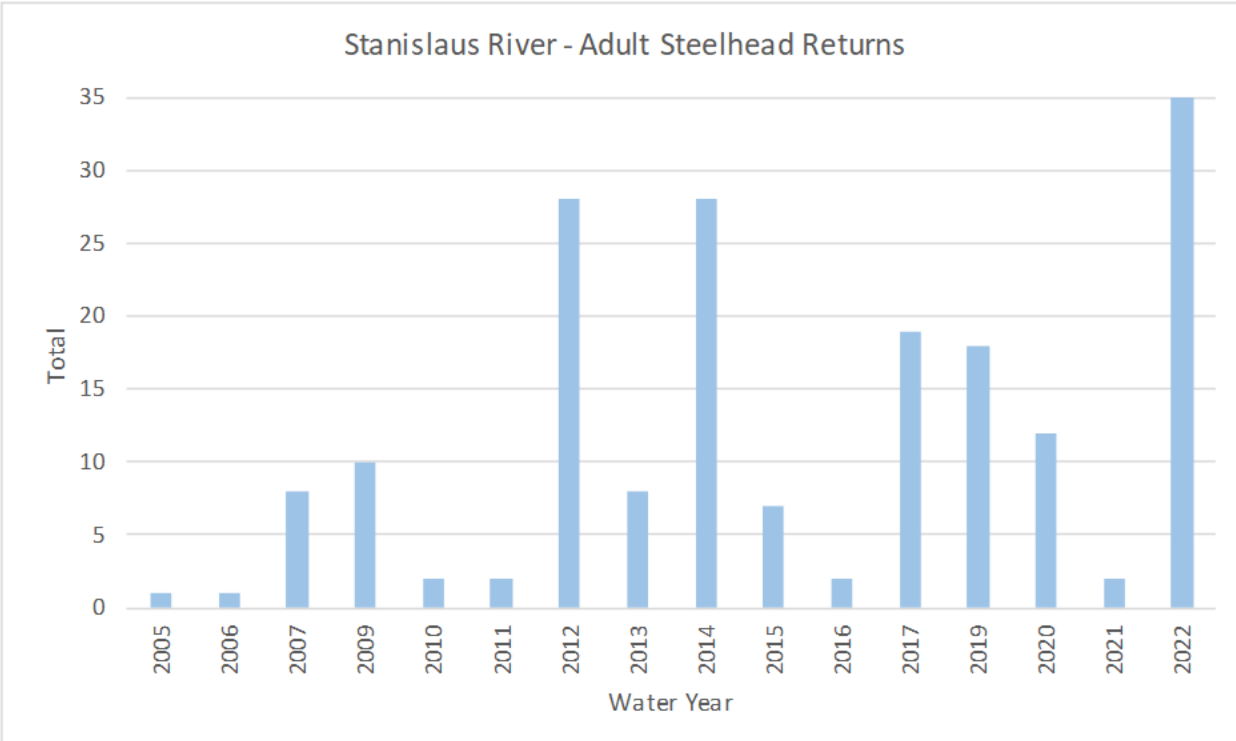
Steelhead redds observed in the American River have ranged from 12 individuals in 2017 to 314 individuals in 2013 (Figure 7-13).



Cramer Fish Sciences (2022).

Figure 7-13. Observed Steelhead Redds, American River, 2002-2022.

Adult steelhead returns in the Stanislas River weir between Water Years 2005 and 2022 have ranged from 1 individual in Water Years 2005 and 2006 to 35 individuals in Water Year 2022 (Figure 7-14).

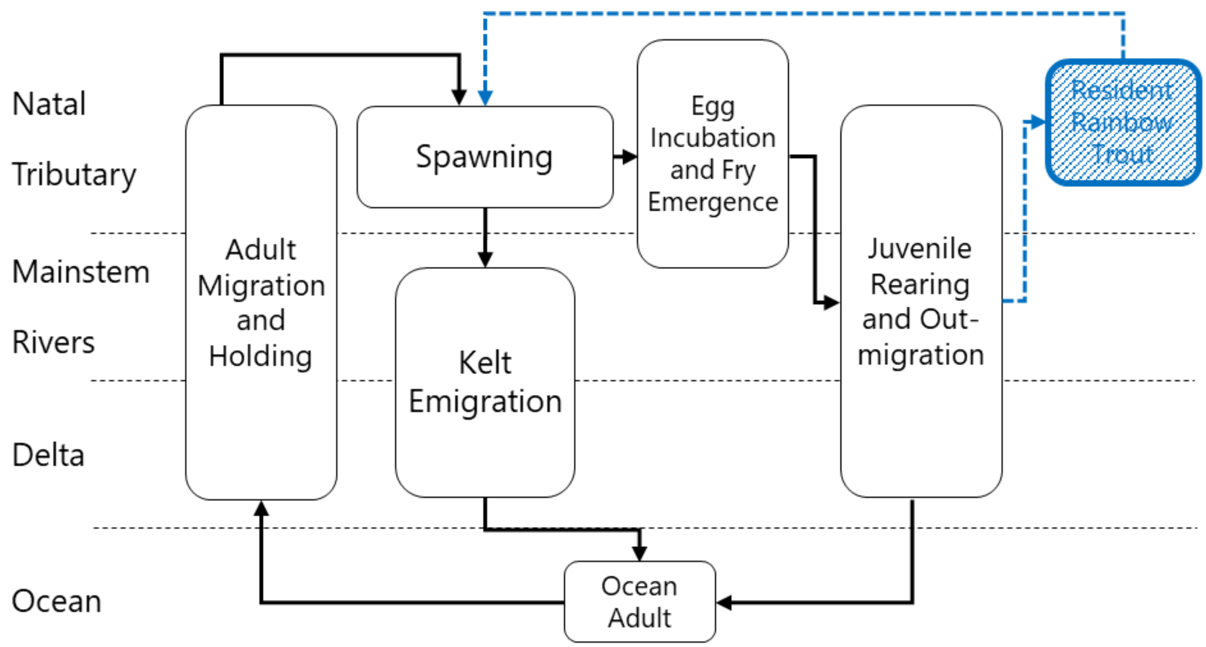


Source: Hellmair 2022.

Figure 7-14. Adult Steelhead Weir Returns, Stanislaus River, Water Years 2005-2022.

7.1.2 Life History and Habitat Requirements

The Salmon and Sturgeon Assessment of Indicators by Lifestage (SAIL) and winter-run Chinook salmon conceptual model (Windell et al. 2017) has been adapted for *O. mykiss* by generalizing to natal tributaries and with the addition of an adult emigration element of life history as well as the consideration of resident rainbow trout to describe life stages and geographic locations for this effects analyses (Figure 7-15). An action may affect fish when the change in conditions overlap with the location and timing of fish and/or their habitats.



Source: Adapted from Windell et al. 2017.

Figure 7-15. Simplified Geographic Life Stage Domains for Steelhead.

Section 7.2, *Effects Analysis*, uses temporal domains from the available monitoring data (redd surveys, weir video footage, RSTs trawls, and beach seines) described in detail in Appendix C, *Species Spatial and Temporal Domains*. Figure 7-16 shows generalized timing of steelhead presence in the Sacramento River basin and San Joaquin River basin.

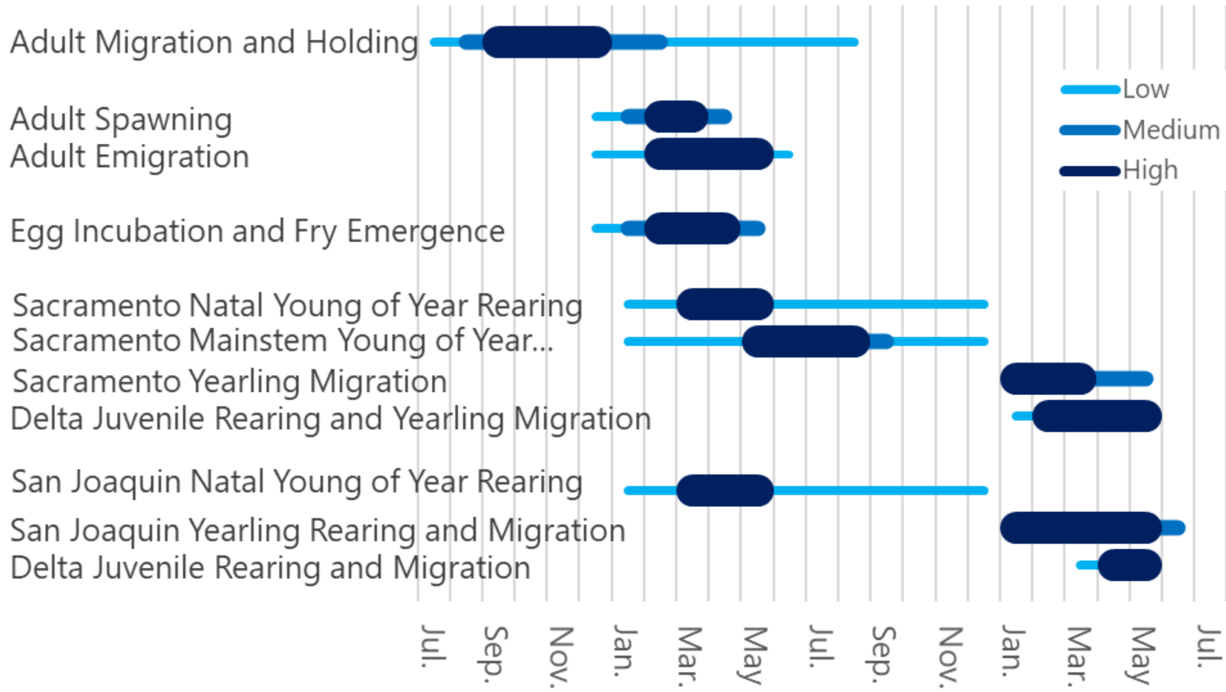


Figure 7-16. Generalized Temporal Life Stage Domains for Steelhead.

Steelhead have a complex suite of life history traits, including the capability to be anadromous or to be resident (i.e., rainbow trout). Spawning and rearing habitat for steelhead is usually characterized as perennial streams with clear, cool to cold, fast flowing water with a high dissolved oxygen content and abundant gravels and riffles. The DPS includes all naturally spawned anadromous steelhead in the Sacramento and San Joaquin Rivers and their tributaries below impassable barriers, excluding steelhead from San Francisco and San Pablo Bays and their tributaries. The DPS also includes steelhead from Coleman National Fish Hatchery, Feather River Fish Hatchery, and Mokelumne River Hatchery.

Adult steelhead immigration into Central Valley streams typically begins in August, continues into March or April (McEwan 2001; National Marine Fisheries Service 2014), and generally peaks during January and February (Moyle 2002), but adult steelhead immigration can potentially occur during all months of the year (National Marine Fisheries Service 2009). Juvenile steelhead typically migrate to the ocean after spending one to three years in freshwater (California Department of Fish and Wildlife 1996). Steelhead spawning generally occurs from December through April, with peaks from January through March, in small streams and tributaries (National Marine Fisheries Service 2009). Eggs usually hatch within four weeks, depending on stream temperature, and the yolk sac fry remain in the gravel after hatching for another four to six weeks (California Department of Fish and Game 1996). Steelhead fry rear and migrate downstream in the Sacramento River during most months of the year, but the peak period of emigration is January to June (Hallock et al. 1961; McEwan 2001). Because of their varied freshwater residence times juvenile steelhead can be rearing and migrating in the Sacramento River year-round (McEwan 2001).

Steelhead prefer flow velocity is in the range of one to three feet per second (Raleigh et al. 1986). Steelhead use various mixtures of sand-gravel and gravel-cobble substrate for spawning, but optimal spawning substrate reportedly ranges from 0.25 to 4.0 inches in diameter (Reiser and Bjornn 1979). Optimal water temperatures for steelhead adult immigration are reported to range from 39°F to 66.2°F (Keefer et al. 2009). Optimal conditions for steelhead spawning and embryo incubation reportedly occur at water temperatures 42°F to 55°F (Richter and Kolmes 2005; McCullough 2001; Federal Energy Regulatory Commission 1993). The recommended water temperatures for optimal growth of juvenile steelhead ranges from 52°F to 66°F (Myrick and Cech 2005). However, one study did find that juvenile steelhead could achieve average growth rates exceeding 1 mm/day in the American River with abundant food availability and limited competition when summer water temperatures regularly exceed 68°F (Sogard et al. 2012; National Marine Fisheries Service 2019).

7.1.3 Limiting Factors, Threats, and Stressors

Risks to steelhead include degradation of the remaining accessible habitat through reducing flow variability, blocking coarse sediment recruitment, operation of outdated fish screens, ladders and diversion dams, simplified habitat due to levee construction and maintenance and disconnection of off-channel habitat, water delivery and hydroelectric operation on both the Sacramento and Feather rivers.

Future increasing temperatures and altered precipitation patterns due to climate change will pose stressors on steelhead (Crozier et al. 2019). Reverse flows in the central and south Delta resulting from water exports may exacerbate interior Delta entrainment by confounding flow and temperature-related migratory cues in out-migrating steelhead juveniles. Drought (2007 – 2009; 2012 – 2016; 2020 – 2021) conditions within the Central Valley increases stressors on steelhead. Access to historic habitat remains blocked in many cases and fundamental problems still remain with the quality of the species' remaining habitat (see Lindley et al. 2009 and Cummins et al. 2008) and it continues to be highly degraded. The loss of historical habitat and the degradation of remaining habitat both continue to be major threats to this DPS (National Marine Fisheries Service Recovery Plan 2014).

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, holding, spawning and rearing, egg incubation and fry emergence, and juvenile rearing and outmigration. Each stressor is briefly summarized from Windell et al. 2017:

7.1.3.1 Adult Migration, Holding, Spawning, and Rearing

- In-river fishery and poaching: Targeted (poaching) or incidental hooking of steelhead due to in-river fishing has a direct influence on adult survival during migration and can also function to delay migration. Human activities such as poaching and harassment that temporarily or permanently displace fish from holding or spawning areas, can reduce energy reserves needed for survival or successful spawning in preferred habitats (Cooke et al. 2012).

- Toxicity from contaminants: Water quality and toxicity can influence their exposure and susceptibility to disease, olfactory navigation cues, and migration success. Contaminant loading of heavy metals from mines, or oil and other toxins from non-point sources such as stormwater runoff, have been identified as stressors that reduce spawning success or cause mortality.
- Stranding risk: Water operations can influence the flows which could result in stranding risks to steelhead.
- Water temperature: Water quality influence their exposure and susceptibility to disease, olfactory navigation cues, and migration success. Warm water temperatures generally decrease DO, increase physiological stress and metabolic rates.
- Dissolved oxygen: Water quality influence their exposure and susceptibility to disease, olfactory navigation cues, and migration success.
- Pathogens: The condition of migrating adults, as well as water quality and toxicity can influence their exposure and susceptibility to disease, olfactory navigation cues, and migration success. Warm water temperatures generally decrease DO, and decrease immune responses to pathogens. Decreased flows can concentrate fish within a smaller habitat area, and fish densities increase the potential for lateral transmission of disease and pre-spawn mortality becomes higher.
- Spawning habitat: Returning adult hatchery fish can influence natural adult spawners through competition of spawning habitat.
- Competition, introgression, and broodstock removal: Returning adult hatchery fish can influence natural adult spawners through competition. When mortality is high for natural-origin juveniles (e.g., drought years), increasing hatchery production may elevate the overall extinction risk due to genetic impacts of hatchery introgression due to the return of a disproportionately large number of hatchery adults.

7.1.3.2 Eggs Incubation to Fry Emergence

- In-river fishery and trampling: Human activity, such as recreational fishing, could also negatively impair redds due to disturbances such as trampling.
- Toxicity and contaminants: Disease and contaminants affect the survival of eggs and the condition of emerging fry.
- Stranding and dewatering: If flows decrease substantially after adult spawning has occurred, redds face the risk of stranding (when the surface of the redd is above the surface of the water and the redds become disconnected from the main channel) and dewatering (when the water surface drops below the redd).
- Water temperature: Water temperature affects the rate of development of embryos and alevins.
- Dissolved oxygen: Dissolved oxygen within the stream has been positively correlated with larval growth.
- Pathogens: Pathogens, disease, and contaminants affect the survival of eggs and the condition of emerging fry.

- Sedimentation and gravel quantity: The deposition of fine sediment can affect egg survival, compromising an embryo's ability to acquire oxygen and dispose of metabolic waste, potentially resulting in stunted embryo and alevin development. Gravel augmentation projects increase the availability of suitable spawning habitat.
- Redd quality: Redd quality is affected by gravel size and composition, flow, temperature, dissolved oxygen, contaminants, sedimentation, and pathogens and diseases.
- Predation risk: Native and non-native fish predate on salmon eggs. Water temperature can also impact the predation rate on eggs, embryos, and fry because predator metabolic demands increase with temperature.

7.1.3.3 Juvenile Rearing to Outmigration

- 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 increases contaminant loading of heavy metals in the system.
- Stranding risk: Significant flow reductions present a stranding risk to juveniles.
- Outmigration cues: Storage of unimpeded runoff and the use of stored water for irrigation and export have altered the natural hydrograph by which steelhead base their migrations.
- Water temperature: Fry are confined to the low-elevation habitats and are dependent on cold water.
- Dissolved oxygen: Water quality influence their exposure and susceptibility to disease, olfactory navigation cues, and migration success.
- Pathogens and disease: The condition of juveniles, as well as water quality and toxicity can influence their exposure and susceptibility to disease. Lower flows may influence pathogen and disease exposure, including increased transfer from hatchery fish to natural-origin juveniles.
- 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 steelhead fry by native and non-native fishes.

7.1.4 Current Incidental Take Statement

Quantitative incidental take from the 2019 National Marine Fisheries Service (NMFS) Biological Opinion on the Long-term Operation of the CVP and SWP is described below.

7.1.4.1 Adults

The ecological surrogate to define the amount or extent of take of all Central Valley (CV) steelhead life stages in the Stanislaus River is flow. Take will be exceeded if flow releases to the Stanislaus River measured at Goodwin Dam decrease to levels lower than the Stepped Release Plan, or those scheduled by the Stanislaus Watershed Team.

7.1.4.2 Eggs

- The ecological surrogate to define the amount or extent of take for CV steelhead egg-to-fry is the extent of egg habitat that is dewatered as a result of the Proposed Action and exposed to the stressors from lower flows from January through May.
- The ecological surrogate to define the amount or extent of take of CV steelhead egg-to-fry life stage from redd scouring is flow magnitude and rate created by releases from Nimbus Dam during egg incubation (i.e., January through May).
- The extent of take is all redds exposed to temperatures above 54°F in the vicinity of Watt Avenue December 1 through May 31.
- The extent of take is all redds exposed to temperatures above 54°F in the vicinity of Orange Blossom Bridge December 1 through May 31.
- The ecological surrogate to define the amount or extent of take of all CV steelhead life stages in the Stanislaus River is flow. Take will be exceeded if flow releases to the Stanislaus River measured at Goodwin Dam decrease to levels lower than the Stepped Release Plan, or those scheduled by the Stanislaus Watershed Team.

7.1.4.3 Juveniles

- Maximum anticipated annual incidental take levels of listed species at the Delta pumping facilities.
    - 1,571 juveniles as a three-year rolling average or total loss of 2,760 in any single year
    - 1,725 juveniles as a three-year rolling average or total loss of 3,040 in any single year
- The ecological surrogate for the amount or extent of take during base flows for the CV spring-run Chinook salmon and steelhead egg-to-fry life stage is flow lower than 200 cfs for all water year types except critically dry years, which could go below 150 cfs depending on the available water supply. The anticipated level of take will be exceeded in non-critical years if flows in Clear Creek, as measured at Igo, are lower than 200 cfs between October 1 and May 31 and 150 cfs from June 1 to September 30.

- The ecological surrogate to define the amount or extent of take of CV steelhead juvenile life stage is daily average temperature at Watt Avenue May 15 to October 31. The anticipated level of take will be exceeded if temperatures at Watt Avenue exceed 68^{o}F from May 15 to October 31 for more than seven consecutive days unless it is a critical year based on the Sacramento Valley index or following one or more critical years. In critical years, and years immediately after a critical year, anticipated level of take is exceeded if temperature exceeds 68^{o}F at Hazel Avenue.
- The ecological surrogate to define the amount or extent of take of CV steelhead juvenile life stages is the ramping rate that results in isolation. Take will be exceeded if flow decreases occur at a rate greater than the ramping rates described in the Proposed Action, with the exception of flood control or emergency conditions.
- The ecological surrogate to define the amount or extent of take of steelhead juvenile life stage is daily average temperature at Orange Blossom Bridge May 15 to October 31. The anticipated level of take will be exceeded if temperatures at Orange Blossom Bridge exceed 68oF between May 15 to October 31 for more than seven consecutive days unless Reclamation and NMFS agree that it is an acceptable exceedance given the hydrologic and meteorological conditions for that year.
- The ecological surrogate to define the amount or extent of take of all CV steelhead life stages in the Stanislaus River is flow. Take will be exceeded if flow releases to the Stanislaus River measured at Goodwin Dam decrease to levels lower than the Stepped Release Plan, or those scheduled by the Stanislaus Watershed Team.
- Cumulative incidental take for predator fish reduction electrofishing and predatory fish relocation studies. California Central Valley steelhead (unclipped).
    - Two-year Non-lethal Incidental Take (juveniles and adults) of 20 individuals.
    - Lethal Incidental Take (juveniles) of 5 individuals.
- Incidental take of salmonids was reasonably likely to occur due to Barker Slough Pumping Plant Sediment and Weed Control Operations. The anticipated level of take will be exceeded if more than five (5) unclipped listed salmonids (cumulative) are entrained per year through any combination of Sacramento River winter-run Chinook salmon, CV spring-run Chinook salmon, and CV steelhead.

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

7.1.5 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.

7.1.5.1 Recovery Plan Activities Related to the Long-Term Operation of the CVP and SWP

The following recovery and research focused management activities, identified in the 2014 Recovery Plan, are focused solely on steelhead and are associated with the operation of the CVP and SWP or related facilities are listed below by watershed.

Additional recovery and research focused management activities identified in the 2014 Recovery Plan that focused on winter-run Chinook salmon, spring-run Chinook salmon, and steelhead are included in Chapter 5, *Winter-Run Chinook Salmon*, under Section 5.1.4, *Management Activities*. Additional recovery and research focused management activities identified in the 2014 Recovery Plan that focused on spring-run Chinook salmon and steelhead are included in Chapter 6, *Spring-Run Chinook Salmon*, under Section 6.1.4, *Management Activities*.

- **American River**
  - *Develop an annual water temperature management plan for the lower American River.* Ongoing as part of operations and addressed in this consultation.
  - *Implement the flow management related actions (i.e., Reasonable and Prudent Alternative (RPA) actions II.1 and II.4) identified in the reasonable and prudent alternative from the 2009 Biological Opinion for the long-term operations of the CVP and SWP.* Ongoing as part of operations and addressed in this consultation.
- **Stanislaus River**
  - *Manage releases from Tulloch, Goodwin, and New Melones dams to provide suitable water temperatures and flows for all steelhead life stages.* Ongoing as part of operations and addressed in this consultation.
  - *Evaluate whether pulse flows in the Stanislaus River are beneficial to adult steelhead immigration and juvenile steelhead emigration; if pulse flows are determined to be effective, implement the most beneficial pulse flow regime.* Ongoing as part of operations and addressed in this consultation.

7.1.5.2 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 Reclamation authorities to contribute to the recovery of listed species as projects and programs with their own administration and consultation processes. Activities which are currently ongoing as a separate program and, therefore, not addressed in this consultation are listed below.

- **Clear Creek**
  - *Adaptively manage Whiskeytown Reservoir releases and water temperatures to evaluate whether anadromy in O. mykiss can be increased, without causing adverse impacts to other species.*

- **American River**
    - *Implement a long-term gravel management program in the lower American River to provide suitable spawning habitat.* This activity is being conducted as part of the Central Valley Project Improvement Act (1992) (CVPIA).
    - *Implement a long-term wood management program to provide habitat complexity and predator refuge habitat.*
    - *Develop education and outreach programs to encourage river stewardship in the American River watershed.*
    - *Develop and implement programs and projects that focus on retaining, restoring and creating river riparian corridors within their jurisdiction in the American River watershed.*
    - *Inventory locations on the American River for creating shallow inundated floodplain habitat for multi-species benefits and implement where suitable opportunities are available.*
    - *Implement the recommendations of the 2012 California Hatchery Scientific Review Group Report regarding the steelhead program at Nimbus Hatchery.*
    - *Develop and implement a HGMP for the steelhead program at Nimbus Hatchery.*
    - *Implement physical and structural modifications to the American River Division of the CVP in order to improve water temperature management.*
- **Stanislaus River**
    - *Develop a Stanislaus River steelhead team to help guide collection and evaluation of baseline data to help address hypotheses for why resident O. mykiss are more abundant than anadromous O. mykiss in the Stanislaus River.*
    - *Continue to implement projects to increase the availability and quality of spawning and rearing habitat in the Stanislaus River.*
    - *Identify and implement floodplain and side channel projects to improve river function and increase habitat diversity in the Stanislaus River.*
    - *Work with local landowners to restore riparian habitats along the Stanislaus River.*
    - *Evaluate programs and measures designed to minimize predation in the Stanislaus River.*
    - *Implement projects to increase instream habitat complexity and predator refuge cover in the Stanislaus River, including the addition of large woody material.*
    - *Work with State and Federal water acquisition programs to dedicate instream water in the Stanislaus River.*

- *Negotiate agreements with landowners, water districts, and Federal and State agencies to provide additional instream flows or purchase water rights in the Stanislaus River.*

- **San Joaquin River**
  - *Implement habitat enhancement or augmentation actions designed to minimize predation on steelhead in the San Joaquin River.*
  - *Implement studies designed to quantify the impact of predation on steelhead in the San Joaquin River and identify specific locations where predation is a problem.*

7.1.5.3 Monitoring

Assessing the temporal occurrence of each life stage is done through monitoring data in the Sacramento and San Joaquin rivers and Delta as well as salvage data from the Tracy and Skinner fish collection facilities in the south Delta.

Since 1995, the CVPIA Clear Creek Restoration Program, and later the California Ecosystem Restoration Program have taken restoration actions to improve anadromous salmonid habitat in Clear Creek. The USFWS Red Bluff Office has conducted CV steelhead/rainbow trout and late-fall run Chinook Salmon spawning ground surveys in Clear Creek since 2003. The purpose of these surveys is to evaluate population trends of these species on an annual basis through redd counts and carcass recoveries. Surveyors observed 149 California CV steelhead/rainbow trout and 22 late-fall Chinook Salmon redds over eight creek-length surveys from December 2015 to April 2016 (Schaefer et al, 2016).

The American and Stanislaus Rivers Rotary Screw Trap Project's purpose is to estimate the timing of outmigration and annual production of outmigrating juvenile Chinook salmon and steelhead in the American and Stanislaus rivers using RSTs.

The CVPIA Head of Old River Scour Hole Habitat Restoration project's purpose is to determine the best option for reducing predator habitat and entrainment towards the facilities. This may improve the survival of juvenile steelhead through this reach of the lower San Joaquin River.

The CVPIA six-year San Joaquin River Steelhead Telemetry Study uses acoustically tagged salmonids to track outmigrant route selection and survival to inform real-time operation of the CVP.

The Stanislaus Steelhead Life Cycle Monitoring Program's purpose is to evaluate how actions related to stream flow enhancement, habitat restoration, and/or water export restrictions affect biological outcomes including population abundance, age structure, growth and smoltification rates, and anadromy.

Seasonal Fish Assemblage Trawls and Delta Juvenile Fish Monitoring Program in the Sacramento River, Mossdale, and Chipps Island continue to monitor salmonids migrating to the Sacramento–San Joaquin Delta (Delta), through the Delta, and exiting the Delta to assist with resource management.

Below are summaries of steelhead take and mortality by lifestage for 2020 (Table 7-1), 2021 (Table 7-2), and 2022 (Table 7-3).

Table 7-1. Summary of steelhead take and mortality by life stage, 2020.

Steelhead 2020	Sum of Expected Take	Sum of Actual Take	Sum of Indirect Mortality	Sum of Actual Mortality
Adult	17570	903	56	5
Egg	2500	0	0	0
Fry	2700	100	80	5
Juvenile	1226659	1218	1050	15
Smolt	3678	1	72	0
Spawned Adult/Carcass	415	61	0	0
Not Specified	0	488	0	0
Grand Total	**1253522**	**2771**	**1258**	**25**

Table 7-2. Summary of steelhead take and mortality by life stage, 2021

Steelhead 2021	Sum of Expected Take	Sum of Actual Take	Sum of Indirect Mortality	Sum of Actual Mortality
Adult	15169	300	25	0
Egg	2500	0	0	0
Fry	14200	271	605	23
Juvenile	496534	875	1349	3
Smolt	3670	1558	70	56
Spawned Adult/Carcass	415	4	0	0
Not Specified	0	197	0	0
Grand Total	**532488**	**3205**	**2049**	**82**

Table 7-3. Summary of steelhead take and mortality by life stage, 2022

Steelhead - 2022	Sum of Expected Take	Sum of Actual Take	Sum of Indirect Mortality	Sum of Actual Mortality
Adult	17873	260	54	1
Egg	2500	0	0	0
Fry	4700	847	110	33
Juvenile	486859	1202	1060	11
Smolt	3770	1017	72	40
Spawned Adult/Carcass	415	5	0	0
Not Specified	0	394	0	0
Grand Total	**516117**	**3725**	**1296**	**85**

7.2 Effects Analysis

The following sections summarize potential effects of the Proposed Action to steelhead by life stage and stressors identified in the winter-run Chinook salmon Salmon and SAIL conceptual model (Windell et. al, 2017), as adapted to steelhead. 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.

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 from the proposed operation of CVP and SWP facilities to store, release, divert, route, or blend water. Appendix G, *Specific Facility and Water Operations Deconstruction*, analyzes potential stressors due to facility specific operations, and Appendices H through R analyze conservation measures to minimize or compensate for adverse effects. Stressors not linked to the operation of the CVP and SWP Proposed Action were identified as "not anticipated to change". Stressors that the Proposed Action may change to an extent insignificant or discountable by the Proposed Action 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 those extremely unlikely to occur. Based on best judgment, a person would not be able to expect discountable effects to occur.

Stressors exacerbated by the Proposed Action that may result in effects on listed species were documented and the proposed conservation measures identified.

The CVP has six regions with California CV steelhead DPS. These six regions include the Sacramento River, American River, Clear Creek, San Joaquin River, Stanislaus River, and Delta. Steelhead populations in each watershed are evaluated individually, rather than for the entire Central Valley DPS, since it is unknown what fractions of the DPS are in each respective watershed, and which proportions are in other non-CVP watersheds like the Mokelumne River, Feather River, Yuba River, and Battle Creek.

Within these six regions of the CVP, there are four geographically distinct diversity groups. The populations in the American River are within the Northern Sierra Nevada group, Clear Creek are within the Northwestern California group, the Stanislaus and San Joaquin rivers are within the Southern Sierra group, and the Sacramento River can have individuals from three groups (Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada). The Delta region may have individuals from all four diversity groups.

7.2.1 Adult Migration and Holding

Adult steelhead enter the San Francisco Estuary from the Pacific Ocean and will either spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006).

Migration timing in the Delta ranges from July until May, with peaks at both the beginning of the spawning season, as migrants move to their natal streams, and at the end of the season, in May, as some post-spawn kelts emigrate back to the ocean (Moyle 2002; Hallock 1961). See Section 7.2.3, *Kelt Emigration*, for more details on stressors during kelt emigration.

Historical data at the Fremont Weir have shown that adult steelhead migrate upstream in the Sacramento River during most months of the year, beginning in July, peaking in September, and continuing through March (Hallock 1989; McEwan 2001; Hallock et al. 1957).

Adult migration data are limited for other rivers and tributaries of the CVP.

In Clear Creek, *O. mykiss* greater than 16 inches have been seen migrating upstream through video monitoring as early as August and throughout February (Killam 2022).

Estimates of migrating adults in the San Joaquin River are made from CDFW angler report cards and suggest that migration starts in July, peaks in December and January, and ends in March (California Department of Fish and Wildlife 2007).

In the American River, adult steelhead migration may occur as early as July and through early April, with peak abundance in January and February (Sacramento Water Forum 2015; Hallock 1989; Hallock et al. 1957).

In the Stanislaus River, *O. mykiss* greater than 16 inches have been seen migrating upstream through video monitoring as early as September and throughout March, and can be recovered in the RST in Oakdale from November through April (Hellmair 2022; Eschenroeder et al. 2022).

The stressors influencing adult steelhead migration and holding include in-river fishery and poaching, toxicity from contaminants, stranding risk, water temperature, dissolved oxygen, pathogens and disease, competition, introgression, and broodstock removal and are described in Section 7.1.3, *Limiting Factors, Threats, and Stressors*.

The Proposed Action is not anticipated to change the stressors for I*n-River Fishery and Poaching, Stranding Risk, Competition, Introgression*, and *Broodstock Removal* during adult migration and holding.

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

- The Proposed Action may increase or decrease the *toxicity from contaminants stressor* in the CVP rivers and tributaries and in the Delta. During the adult migration and holding period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. The Proposed Action will also decrease inflow into the Delta in the winter and spring and increase inflow in the summer. In the San Joaquin River, operations would result in decreased flows throughout the year. Reduced flows may concentrate contaminants when present, while increased flows may dilute contaminants. During migration, adults do not typically eat, which reduces their exposure to contaminants in prey during this life stage.

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.

- The Proposed Action may increase or decrease the *dissolved oxygen* stressor in the CVP rivers and tributaries. The stressor is not anticipated to change in the Delta, because it is unlikely the changes in flows from the Proposed Action operations will cause changes to dissolved oxygen in the Delta. During the adult migration and holding period, reduced releases will decrease flows in the Sacramento River, Clear Creek, American River, and Stanislaus River in the winter and spring and decrease inflow into the Delta. In the San Joaquin River, operations would result in decreased flows throughout the year. Releases of storage in the summer from the Sacramento River, Clear Creek, American River, and Stanislaus River may decrease the stressor. Releases of storage may result in cooler water temperatures and higher flows that may provide a higher dissolved oxygen saturation potential while storing water may do the opposite.

  Studies on salmonids have demonstrated that adults wait to migrate when dissolved oxygen levels are at least 5.0 mg/l (Carter 2005; Hallock 1970) and historical water quality monitoring has not shown dissolved oxygen at levels below 5.0 mg/l. On the Sacramento River at Rio Vista Bridge in the Delta, historical dissolved oxygen levels (2007 – 2022) fluctuate on a seasonal basis, typically recorded around 10 mg/L in the winter and 8 mg/L in the summer. Levels were recorded at or below 6.0 mg/L in 2021 and 2008 for short periods of time during November and December. However, generally the dissolved oxygen stressor is not anticipated to change in the Delta. Water quality monitoring in the Sacramento, Stanislaus, and San Joaquin rivers suggest dissolved oxygen levels are well above 5.0 mg/L during this period.

  Historical DO measurements for the American River and Clear Creek are limited, however, dissolved oxygen levels in the American River and Clear Creek are not expected to be below this threshold during adult migration and holding. Upper Clear Creek is steep and there is often white water. During adult migration and holding on Clear Creek, dissolved oxygen is likely at saturation due to the facilitation of gas exchange in white water conditions. On the Sacramento River above Clear Creek and at Red Bluff Diversion Dam (2006 – 2022), August to February, daily dissolved oxygen levels fluctuate but on average are above 10 mg/L in most years. In the American River, dissolved oxygen levels may drop as side channels become dry below Nimbus Dam early in the migration season in November, but water quality monitoring reports from the main stem are above 5.0 mg/L during this period (LSA Associates 2003; Day and Starr 2021). Weekly environmental monitoring from the 2021 drought year in the Lower American River rotary screw traps reported dissolved oxygen levels between 8.10 – 11.30 mg/L from January to June (Day and Starr 2021).

- The Proposed Action may increase or decrease the *food availability and quality* stressor in the CVP rivers and tributaries and Delta. During the adult migration and holding period, reduced releases will decrease flows in the Sacramento River, Clear Creek, American River, and Stanislaus River in the winter and spring and decrease inflow into the Delta. In the San Joaquin River, operations would result in decreased flows throughout the year. Releases of storage in the summer from the Sacramento River, Clear Creek, American River, and Stanislaus River may decrease the stressor. Operations resulting in decreased flows would provide less inundated habitats, while an increase in flows may do the opposite. These changes may modify food web processes and cause a decrease in the quality of food available to steelhead.

Prior to freshwater migration, steelhead will store sufficient energy at sea from a marine diet and fast until they reach their natal spawning rivers and streams. Adult steelhead may occasionally feed while in-river, but it is not considered essential to successful spawning, as many adults will fast in freshwater.

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 provided.

7.2.1.1 Water Temperature

The proposed storing and diverting of water may generally decrease the water temperature stressor. During the adult migration and holding period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer and fall resulting in increased flows. Appendix L, *Shasta Coldwater Pool Management*, Appendix M, *Folsom Reservoir Flow and Temperature Management*, and Appendix N, *New Melones Stepped Release Plan*, address temperature related effects associated with the Proposed Action.

The Proposed Action includes the following components/conservation measures to address: (1) Reclamation, through Governance, will continue to annually prepare a Temperature Management Plan (TMP) for the summer through fall. TMP to contains: (a) forecasts of hydrology and storage; and (b) modeling run or runs, using these forecasts, demonstrating what temperature compliance schedule can be attained; (2) Reclamation will plan shutter configurations to attain the best possible (lowest numbered) temperature schedule; (3) Reclamation will implement the Automated Temperature Selection Procedure (ATSP) in developing the TMP. For greater than 56°F at Hazel Avenue in November, the TMP will evaluate a power bypass.

Evidence from watersheds outside of the Central Valley suggests that water temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Keefer et al. 2018). Optimal water temperatures for steelhead vary across watersheds but generally fall in the range of 41-66°F with migration impairment at daily maximum temperatures above 66.2°F in the Pacific Northwest (Keefer et al. 2009). No migration impairment thresholds have been established for the Central Valley.

The Proposed Action is expected to result in **insignificant** changes to water temperature in the Sacramento River, Clear Creek and San Joaquin River, and the Delta. Water temperatures in the Delta, Sacramento River and Clear Creek are below adult migration and holding criteria throughout this period. The Proposed Action is expected to have insignificant changes to water temperature in the San Joaquin River (see Chapter 4, *Seasonal Operations*, Figure 4-53).

The decrease in the water temperature stressor in the American and Stanislaus rivers are expected to be **beneficial**. Water temperatures below the criteria during the adult migration and holding period may decrease stress on adults taxed from upstream migration and spawning. Moreover, water temperatures below the criteria could increase spawning success and reduce mortality.

Although the Proposed Action may increase the water temperature stressor, unsuitable water temperatures for adult steelhead migration and holding 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.

Prior to the construction of Folsom and Nimbus dams, CV steelhead would seek out cold water refuges in higher elevation habitats of the basin. Up until completion of the dams in 1955, maximum water temperatures during summer frequently reached temperatures as high as 75°F to 80°F in the lower American River (Gerstung 1971). During the late 1960s, Reclamation designed a modification to the trash rack structures to provide selective withdrawal capability at Folsom Dam through the Folsom Power Plant. The steel trash racks are now equipped with three groups of shutters that can pull water from various elevations, which have different temperatures when the lake is thermally stratified. This allows for limited discretionary water temperature management of the lower American River.

In addition to steelhead, fall-run Chinook salmon also spawn in the American River below Nimbus Dam. The Nimbus Fish Hatchery, located just below Nimbus Dam, supports populations of both CV steelhead and fall-run Chinook salmon in the lower American River. Operating Folsom Dam to provide suitable water temperatures for returning fall-run Chinook salmon often limits the amount of coldwater available for steelhead spawning and rearing in the lower American River.

In 1997, Reclamation completed the Temperature Control Device (TCD) at Shasta Reservoir, which can be used to effectively blend water from the warmer upper reservoir levels and, thereby, extend the time 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. Different approaches have targeted different water temperatures and locations throughout the years including a warmwater bypasses to conserve limited coldwater pool.

In 1992 Reclamation installed two temperature curtains in Whiskeytown Reservoir in an effort to improve passage of coldwater through the reservoir during the warm months of the year for Clear Creek 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 cold-water pool in Whiskeytown becomes limited, and in some cases may result in less cold water available through October 15.

Adult steelhead use the San Joaquin River to migrate to natal streams where they spawn. On the San Joaquin River, Reclamation operates Friant Dam, which creates Millerton Lake and diverts water down the Friant-Kern and Madera Canals for water supply purposes. Historically, the presence and operation of Friant Dam resulted in significant portions of the San Joaquin River between Friant Dam and the confluence of the Merced River being dry during a significant portion of the year in most years. Reclamation has undertaken river restoration projects and provided in-stream flows for the San Joaquin River. The San Joaquin River Restoration Program is outside of this consultation.

In 2009, NMFS issued an RPA that required Reclamation to prepare and implement a water TMP by May 15 each year for the American River. Reclamation proposed a similar temperature management operation in 2019.

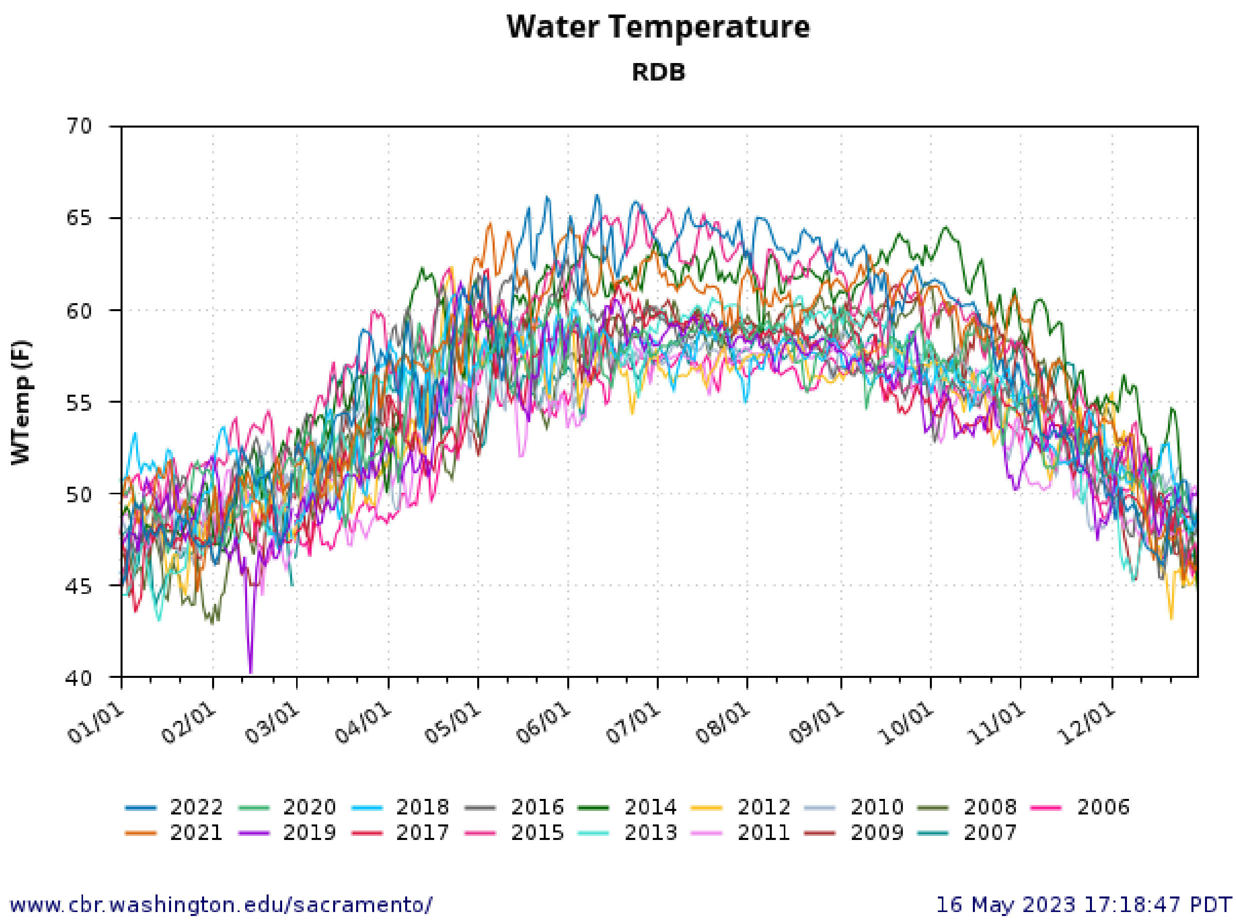
To reduce the water temperature stressor in the American River, Reclamation recently completed the Water Temperature Modeling Platform (WTMP) effort, which is intended to enhance modeling capabilities to predict summer and fall water temperature through facilities operations, such as the Folsom Dam Temperature Shutters.

On the Stanislaus River, the completion of Goodwin Dam, owned and operated by the Oakdale Irrigation District (OID) and South San Joaquin Irrigation District (SSJID), in 1912 has excluded salmon and steelhead from 100 percent of their historical spawning and rearing habitat on the Stanislaus River (Lindley et al. 2006). Since that time, salmon and steelhead have had to spawn downstream of Goodwin Dam on the Stanislaus River which experience greater water temperatures. In 1926 and 1958, respectively, OID and SSJID built the old Melones Dam and Tulloch Dam on the Stanislaus River (both are above Goodwin Dam). In 1978, above both Goodwin and Tulloch Dams, the U.S. Army Corps of Engineers (USACE) completed construction of New Melones Dam and Reservoir, which inundated the old Melones Dam. None of the dams on the Stanislaus River have a temperature control device, so the only mechanism for temperature management on the Stanislaus River is direct flow management. Reclamation currently operates New Melones Dam.

Past operational releases from New Melones Dam have influenced the extent of coolwater habitat available below Goodwin Dam. In 2009, NMFS issued an RPA that dictated specific temperature targets for the Stanislaus River to benefit steelhead. Since 2019, Reclamation has implemented an SRP for the Stanislaus River. The SRP does not set water temperature standards for the Stanislaus River, but it does include minimum flow targets that are intended to benefit CV steelhead, including water temperature benefits and preservation of coldwater pool. The regularly convened Stanislaus Watershed Team provides input on the shaping and timing of monthly and/or seasonal flow volumes to optimize biological benefits.

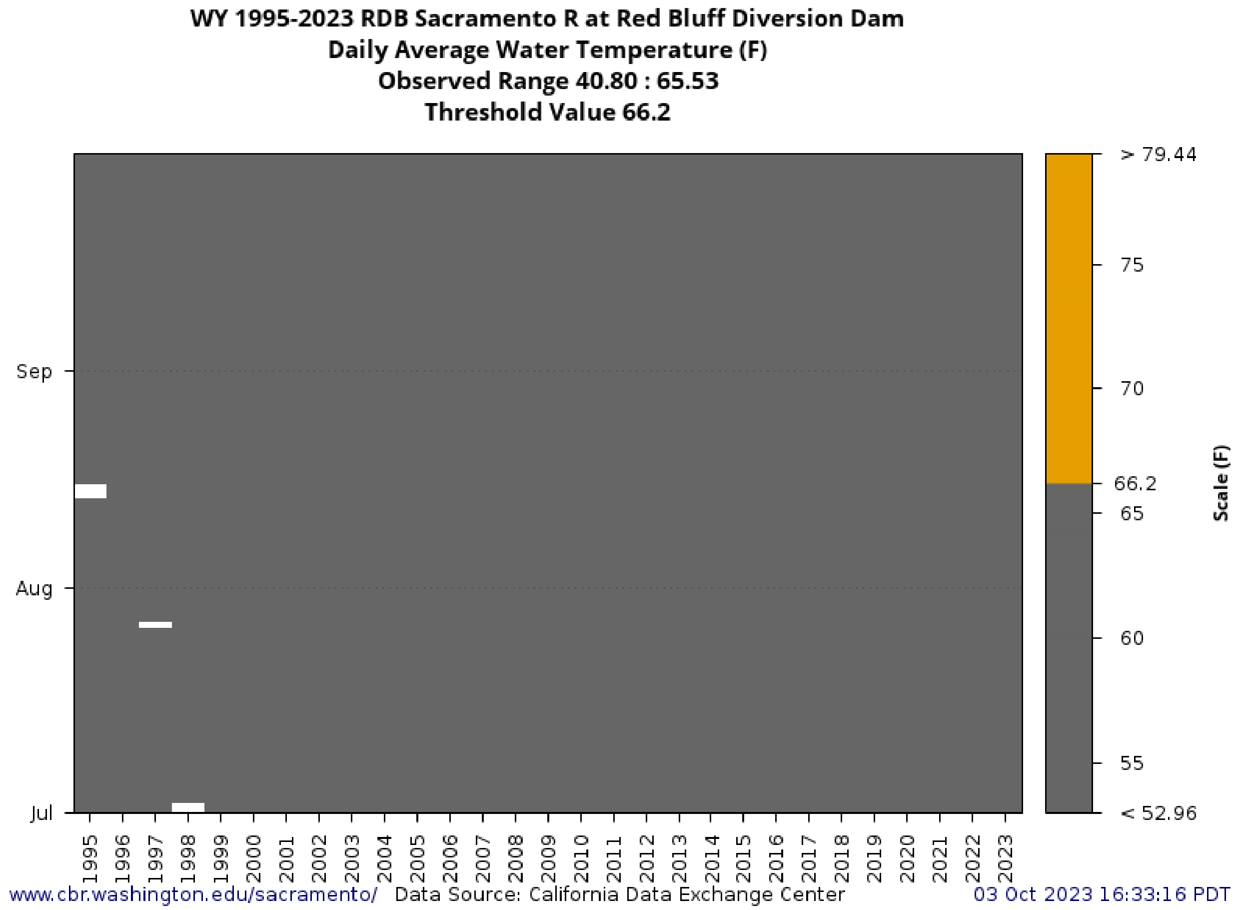
In the winter and spring, Reclamation operates to D-1641 and for flood control in accordance with the *USACE Standard Operation and Maintenance Manual for the Lower San Joaquin River Levees Lower San Joaquin River and Tributaries Project*, California (April 1959). During the summer, Reclamation is required to maintain applicable dissolved oxygen standards on the lower Stanislaus River for species protection. Reclamation operates to a 7.0 milligrams per liter (mg/L) dissolved oxygen requirement at Ripon from June 1 to September 30.

The **proportion** of the population affected by the Proposed Action depends on temperature management and peak migration timing. During the adult migration and holding period in the Sacramento River, historical daily average water temperatures are below the thermal impairment limit of 66.2°F July through March (Figure 7-17; Figure 7-18; Figure 7-19). Out of the 28 years of historical data for Sacramento River at Red Bluff Diversion Dam (RBDD), none of the years have recorded water temperatures that exceed the thermal limit that blocks migration at 69.8°F. While maintenance of Shasta storage may increase the stressor in the winter and spring, it is expected to have an insignificant impact on the water temperature stressor for adult migration and holding.



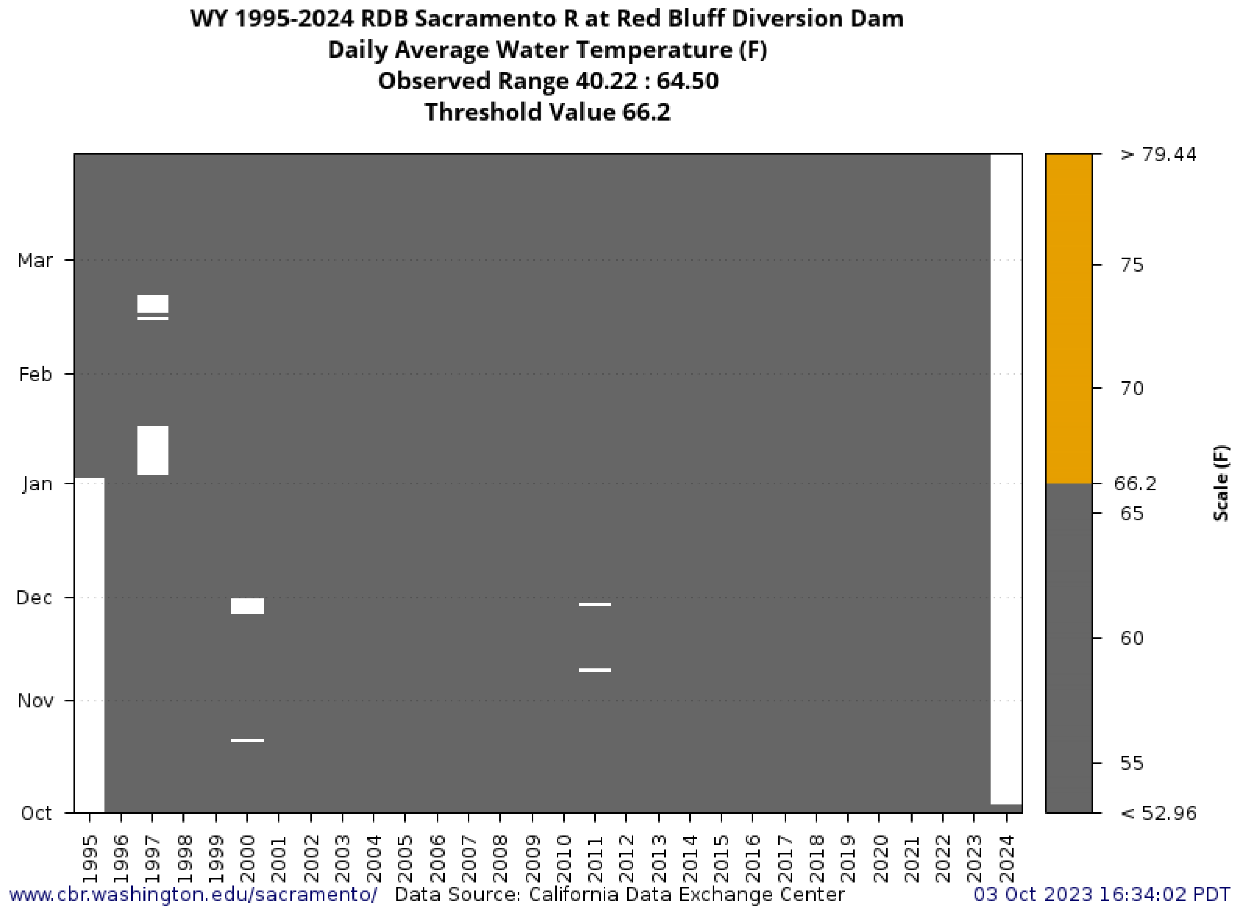
Source: Columbia Basin Research 2023.

Figure 7-17. Historical Water Temperatures at RBDD from 2006-2022.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-18. Days exceeding water temperatures 66.2°F at RBDD 1995 – 2022, July through September.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

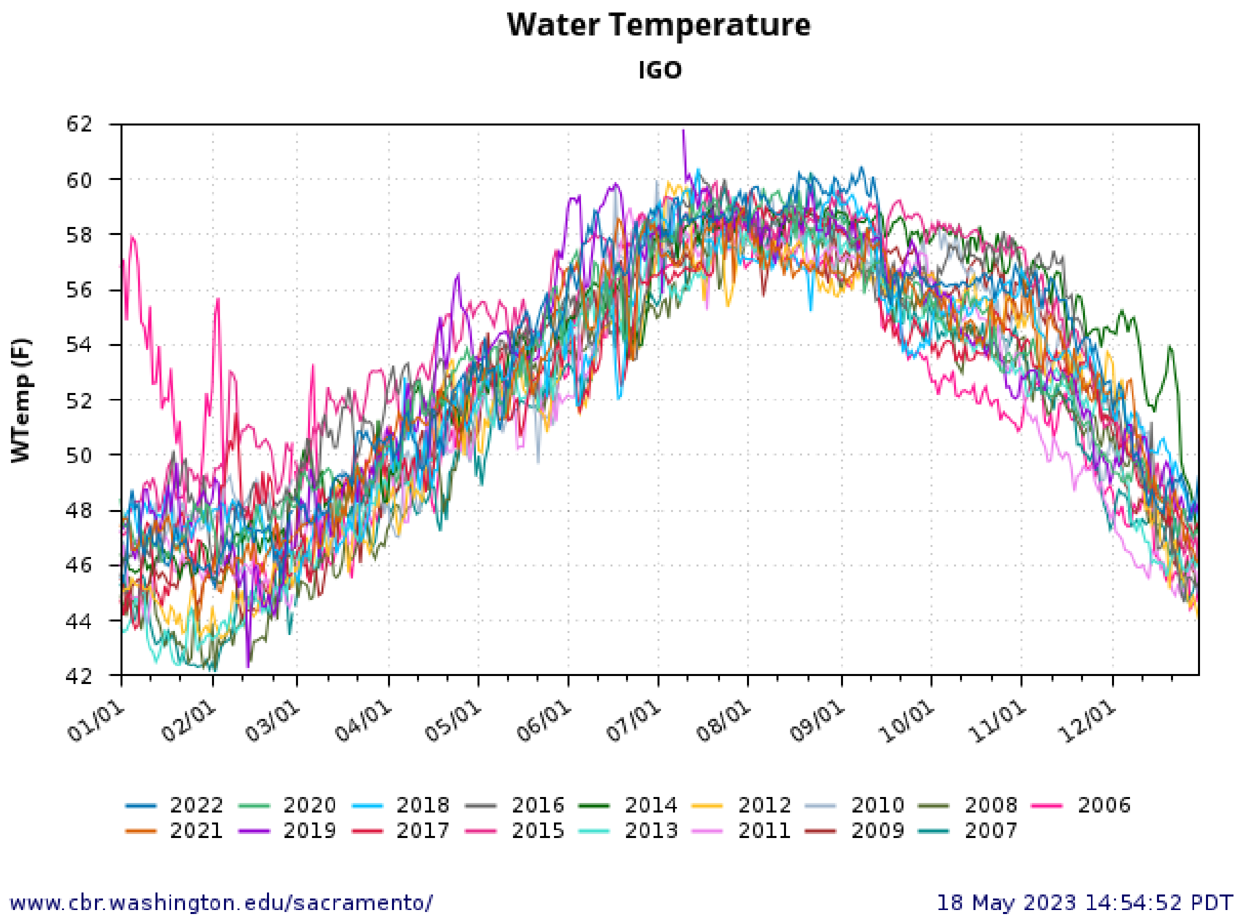
Figure 7-19. Days exceeding water temperatures 66.2°F at RBDD 1995 – 2023, October through March.

Literature on critical water temperatures historically identified 66.2°F as the threshold temperature to impair steelhead migration and 69.8°F as the lethal limit to block migration.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

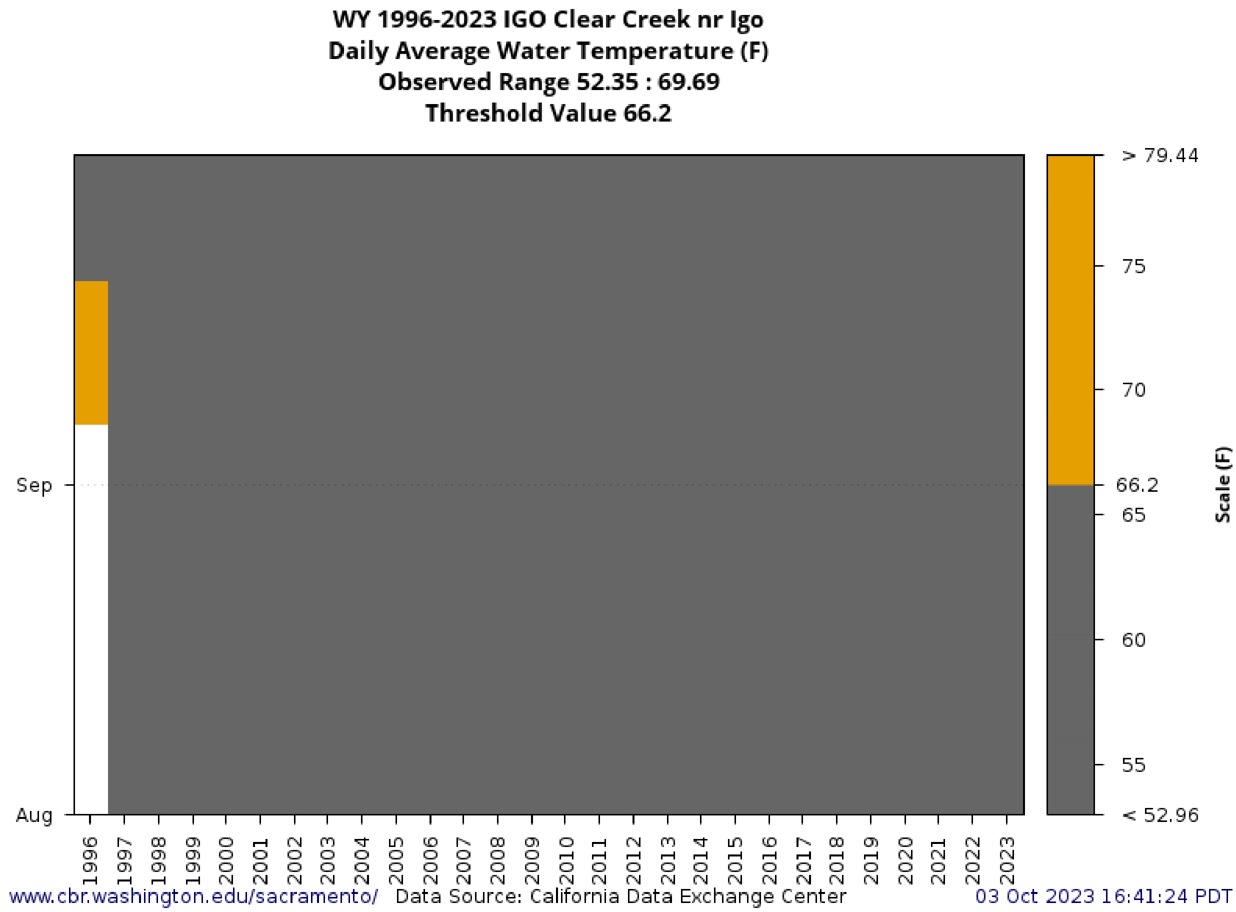
Models provide quantitative estimates of future conditions under the Proposed Action. Reclamation evaluated multiple lines of evidence, with different assumptions and complexity, to narrow the likely range of potential effects. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed water temperature criteria obtained from scientific literature.

During the adult migration and holding period in Clear Creek, historical daily average water temperatures are below the thermal impairment limit of 66.2°F August through February (Figure 7-20; Figure 7-21; Figure 7-22). Out of the 27 years of historical data for the Clear Creek at Igo, none of the years have recorded water temperatures that exceed the thermal limit that blocks migration at 69.8°F. While maintenance of Whiskeytown storage may increase the stressor in the winter and spring, it is expected to have an insignificant impact on the water temperature stressor for adult migration and holding as water temperatures are below the criteria during this period.



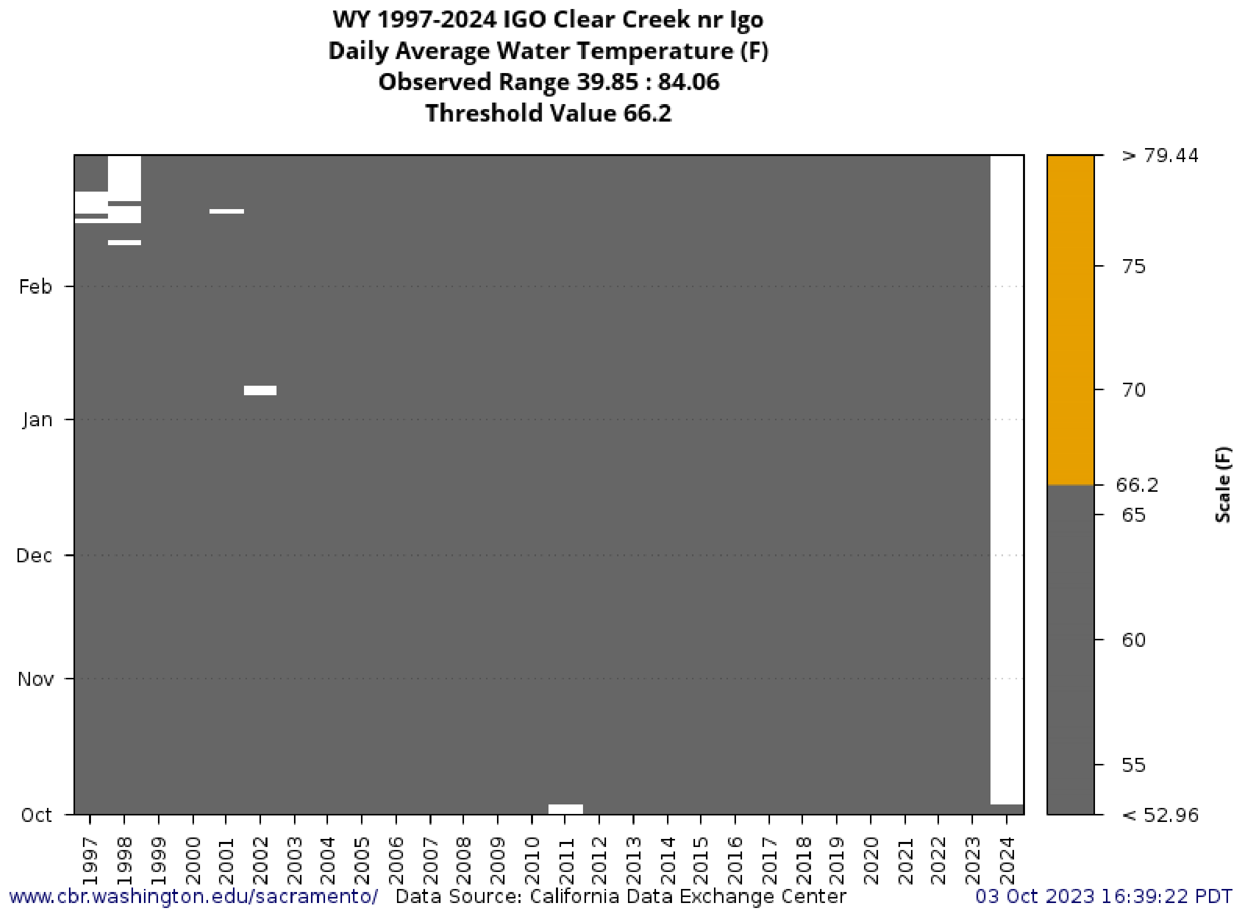
Source: Columbia Basin Research 2023.

Figure 7-20. Water temperatures, Clear Creek near Igo, 2006 – 2022.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

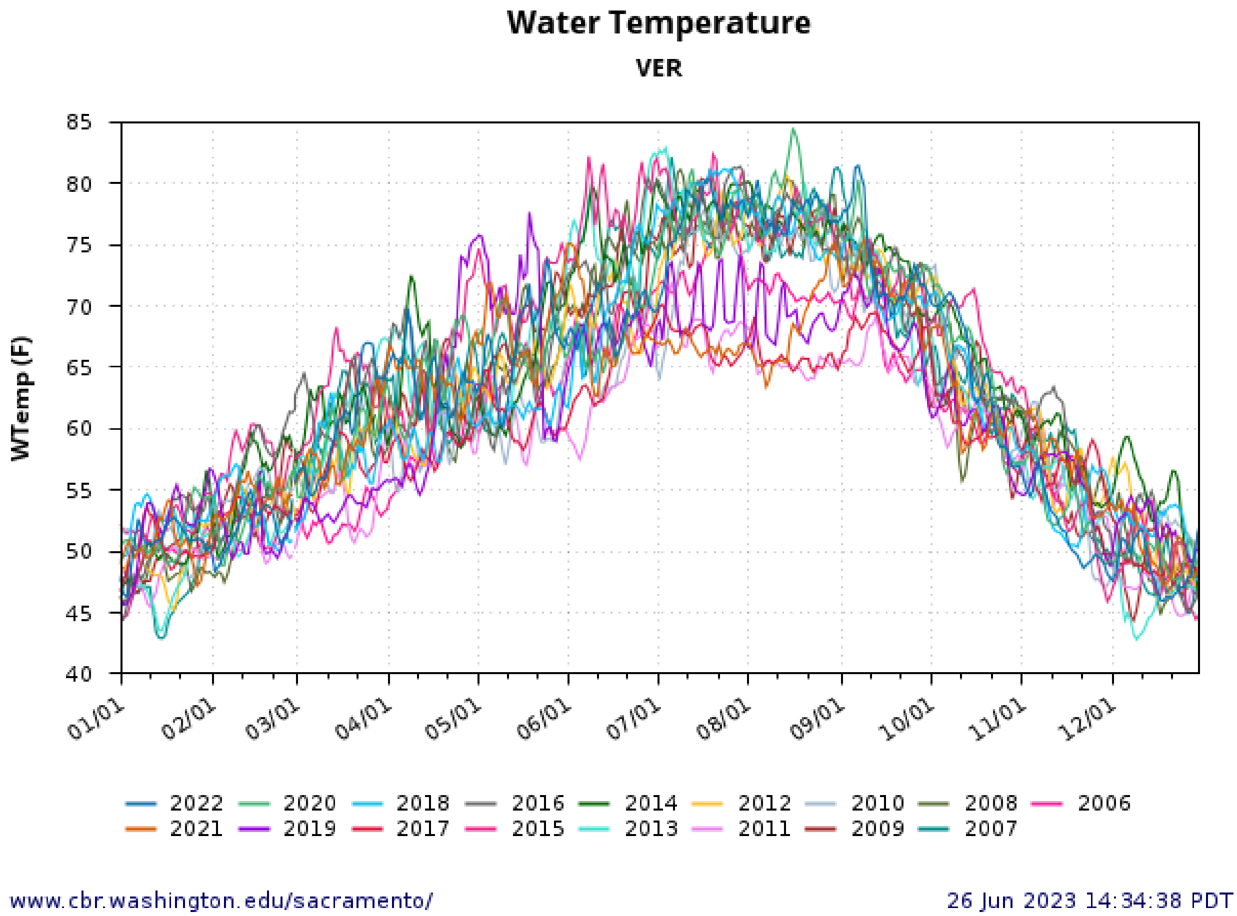
Figure 7-21. Days exceeding water temperatures of 66.2°F in Clear Creek near Igo, 1996 – 2022, August and September.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

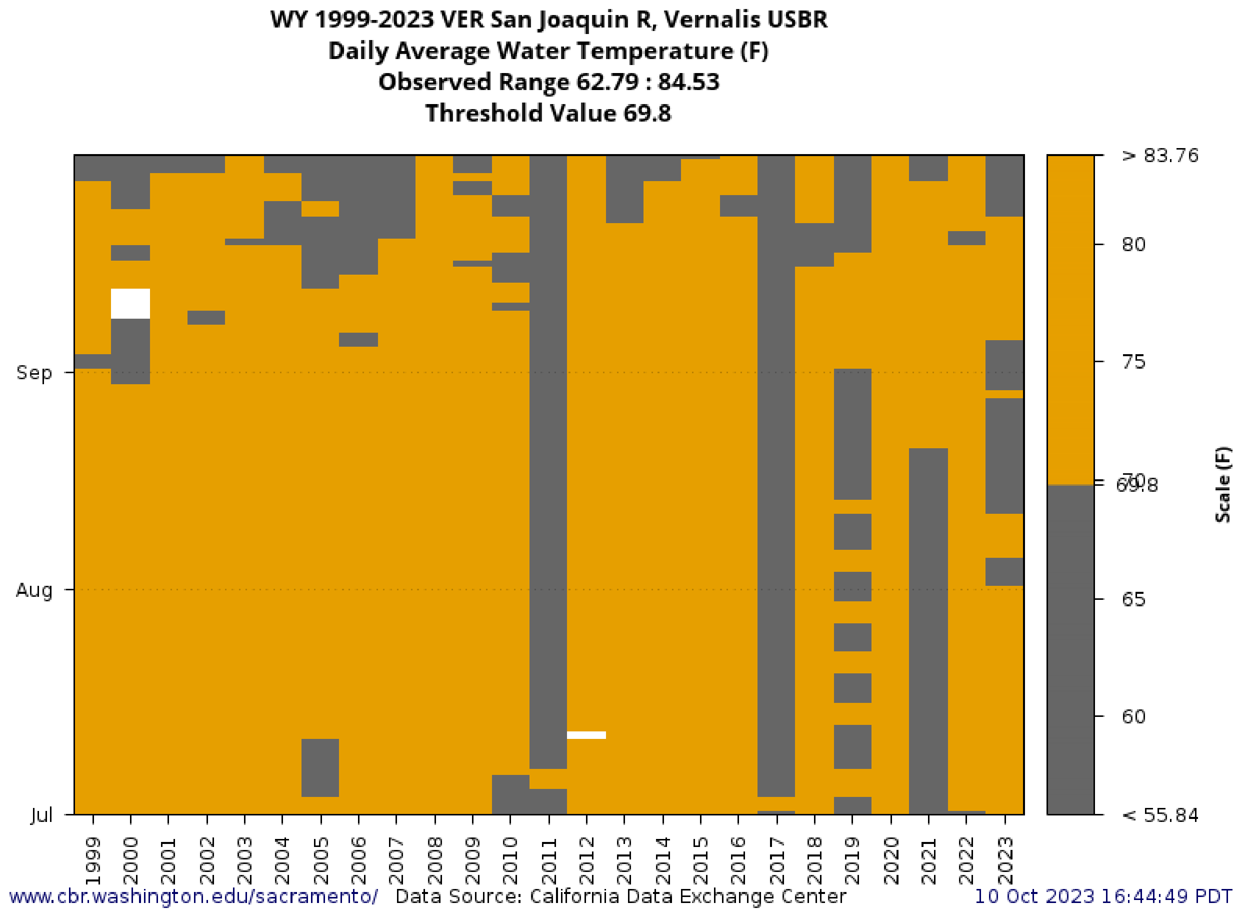
Figure 7-22. Days exceeding water temperatures of 66.2°F in Clear Creek near Igo, 1997 – 2023, October through February.

During the adult migration and holding period in the San Joaquin River, historical data suggests water temperatures have been in the range that is lethal. Water temperatures have been above the lethal limit of 69.8°F for adult steelhead migration and holding from July through October (Figure 7-23; Figure 7-24; Figure 7-25). However, the Proposed Action is not anticipated to significantly change water temperatures between phases and increases to the water temperature stressor are likely insignificant (see Chapter 4, Figure 4-53).



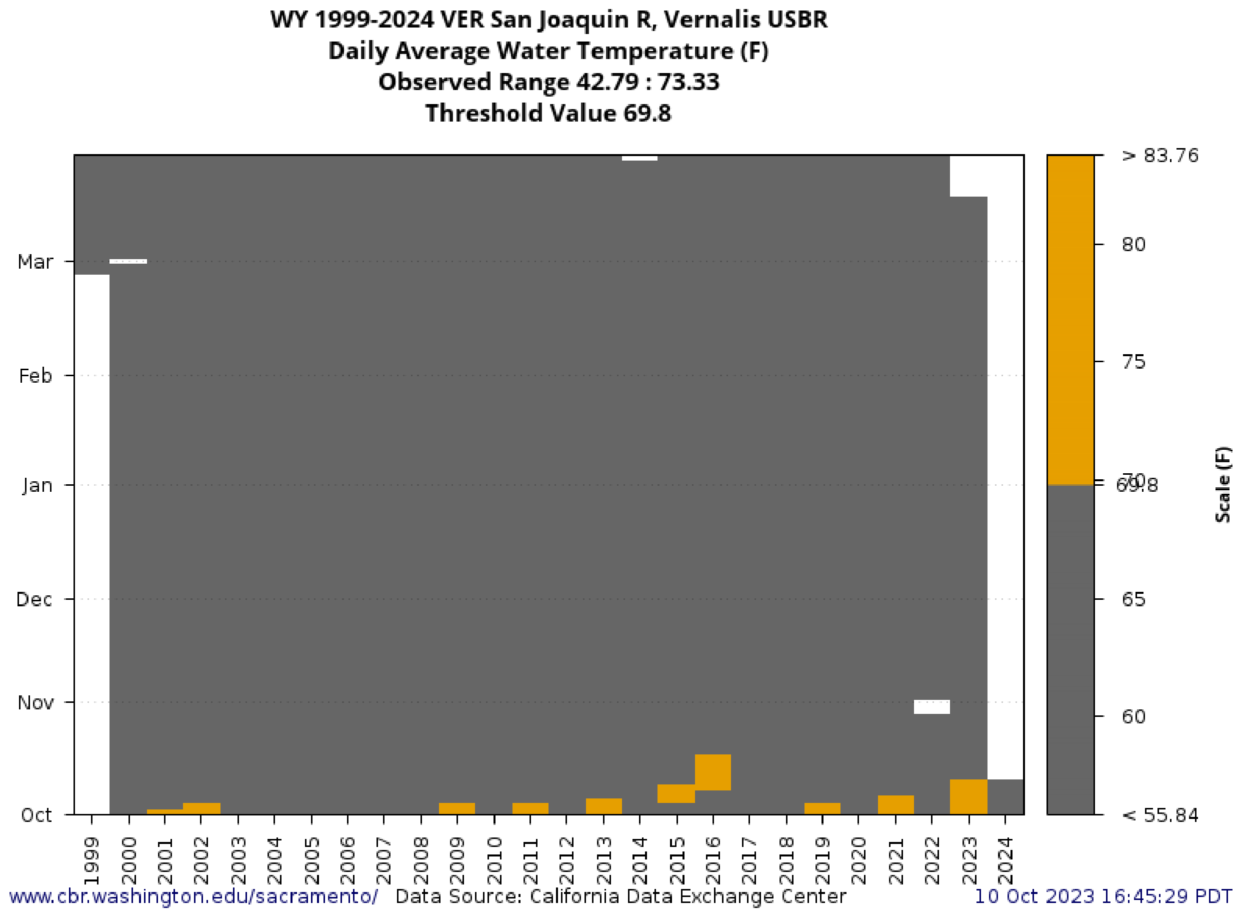
Source: Columbia Basin Research 2023.

Figure 7-23. San Joaquin River near Vernalis water temperatures 2006 – 2022.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

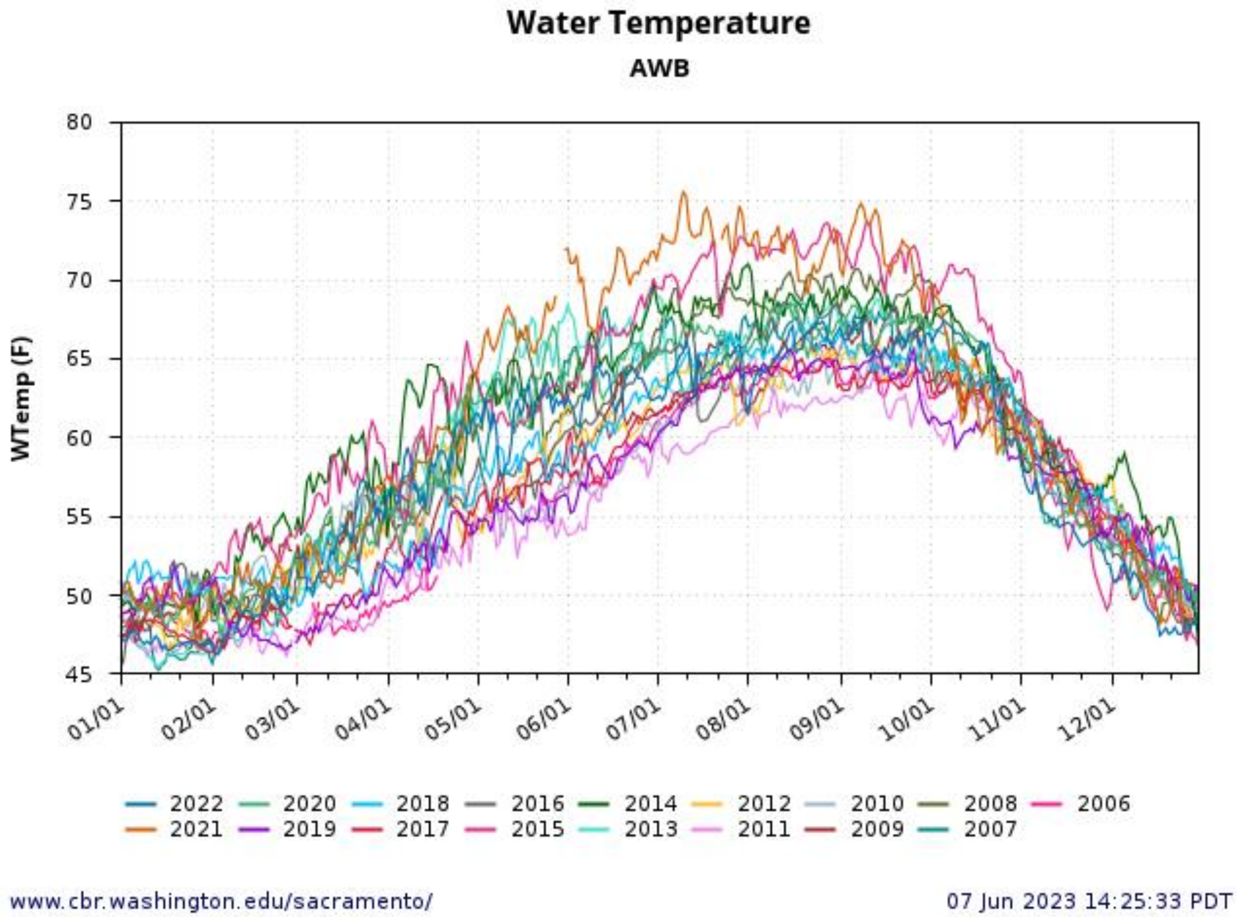
Figure 7-24. Days exceeding water temperatures of 69.8°F in the San Joaquin River near Vernalis 1999 – 2022, July through September.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-25. Days exceeding water temperatures 69.8°F in the San Joaquin River near Vernalis 1999 – 2023, October through March.

During the adult migration and holding period in the American River, historical daily average water temperatures are above the lethal limit that blocks migration of 69.8°F from July through October (Figure 7-26). The **proportion** of adults in the American River when water temperatures are at the lethal threshold is likely **small**, as water temperatures exceed the threshold towards the beginning of adult migration, and temperatures are below the criteria during peak migration in January and February.



Source: Columbia Basin Research 2023.

Figure 7-26. Water temperatures, American River near Watt Avenue, 2006 - 2022.

Results for the 69.8°F upper water temperature limit are presented in Table 7-4 for the American River at Hazel Avenue and in Table 7-5 for Watt Avenue. At Hazel Avenue, the percentage of months above the limit range from 0% in Above Normal water years to 3.8% in Critically Dry water years under all three Proposed Action phases. In general, the percentage of months above the water temperature limit was similar for each of the Proposed Action phases, but varied across water year types with the highest percentage of months above the limit in Critically Dry water years during the period of July through April.

Table 7-4. Percent of months above the 69.8°F lethal water temperature limit for adult steelhead migration by water year type and for all years combined, American River at Hazel Ave., July through April.

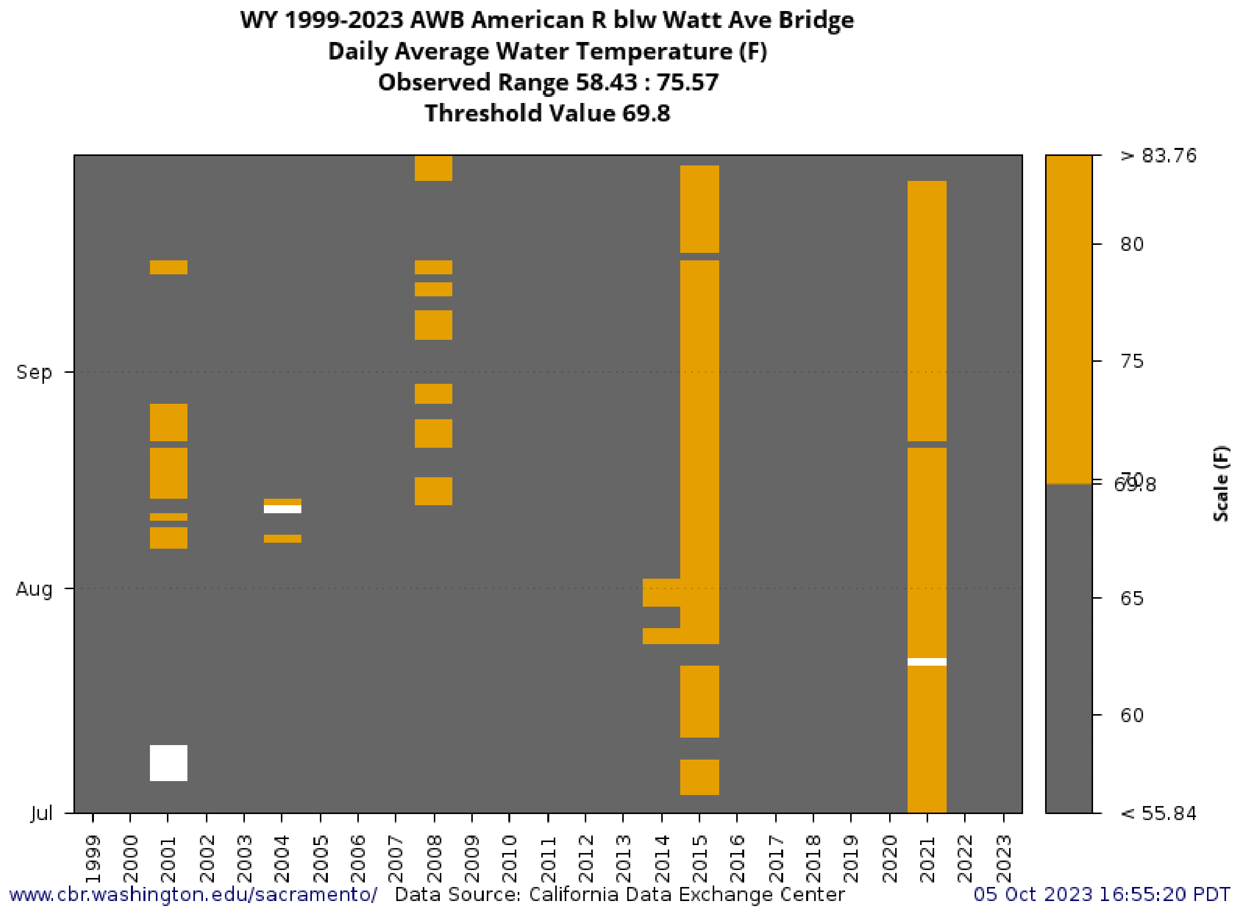
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	18.2	0.4	0.7	1.4	1.4	1.4
AN	18.9	1.5	0.0	1.5	0.8	0.0
BN	22.2	0.0	1.1	1.7	1.7	2.2
D	25.0	1.3	1.7	1.7	1.7	0.8
C	29.9	0.0	7.0	3.8	3.8	2.5
All	22.5	0.6	1.9	1.9	1.8	1.4

At Watt Avenue, the percentage of months above the 69.8°F upper water temperature limit ranged from 7.6% in Above Normal water years to 29.9% in Critically Dry water years under all three Proposed Action phases. In general, the percentage of months above the water temperature limit was similar for each of the Proposed Action phases but varied across water year types with the highest percentage of months above the limit in Critically Dry water years during the period of July through April.

Table 7-5. Percent of months above the 69.8°F lethal water temperature limit for adult steelhead migration by water year type and for all years combined, American River at Watt Ave., July through April.

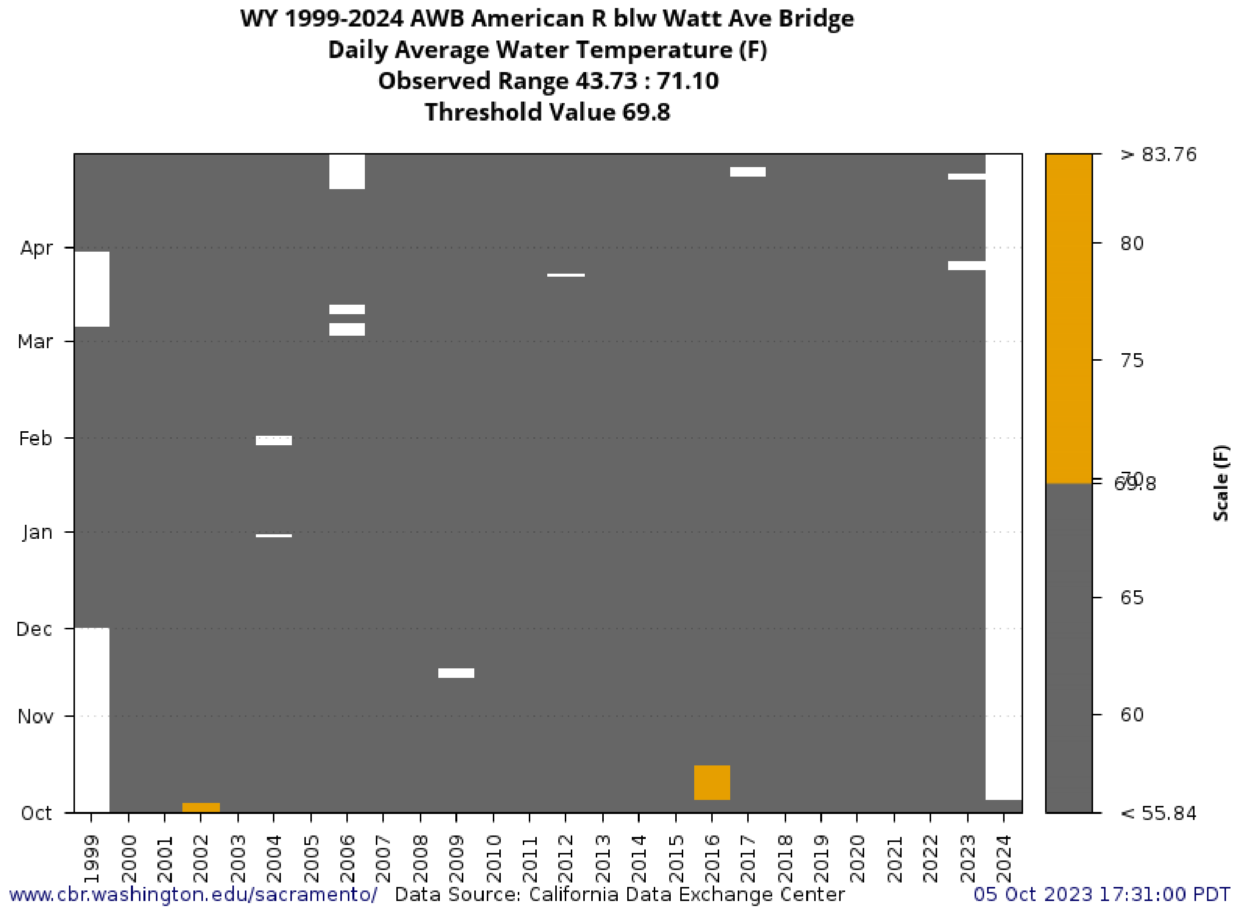
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	27.9	19.3	12.5	13.2	13.2	13.9
AN	28.0	18.2	9.1	9.8	9.1	7.6
BN	28.3	22.2	10.6	11.1	11.7	13.3
D	30.0	26.3	15.0	16.7	15.8	14.2
C	34.4	30.6	28.0	29.9	29.9	29.3
All	29.5	23.2	14.8	15.9	15.7	15.5

Historical water temperatures near Watt Ave (Figure 7-27 and Figure 7-28) indicate the frequency of occurrence is likely **medium**, as the threshold is reached in 6 out of 24 years. From July through September, releases of storage are expected to increase flows, which may decrease the stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

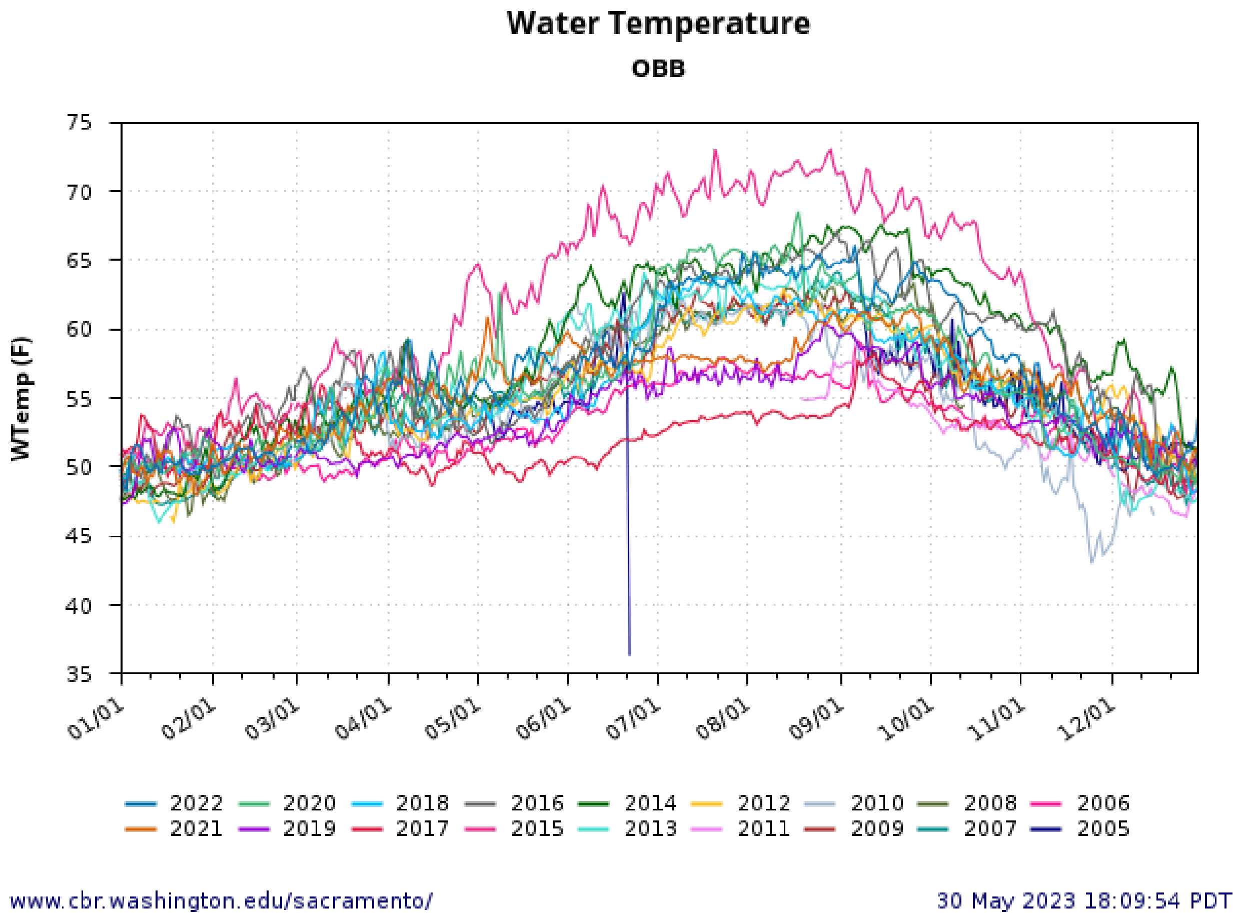
Figure 7-27. Days exceeding water temperatures 69.8°F in the American River near Watt Ave 1999 – 2023, July through September.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-28. Days exceeding water temperatures 69.8°F in the American River near Watt Avenue, 1999 – 2023, October through April.

During the adult migration and holding period in the Stanislaus River, historical daily average water temperatures are above the thermal impairment limit of 66.2°F for adult steelhead migration and holding in September and October (Figure 7-29). The **proportion** of adults in the Stanislaus River when water temperatures are above the impairment threshold is likely **small**, as adult steelhead start migrating in September.



Source: Columbia Basin Research 2023.

Figure 7-29. Water temperatures on the Stanislaus River at Orange Blossom Bridge, 2005 – 2022.

Results for the 41°F to 66.2°F range are presented in Table 7-6 for Orange Blossom Bridge and Table 7-7 for the confluence. At Orange Blossom Bridge, the percentage of months outside the range was between 0% in Wet, Above Normal, and Dry water years and 2.4% in Critically Dry water years for all Proposed Action phases. In Wet, Above Normal, and Dry water years, water temperatures were inside the range 100% of the time. In general, the percentage of months outside of the optimal temperature range was similar for each of the Proposed Action phases, with some variation across water year types. The highest percentage of months outside of the temperature range was in Critically Dry water years during the period of July through March.

Table 7-6. Percent of months outside the 41°F to 66.2°F water temperature range for minimal adult steelhead migration impairment by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, July through March.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	35.9	11.1	0.0	0.0	0.0	0.0
AN	38.9	11.1	0.0	0.0	0.0	0.0
BN	35.9	10.2	0.0	0.8	0.8	0.8
D	38.6	9.2	0.0	0.0	0.0	0.0
C	39.5	11.6	2.0	2.4	2.4	2.0
All	37.9	10.8	0.7	0.0	0.9	0.8

At the confluence, the percent of months outside the 41°F to 66.2°F range under the Proposed Action phases range from 23.7% during Wet water years to 33.3% of months during Dry water years. Overall, the percent of months outside the range increased from wetter to drier water year types. In general, the percentage of months outside of the optimal temperature range was similar for each of the Proposed Action phases and across water year types. The highest percentage of months outside of the temperature range was in Dry water years during the period of July through March.

Table 7-7. Percent of months outside the 41°F to 66.2°F water temperature range for minimal adult steelhead migration impairment by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River above confluence with San Joaquin River, July through March.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	39.4	18.2	24.2	23.7	23.7	23.7
AN	38.9	30.6	33.3	32.4	32.4	32.4
BN	38.3	30.5	32.8	32.8	32.8	32.8
D	37.3	34.0	33.3	33.3	33.3	33.3
C	39.8	35.4	34.4	33.0	33.0	33.0
All	38.9	30.0	31.6	30.9	30.9	30.9

Results for the 69.8°F upper limit are presented in Table 7-8 for Orange Blossom Bridge and Table 7-9 for the confluence. At Orange Blossom Bridge, the percentage of months above the limit for all water year types combined were 0% under the Proposed Action phases (Table 7-4). Among all water year types, the percentage of months outside the range remained at 0% for all three of the Proposed Action phases.

Table 7-8. Percent of months above the 69.8°F lethal water temperature limit for adult steelhead migration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, July through March.

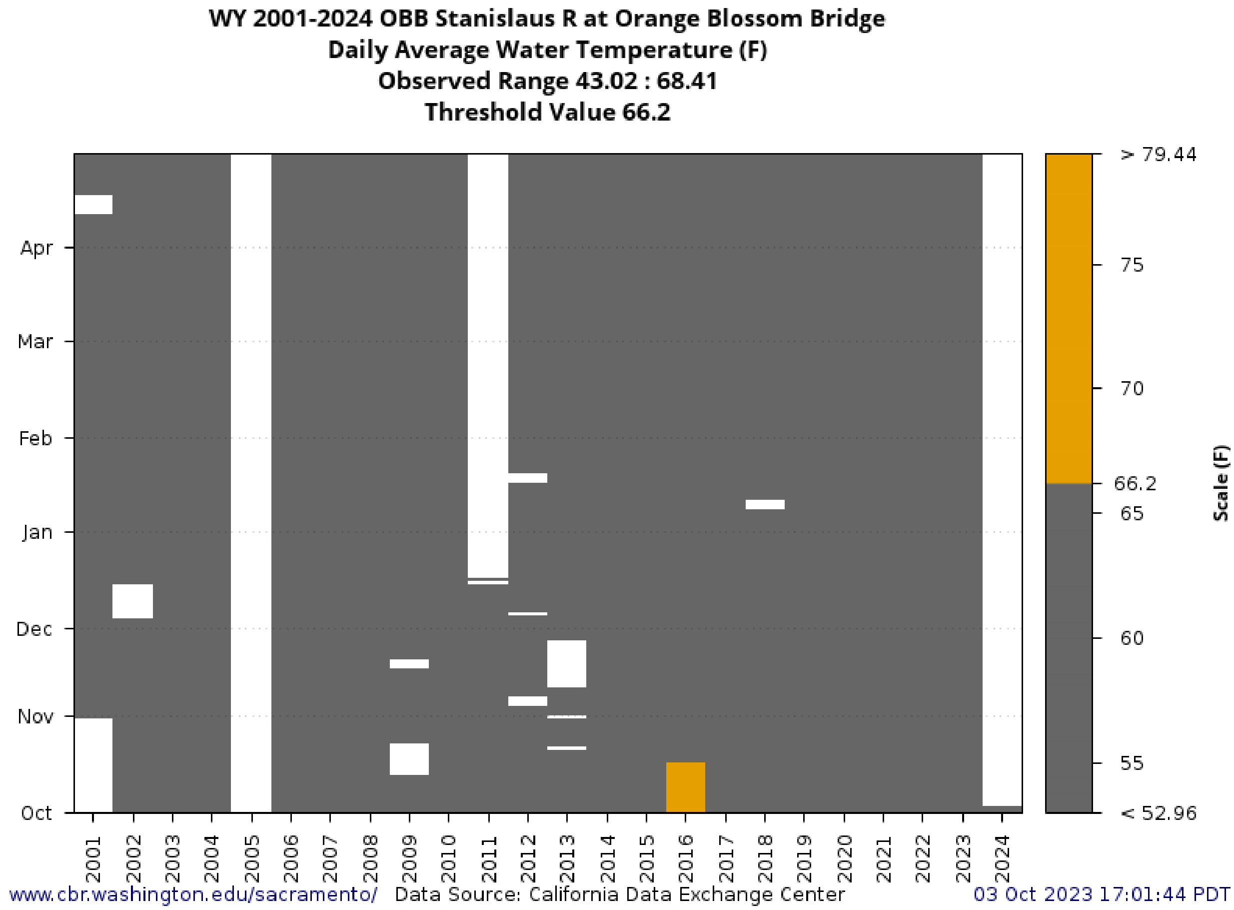
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	30.3	10.6	0.0	0.0	0.0	0.0
AN	28.7	4.6	0.0	0.0	0.0	0.0
BN	25.0	4.7	0.0	0.0	0.0	0.0
D	22.9	0.7	0.0	0.0	0.0	0.0
C	19.7	0.7	0.0	0.0	0.0	0.0
All	24.5	4.0	0.0	0.0	0.0	0.0

At the confluence, the average percentage of months above the limit for all water year types combined were 26.0% under the Proposed Action phases. In general, the percentage of months outside of the optimal temperature range was similar for each of the Proposed Action phases, but varied across water year types with the highest percentage of months outside of the temperature range in Above Normal water year types during the period of July through March.

Table 7-9. Percent of months above the 69.8°F lethal water temperature limit for adult steelhead migration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River above confluence with San Joaquin River, July through March.

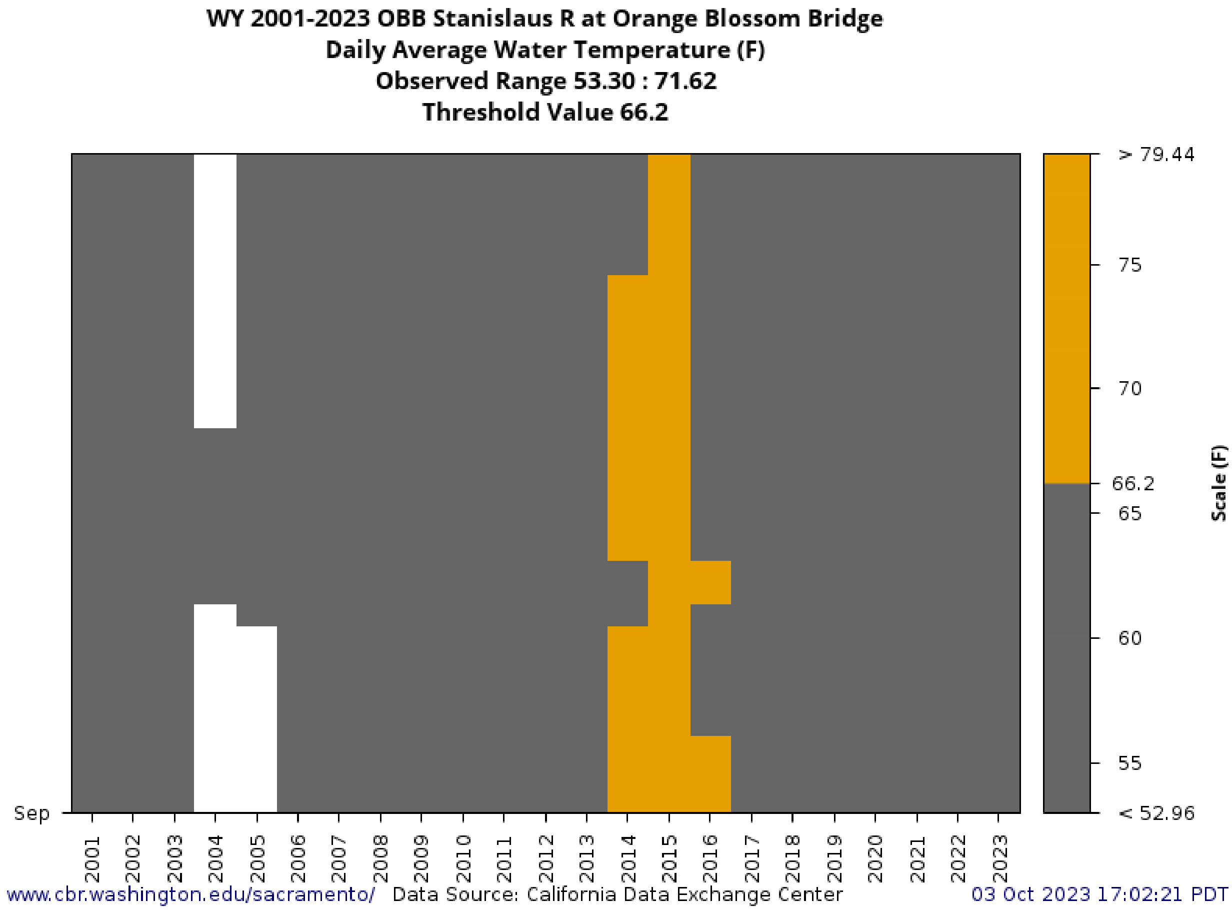
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	32.8	17.2	17.7	16.7	16.7	16.7
AN	33.3	27.8	30.6	30.6	30.6	30.6
BN	32.8	30.5	28.9	28.9	28.9	28.9
D	32.7	32.7	28.8	28.8	28.8	28.8
C	33.7	33.7	30.6	27.9	27.9	27.9
All	33.1	28.6	27.1	26.0	26.0	26.0

Historical water temperatures near Orange Blossom (Figure 7-30 and Figure 7-31) indicate the frequency of occurrence is likely **low**, as the impairment limit is reached in three out of 23 years from 2001-2022. In one out of 23 years, the thermal limit that blocks migration is met during this period. In the fall, storage may reduce flows which may increase the water temperature stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-30. Days exceeding water temperatures 66.2°F on the Stanislaus River at Orange Blossom Bridge, 2001 – 2023, October through April.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-31. Days exceeding water temperatures 66.2°F on the Stanislaus River at Orange Blossom Bridge, 2001 – 2023, September.

To evaluate the **weight of evidence** for the water temperature stressor, there are water temperature thresholds from several peer reviewed articles and state issued water quality documents that are specific to *O. mykiss* but these studies are not specific to populations from the Central Valley. The water quality monitoring data through SacPAS provides quantitative data on each watershed to assess whether a threshold was met (Columbia Basin Research 2023).

- Coutant (1970) is quantitative, species-specific, not location specific, published research on lethal water temperature thresholds for adult migration
- Keefer et al. (2018) is quantitative, species-specific, not location specific, published research on lethal water temperature thresholds for adult migration.
- Keefer et al. (2009) is quantitative, species-specific, not location specific, published research on sub-lethal (impairment) water temperature thresholds for adult migration.

- Historical water temperatures are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed from long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- Historical adult migration-timing observations are quantitative, species-specific, and location-specific. The observations are published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- HEC-5Q water temperature modeling are quantitative, not species-specific (environmental variable) and location-specific. The model was developed to evaluate reservoir systems using control points, and is widely accepted as the temperature modeling system for use in the upper Central Valley 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
- Clear Creek
    - Water Temperature Management
- American River
    - Water Temperature Management
- Stanislaus River
    - Stepped Release Plan

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)
- American River
    - Fall and Winter Base Flows for Shasta Reservoir Refill and Redd Maintenance
    - Rebalancing between other CVP Reservoirs for Shasta Reservoir End of September Storage
    - Reduced Wilkins Slough Minimum Flows for Shasta Reservoir End of September Storage
- Drought Actions

7.2.1.2 Pathogens and Disease

The proposed storing, diverting and releasing of water may decrease the pathogens and disease stressor. Water temperatures below the criteria may decrease pathogen virulence and prevalence of disease. During the adult migration and holding period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring. The Proposed Action will release storage in those locations in the summer resulting in increased flows. The Proposed Action may result in decreased flows in the fall in the Stanislaus River below Goodwin Dam. As part of the drought toolkit, Reclamation may operate the TCD to release warmer water temperatures to preserve water for egg incubation later in the year and those water temperatures may not be colder than would occur without the Proposed Action. Appendices L, M, and N address temperature related effects in the Proposed Action.

The Proposed Action is expected to result in insignificant changes to water temperature in the San Joaquin River and the Delta. Water temperatures in the Delta are below pathogen criteria throughout the adult migration period. The Proposed Action is expected to have insignificant changes to water temperature in the San Joaquin River (see Chapter 4, Figure 4-53).

While the water temperature stressor listed above is insignificant in Clear Creek and the Sacramento River, the pathogens and disease water temperature criteria is a lower threshold and, therefore, changes to water temperature below this threshold are significant.

The decreases in the pathogens and disease stressor are expected to be **beneficial** in Clear Creek, the Sacramento, American, and Stanislaus rivers. Reductions in the prevalence of pathogens and disease may decrease stress on adult steelhead, improving fitness and migration. Salmonid pathogens and disease can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Seasonal operations that result in decreased flows may increase pathogen concentration and horizontal transmission, while increasing temperature may increase pathogen virulence. Diseases affecting salmonids become highly virulent at temperatures above 59.9°F (McCullough 1999).

Although the Proposed Action may, increase the pathogens and disease stressor, pathogens and diseases that may affect steelhead adult migration and holding 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 (National Marine Fisheries Service 1998).

Natural steelhead 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 steelhead survival. Salmonids are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment (National Marine Fisheries Service 1996, 1998a, 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 steelhead (National Marine Fisheries Service 1996, 1998a, 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 WTMP 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.

Literature on critical water temperatures for pathogens and disease historically identified 59.9°F as the threshold temperature to increase virulence of pathogens.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

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. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed pathogens and disease water temperature criteria obtained from scientific literature.

The **proportion** of the population affected by Proposed Action depends on temperature management and peak migration timing. During the adult migration and holding period in the Sacramento River, historical daily average water temperatures are above the virulence threshold of 59.9°F from July through November (Figure 7-17). The **proportion** of adults in the Sacramento River when water temperatures are above the criteria is likely **large**, as adult steelhead migration peaks in September.

Results for the 59.9°F pathogen water temperature threshold are presented in Table 7-10 for Keswick, in Table 7-11 for Hamilton City, and in Table 7-12 for RBDD. At Keswick, the percentage of months above the pathogen virulence limit for all water year types except Critically Dry water years was 0% under all three Proposed Action phases. For Critically Dry water years the percentage of months above the limit was 13.5% under the Proposed Action phases.

Table 7-10. Percent of months above the 59.9°F pathogen virulence water temperature threshold for adult steelhead migration by water year type and for all years combined, Sacramento River at Keswick, July through March.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	39.7	0.0	0.0	0.0	0.0	0.0
AN	37.0	0.0	0.0	0.0	0.0	0.0
BN	37.0	0.0	0.0	0.0	0.0	0.0
D	34.7	0.0	0.0	0.0	0.0	0.0
C	39.0	4.3	12.1	13.5	13.5	13.5
All	37.5	0.7	1.9	2.1	2.1	2.1

At Hamilton City, the percentage of months above the pathogen virulence water temperature limit ranged from 27.7% in Above Normal water years to 44% in Critically Dry water years under the Proposed Action phases. Overall, the percentage of months outside the range increased from wetter to drier water year types.

Table 7-11. Percent of months above the 59.9°F pathogen virulence water temperature threshold for adult steelhead migration by water year type and for all years combined, Sacramento River at Hamilton City, July through March.

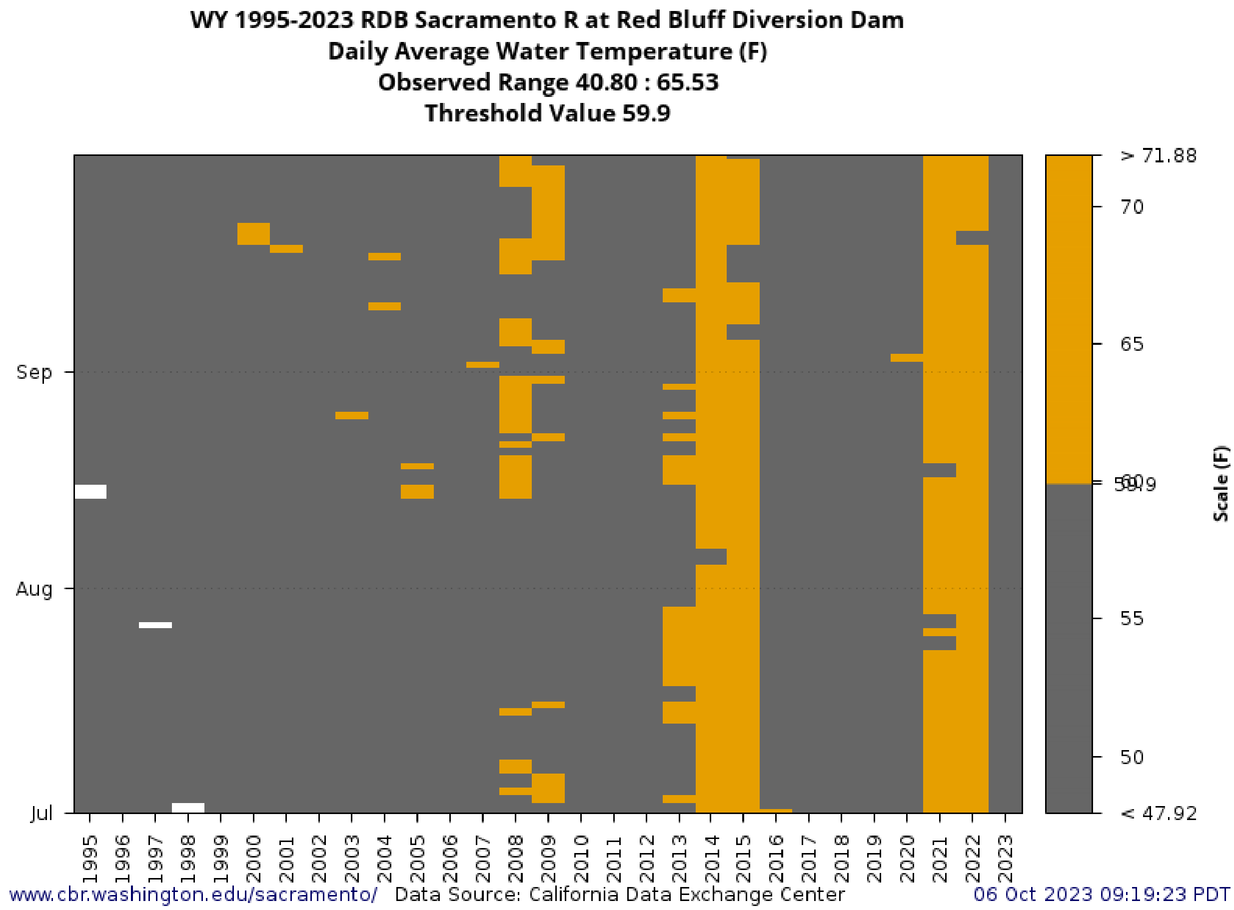
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	44.4	37.3	29.8	29.4	29.4	29.0
AN	43.7	38.7	27.7	27.7	28.6	28.6
BN	44.4	40.1	35.2	35.8	35.2	35.8
D	43.5	39.4	38.4	39.4	39.4	39.4
C	44.7	43.3	44.0	44.0	43.3	43.3
All	44.2	39.4	34.8	35.1	34.9	34.9

At RBDD, the percentage of months above the pathogen virulence water temperature limit was 0% in Above Normal water years. In all other water year types the percentage of months above the limit ranged from 2% in Wet water years to 33.3% in Critically Dry water years under the Proposed Action phases. Overall, the percentage of months outside the range increased from wetter to drier water year types.

Table 7-12. Percent of months above the 59.9°F pathogen virulence water temperature threshold for adult steelhead migration by water year type and for all years combined, Sacramento River at the Red Bluff Diversion Dam, July through March.

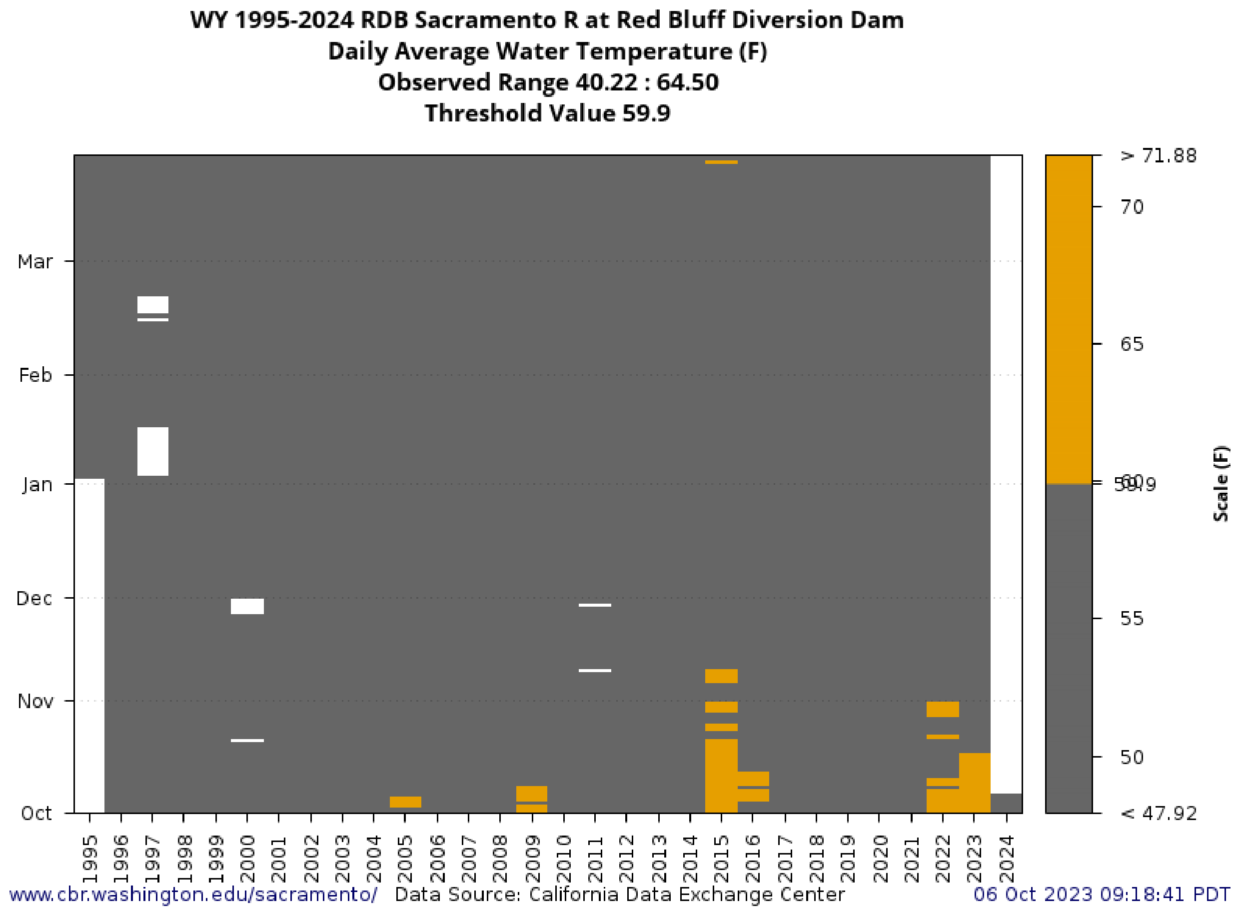
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	43.3	17.9	2.8	2.0	2.0	2.0
AN	42.0	10.9	0.0	0.0	0.0	0.0
BN	41.4	12.3	8.6	4.3	4.9	5.6
D	41.7	8.3	8.3	5.1	5.1	6.0
C	44.7	31.2	35.5	34.8	33.3	31.9
All	42.6	15.7	10.0	8.1	8.0	8.1

Historical water temperatures near RBDD (Figure 7-32 and Figure 7-33) indicate the frequency of occurrence is likely **medium**, as the virulence threshold is reached in 11 out of 29 years. In the summer and fall, releases of storage are expected to increase flows, which may decrease the water temperature stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-32. Days exceeding water temperatures of 59.9°F in Sacramento River at RBDD, 1995 – 2022, July through September.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-33. Days exceeding water temperatures of 59.9°F in Sacramento River at Red Bluff Diversion Dam (RBDD), 1995 – 2022, October through March.

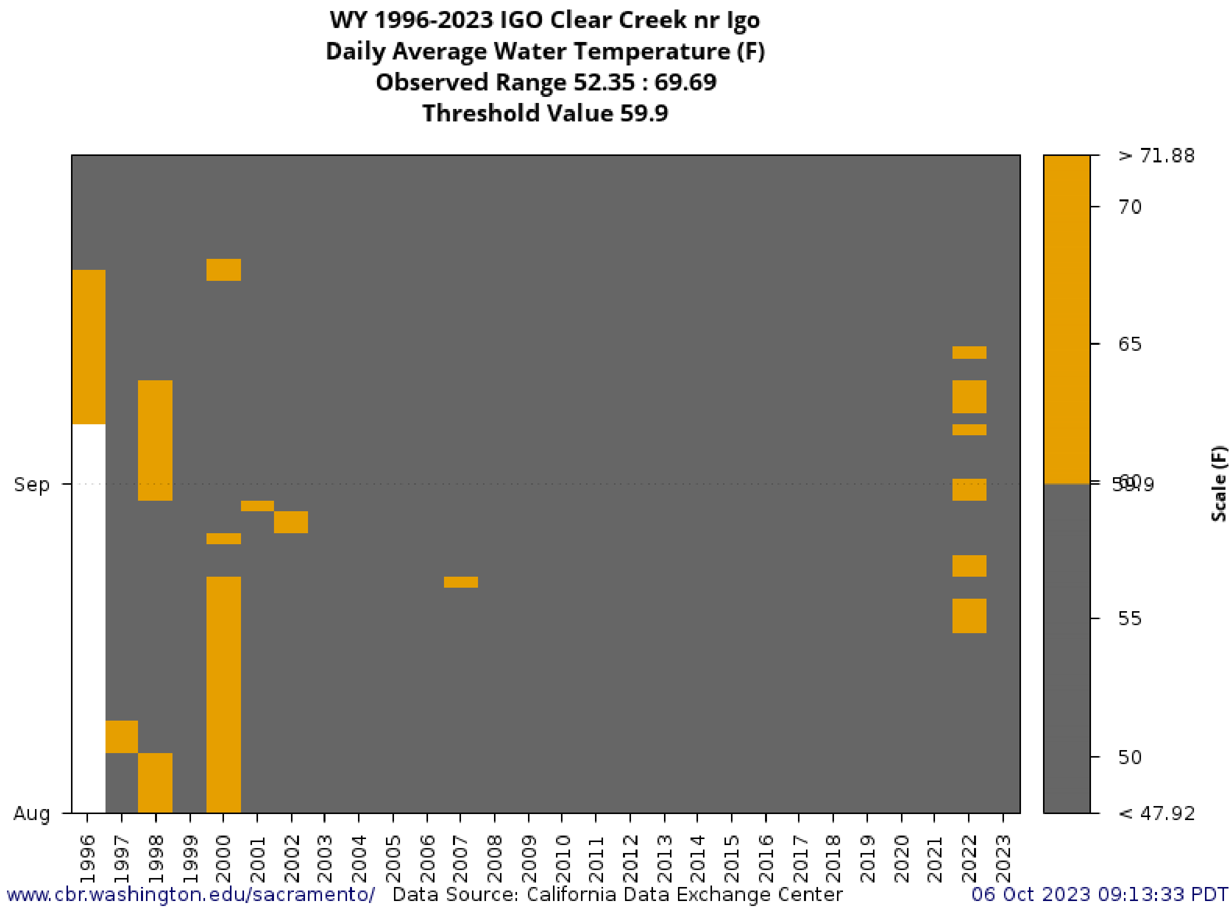
During the adult migration and holding period in Clear Creek, historical daily average water temperatures are above the virulence threshold of 59.9°F in August and September during this life stage (Figure 7-20). The **proportion** of adults in Clear Creek when water temperatures are above this threshold is likely **small**, as temperatures exceed the thermal impairment threshold towards the beginning of adult migration.

Results for the 59.9°F pathogen water temperature threshold are presented in Table 7-13 for Clear Creek below Keswick. At Clear Creek, the percentage of months above the pathogen virulence limit for all water year types except Below Normal and Critically Dry water years was 0% under all three Proposed Action phases. For Below Normal water years the percentage of months above the limit was 1.2% and for Critically Dry water years the percentage of months above the limit ranged from 8.5% to 9.2% under the Proposed Action phases.

Table 7-13. Percent of months above the 59.9°F pathogen virulence water temperature threshold for adult steelhead migration by water year type and for all years combined, Clear Creek below Whiskeytown, July through March.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	36.1	0.0	0.0	0.0	0.0	0.4
AN	33.6	0.0	0.0	0.0	0.0	0.0
BN	40.1	4.3	0.6	1.2	1.2	1.2
D	41.7	14.8	0.0	0.0	0.0	0.0
C	44.7	17.0	2.1	9.2	8.5	8.5
All	39.2	7.1	0.4	1.7	1.6	1.7

Historical water temperatures near IgO (Figure 7-34) indicate the frequency of occurrence is likely **medium**, as the virulence threshold is reached in 8 out of 28 years. In August and September, water temperatures are expected to be below Run of River and Minimum Releases which may decrease the water temperature stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-34. Days exceeding water temperatures of 59.9°F in Clear Creek near Igo, 1996 – 2022, August and September.

During the adult migration and holding period in the American River, historical daily average water temperatures are above the virulence threshold of 59.9°F July through November and March through April (Figure 7-26). The **proportion** of adults in the American River when water temperatures are above the criteria is likely **medium**, as temperatures exceed the thermal impairment threshold towards the tail ends of adult migration.

Results for the 59.9°F pathogen water temperature threshold are presented in Table 7-14 for Hazel Avenue and in Table 7-15 for Watt Avenue. At Hazel Avenue, the percentage of months above the pathogen virulence limit for all water year types range from 37.8% in Below Normal water years and 45.2% in Critically Dry water years under all three Proposed Action phases. In general, the percentage of months above the virulence temperature threshold was similar under the Proposed Action phases, but varied across water year types with the highest percentage of months above the temperature limit in Critically Dry water year types during the period of July through April.

Table 7-14. Percent of months above the 59.9°F pathogen virulence water temperature threshold for adult steelhead migration by water year type and for all years combined, American River at Hazel Ave., July through April.

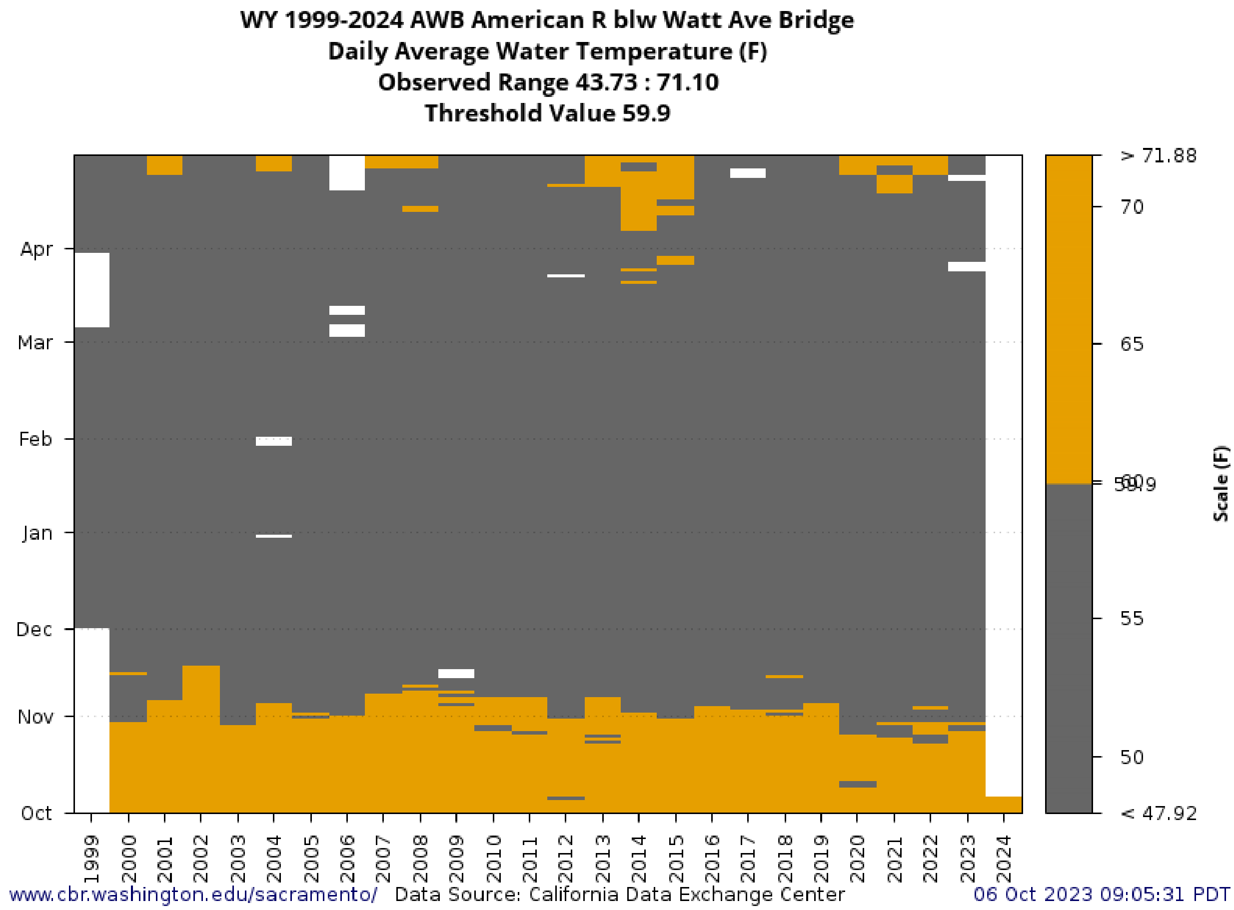
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	39.6	43.6	40.0	40.4	40.4	40.7
AN	39.4	42.4	37.9	37.9	38.6	38.6
BN	39.4	45.6	38.3	37.8	38.3	38.3
D	40.8	45.4	40.0	40.0	40.4	40.0
C	49.0	47.8	44.6	45.2	44.6	43.3
All	41.4	44.9	40.1	40.2	40.4	40.2

At Watt Avenue, the percentage of months above the pathogen virulence limit for all water year types range from 39.4% in Above Normal water years and 50.3% in Critically Dry water years under all three Proposed Action phases. Overall, the percentage of months above the temperature limit increased from wetter to drier water year types.

Table 7-15. Percent of months above the 59.9°F pathogen virulence water temperature threshold for adult steelhead migration by water year type and for all years combined, American River at Watt Ave., July through April.

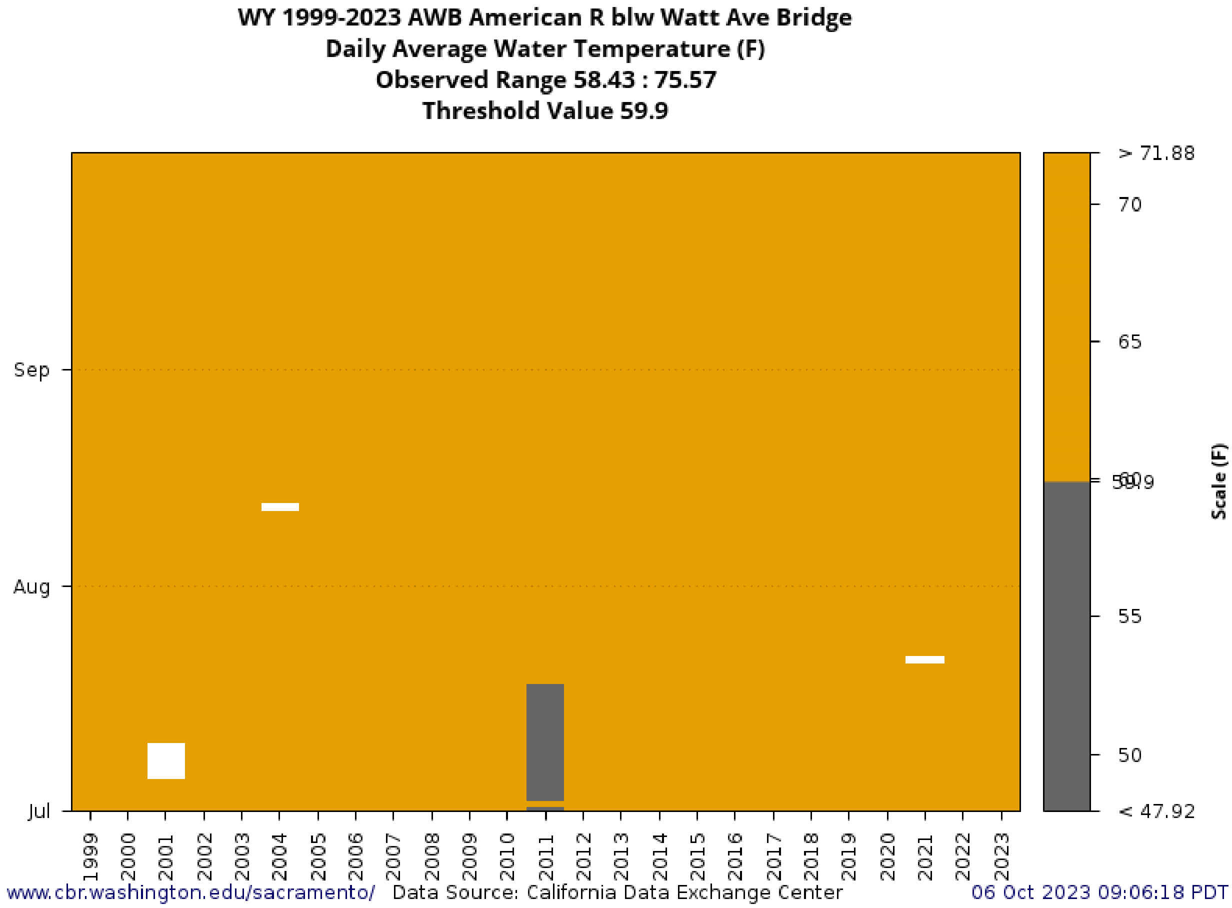
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	40.0	44.3	40.4	40.7	40.4	40.7
AN	40.9	42.4	39.4	39.4	40.2	40.2
BN	43.9	46.1	40.6	41.1	41.7	41.1
D	44.2	47.5	42.1	42.5	43.3	42.5
C	51.6	54.1	51.6	49.0	50.3	48.4
All	43.7	46.7	42.5	42.4	42.9	42.4

Historical water temperatures near Watt Ave (Figure 7-35; Figure 7-36) indicate the frequency of occurrence is likely **high**, as the virulence threshold is reached in almost all years during this period. July through September, releases of storage are expected to increase flows which may decrease the stressor. In the spring, the Proposed Action is likely to have insignificant changes to the water temperature stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-35. Days exceeding water temperatures of 59.9°F in American River below Watt Avenue, 1999 – 2023, November through April.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-36. Days exceeding water temperatures of 59.9°F in American River below Watt Avenue, 1999 – 2023, July through September.

During the adult migration and holding period in the Stanislaus River, historical daily average water temperatures are above the virulence threshold of 59.9°F in September and October (Figure 7-29). The **proportion** of adults in the Stanislaus River when water temperatures are above the virulence threshold is likely **small**, as adult steelhead start migrating in September.

Results for the 59.9°F pathogen virulence limit are presented in Table 7-16 for Orange Blossom Bridge and Table 7-17 for the confluence. At Orange Blossom Bridge, the percent of months above the limit for all water year types combined is 28.0% under the Proposed Action phases. The highest percent of months above the limit occurred in critical water years and the lowest percent of months above the limit occurred in wet years.

Table 7-16. Percent of months above the 59.9°F pathogen virulence water temperature threshold for adult steelhead migration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, July through March.

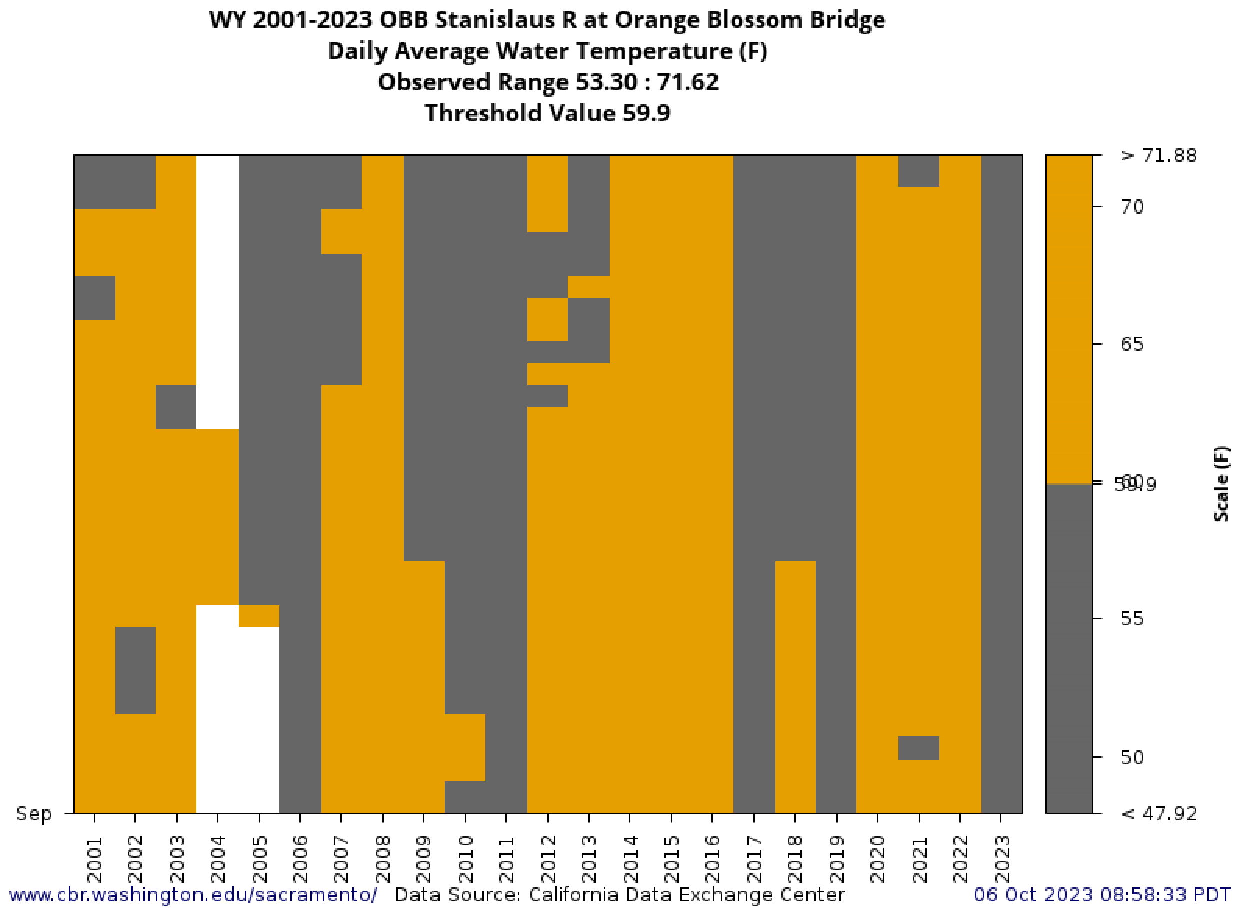
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	46.0	16.7	17.2	17.7	17.7	17.7
AN	44.4	26.9	29.6	29.6	29.6	29.6
BN	45.3	29.7	27.3	27.3	27.3	27.3
D	45.1	33.3	31.4	31.4	31.4	31.4
C	48.0	35.4	35.0	33.0	33.0	33.0
All	46.2	28.9	28.6	28.0	28.0	28.0

At the confluence, the percent of months above the limit for all water year types is 43.5% under the Proposed Action phases (Table 7-17). The highest percent of months above the limit occurred in critical water years and the lowest percent of months above the limit occurred in wet years.

Table 7-17. Percent of months above the 59.9°F pathogen virulence water temperature threshold for adult steelhead migration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River above confluence with San Joaquin River, July through March.

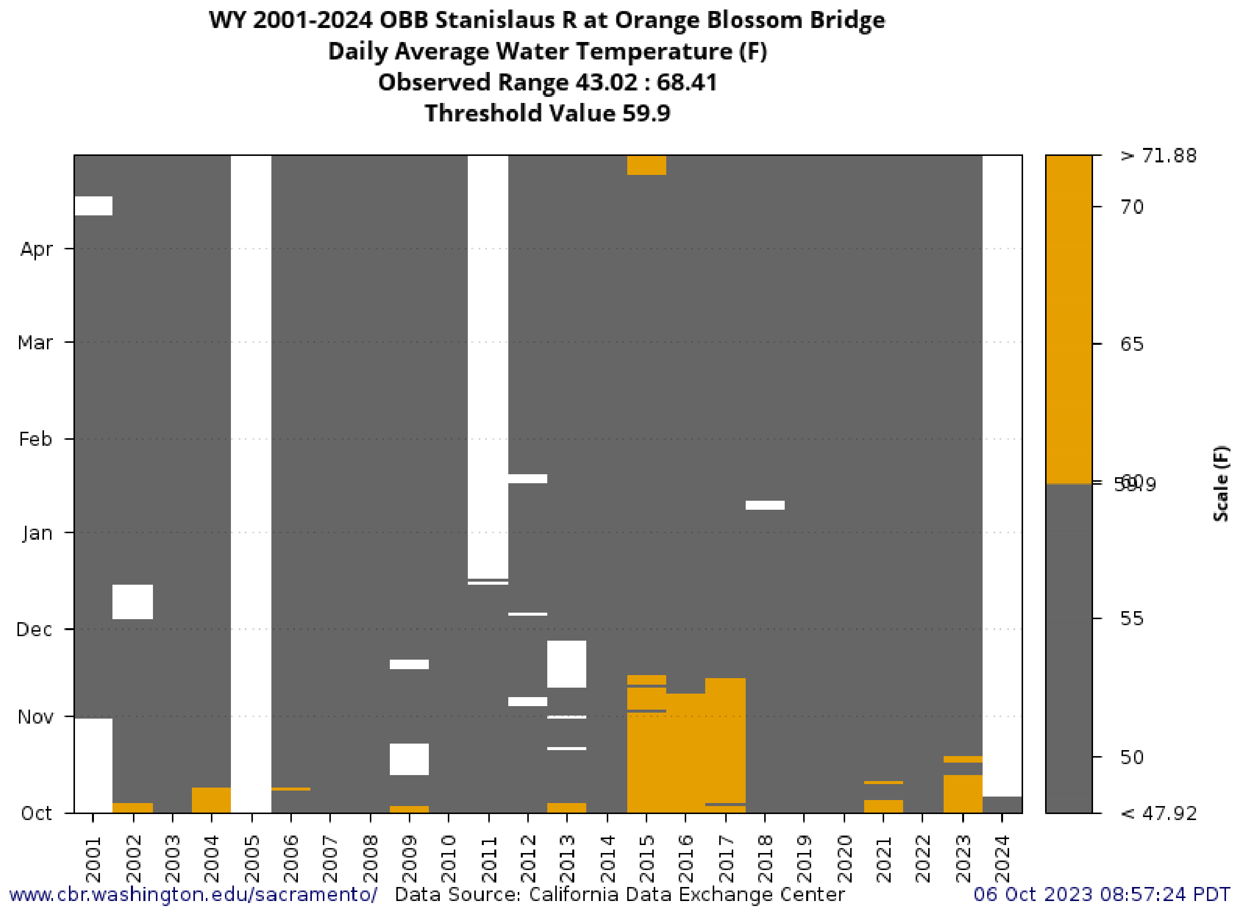
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	46.5	31.8	34.8	35.4	35.4	35.4
AN	44.4	38.9	38.9	39.8	39.8	39.8
BN	44.5	43.0	38.3	38.3	38.3	38.3
D	46.4	49.0	46.4	46.4	46.4	46.4
C	48.0	53.4	52.4	51.0	51.0	51.0
All	46.4	44.5	43.7	43.5	43.5	43.5

Historical water temperatures near Orange Blossom (Figure 7-37; Figure 7-38) indicate the frequency of occurrence is likely **high**, as the threshold is reached in 18 out of 23 years. In the fall, storage may reduce flows which may increase the water temperature stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-37. Days exceeding water temperatures of 59.9°F in Stanislaus River at Orange Blossom Bridge, 2001 – 2022, September.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-38. Days exceeding water temperatures of 59.9°F in Stanislaus River at Orange Blossom Bridge, 2001 – 2023, October through March.

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 *O. mykiss* nor to populations from the CVP rivers and tributaries of the Central Valley. The water quality monitoring data through SacPAS provides quantitative data on each watershed to assess whether a threshold was met (Columbia Basin Research 2023).

- McCullough (1999) is quantitative, not species-specific, not location specific, published research on virulence temperature thresholds.
- Historical water temperatures are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed from long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.

- Historical adult migration-timing observations are quantitative, species-specific, location-specific, published in technical memos and annual reports from technical teams, not expected to have statistical power.
- HEC-5Q water temperature modeling are quantitative, not species-specific (environmental variable) and location-specific. The model was developed to evaluate reservoir systems using control points, and is widely accepted as the temperature modeling system for use in the upper Central Valley 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
- Clear Creek
    - Water Temperature Management
- American River
    - Water Temperature Management
- Stanislaus River
    - Stepped Release Plan

7.2.2 Adult Spawning

Steelhead are found throughout the Central Valley. Adult steelhead are known to spawn in the American River, Stanislaus River, Clear Creek, and the Sacramento River from Keswick Dam downstream to Red Bluff. No spawning has been reported in the Delta or San Joaquin River. Females will choose cold oxygenated gravel-sized material for building redds and may include mixtures of sand and cobble (Bovee 1978).

The spawning timing varies slightly depending on the watershed. Construction of redds provide observations of spawning, although redd data are not typically linked to life-history type.

Steelhead mostly use the Sacramento River as a migratory corridor for reaching other tributaries to spawn. Data on steelhead spawning in the mainstem Sacramento River is limited and likely restricted to the area upstream of Red Bluff (National Marine Fisheries Service 2009). No steelhead specific spawner surveys occur in the upper Sacramento River. Data from recent surveys for the four runs of Chinook salmon have found carcasses of *O. mykiss* but the majority are thought to be resident trout adults (Killam 2022). For the Sacramento River, spawning timing was taken from historical data by Hallock (1989) which indicates spawning starts in December, peaks in February, and can last until May.

In Clear Creek, the temporal distribution of redd count data shows spawning December through April, with peak spawning January (Schaefer et al. 2019; Provins and Chamberlain 2019a, 2019b, 2020).

In the lower American River, redd surveys have reported spawning January through mid-April, with peak spawning in February (Sweeney et al. 2021). The median months of spawning from 2002-2021 were from January through March. Redd surveys on the lower American River do not occur until the first week of January, and there are reports from the Sacramento Water Forum (2015) that indicate spawning starts in late December. Therefore, the timing window of spawning on the American River was analyzed from late December until March.

Data on steelhead spawning in the Stanislaus River is limited, but adults appear to spawn primarily from January to April. In 2021, as part of the reasonable and prudent measure to accelerate steelhead monitoring and research in the NMFS (2019) BiOp, CDFW initiated the Stanislaus River Life Cycle Monitoring Program. Based on the initial redd survey report, which had a late start due to COVID-19 restrictions, spawning appears to start in February and last until April (Kok and Keller 2023). Although few steelhead spawning surveys have been conducted in the Stanislaus River, spawning *O. mykiss* have been documented upstream of the Highway 120 Bridge in Oakdale, between Goodwin Dam and the Oakdale Recreation Area.

The stressors influencing adult steelhead spawning include in-river fishery and poaching, stranding risk, competition, introgression, and broodstock removal, toxicity from contaminants, dissolved oxygen, food availability and quality, water temperature, pathogens and disease, and spawning habitat and are described in Section 7.1.3, *Limiting Factors, Threats, and Stressors*.

The Proposed Action is not anticipated to change the stressors for *In-River Fishery and Poaching, Stranding Risk, Competition, Introgression*, and *Broodstock Removal*.

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

- The Proposed Action may increase the *toxicity from contaminants stressor* in the CVP rivers and tributaries. During the spawning period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam. Reduced flows may concentrate contaminants when contaminants are present. During spawning, adults do not typically eat, which reduces their exposure to contaminants in prey during this life stage.

  Monitoring of adults on Clear Creek and the Sacramento, American, and Stanislaus rivers has not shown fish kills that may be indicative of contaminants at levels likely to affect adult steelhead. Evidence presented in the toxicity and contaminants discussion for Section 7.2.1, *Adult Migration and Holding*, above is applicable for the toxicity and contaminants section for Adult Spawning.

- The Proposed Action may increase the *dissolved oxygen* stressor in the CVP rivers and tributaries. During the spawning period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam. Changing flows from seasonal operations may result in warmer water temperatures and lower dissolved oxygen.

Water quality monitoring in the Sacramento River and Stanislaus River suggest dissolved oxygen levels are well above 5.0 mg/L during this period. Historical DO measurements for the American River and Clear Creek are limited, however, dissolved oxygen levels in the American River and Clear Creek are not expected to be below this threshold during spawning.

Evidence presented in the dissolved oxygen discussion for the Section 7.2.1, *Adult Migration and Holding,* above is applicable for the dissolved oxygen section for Adult Spawning.

- The Proposed Action may increase the *food availability and quality* stressor in the CVP rivers and tributaries. During the spawning period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam. Operations resulting in decreased flows would provide less inundated habitats. These changes may modify food web processes and cause a decrease in the quality of food available to steelhead.

  Adult steelhead may occasionally feed while in-river, but it is not considered essential to successful spawning, as many adults will fast in freshwater. Therefore, impacts to macroinvertebrate communities, mollusks, and forage fish as a result of seasonal operations are expected to be discountable.

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 provided.

7.2.2.1 Water Temperature

The proposed storing and diverting of water may generally increase the water temperature stressor. Under the Proposed Action, the water temperature stressor may increase the Clear Creek and Sacramento, American and Stanislaus rivers. During the adult spawning period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring. As part of the drought toolkit, Reclamation may operate the TCD to release warmer water temperatures to preserve water for winter-run Chinook salmon egg incubation later in the year. Warmer water temperatures may add stress on adults and reduce spawning success. Warmer water temperatures may add stress on adults taxed from escapement and reduce spawning success. Appendices L, M, and N address temperature related effects associated with the Proposed Action.

The Proposed Action includes the following components/conservation measures to address water temperature management in the American River: (1) Reclamation, through Governance, will continue to annually prepare a TMP for the summer through fall. TMP to contains: (a) forecasts of hydrology and storage; and (b) modeling run or runs, using these forecasts, demonstrating what temperature compliance schedule can be attained; (2) Reclamation will plan shutter configurations to attain the best possible (lowest numbered) temperature schedule; (3)

Reclamation will implement the ATSP in developing the TMP. For greater than 56°F at Hazel Avenue in November, the TMP will evaluate a power bypass.

The Proposed Action also includes a Stepped Release Plan for the Stanislaus River.

Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F (Bell 1991; Richter and Kolmes 2005, Federal Energy Regulatory Commission 1993:124).

The increase in water temperature stressor in the Sacramento River, Clear Creek, American River and Stanislaus River is expected to be **sub-lethal**. Water temperatures above the criteria may increase overall harm to adults spawning and reduce spawning success.

Although the Proposed Action may increase the water temperature stressor, unsuitable water temperatures for adult steelhead 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 time-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 winter-run Chinook adult holding and spawning by using the TCD, and this may affect steelhead eggs and juvenile rearing. Different approaches have targeted different water temperatures and locations throughout the years including a warmwater bypasses to conserve limited coldwater pool.

Prior to the construction of Folsom and Nimbus dams, CV steelhead would seek out coldwater refuges in higher elevation habitats of the basin. Up until completion of the dams in 1955, maximum water temperatures during summer frequently reached water temperatures as high as 75°F to 80°F in the lower American River (Gerstung 1971). During the late 1960s, Reclamation designed a modification to the trash rack structures to provide selective withdrawal capability at Folsom Dam through the Folsom Power Plant. The steel trash racks are now equipped with three groups of shutters that can pull water from various elevations, which have different temperatures when the lake is thermally stratified. This allows for limited discretionary temperature management of the lower American River.

In addition to steelhead, fall-run Chinook salmon also spawn in the American River below Nimbus Dam. The Nimbus Fish Hatchery, located just below Nimbus Dam, supports populations of both CV steelhead and fall-run Chinook salmon in the lower American River. Operating Folsom Dam to provide suitable water temperatures for returning fall-run Chinook salmon often limits the amount of coldwater available for steelhead spawning and rearing in the lower American River.

In 2009, NMFS issued an RPA that required Reclamation to prepare and implement a TMP by May 15 each year for the American River. Reclamation proposed a similar TMP in 2019.

To reduce the water temperature stressor in the American River, Reclamation recently completed the WTMP effort, which is intended to enhance modeling capabilities to predict summer and fall water temperature through facilities operations, such as the Folsom Dam Temperature Shutters.

In addition, past, current, and ongoing restoration projects on the American River increase the amount of suitable spawning habitat conditions for steelhead. If monitoring conditions exist, steelhead spawning survey reports are completed annually to assist in the enhancement or creation of additional spawning habitat areas for steelhead on the American River.

On the Stanislaus River, the completion of Goodwin Dam, owned and operated by the OID and SSJID, in 1912 has excluded salmon and steelhead from 100 percent of their historical spawning and rearing habitat on the Stanislaus River (Lindley et al. 2006). Since that time, salmon and steelhead have had to spawn downstream of Goodwin Dam on the Stanislaus River which experience greater water temperatures. In 1926 and 1958, respectively, OID and SSJID built the old Melones Dam and Tulloch Dam on the Stanislaus River (both are above Goodwin Dam). In 1978, above both Goodwin and Tulloch Dams, the USACE completed construction of New Melones Dam and Reservoir, which inundated the old Melones Dam. None of the dams on the Stanislaus River have a TCD, so the only mechanism for temperature management on the Stanislaus River is direct flow management. Reclamation currently operates New Melones Dam. Past operational releases from New Melones Dam have influenced the extent of cool water habitat available below Goodwin Dam. In 2009, NMFS issued an RPA that dictated specific temperature targets for the Stanislaus River to benefit steelhead. Since 2019, Reclamation has implemented an SRP for the Stanislaus River. The SRP does not set water temperature standards for the Stanislaus River, but it does include minimum flow targets that are intended to benefit CV steelhead, including water temperature benefits. The minimum volumes included in the SRP will continue to be implemented to provide benefits to steelhead spawning in the Stanislaus River.

Each year, several pulse flows occur to benefit different life stages of steelhead and other salmonids. Fall pulse flows usually occur in October through early November prior to peak spawning by adults, and timing may vary based on environmental conditions to achieve suitable habitat (DO and temperature) conditions for migration and holding.

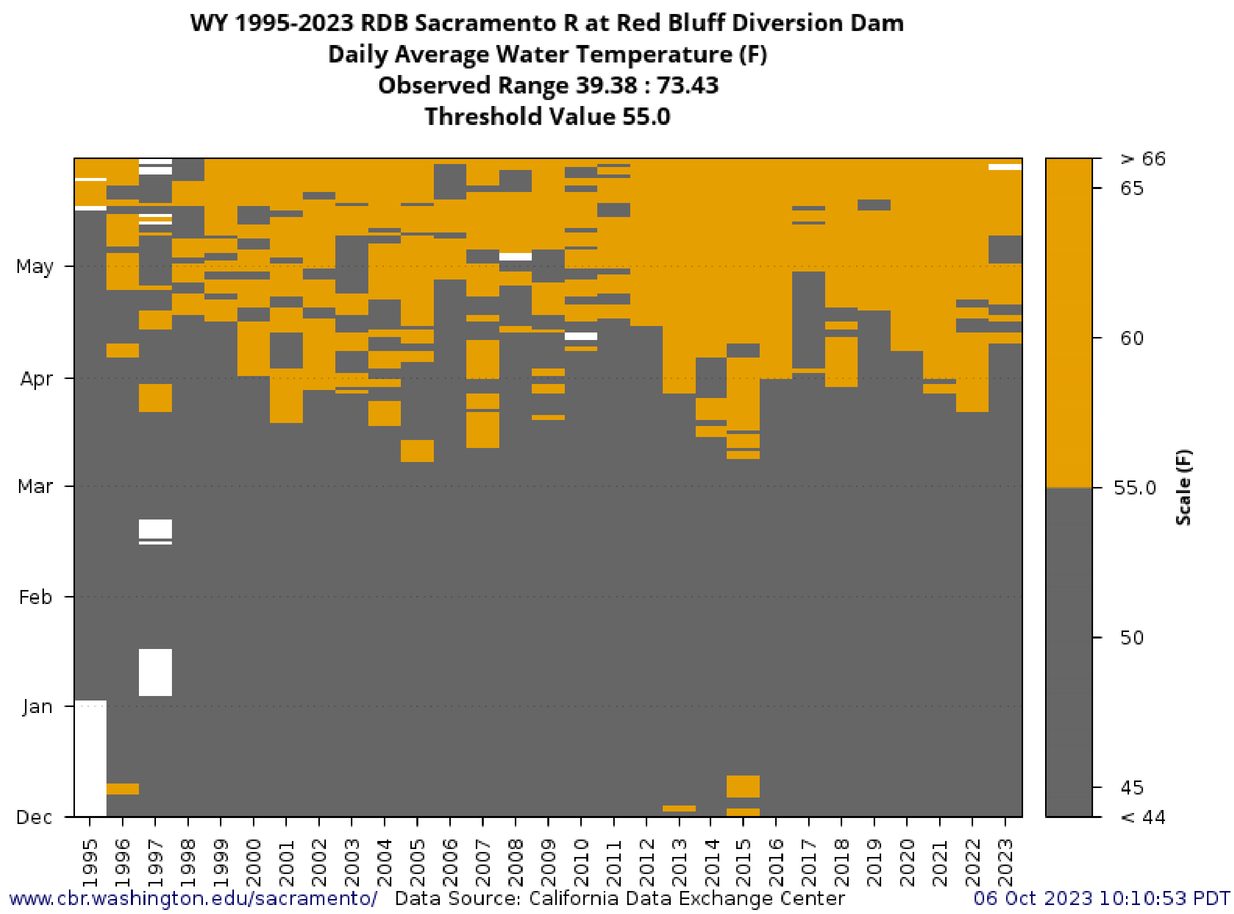
The **proportion** of the population affected by the Proposed Action depends on when temperature management starts. The proportion of adults in the Sacramento River when water temperatures are above the criteria is likely **small**, as adult steelhead spawning peaks in February.

Literature on critical water temperatures historically identified 55°F as the threshold temperature to impair successful spawning.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

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. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed water temperature criteria obtained from scientific literature.

During the adult spawning period in the Sacramento River, historical daily average water temperatures are above the thermal threshold for successful spawning of 55°F from March through May (Figure 7-39).



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-39. Days exceeding water temperatures of 55°F in Sacramento River at Red Bluff Diversion Damn (RBDD), 1995 – 2023, December through May.

Results for the 41°F to 55°F range are presented in Table 7-18 for the Sacramento River at Keswick and Table 7-19 for the Sacramento River at the RBDD. At Keswick, the percentage of months outside the optimal temperature range were from 6.3% in Dry to 1.3% in Above Normal water year types. In general, the percentage of months outside of the optimal temperature range was similar under the Proposed Action phases, but varied across water year types with the highest percentage of months outside of the temperature range in Dry water year types during the period of December through May.

Table 7-18. Percent of months outside the 41°F to 55°F water temperature range for successful steelhead spawning by water year type and for all years combined, Sacramento River at Keswick, December through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	39.9	4.8	4.2	1.8	1.8	1.8
AN	48.1	3.8	3.8	1.3	1.3	1.3
BN	59.3	4.6	8.3	2.8	3.7	2.8
D	61.1	4.9	13.2	5.6	5.6	6.3
C	58.9	7.4	8.4	4.2	3.2	3.2
All	52.7	5.1	7.7	3.2	3.2	3.2

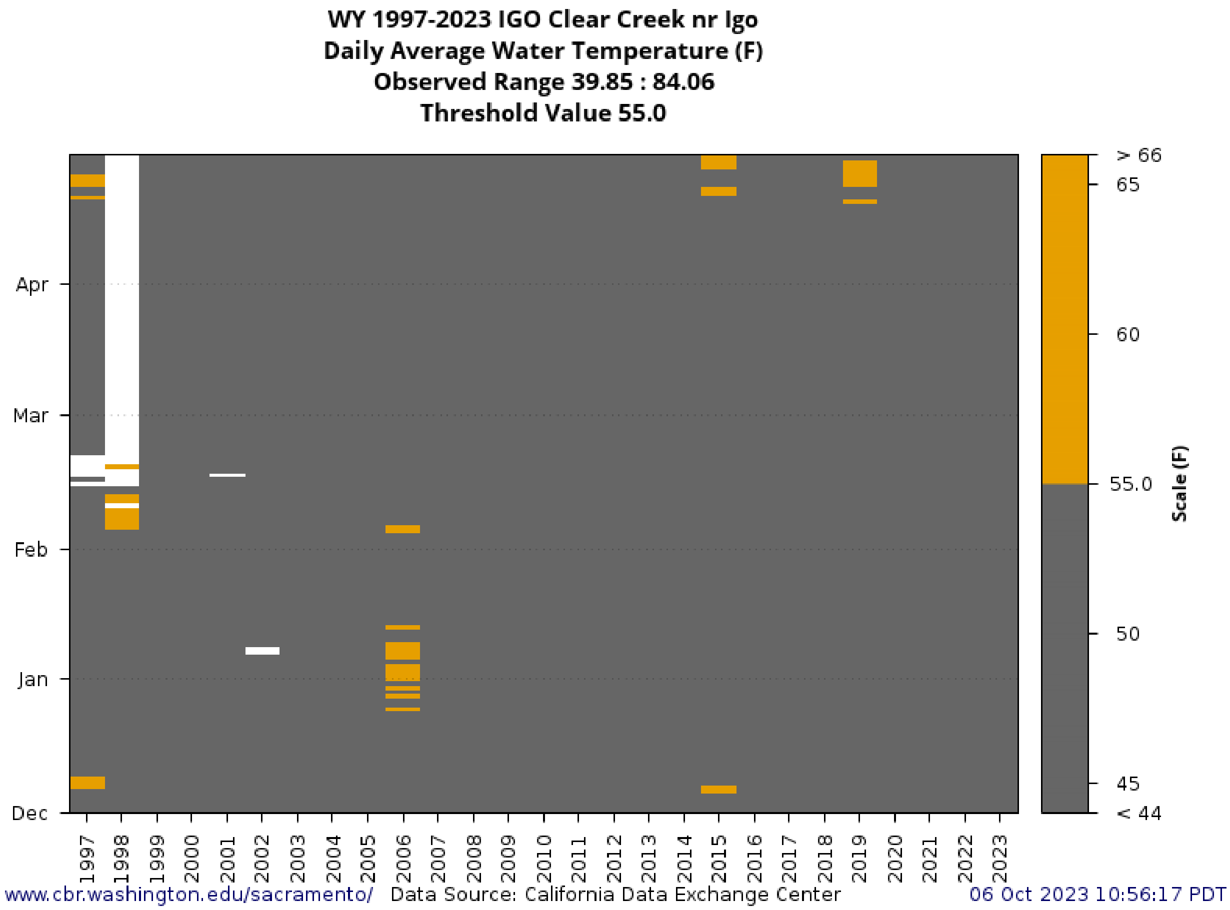
At the Sacramento River at the RBDD, the percentage of months outside the 41°F to 55°F range under the Proposed Action phases range from 40.0% during Critical water years to 30.4% of months during Wet water years. Overall, the percentage of months outside the range increased from wetter to drier water year types during the period of December through May.

Table 7-19. Percent of months outside the 41°F to 55°F water temperature range for successful steelhead spawning by water year type and for all years combined, Sacramento River at Red Bluff Diversion Dam, December through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	41.7	29.8	30.4	30.4	30.4	30.4
AN	51.9	32.9	32.9	32.9	32.9	32.9
BN	53.7	37.0	35.2	35.2	35.2	35.2
D	48.6	37.5	33.3	34.0	34.7	34.7
C	49.5	44.2	42.1	40.0	40.0	40.0
All	48.1	35.7	34.2	34.0	34.2	34.2

Historical water temperatures near RBDD (Figure 7-39) indicate the **frequency** of occurrence is likely **high**, as the threshold is reached in all years. In the spring, storage may reduce flows, which may increase the stressor.

During the adult spawning period in Clear Creek, historical daily average water temperatures occasionally exceed the thermal threshold for successful spawning of 55°F from December through April (Figure 7-40). The **proportion** of the population affected by the Proposed Action is **likely small**, as the threshold is met at the end of the spawning season but is below the threshold during peak spawning in February.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-40. Days exceeding water temperatures of 55°F in Clear Creek near Igo, 1997 – 2023, December through April.

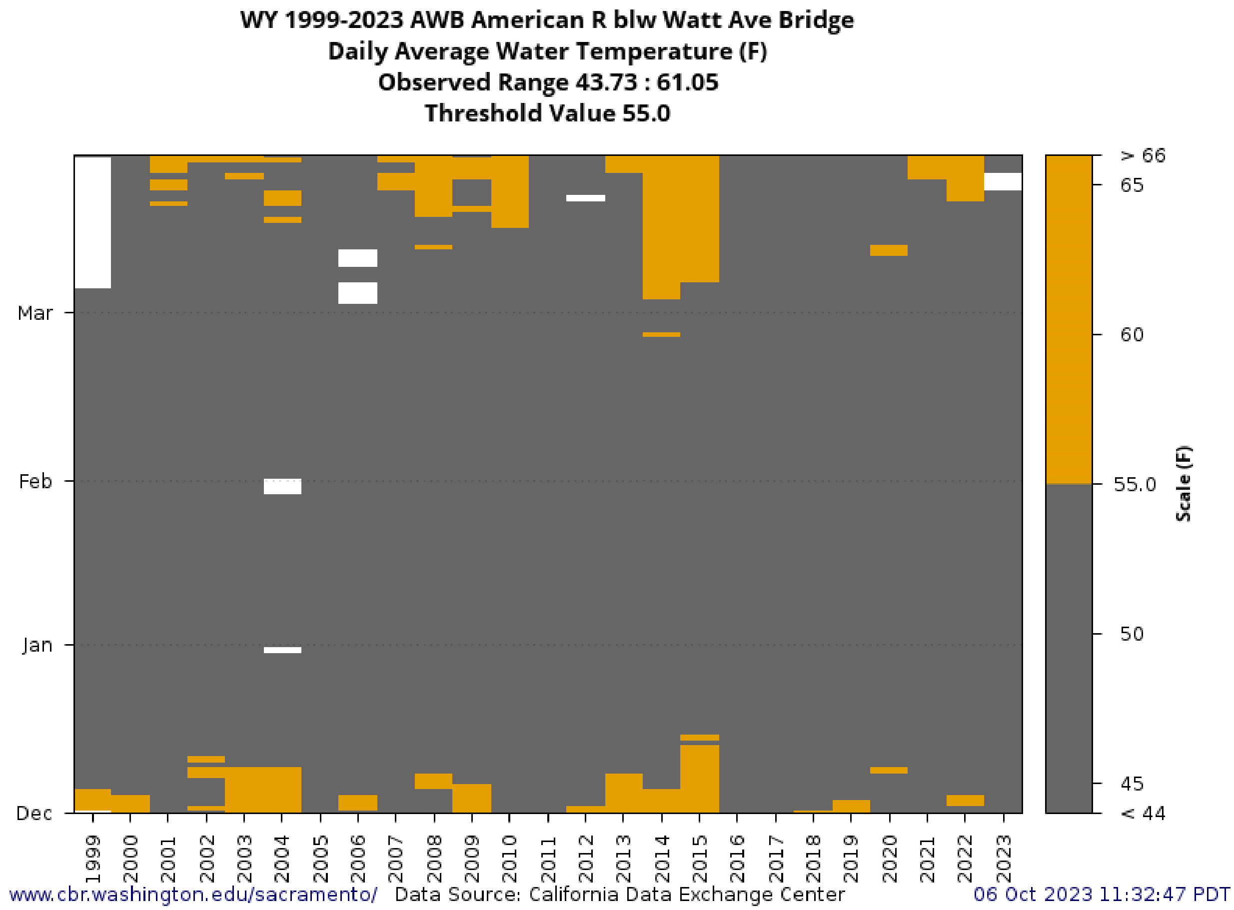
Results for the 42.1°F to 55°F range are presented in Table 7-20 for Clear Creek below Whiskeytown. At Clear Creek the percentage of months outside the optimal temperature range were from 23.8% in Wet to 5.3% in Critical water year types. Overall, the percentage of months outside the optimal range increased from drier to wetter water year types during the period of December through May.

Table 7-20. Percent of months outside the 41°F to 55°F water temperature range for successful steelhead spawning by water year type and for all years combined, Clear Creek below Whiskeytown, December through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	60.1	13.7	22.6	23.8	23.8	23.8
AN	63.3	7.6	12.7	16.5	17.7	17.7
BN	57.4	17.6	17.6	15.7	15.7	15.7
D	55.6	9.0	8.3	8.3	8.3	7.6
C	52.6	5.3	4.2	5.3	5.3	5.3
All	57.7	11.1	14.0	14.6	14.8	14.6

The **frequency** of occurrence is likely **low** as 5 out of 27 years had water temperatures above the thermal impairment threshold during the adult spawning period on Clear Creek (Figure 7-40). In the winter and spring, storage may reduce flows which may increase the stressor.

During the adult spawning period in the American River, historical daily average water temperatures have been above the thermal threshold for successful spawning of 55°F towards the beginning and end of the spawning period (Figure 7-41). The **proportion** of adults in the American River when water temperatures are warmer is likely **small**, as adult steelhead spawning peaks in February and most of the thresholds are exceeded towards the tail ends of the spawning season.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-41. Days exceeding water temperatures of 55°F in American River below Watt Avenue, 1999 – 2023, December through March.

Results for the 45°F to 55°F optimal temperature range for steelhead spawning are presented in Table 7-21 for the American River at Hazel Ave., and Table 7-22 for the American River at Watt Ave. At Hazel Ave., the percentage of months outside the range were from 7.9% in Critical to 1.9% in Above Normal water year types. During Below Normal water year types the percentage of months outside of the optimal temperature range remained at 0.0% for all phases of the Proposed Action during the period of December through March.

Table 7-21. Percent of months outside the 45°F to 55°F water temperature range for successful steelhead spawning by water year type and for all years combined, American River at Hazel Ave., December through March.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	33.0	7.1	5.4	7.1	5.4	5.4
AN	30.2	3.8	1.9	1.9	1.9	1.9
BN	25.0	2.8	0.0	0.0	0.0	0.0
D	27.1	4.2	3.1	4.2	2.1	2.1
C	30.2	6.3	3.2	4.8	7.9	4.8
All	29.3	5.1	3.0	4.0	3.5	3.0

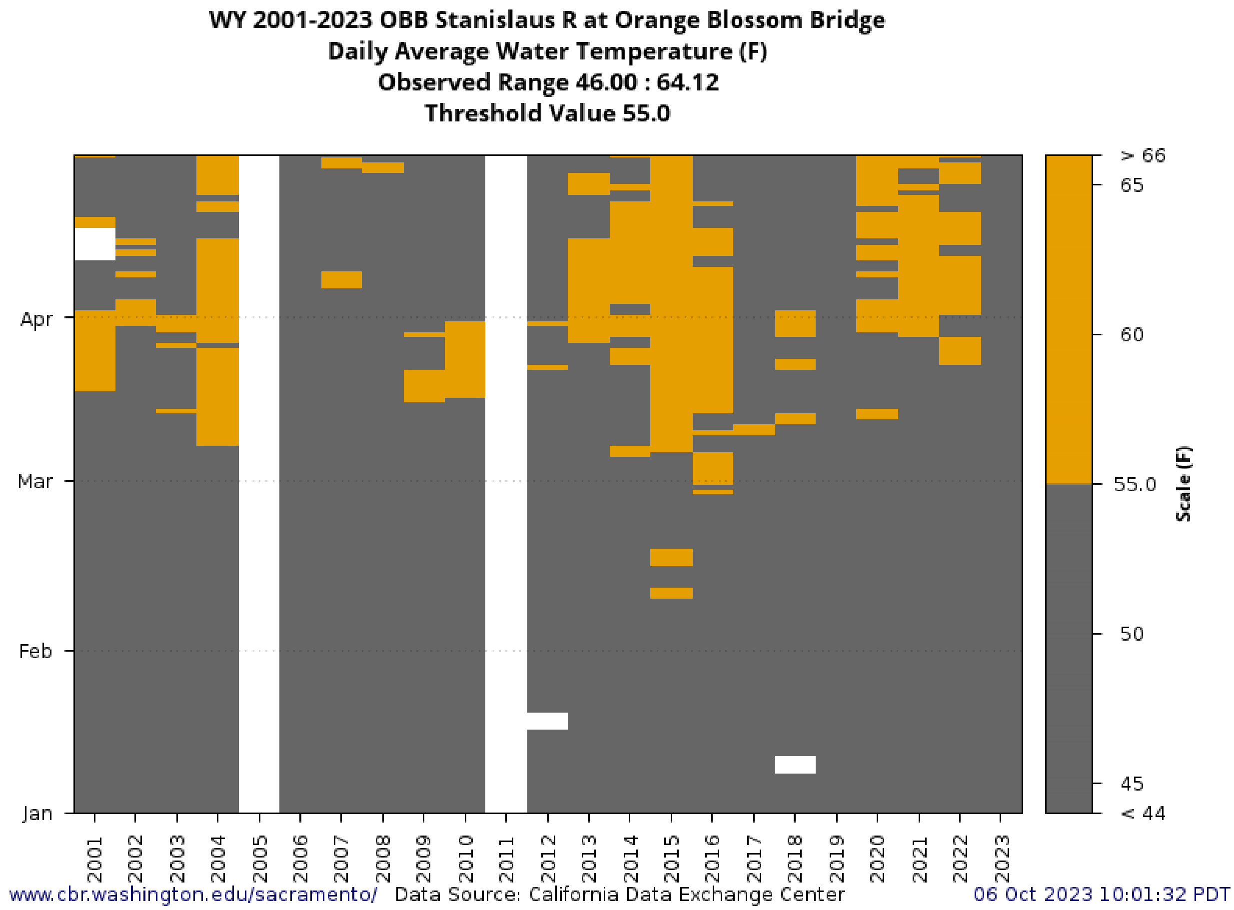
At the American River at Watt Ave., the percent of months outside the 45°F to 55°F optimal temperature range under the Proposed Action phases range from 30.2% during Critical water years to 1.8% of months during Wet water years. Overall, the percentage of months outside the range increased from wetter to drier water year types during the period of December through March.

Table 7-22. Percent of months outside the 45°F to 55°F water temperature range for successful steelhead spawning by water year type and for all years combined, American River at Watt Ave., December through March.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	25.9	6.3	1.8	1.8	1.8	1.8
AN	17.0	7.5	5.7	5.7	5.7	5.7
BN	20.8	9.7	4.2	4.2	5.6	5.6
D	29.2	14.6	11.5	12.5	12.5	12.5
C	31.7	27.0	23.8	25.4	30.2	28.6
All	25.5	12.4	8.6	9.1	10.1	9.8

Historical water temperatures near Watt Ave (Figure 7-41) indicate the **frequency** of occurrence is likely **high**, as the threshold is reached in 20 out of 25 years. In the winter and spring, proposed storage may reduce flows which may increase the stressor.

During the adult spawning period in the Stanislaus River, historical daily average water temperatures have been above the thermal threshold for successful spawning of 55°F towards the end of the spawning period (Figure 7-42). The **proportion** of adults in the Stanislaus River when water temperatures are above the threshold is likely **medium**, as adult steelhead spawning likely peaks in February.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-42. Days exceeding water temperatures of 55°F in Stanislaus River at Orange Blossom Bridge, 2001 – 2023, January through April.

Results for the 45°F to 55°F range are presented in Table 7-23 for Orange Blossom Bridge. The percentage of months outside of the optimal temperature range were from 45.2% in Critical to 1.4% of months in Above Normal water year types. Among water year types, the percentage of months outside the range generally increased from wetter to drier water year types, with the exception of Above Normal water years during the period of December through May.

Table 7-23. Percent of months outside the 45°F to 55°F water temperature range for successful steelhead spawning by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, December through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	12.1	3.8	3.0	2.3	3.0	3.0
AN	15.3	4.2	2.8	1.4	1.4	1.4
BN	17.6	11.8	3.5	4.7	4.7	4.7
D	20.6	39.2	30.4	34.3	34.3	34.3
C	37.1	50.3	43.7	45.2	45.2	45.2
All	23.1	26.7	21.4	22.4	22.6	22.6

Historical water temperatures near Orange Blossom Bridge (Figure 7-42) indicate the **frequency** of occurrence is likely **high**, as the threshold is reached in 18 out of 23 years. In the winter and spring, storage may reduce flows, which may increase the stressor.

To evaluate the **weight of evidence** for the water temperature stressor, there are water temperature thresholds from several peer reviewed articles and state issued water quality documents that are specific to *O. mykiss* and the Central Valley but aren't specific to the watersheds in this analysis. The water quality monitoring data through SacPAS provides quantitative data on each watershed to assess whether a threshold was met (Columbia Basin Research 2023).

- Richter and Kolmes (2005) is quantitative, species-specific, not location specific, published report with foundation for guidance on spawning water temperature criteria.
- Bell (1991) is quantitative, species-specific, not location specific, handbook for biological criteria and temperature effects on fish.
- Federal Energy Regulatory Commission (1993) is quantitative, species-specific, specific to Central Valley but not in locations under the CVP, literature review of optimal spawning water temperature criteria.
- Historical water temperatures are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed from long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- Historic adult spawning-timing observations are quantitative, species-specific, location-specific, published in technical memos and annual reports from technical teams, not expected to have statistical power.
- HEC-5Q water temperature modeling are quantitative, not species-specific (environmental variable) and location-specific. The model was developed to evaluate reservoir systems using control points, and is widely accepted as the temperature modeling system for use in the upper Central Valley 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
- Clear Creek
    - Water Temperature Management
- American River
    - Water Temperature Management
- Stanislaus River
    - 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
    - Drought Tool Kit Shasta Warmwater Bypass

7.2.2.2 Pathogens and Disease

The proposed storing and diverting of water may increase the pathogens and disease stressor. During the adult spawning period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring. As part of the drought toolkit, Reclamation may operate the TCD to release warmer water temperatures to preserve water for egg incubation later in the year. Appendices L, M, and N address water temperature related effects in the Proposed Action.

The increases in the pathogens and disease stressor is expected to be **sub-lethal** in the Sacramento River. Presence of pathogens and disease may increase stress on adult steelhead, reducing fitness and successful spawning. Pathogens and disease can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Seasonal operations that result in decreased flows and increased water temperature may increase pathogen concentration, horizontal transmission and pathogen virulence. Diseases affecting salmonids become highly virulent at temperatures above 59.9°F (McCullough 1999).

The Proposed Action is expected to result in insignificant changes to pathogens and disease in Clear Creek, American and Stanislaus rivers. Water temperatures are below pathogen criteria in these locations throughout the adult spawning period.

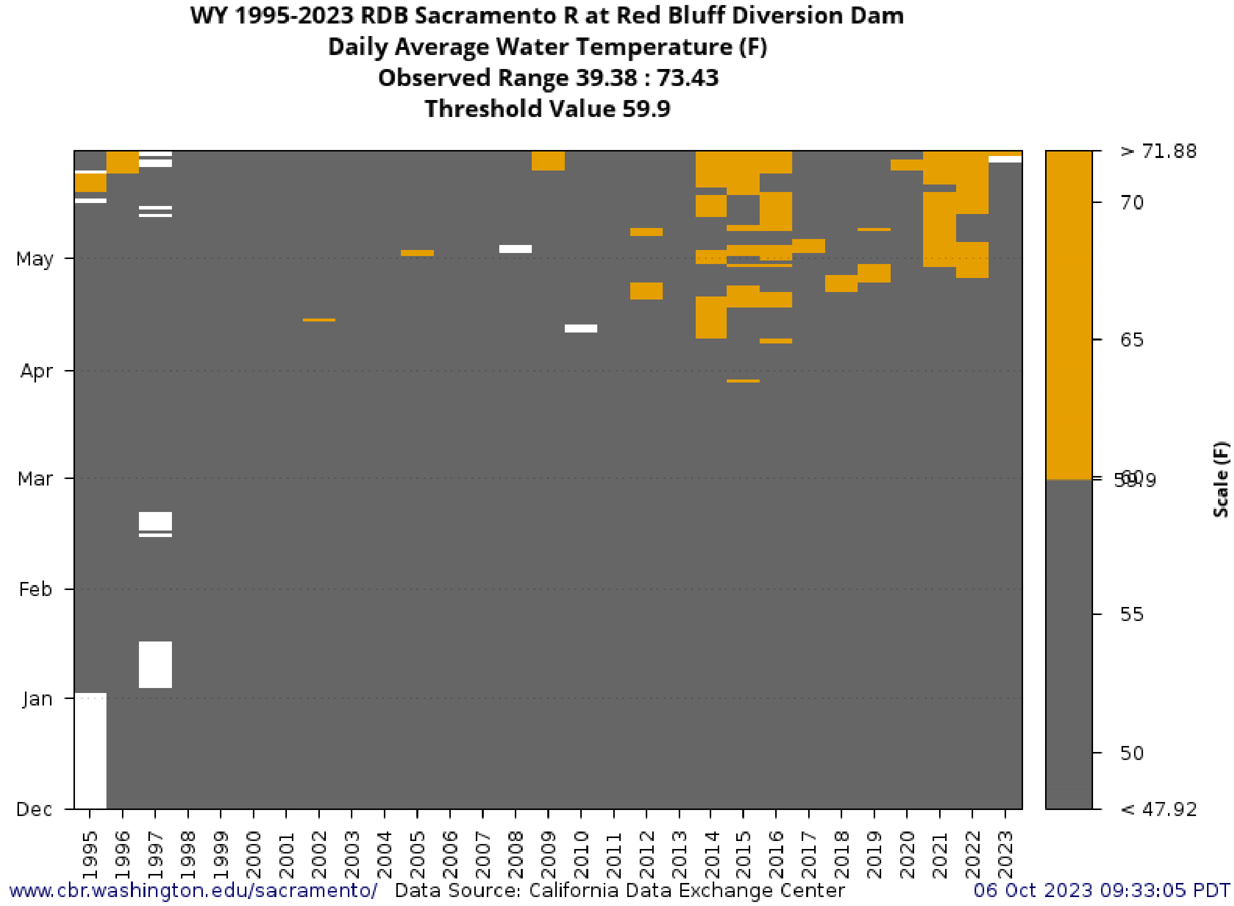
Although the Proposed Action may increase the pathogens and disease stressor in the Sacramento River, pathogens and diseases that may affect steelhead spawning exists in the **environmental baseline** (without the Proposed Action). Pathogens and disease have been present in the ambient environment since 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 (National Marine Fisheries Service 1998).

Natural steelhead 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 steelhead survival. Salmonids are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment (National Marine Fisheries Service 1996, 1998a, 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 steelhead (National Marine Fisheries Service 1996, 1998a, 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 WTMP 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 water temperature management and peak migration timing. During the adult spawning period in the Sacramento River, historical daily average water temperatures have been above the virulence threshold towards the end of the spawning period (Figure 7-43). The **proportion** of adults in the Sacramento River when water temperatures are warmer is likely **small**, as adult steelhead spawning peaks in February.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-43. Days exceeding water temperatures of 59.9°F in Sacramento River at Red Bluff Diversion Dam, 1995 – 2023, December through May.

Literature on critical water temperatures for pathogens and disease historically identified 59.9°F as the threshold temperature to increase virulence of pathogens.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

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. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed pathogens and disease water temperature criteria obtained from scientific literature.

Results for the exceedance of the 59.9°F pathogen virulence temperature threshold are presented in Table 7-24 for the Sacramento River at Keswick and Table 7-25 for the Sacramento River at the RBDD. At Keswick, the percentage of months that exceeded the temperature threshold remained at 0.0% for all phases of the Proposed Action, in all water year types, during the period of December through May.

Table 7-24. Percent of months above the 59.9°F pathogen virulence water temperature threshold for adult steelhead migration by water year type and for all years combined, Sacramento River at Keswick, December through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	0.0	0.0	0.0	0.0	0.0	0.0
AN	2.5	0.0	0.0	0.0	0.0	0.0
BN	6.5	0.0	0.0	0.0	0.0	0.0
D	4.9	0.0	0.0	0.0	0.0	0.0
C	8.4	0.0	0.0	0.0	0.0	0.0
All	4.0	0.0	0.0	0.0	0.0	0.0

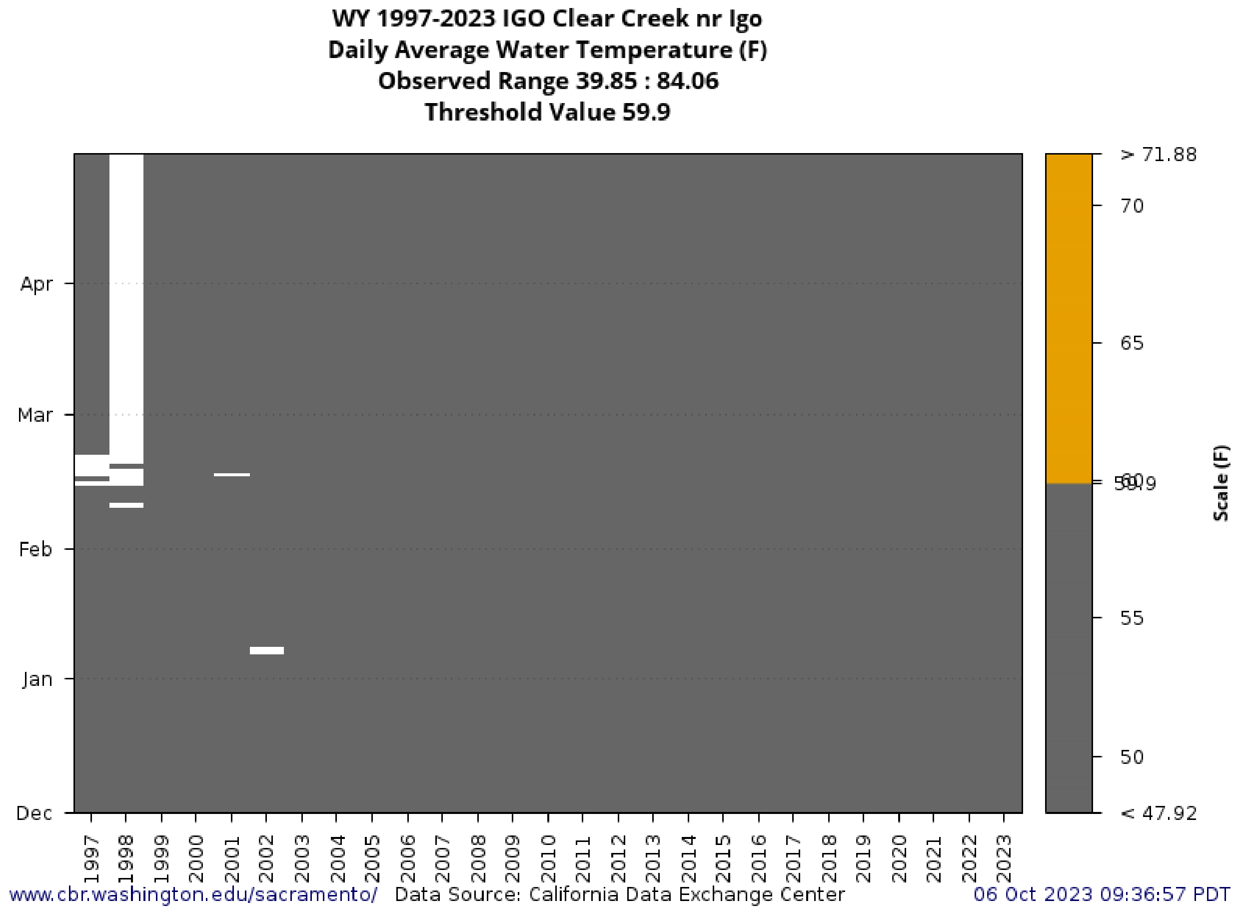
At the Sacramento River at the RBDD, the percent of months that exceeded the temperature threshold under the Proposed Action phases range from 12.5% during Dry water years to 4.6% of months during Below Normal water years. Overall, each phase under the Proposed Action performed similarly across all water year types with Below Normal, and Wet water year types having a notably lower percentage of months that exceeded the temperature threshold during the period of December through May.

Table 7-25. Percent of months above the 59.9°F pathogen virulence water temperature threshold for adult steelhead migration by water year type and for all years combined, Sacramento River at the Red Bluff Diversion Dam, December through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	10.1	11.9	12.5	7.1	7.1	7.1
AN	15.2	16.5	12.7	10.1	10.1	7.6
BN	15.7	13.0	9.3	6.5	6.5	4.6
D	17.4	20.1	15.3	12.5	10.4	12.5
C	25.3	20.0	15.8	9.5	9.5	10.5
All	16.0	16.0	13.1	9.1	8.6	8.6

Historical water temperatures near RBDD indicate the **frequency** of occurrence is likely **medium**, as the threshold is reached in 16 out of 29 years (Figure 7-43). In the spring, storage may reduce flows, which may increase the stressor.

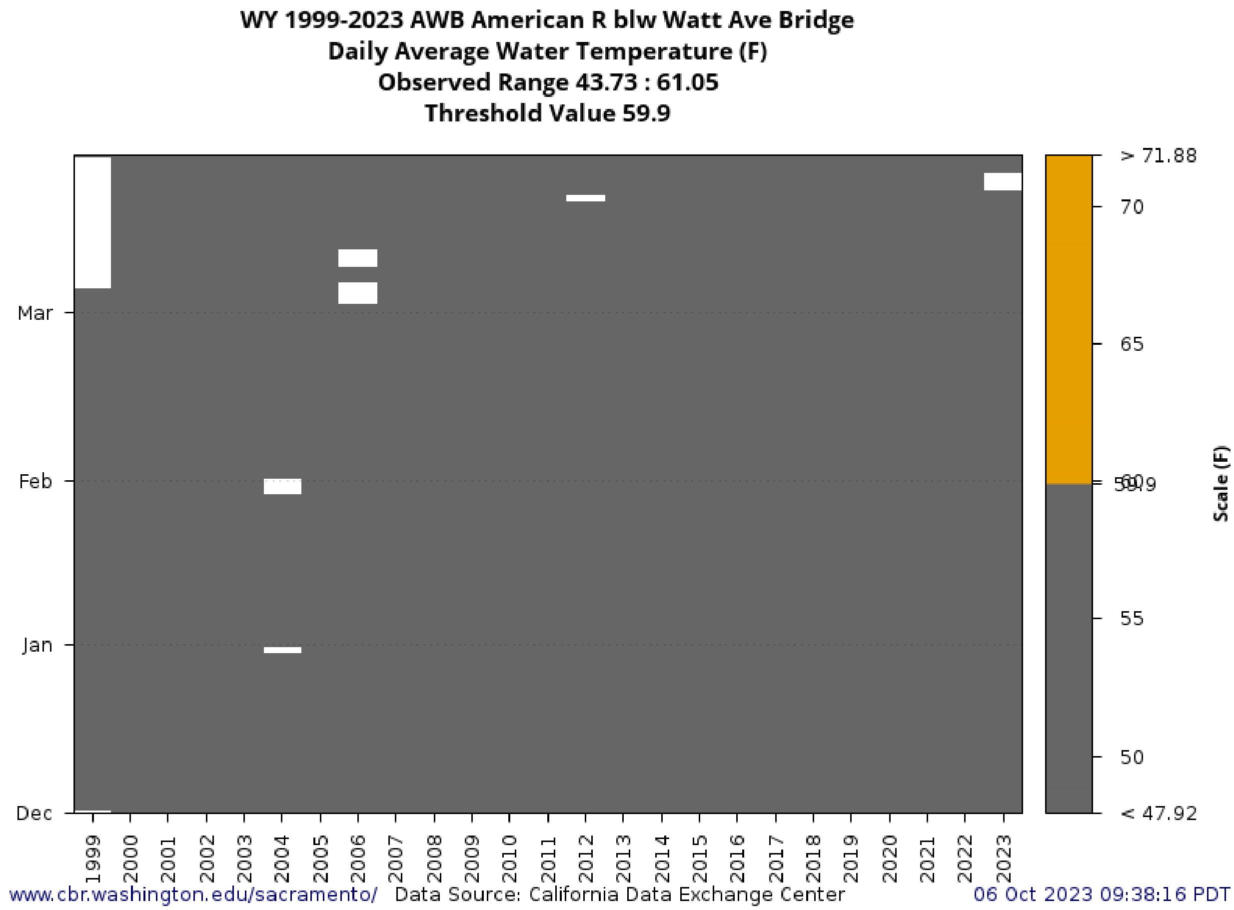
During the adult spawning period in Clear Creek, historical daily average water temperatures are below the virulence threshold throughout the spawning period of December through April (Figure 7-20; Figure 7-44).



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-44. Days exceeding water temperatures of 59.9°F in Clear Creek near Igo, 1997 – 2023, December through April.

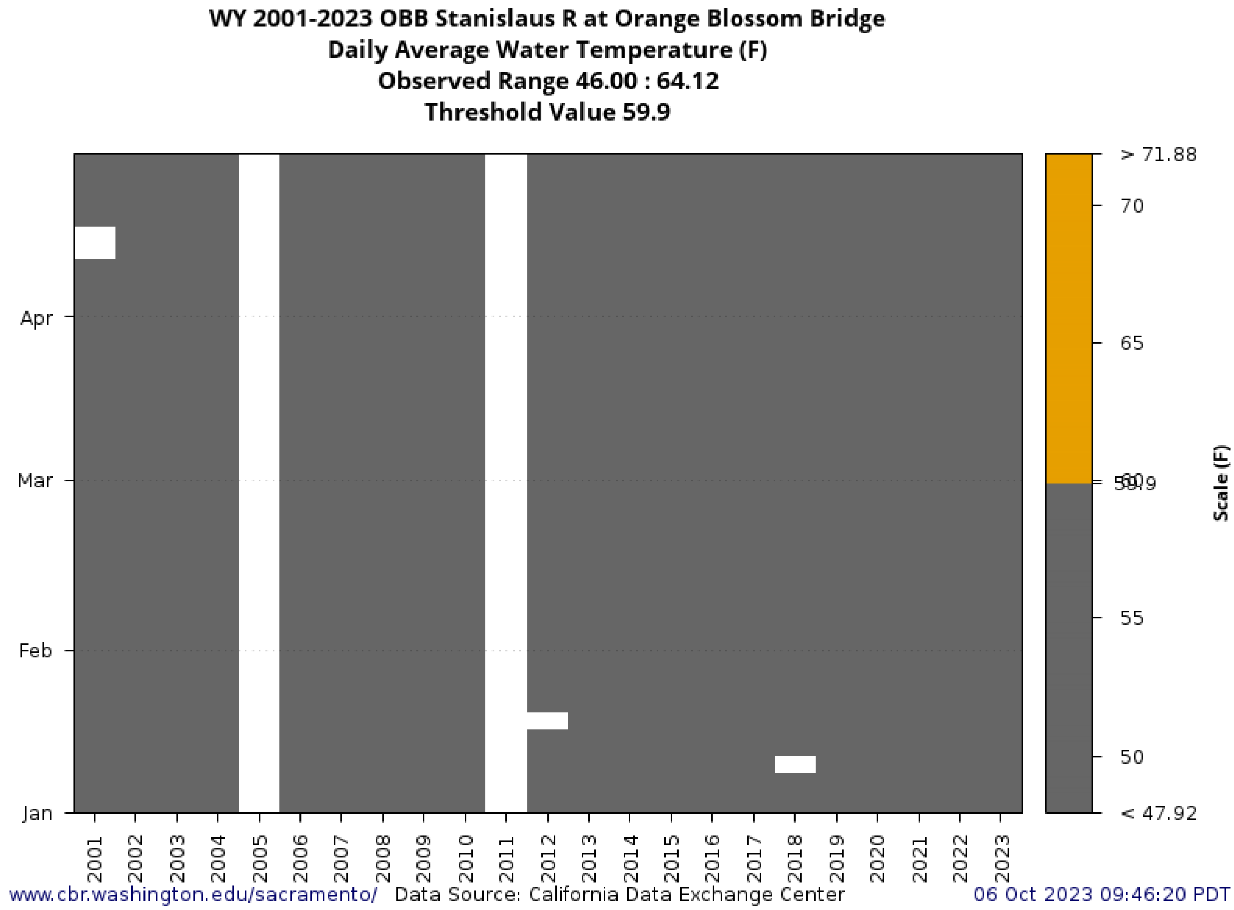
During the adult spawning period in the American River, historical daily average water temperatures have been below the virulence threshold throughout the median spawning period (Figure 7-45).



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-45. Days exceeding water temperatures of 59.9°F in American River below Watt Avenue, 1999 – 2023, December through March.

During the adult spawning period in the Stanislaus River, historical daily average water temperatures have been below the virulence threshold throughout the spawning period (Figure 7-46).



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-46. Days exceeding water temperatures of 59.9°F in Stanislaus River at Orange Blossom Bridge, 2001 – 2023, January through April.

To evaluate the **weight of evidence** for the pathogens and disease stressor, there are water temperature criteria thresholds from published literature for pathogen and disease virulence specific to Chinook salmon. These thresholds, however, are not specific to steelhead nor to the CVP rivers and tributaries of the Central Valley. The water quality monitoring data through SacPAS provides quantitative data on each watershed to assess whether a threshold was met (Columbia Basin Research 2023).

- McCullough (1999) is quantitative, not species-specific, not location specific, published research on virulence temperature thresholds
- Historical water temperatures are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed from long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.

- Historical adult spawning-timing observations are quantitative, species-specific, and location-specific. The observations are published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- HEC-5Q water temperature modeling are quantitative, not species-specific (environmental variable) and location-specific. The model was developed to evaluate reservoir systems using control points, and is widely accepted as the temperature modeling system for use in the upper Central Valley 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
- Clear Creek
  - Water Temperature Management
- American River
  - Water Temperature Management
- Stanislaus River
  - Stepped Release Plan

7.2.2.3 Spawning Habitat

The proposed storing and diverting of water may decrease the spawning habitat stressor. During the spawning period, the Proposed Action will store and divert water resulting in decreased flows in Clear Creek below Whiskeytown Dam, American River below Folsom Dam and Stanislaus River below Goodwin Dam in the winter and spring. Dudley et al. (2019) shows higher flows result in higher velocities and the potential increase of superimposition, and less suitable spawning habitat in salmonids. Appendix M, Appendix N, and Appendix O, *Tributary Habitat Restoration*, present analysis of this stressor based on suitable depths, velocities, and substrate.

The decrease in the spawning habitat stressors is potentially **beneficial**. Increases in the available spawning habitat through suitable flows may increase spawning success.

Changes to the stressor are discountable in the Sacramento River. Habitat suitability curves show lower flows increase steelhead spawning habitat quantity and quality in the Sacramento Rivers (U.S. Fish and Wildlife Service 2003). Decreased flows under seasonal operations will increase the available spawning habitat, but spawning habitat is not a limiting resource. Flow alterations outside of the 3,250 – 7,000 cfs range may result in less suitable spawning habitat in the Sacramento River, but most adults will likely spawn within the tributaries (National Marine Fisheries Service 2019).

Although the Proposed Action may decrease the spawning habitat stressor, changes in spawning habitat for steelhead exists 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.

Generally, the presence and operation of dams influence downstream spawning habitat. Dams not only influence flows and water temperatures needed to support salmon spawning, but influence the depth, quality and distribution of spawning habitat. 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. Steady base flows, together with reduced occurrence and magnitude of channel forming flows from existing structures, have resulted in the stabilization of gravel bars, riparian vegetation encroachment, and decreased habitat complexity (Graham Matthews and Associates 2011; McBain and Trush 2001).

On Clear Creek, since removal of the McKormick-Saeltzer Dam in 2000, Chinook salmon and steelhead spawn occurs below Whiskeytown Dam. The removal of the McKormick-Saeltzer Dam opened up approximately 12 miles of Clear Creek to Chinook salmon and steelhead.

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 in Clear Creek from 1997 to 2022 are summarized below in Table 7-26. The removal of the McKormick-Saeltzer Dam and restoration efforts should have reduced the spawning habitat stressor on steelhead.

Table 7-26. Gravel Placement in the Sacramento River and Clear Creek and percent of the 10,000 ton Target.

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.
Clear Creek does not have established annual gravel injection targets.

Since the 1960s, Reclamation has provided minimum flows to lower Clear Creek in accordance with a 1960 agreement with CDFW, a 1963 agreement with USFWS, and a 2002 amendment to its water rights. Those flows vary by season and water year type. Since 2009, Reclamation has provided channel maintenance flows, which are intended to increase the amount of spawning habitat available to steelhead. Except in years with significant uncontrolled spill, Reclamation will release up to 10,000 acre-feet from Whiskeytown Dam for channel maintenance, spring attraction flows, and to meet other physical and biological objectives.

On the American River, Folsom and Nimbus dams block access to historical steelhead spawning habitat. The presence and operation of the dams reduce the recruitment of spawning gravel in the American River below Nimbus Dam. To mitigate those effects, in the lower American River, roughly 24 acres have been devoted to gravel augmentation, while approximately 50 acres have focused on side channel creation. Habitat restoration projects completed in October 2022 at Nimbus Basin and Lower Sailor Bar enhanced habitat for steelhead by laying approximately 41,000 cubic yards of clean gravel into the river and excavated side channel habitat (Water Forum 2022). Those projects have improved spawning habitat for both Chinook salmon and steelhead spawning in the American River. Reclamation's habitat programs will continue through separate environmental compliance and future restoration plans as independent programs.

Whiskeytown Dam blocks coarse sediment transport and has led to channel simplification alterations in the quantity and quality of spawning habitat. 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). This project does not have specified annual gravel augmentation tonnage targets, but rather looks for continued projects (i.e., annual augmentations) to restore and manage habitat within Clear Creek. Years where a project is not implemented is considered outside of the target. Additionally, supplying ample gravel to replace lost gravel storage and reaching full gravel routing from Whiskeytown Dam to the Sacramento River confluence have been recommended as targeted outcomes, though they have yet to be fully achieved (Table 7-26 above; McBain and Trush 2001).

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.

Literature does not uniquely inform the proportion of the population.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models. A review of carcass and redd surveys does not identify redd superimposition.

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 weighted usable area (WUA) analyses are 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 Decision Support Model (DSM) are based on flow to suitable habitat area relationships used to estimate steelhead spawning habitat in all CVP tributaries.

The Sacramento River Weighted Usable Area Analysis (Appendix O, Attachment O.3, *Sacramento Weighted Usable Area Analysis*) provides context for the weighted usable area available for steelhead spawning downstream of Keswick releases. Spawning weighted usable area for steelhead peaks at approximately 3,500 cfs upstream of ACID Dam and at approximately 6,500 cfs between ACID Dam and the Cow Creek confluence, where most steelhead spawn. The WUA habitat value under the Proposed Action phases range from 68,835 to 120,958 (Figure 7-47). These WUA habitat values are consistently lowest in wet water years and successively increase in drier years, with the highest values in critical water years. These differences are attributable to the relatively low flows at which steelhead spawning WUA in the Sacramento River peaks.

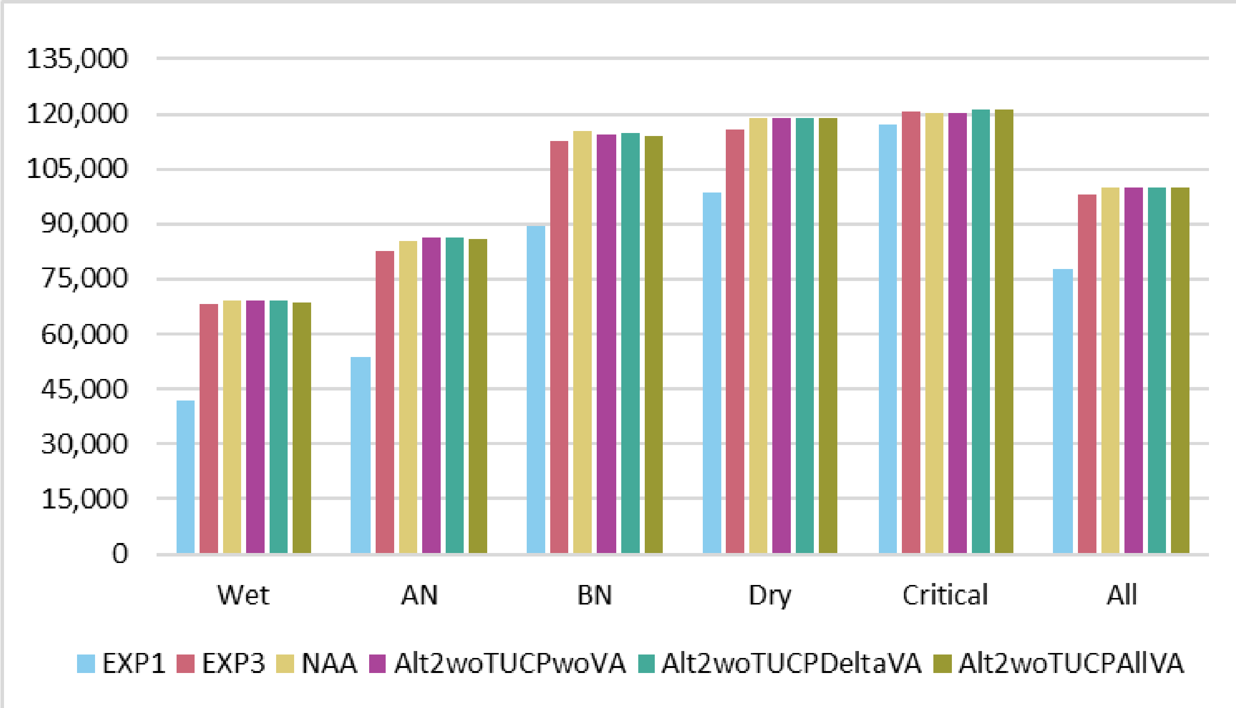
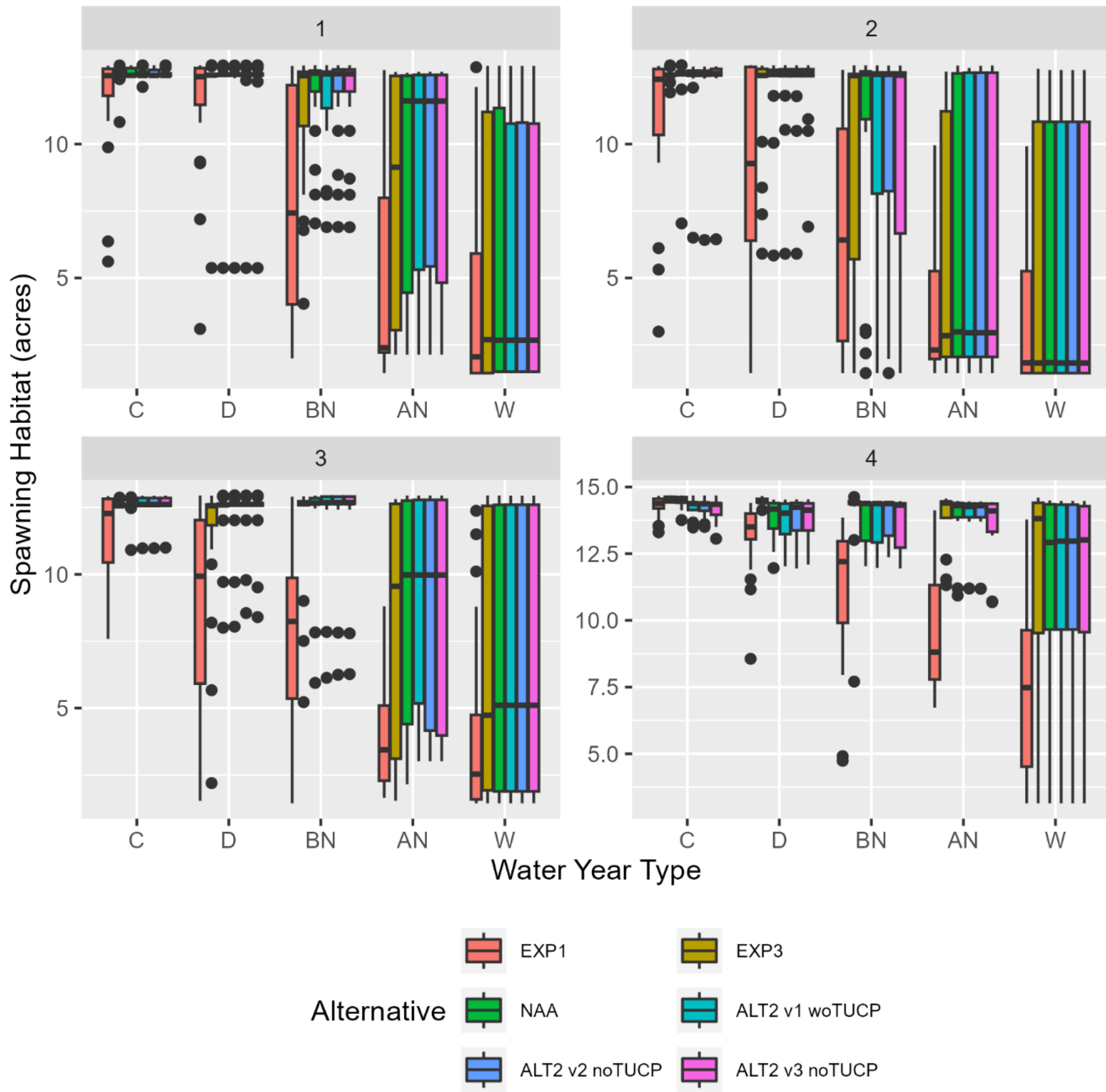


Figure 7-47. Mean Weighted Usable Area for Segments 4-6 Combined, by Water Year Type, Steelhead Spawning in the Sacramento River

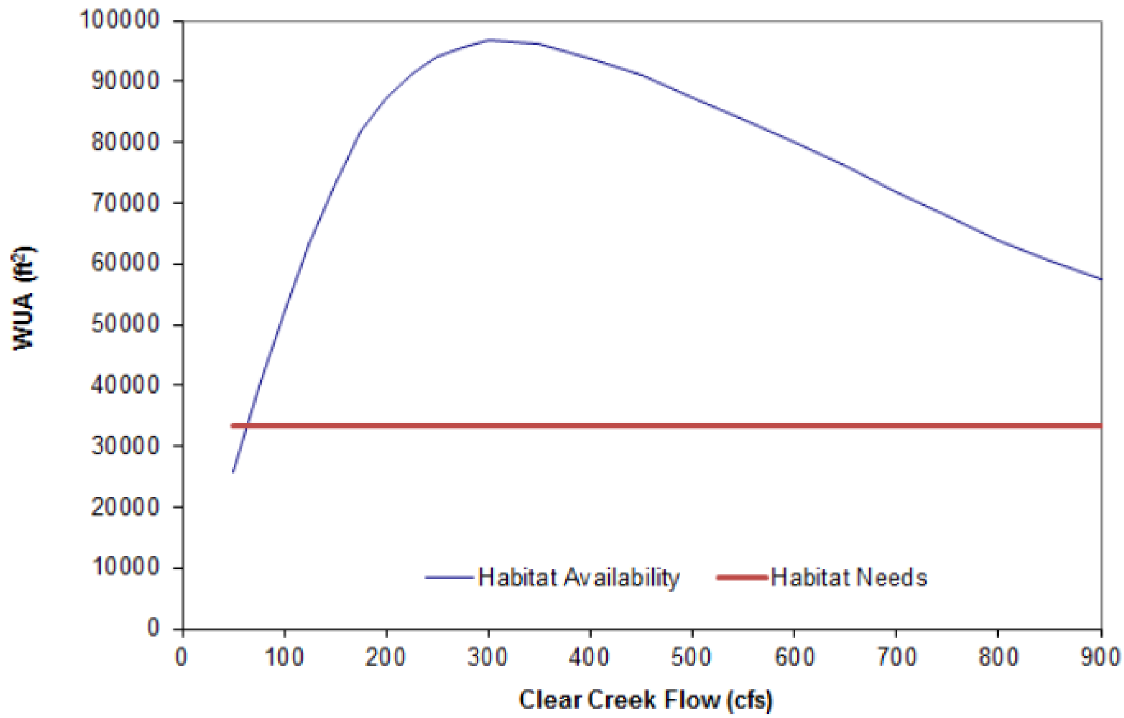
The SIT LCM Habitat Estimates, Tributary Habitat, Appendix O, Attachment O.2, *SIT LCM Habitat Estimates*, provides context for the habitat area available for steelhead spawning in the Sacramento River. The monthly habitat value under the Proposed Action phases ranges from approximately 0 to 13.24 acres (Figure 7-48). Spawning weighted usable area for steelhead peaks at approximately 3,750 cfs in the Sacramento River. Overall, the habitat values do not vary much among months or water year types, with the exception that acreage of spawning habitat was generally lower in Above Normal or Wet water year types as compared to other water year types, except in April, which was the month with the greatest acreage of spawning habitat across all months. The lowest habitat values under the Proposed Action phases occurred in February in Above Normal and Wet water year types.



Variability within months (January – April) reflects variation across CalSim WYs.

Figure 7-48. Estimated spawning habitat for Steelhead in the Upper Sacramento River.

The **proportion** of adults in Clear Creek when flows are potentially within the suitable range is likely **large**. The Clear Creek Weighted Usable Area Analysis, Appendix O, Attachment O.1, *CWP Clear Creek Weighted Usable Area Analysis*, provides context for the weighted usable area available for steelhead spawning downstream of Whiskeytown releases. Spawning weighted usable area for steelhead peaks around 300 cfs for the Upper and Lower Alluvial segments. Flow-habitat availability relationships from the Clear Creek Synthesis report also show spawning habitat availability in the Clear Creek also peaks around 300 cfs before gradually declining (Figure 7-49; U.S. Fish and Wildlife Service 2015), with a range that meets habitat needs from 50 cfs – 900 cfs. Flows may decrease in Clear Creek during winter and spring seasonal operations of Whiskeytown Reservoir and increase the total spawning habitat available for steelhead. The WUA habitat value under the Proposed Action phases range from 38,618 to 43,452 (Figure 7-50). These WUA habitat values are consistently highest in wet water years and successively decrease in drier years, with the lowest values in critical water years.



Source: U.S. Fish and Wildlife Service 2015.

Figure 7-49. Flow-habitat availability relationships in Clear Creek - WUA by Clear Creek flow (cfs).

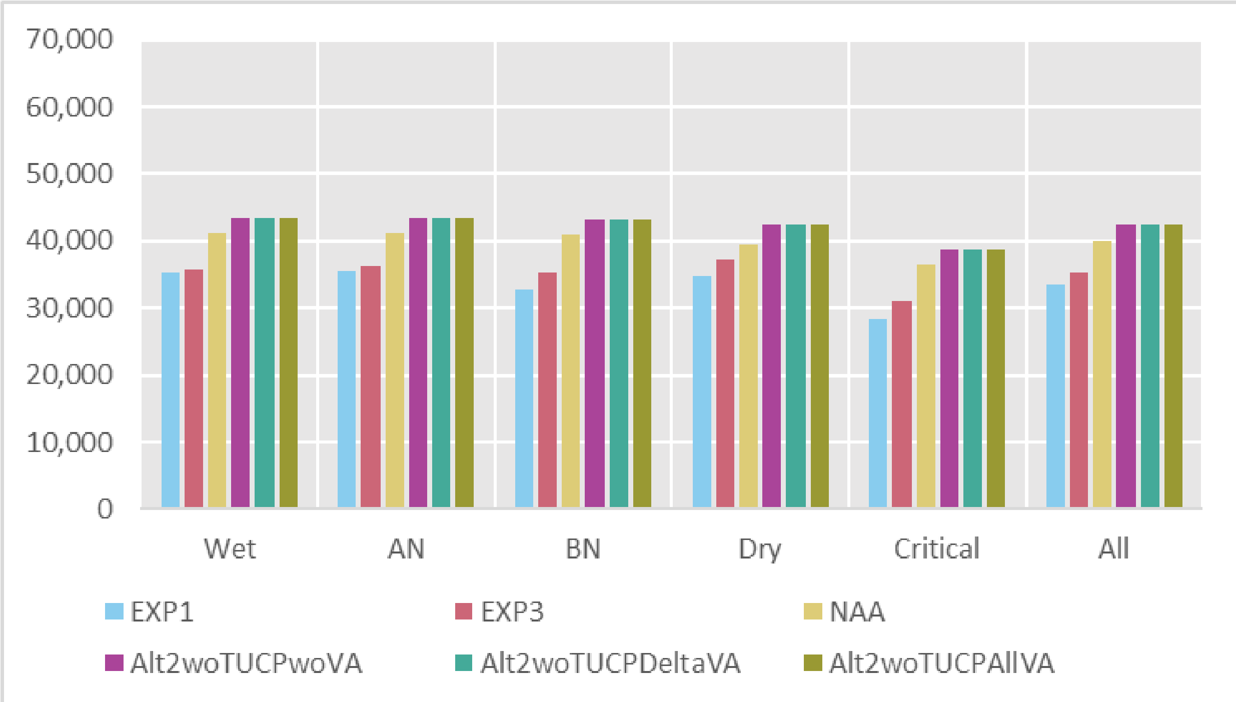
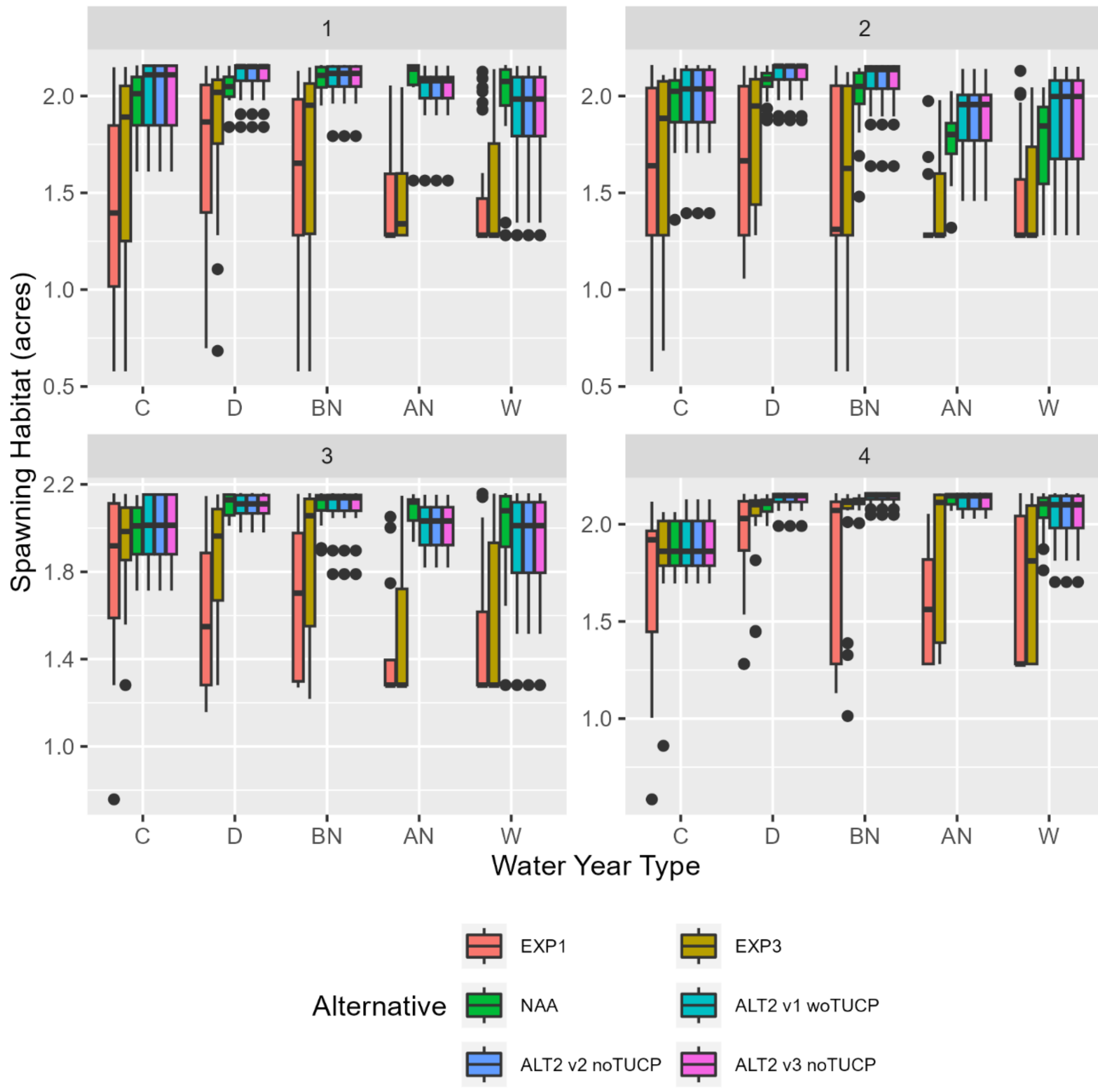


Figure 7-50. Mean Weighted Usable Area for Combined Lower Alluvial, Upper Alluvial and Canyon Segments by Water Year Type, Steelhead Spawning in Clear Creek

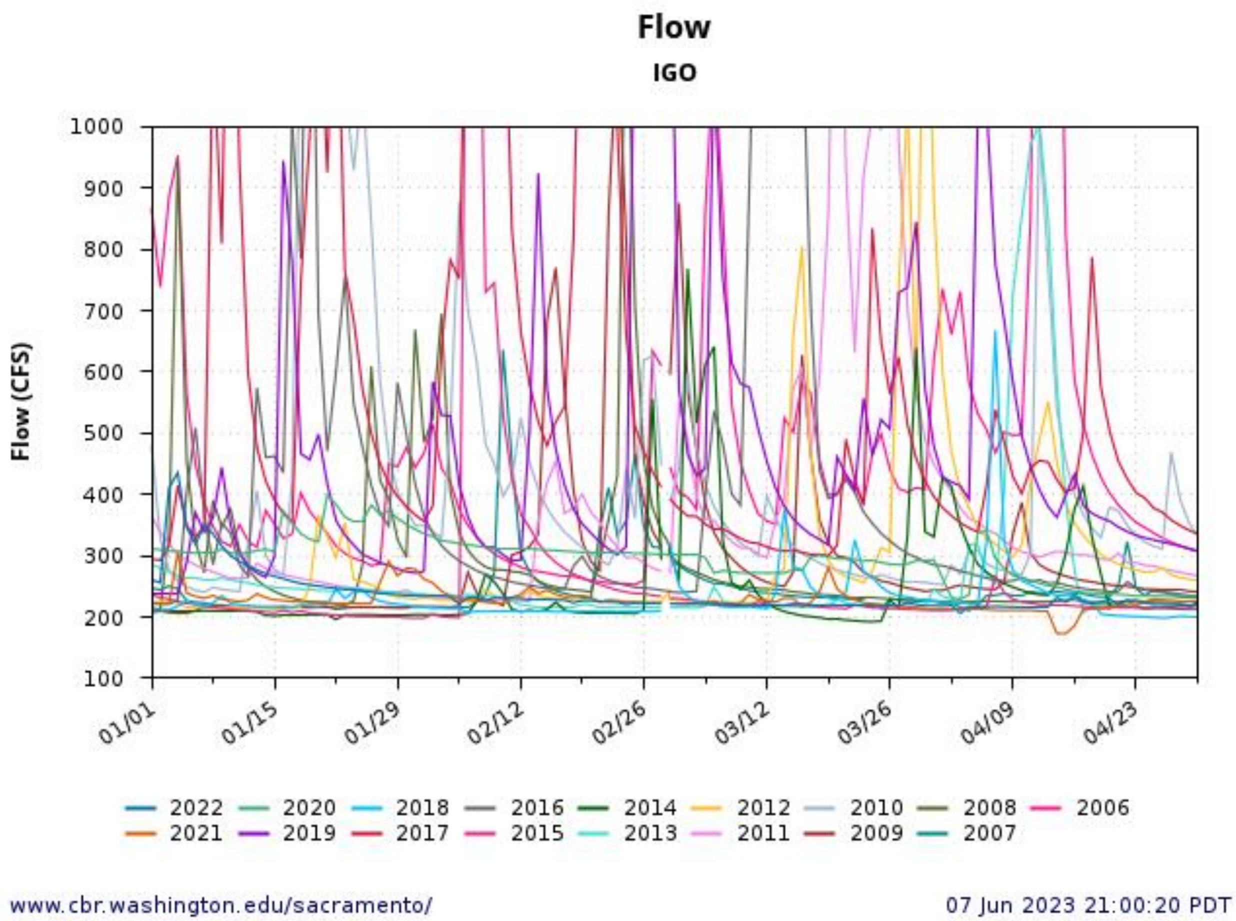
The SIT LCM Habitat Estimates, Tributary Habitat, Appendix O, Attachment O.2, provides context for the habitat area available for Steelhead spawning in Clear Creek. The monthly habitat value under the Proposed Action phases ranges from approximately 1.25 to 2.2 acres (Figure 7-51). Spawning weighted usable area for Steelhead peaks at approximately 250 cfs in Clear Creek. Overall, the habitat values do not vary much among months or water year types, with the exception that acreage of spawning habitat was lowest in April of Critical years under all Proposed Action phases.



Variability within months (January-April) reflects variation across CalSim WYs.

Figure 7-51. Estimated spawning habitat for Steelhead in Clear Creek by Water Year Type.

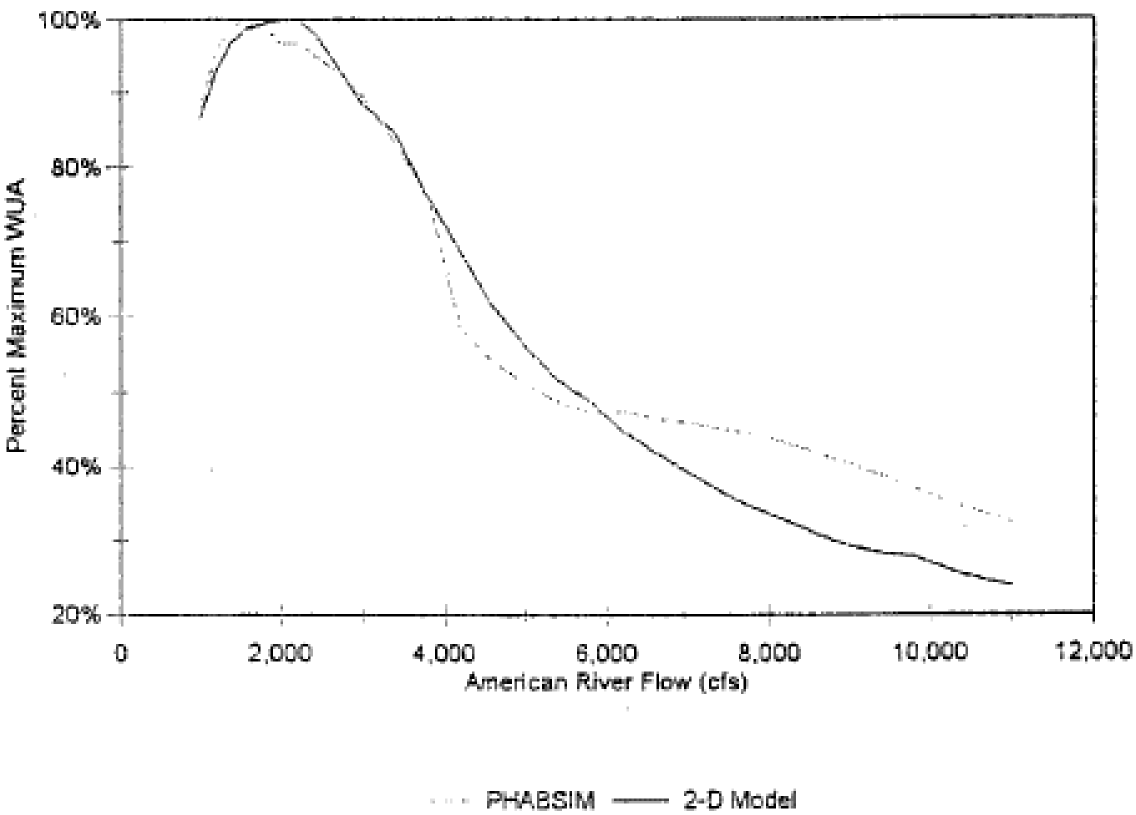
While the area of suitable habitat is affected in all years, the **frequency** of when the Proposed Action may provide a benefit is likely **medium**, as 7 out of 17 years have flows outside of the 900 cfs range (Figure 7-52).



Source: Columbia Basin Research 2023.

Figure 7-52. Flow (cfs), Clear Creek near Igo, 2006 – 2022, January through April.

The **proportion** of adults in the American River when flows are potentially within the suitable range is likely **large**. In the American River, there have been several habitat restoration projects to create side channel and floodplain habitat in addition to gravel and cobble additions for spawning habitat. Habitat restoration projects completed in October 2022 at Nimbus Basin and Lower Sailor Bar enhanced habitat for steelhead by laying approximately 41,000 cubic yards of clean gravel into the river and excavated side channel habitat (Water Forum 2022). Flow-habitat relationships show spawning habitat availability through Weight Usable Area in the American River peaks between 1,500 - 2,500 cfs before gradually declining (U.S. Fish and Wildlife Service 2003; Figure 7-53), thus flows outside of this range may result in a decrease in suitable habitat. A lack of sufficient spawning habitat can result in incomplete egg expression and redd superimposition that exposes previously deposited eggs to damage and predation. Management from Folsom Reservoir would potentially prevent flows from exceeding this threshold in the spring.



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

Figure 7-53. Flow-habitat availability relationships - percent maximum WUA by American River flow (cfs).

The American River Weighted Usable Area Analysis, Appendix M, Attachment M.3, *American River Weighted Usable Area Analysis*, provides context for the weighted usable area available for steelhead spawning downstream of Folsom releases. Spawning weighted usable area for steelhead peaks at approximately 1,400 cfs. The mean WUA habitat value under the Proposed Action phases ranges from 29,246 in wet water years to 115,424 in critical years (Figure 7-54). Overall, these WUA habitat values do not vary much among scenarios.

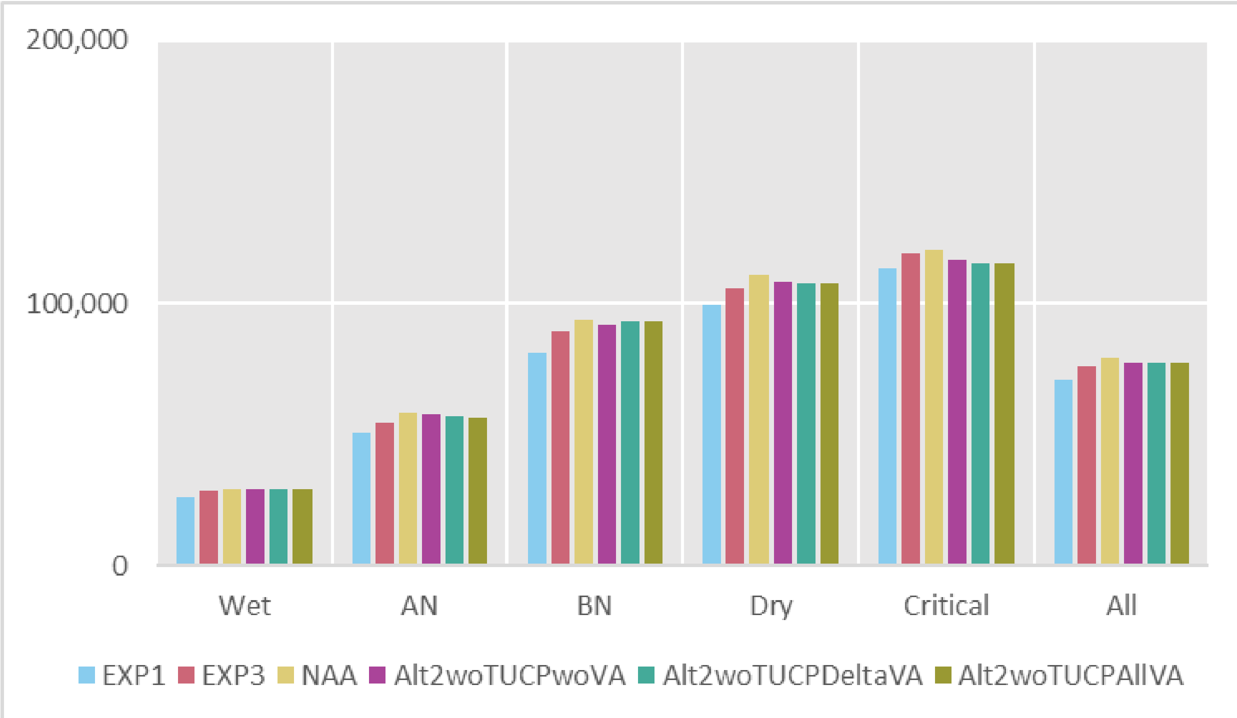
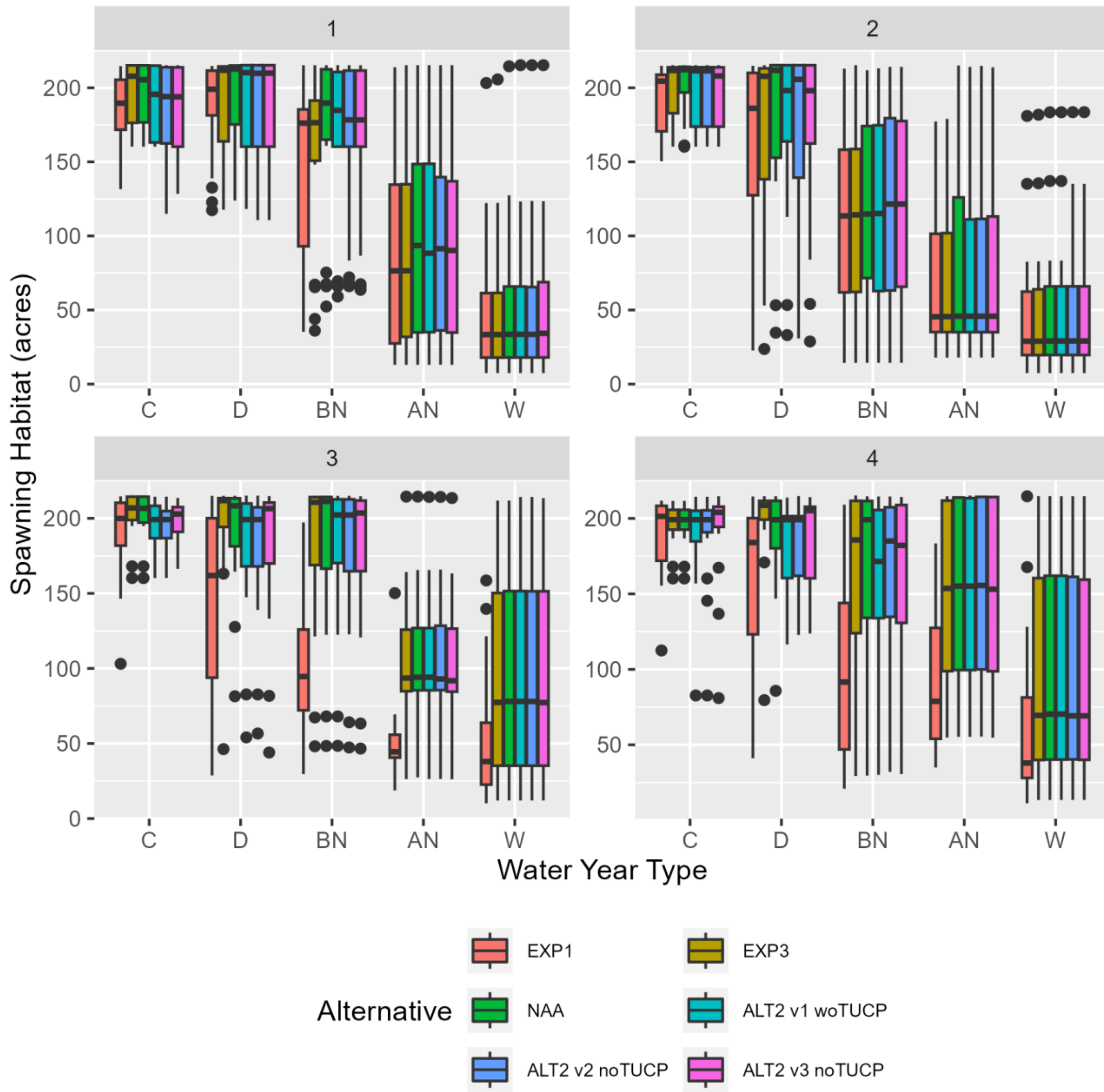


Figure 7-54. WYT mean steelhead spawning WUA habitats, American River

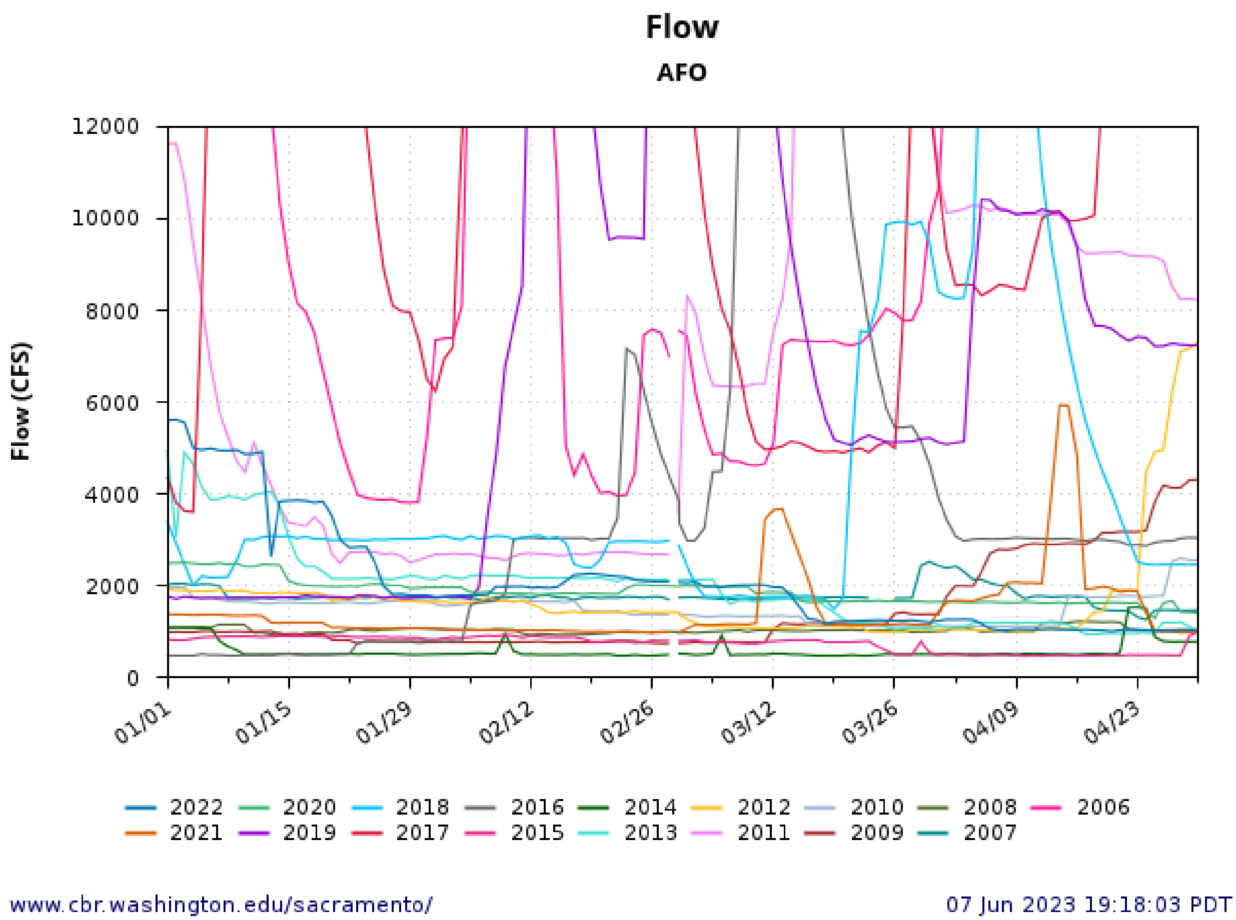
The SIT LCM Habitat Estimates, Tributary Habitat, Appendix O, Attachment O.2, provides context for the habitat area available for Steelhead spawning in the American River. The monthly habitat value under the Proposed Action phases ranges from approximately 10 to 210 acres (Figure 7-55). Spawning weighted usable area for Steelhead peaks at approximately 1,400 cfs in the American River. Overall, the habitat values do not vary much among months or water year types, with the exception that acreage of spawning habitat was generally lower in Above Normal or Wet water year types as compared to other water year types. The lowest habitat values occurred in Proposed Action phases in February in Above Normal and Wet water year types and January in Wet water year types.



Variability within months reflects variation across CalSim WYs.

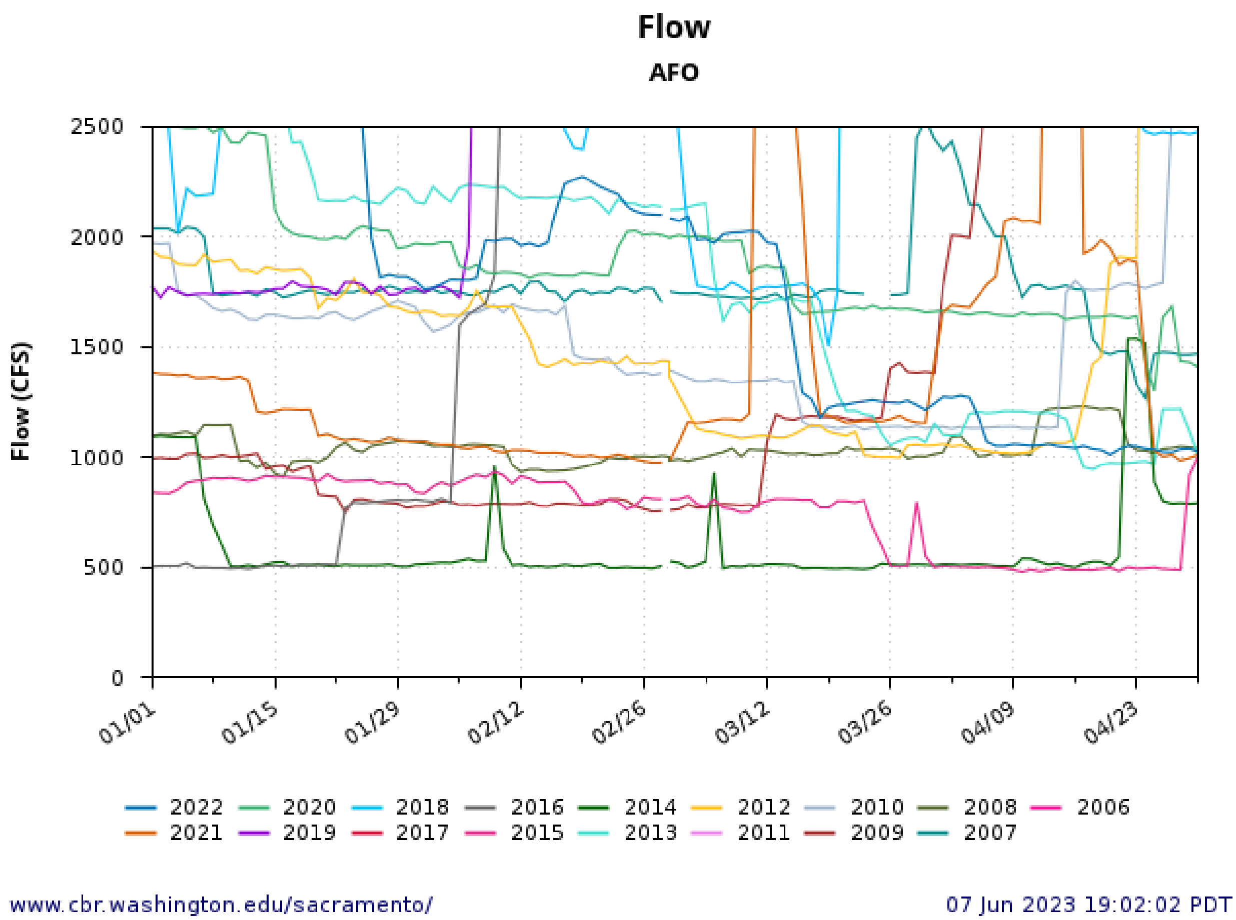
Figure 7-55. Estimated spawning habitat for Steelhead in the American River by Water Year Type.

While the area of suitable habitat is affected in all years, the **frequency** when habitat impacts occur from changes in flow is likely **medium**, as 10 out of 17 years have flows outside of the 1,500-2,500 cfs range (Figure 7-56 and Figure 7-57).



Source: Columbia Basin Research 2023.

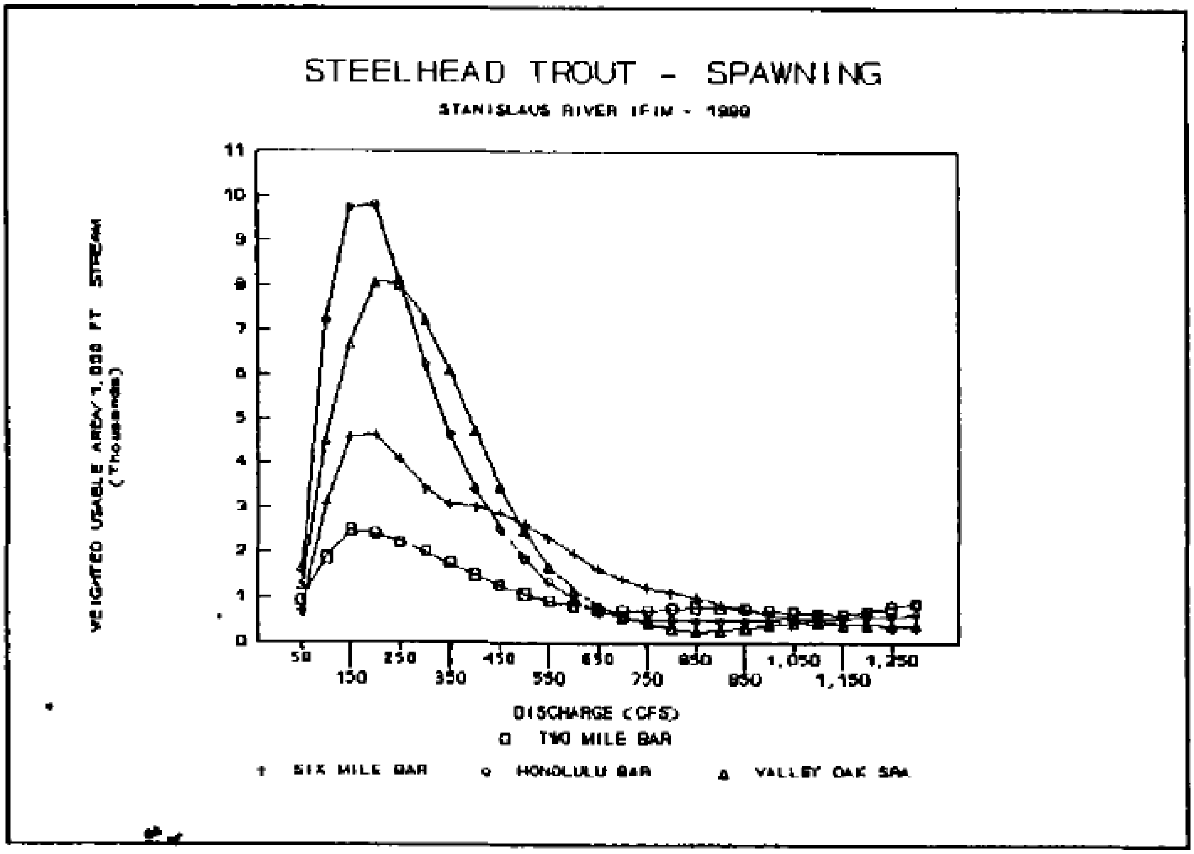
Figure 7-56. River flow in cubic feet per second in the American River at Fair Oaks between January and April 2006-2022.



Source: Columbia Basin Research 2023.

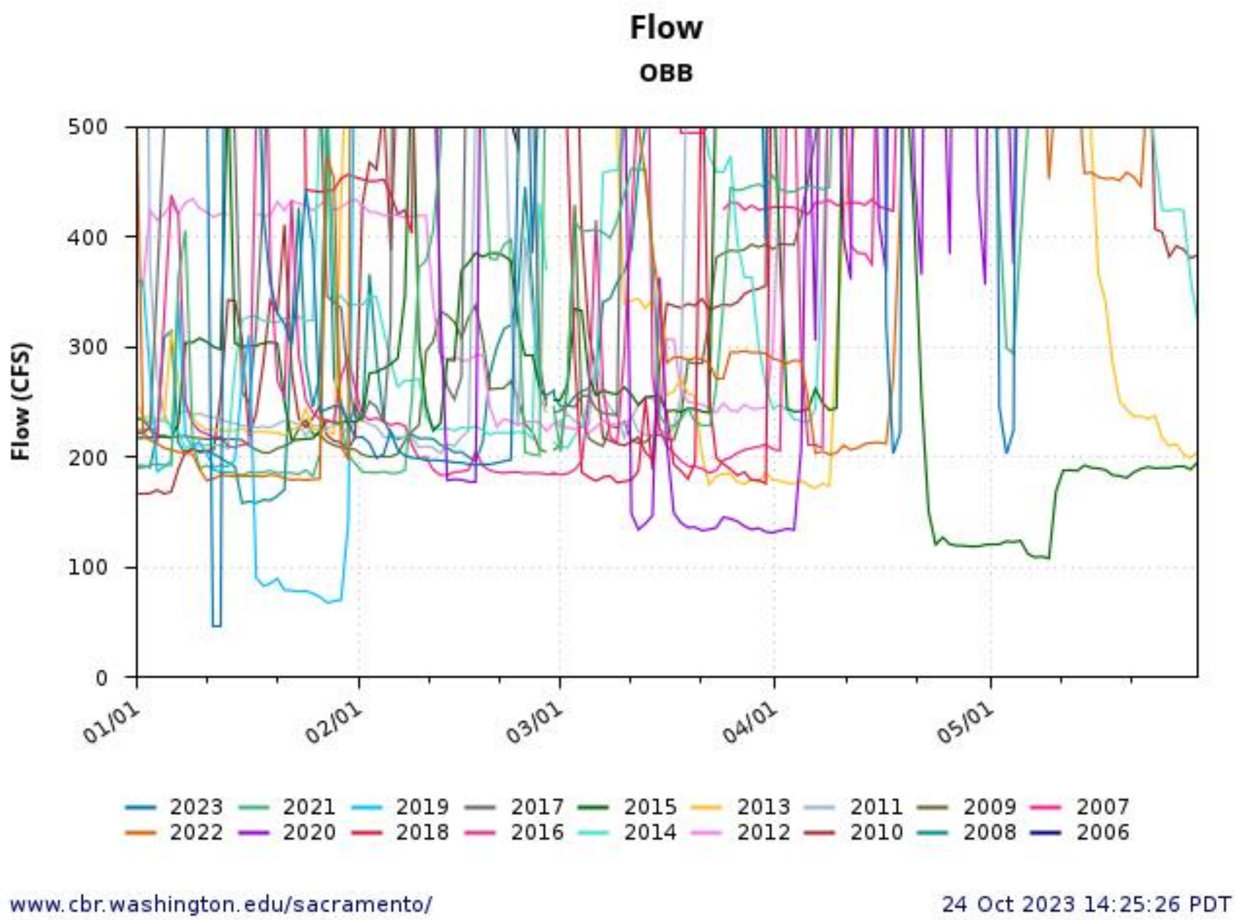
Figure 7-57. River flow between 0 and 2500 cubic feet per second in the American River at Fair Oaks between January and April 2006-2022.

The **proportion** of adults in the Stanislaus River when flows are within the suitable range is likely **large**. Aceituno (1993) determined flows of 200 cfs provided maximum weighted usable area for steelhead spawning in the Stanislaus River.



Source: Aceituno 1993, Appendix D-3.

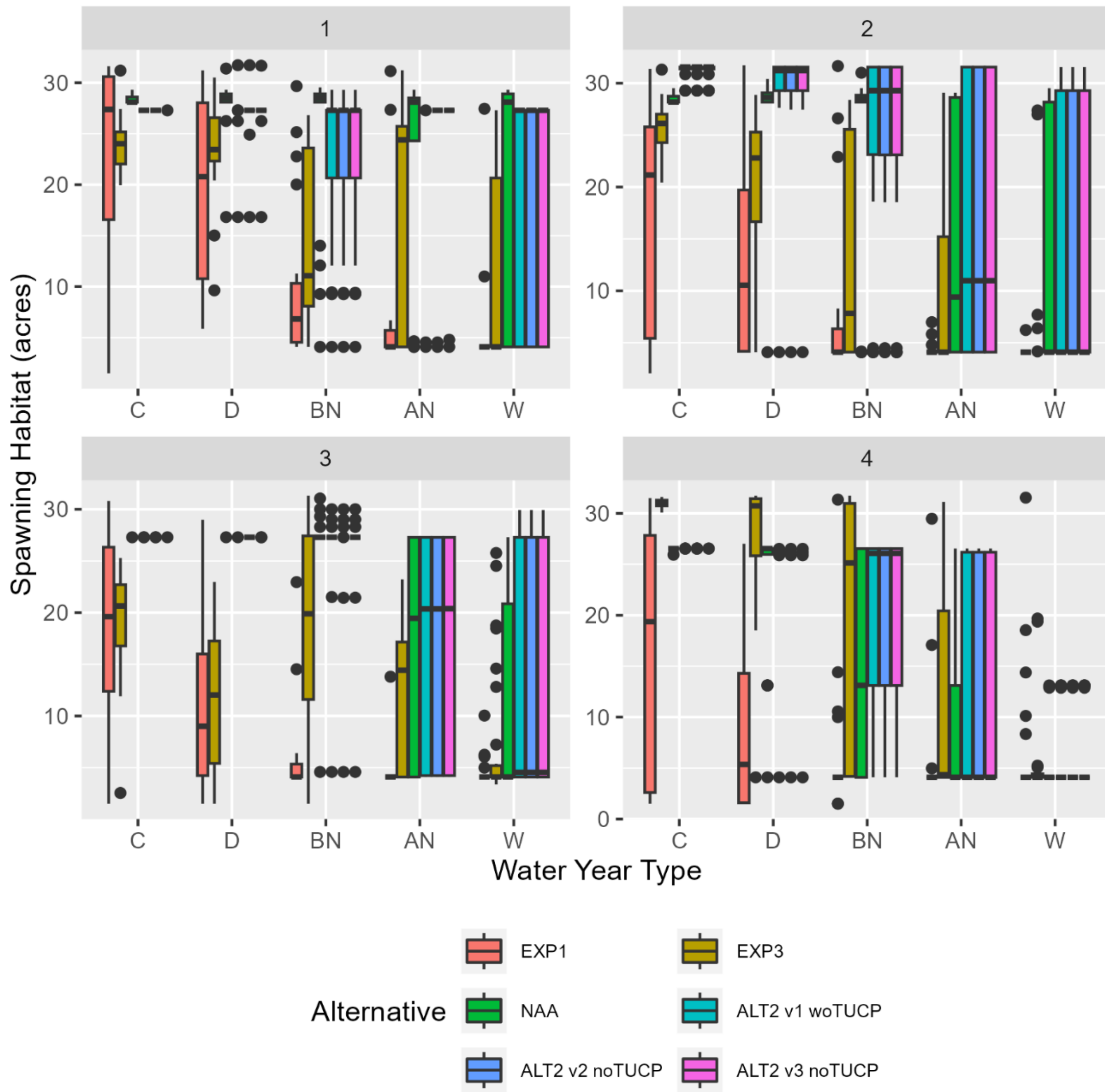
Figure 7-58. PHABSIM Results for Steelhead Spawning Flow Relationships in the Stanislaus River.



Source: Columbia Basin Research 2023.

Figure 7-59. River flow between 0 and 500 cubic feet per second in the Stanislaus River at Orange Blossom Bridge between January and May 2006-2023.

The SIT LCM Habitat Estimates, Tributary Habitat, Appendix O, Attachment O.2, provides context for the habitat area available for Steelhead spawning in the Stanislaus River. The monthly habitat value under the Proposed Action phases ranges from approximately 4 to 31 acres (Figure 7-60). Spawning weighted usable area for Steelhead, based on Aceituno (1993), peaks at approximately 200 cfs in the Stanislaus River. Overall, the habitat values do not vary much among months or water year types, with the exception that acreage of spawning habitat was generally lower in Above Normal or Wet water year types as compared to other water year types. The lowest habitat values occurred in Proposed Action phases in Wet water year types across all months and in April in Above Normal water year types.



Variability within months reflects variation across CalSim WYs.

Figure 7-60. Estimated spawning habitat for Steelhead in the Stanislaus River by Water Year Type.

While the area of suitable habitat is affected in all years, the frequency when habitat impacts occur from changes in flow is likely **high**, as 18 out of 18 years have flows outside of the 200 cfs range (Figure 7-58 and Figure 7-59).

To evaluate the **weight of evidence** for the spawning habitat stressor, flow-habitat relationships from USFWS 2003 and USFWS 2015 were used for the American River and Clear Creek respectively. Both reports use quantitative analyses to assess the suitable flow range for spawning habitat, are location specific and species specific to steelhead from the Central Valley. Since 2003 and 2015, habitat use and location of spawning has changed and additional spawning habitat restoration has occurred, so there is uncertainty in these relationships. Water flow monitoring data through SacPAS provides quantitative data on each watershed to assess whether a threshold was met (Columbia Basin Research 2023).

- Historical superimposition and spawning habitat observations are quantitative, species-specific, and location-specific. The observations are published in technical memos and annual reports from technical teams, not expected to have statistical power.
- Historical flows are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed from a long time-series. They are published in technical memos and annual reports from technical teams, and 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 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.
- American River WUA analysis LOE is quantitative, species-specific, and location-specific to the American River. RIVER2D was one of the hydraulic habitat models used by Bratovich et al. (2017) to develop the American River 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
- American River
    - Minimum Instream Flows

- Stanislaus River
    - Stepped Release Plan

7.2.3 Kelt Emigration

Steelhead can spawn more than once, with post-spawn kelts (typically females) moving back downstream through the Delta after completion of spawning in their natal streams. Some adults will change their life-history strategy post-spawn, as demonstrated in Battle Creek, where kelts chose to stay in freshwater rather than emigrate to the ocean (Null et al. 2013).

Rates of iteroparity in the Central Valley are generally considered low (Eschenroeder et al. 2022), and so much of the available information on repeat spawning for steelhead comes from the Pacific Northwest. In these steelhead populations, timing of kelt emigration starts in February, peaks March through May, and ends by early June (Mayer et al. 2008). The overall proportion of the population for kelt emigration is likely low, but in this effects analysis we assessed each watershed individually rather than for the entire Central Valley DPS.

The stressors influencing kelt emigration include in-river fishery and poaching, stranding risk, competition, introgression, and broodstock removal, toxicity from contaminants, dissolved oxygen, food availability and quality, water temperature, and pathogens and disease, and are described in Section 7.1.3, *Limiting Factors, Threats, and Stressors*.

The Proposed Action is not anticipated to change the stressors for *In-River Fishery and Poaching, Stranding Risk, Competition, Introgression*, and *Broodstock Removal*.

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

- The Proposed Action may increase or decrease the *toxicity from contaminants stressor* in the CVP rivers and tributaries. During the kelt emigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. The Proposed Action will also decrease inflow into the Delta in the winter and spring and increase inflow in the summer, which would apply to kelts emigrating at the end of the season in early June. In the San Joaquin River at Gravelly Ford, flows would be reduced throughout the year with an increase to the stressor. Reduced flows may concentrate contaminants when present while increased flows may dilute contaminants. During migration, adults do not typically eat, which reduces their exposure to contaminants in prey during this life stage.

  Monitoring of adults in the Delta, Sacramento River, Clear Creek, San Joaquin River, American River, and Stanislaus River has not shown fish kills that may be indicative of contaminants at levels likely to affect adult steelhead. Evidence presented in the toxicity and contaminants section for Section 7.2.1, *Adult Migration and Holding*, is applicable for the toxicity and contaminants stressor for kelt emigration.

- The Proposed Action may increase and/or decrease the *dissolved oxygen* stressor in the CVP rivers and tributaries. The stressor is not anticipated to change in the Delta. On the

Sacramento River at Prisoner's Point in the Delta, historical February through June daily water dissolved oxygen 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 dissolved oxygen stressor is not anticipated to change because it is unlikely the Proposed Action operations changes in flows will cause changes to dissolved oxygen in the Delta. During the kelt emigration period, reduced releases will decrease flows in the Sacramento River, Clear Creek, American River, and Stanislaus River in the winter and spring and decrease inflow into the Delta. Reduced releases at Gravelly Ford throughout the year may increase the stressor in the San Joaquin River. Releases of storage in the summer from the Sacramento River, Clear Creek, American River, and Stanislaus River may decrease the stressor. Releases of storage may result in cooler water temperatures and higher flows that may provide a higher dissolved oxygen saturation potential while storing water may do the opposite.

Water quality monitoring in the Sacramento, San Joaquin and Stanislaus rivers suggest dissolved oxygen levels are above 5.0 mg/L during this period. Historical DO measurements for the American River and Clear Creek are limited, however, dissolved oxygen levels in the American River and Clear Creek are not expected to be below this threshold during kelt emigration.

- Evidence presented in the dissolved oxygen section for Section 7.2.1, *Adult Migration and Holding*, is applicable for the dissolved oxygen section for kelt emigration.
- The Proposed Action may increase or decrease the *food availability and quality* stressor in the CVP rivers and tributaries. During the kelt emigration period, reduced releases will decrease flows in the Sacramento River, Clear Creek, American River, and Stanislaus River in the winter and spring and decrease inflow into the Delta. Reduced releases at Gravelly Ford throughout the year may increase the stressor in the San Joaquin River. Releases of storage in the summer from the Sacramento River, Clear Creek, American River, and Stanislaus River may decrease the stressor. Operations resulting in decreased flows would provide less inundated habitats, while an increase in flows may do the opposite. These changes may modify food web processes and cause a decrease in the quality of food available to steelhead.

  Steelhead kelts may occasionally feed while in-river, particularly if they become freshwater residents post-spawn, but anadromous adults typically fast in freshwater.

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 provided.

7.2.3.1 Water Temperature

The proposed storing and diverting of water may increase and decrease the water temperature stressor. During the kelt emigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below

Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. Warmer water temperatures may add stress on kelts after spawning and reduce survival. Appendices L, M, and N address temperature related effects associated with the Proposed Action.

The Proposed Action includes the following components/conservation measures to address: (1) Reclamation, through Governance, will continue to annually prepare a TMP for the summer through fall. TMP to contains: (a) forecasts of hydrology and storage; and (b) modeling run or runs, using these forecasts, demonstrating what temperature compliance schedule can be attained; (2) Reclamation will plan shutter configurations to attain the best possible (lowest numbered) temperature schedule; (3) Reclamation will implement the ATSP in developing the TMP. For greater than 56°F at Hazel Avenue in November, the TMP will evaluate a power bypass.

The same thresholds for migration impairment at 66.2°F and lethality at 69.8°F used in Section 7.2.1.1, *Water Temperatures*, were used for kelt emigration.

The Proposed Action is expected to have insignificant changes to water temperatures in the San Joaquin and Sacramento rivers, the Delta and Clear Creek. It is uncertain how water temperatures may influence the rate of anadromy in kelts. Water temperatures in the Sacramento River and Clear Creek are below kelt emigration water temperature criteria throughout this period. The Proposed Action is expected to have insignificant changes to water temperature in the San Joaquin River (see Chapter 4, Figure 4-53). 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, historical water temperatures February through June (2006 – 2022) were less than 68°F in all years before middle of May and only less than 60.8°F in most years February 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 is a cause for increased 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 water temperature stressor is expected to **sub-lethal** to some kelts in the American River during the spring. Warmer water temperatures may impair emigration or become too energetically taxing for kelts if water temperatures reach the threshold. The water temperature stressor is expected to be **beneficial** in the Stanislaus River and American River in the summer. Cooler water temperatures may reduce overall harm to kelts emigrating back to the ocean.

Although the Proposed Action may increase the water temperature stressor in the spring, unsuitable water temperatures for kelts 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.

Prior to the construction of Folsom and Nimbus dams, CV steelhead would seek out coldwater refuges in higher elevation habitats of the basin. Up until completion of the dams in 1955, maximum water temperatures during summer frequently reached temperatures as high as 75°F to 80°F in the lower American River (Gerstung 1971). During the late 1960s, Reclamation designed a modification to the trash rack structures to provide selective withdrawal capability at Folsom Dam through the Folsom Power Plant. The steel trash racks are now equipped with three groups of shutters that can pull water from various elevations, which have different temperatures when the lake is thermally stratified. This allows for limited discretionary temperature management of the lower American River.

In 2009, National Marine Fisheries Service issued an RPA that required Reclamation to prepare and implement a water TMP by May 15 each year for the American River. Reclamation proposed a similar TMP in 2019.

To reduce the water temperature stressor in the American River, Reclamation recently completed the WTMP effort, which is intended to enhance modeling capabilities to predict summer and fall water temperature through facilities operations, such as the Folsom Dam temperature shutters.

On the Stanislaus River, past operational releases from New Melones Dam have influenced the extent of cool water habitat available below Goodwin Dam. Reclamation has operated New Melones Reservoir to meet dissolved oxygen requirements under SWRCB D-1422 and D-1641. In 2009, National Marine Fisheries Service issued an RPA that dictated specific temperature targets for the Stanislaus River to benefit steelhead. None of the dams on the Stanislaus River have a temperature control device, so the only mechanism for temperature management on the Stanislaus River is direct flow management.

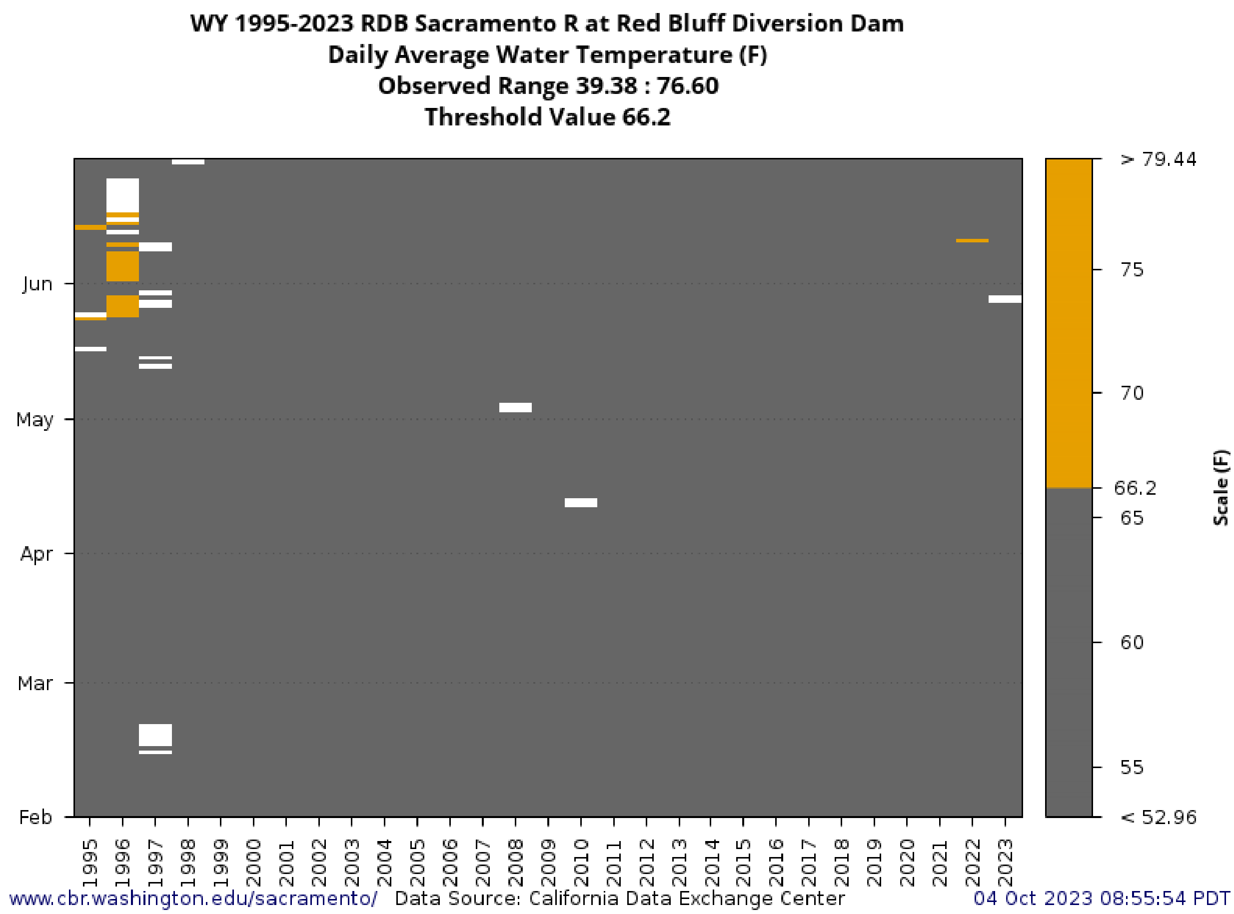
Since 2019, Reclamation has implemented a Stepped Release Plan for the Stanislaus River. The Stepped Release Plan includes the ability to shape monthly and seasonal flow volumes and are Reclamation’s contribution to Vernalis D-1641 standards. The Stepped Release Plan does not set water temperature standards for the Stanislaus River, but it does include minimum flow targets that are intended to benefit steelhead, including water temperature benefits.

The **proportion** of the population affected by the Proposed Action depends on water temperature management and peak migration timing. During the kelt emigration period in the Sacramento River, historical daily average water temperatures have been below the thermal impairment limit of 66.2°F for kelt emigration during this period (Figure 7-61). While maintenance of Shasta Reservoir storage may increase the stressor in the winter and spring, it is expected to have an insignificant impact on the water temperature stressor for kelt emigration. In the summer, releases of storage are expected to increase flows which may decrease the stressor.

Literature on critical water temperatures historically identified 66.2°F as the threshold temperature to impair steelhead migration and 69.8°F as the lethal limit to block migration.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

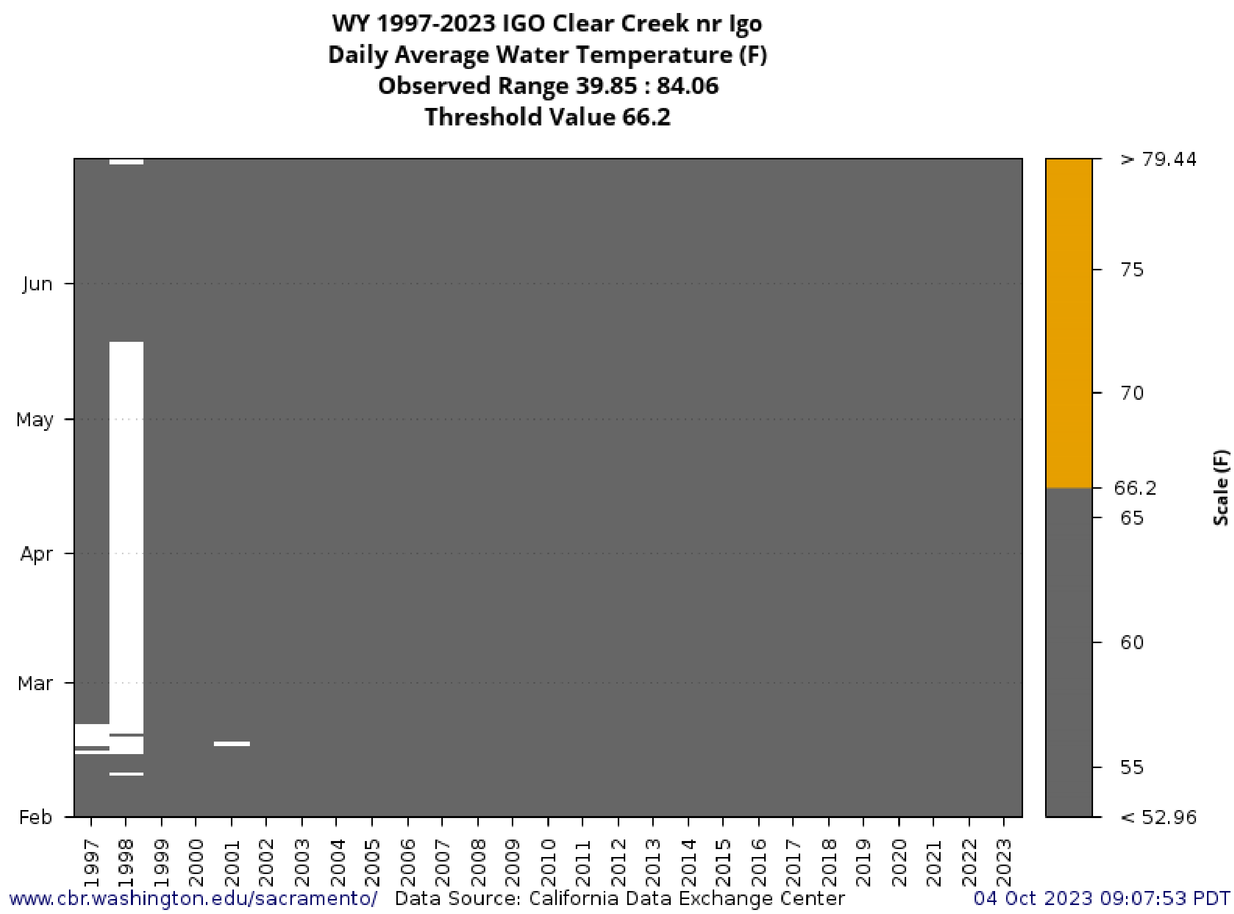
Models provide quantitative estimates of future conditions under the Proposed Action. Reclamation evaluated multiple lines of evidence, with different assumptions and complexity, to narrow the likely range of potential effects. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed water temperature criteria obtained from scientific literature.



Source: Columbia Basin Research 2023. Unavailable data depicted in white.

Figure 7-61. Wate Days exceeding water temperatures of 66.2°F in the Sacramento River at Red Bluff Diversion Dam, 1995 – 2023, February through June.

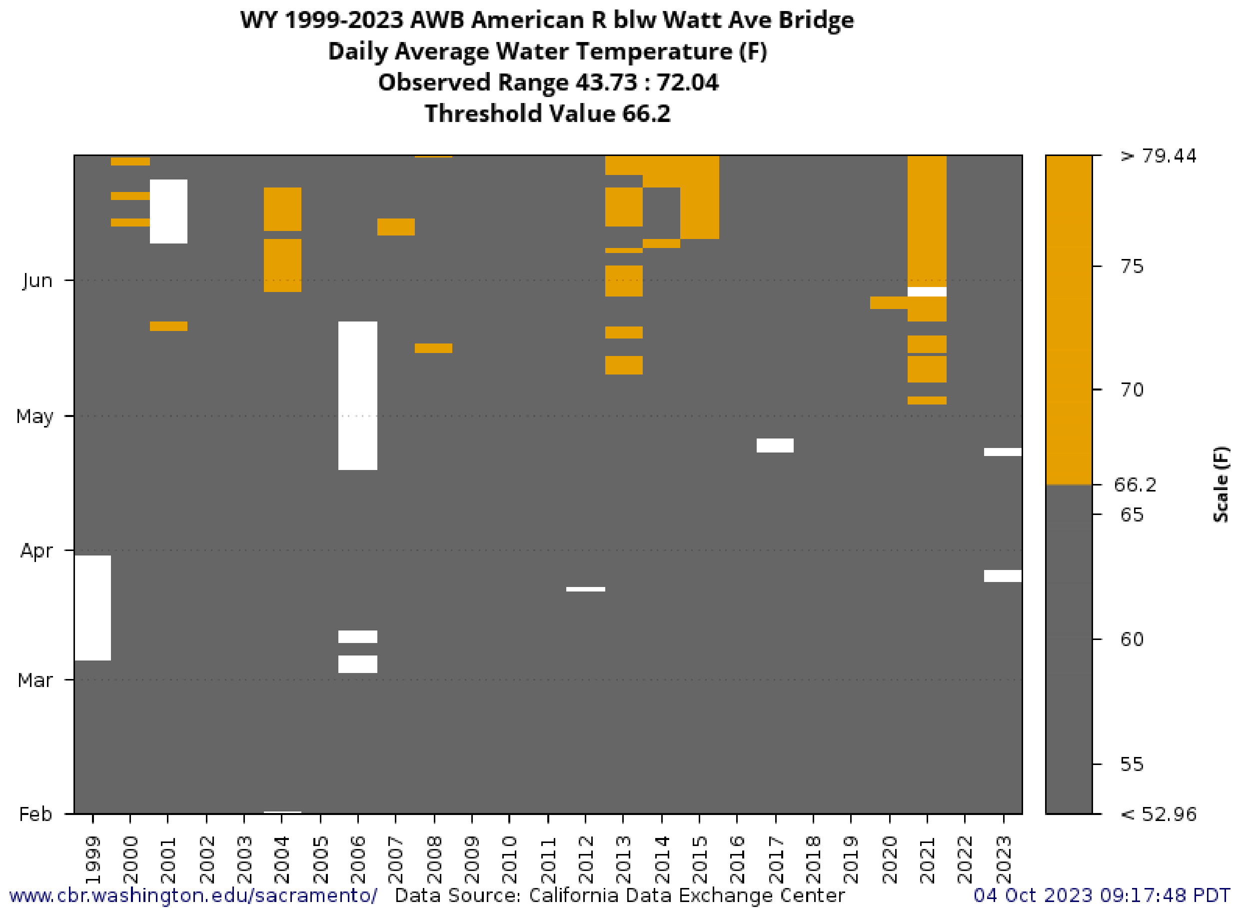
During the kelt emigration period in Clear Creek, historical daily average water temperatures have been below the thermal impairment limit of 66.2°F for kelt emigration (Figure 7-62). Out of the 26 years of historical data for the Clear Creek at IgO from 1997-2023, none of the years have recorded water temperatures that exceed the thermal limit that blocks migration at 69.8°F. While maintenance of Whiskeytown Reservoir storage may increase the stressor in the winter and spring, it is expected to have an insignificant impact on the water temperature stressor for kelt emigration. In the summer, releases of storage are expected to increase flows which may decrease the stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-62. Days exceeding water temperatures of 66.2°F in the Clear Creek near Igo, 1997 – 2023, February through June.

During the kelt emigration period in the American River, historical daily average water temperatures have been above the thermal impairment limit of 66.2°F in May and June (Figure 7-63). The **proportion** of kelts in the American River when water temperatures are above the criteria is likely **small**, as temperatures exceed the thermal impairment threshold towards the end of the kelt emigration period.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-63. Days exceeding water temperatures of 66.2°F in the American River below Watt Avenue, 1999 – 2023, February through June.

Results for the exceedance of the 66.2°F water temperature threshold for migration impairment are presented in Table 7-27 for the American River at Hazel Ave., Table 7-28 for the American River at Watt Ave., At the American River at Hazel Ave., the percentage of months that exceeded the temperature threshold ranged from 10.0% for Critical to 1.4% for Wet water year types. Overall, the percentage of months that exceeded the temperature threshold increased from wetter to drier water year types under all phases of the Proposed Action during the period of February through June.

Table 7-27. Percent of months above the 66.2°F migration impairment water temperature limit for steelhead kelt emigration by water year type and for all years combined, American River at Hazel Ave., February through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	5.0	1.4	1.4	0.7	1.4	1.4
AN	13.8	1.5	4.6	4.6	4.6	3.1
BN	15.6	6.7	4.4	3.3	6.7	7.8
D	17.5	9.2	0.8	2.5	2.5	1.7
C	30.0	15.0	6.3	8.8	10.0	8.8
All	15.2	6.5	3.0	3.4	4.4	4.0

At the American River at Watt Ave., the percent of months that exceeded the temperature threshold under the Proposed Action phases range from 31.3%% during Critical water years to 2.9% of months during Wet water years. Overall, the percent of months that exceeded the temperature threshold increased from wetter to drier water year types under all phases of the Proposed Action and during the period of February through June.

Table 7-28. Percent of months above the 66.2°F migration impairment water temperature limit for steelhead kelt emigration by water year type and for all years combined, American River at Watt Ave., February through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	15.7	7.1	3.6	3.6	3.6	2.9
AN	23.1	16.9	10.8	12.3	12.3	10.8
BN	25.6	22.2	17.8	17.8	17.8	17.8
D	26.7	27.5	15.8	15.8	15.8	16.7
C	42.5	36.3	28.8	31.3	30.0	27.5
All	25.5	20.8	14.1	14.7	14.5	13.9

Results for the exceedance of the 69.8°F lethal water temperature threshold for steelhead kelt emigration are presented in Table 7-29 for the American River at Hazel Ave., Table 7-30 for the American River at Watt Ave. At the American River at Hazel Ave., the percentage of months that exceeded the temperature threshold for Critical was 1.3% under the Proposed Action phases. For Wet, Above Normal, Below Normal, and Dry water year types, the percentage of months that exceeded the lethal temperature threshold remained at 0.0% for all phases of the Proposed Action during the period of February to June.

Table 7-29. Percent of months above the 69.8°F lethal water temperature limit for steelhead kelt emigration by water year type and for all years combined, American River at Hazel Ave., February through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	0.0	0.0	0.0	0.0	0.0	0.0
AN	3.1	0.0	0.0	0.0	0.0	0.0
BN	1.1	0.0	0.0	0.0	0.0	0.0
D	6.7	0.0	0.0	0.0	0.0	0.0
C	13.8	0.0	1.3	1.3	1.3	1.3
All	4.4	0.0	0.2	0.2	0.2	0.2

At the American River at Watt Ave., the percent of months that exceeded the lethal temperature threshold under the Proposed Action phases range from 16.3% during Critical water years to 1.5% of months during Above Normal water years. By and large, the percentage of months that exceeded the temperature threshold increased from wetter to drier water year types under all phases of the Proposed Action. During Wet water year types, the percentage of months that exceeded the lethal temperature threshold remained at 0.0% under the Proposed Action phases during the period of February through June.

Table 7-30. Percent of months above the 69.8°F lethal water temperature limit for steelhead kelt emigration by water year type and for all years combined, American River at Watt Ave., February through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	5.7	1.4	0.0	0.0	0.0	0.0
AN	15.4	6.2	3.1	4.6	3.1	1.5
BN	20.0	10.0	3.3	3.3	3.3	4.4
D	20.8	16.7	4.2	6.7	6.7	5.0
C	33.8	21.3	15.0	16.3	17.5	15.0
All	17.8	10.5	4.4	5.5	5.5	4.6

Historical water temperatures near Watt Ave indicate the frequency of occurrence for the sub-lethal effect is likely **low**, as the impairment threshold is reached in 6 out of 25 years in the spring. Historical water temperatures near Watt Ave indicate the frequency of occurrence for the beneficial effect is likely **medium**, as the impairment threshold is reached in 6 out of 25 years before early June. Out of the 25 years of historical data for the American River at Watt Ave, one year had daily average water temperatures that exceed the thermal limit that blocks migration at 69.8°F. Maintenance of Folsom storage may reduce flows in the spring, and subsequently increase the water temperature stressor. Releases of storage in the summer may increase flows which may decrease the stressor.

During the kelt emigration period in the Stanislaus River, historical daily average water temperatures have been mostly below the thermal impairment limit of 66.2°F (Figure 7-64). The **proportion** of kelts in the Stanislaus River when water temperatures are beneficial is likely **small**, as summer releases are expected to increase flows at the end of the emigration period.

Results for the 66.2°F migration impairment limit are presented in Table 7-31 for Orange Blossom Bridge and Table 7-32 for the confluence. At Orange Blossom Bridge, the percent of months above the limit is 0.2% under the Proposed Action phases. Among water year types, the percent of months above the limit increased from wetter to drier water year types.

Table 7-31. Percent of months above the 66.2°F migration impairment water temperature limit for steelhead kelt emigration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, February through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	1.8	0.0	0.0	0.0	0.0	0.0
AN	15.0	15.0	0.0	0.0	0.0	0.0
BN	20.0	15.7	0.0	0.0	0.0	0.0
D	28.2	17.6	0.0	0.0	0.0	0.0
C	32.1	5.5	0.6	0.6	0.6	0.6
All	20.8	9.0	0.2	0.2	0.2	0.2

At the confluence, the percent of months above the limit is 19.4% under the Proposed Action phases. Among water year types, the percent of months above the limit increased from wetter to drier water year types.

Table 7-32. Percent of months above the 66.2°F migration impairment water temperature limit for steelhead kelt emigration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River above confluence with San Joaquin River, February through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	8.2	7.3	0.9	4.5	4.5	4.5
AN	16.7	20.0	18.3	18.3	18.3	18.3
BN	21.4	20.0	18.6	20.0	20.0	20.0
D	31.8	35.3	20.0	24.7	24.7	24.7
C	42.4	45.5	26.7	26.7	26.7	26.7
All	26.7	28.4	17.6	19.4	19.4	19.4

Results for the 69.8°F lethal limit are presented in Table 7-33 for Orange Blossom Bridge and Table 7-34 for the confluence. At Orange Blossom Bridge, there were not months above the limit under the Proposed Action phases.

Table 7-33. Percent of months above the 69.8°F lethal water temperature limit for steelhead kelt emigration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, February through June.

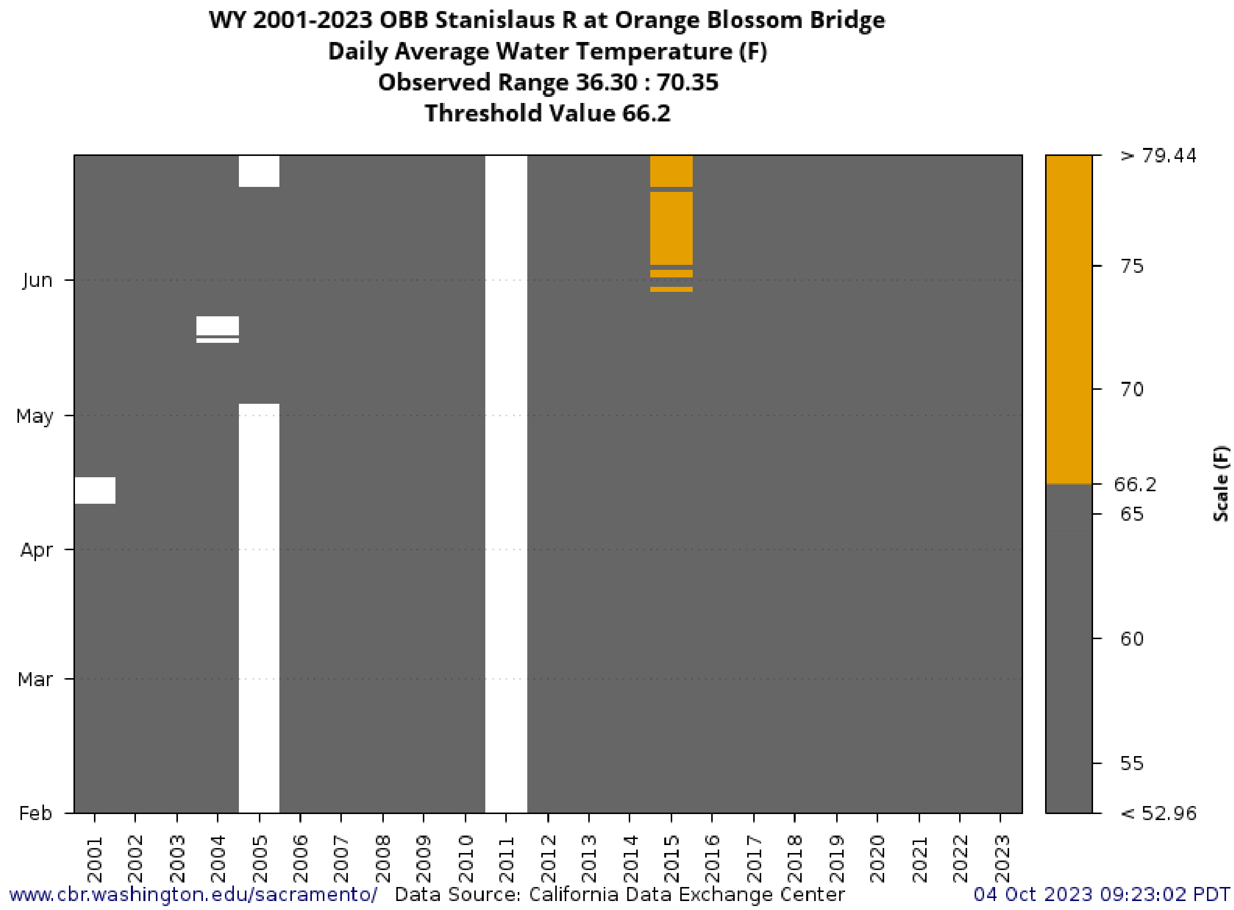
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	1.8	0.0	0.0	0.0	0.0	0.0
AN	15.0	5.0	0.0	0.0	0.0	0.0
BN	17.1	8.6	0.0	0.0	0.0	0.0
D	16.5	10.6	0.0	0.0	0.0	0.0
C	17.0	0.6	0.0	0.0	0.0	0.0
All	13.3	3.9	0.0	0.0	0.0	0.0

At the confluence, the percent of months above the limit under the Proposed Action phases is 8.8% (Table 7-34). Among water year types, the percent of months above the limit generally increased from wetter to drier water year types.

Table 7-34. Percent of months above the 69.8°F lethal water temperature limit for steelhead kelt emigration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, February through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	2.7	0.0	0.0	0.9	0.9	0.9
AN	15.0	18.3	0.0	0.0	0.0	0.0
BN	17.1	17.1	2.9	2.9	2.9	2.9
D	21.2	20.0	12.9	14.1	14.1	14.1
C	28.5	27.3	18.8	17.0	17.0	17.0
All	18.2	17.3	9.0	8.8	8.8	8.8

Historical water temperatures near Orange Blossom (Figure 7-64) indicate the frequency of occurrence is likely **low**, as one out of 23 years have exceeded the impairment limit. The lethal limit that blocks migration was not met in the 23 year historical record. While maintenance of New Melones Reservoir storage may increase the stressor in the winter and spring, it is expected to have an insignificant effect on the water temperature stressor for kelt emigration. In the summer, releases of storage are expected to increase flows, which may decrease the stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-64. Days exceeding water temperatures of 66.2°F in the Stanislaus River at Orange Blossom Bridge, 2001 – 2023, February through June.

To evaluate the **weight of evidence** for the water temperature stressor, there are water temperature thresholds from several peer reviewed articles and state issued water quality documents that are specific to *O. mykiss* but these studies are not specific to populations from the Central Valley. The water quality monitoring data through SacPAS provides quantitative data on each watershed to assess whether a threshold was met (Columbia Basin Research 2023).

- Coutant (1970) is quantitative, species-specific, not location specific, published research on lethal water temperature thresholds for adult migration.
- Keefer et al. (2018) is quantitative, species-specific, not location specific, published research on lethal water temperature thresholds for adult migration.
- Keefer et al. (2009) is quantitative, species-specific, not location specific, published research on sub-lethal (impairment) water temperature thresholds for adult migration.

- Historical water temperatures are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed from long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- Historic kelt emigration-timing observations are quantitative, species-specific, and location-specific. The observations are published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- HEC-5Q water temperature modeling is quantitative, not species-specific (environmental variable) and location-specific. The model was developed to evaluate reservoir systems using control points, and is widely accepted as the temperature modeling system for use in the upper Central Valley 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
- Clear Creek
  - Water Temperature Management
- Sacramento River
  - Water Temperature Management
- Stanislaus River
  - Stepped Release Plan

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

- Drought Tool Kit Shasta Reservoir Warmwater Bypass

7.2.3.2 Pathogens and Disease

The proposed storing and diverting of water may increase the pathogens and disease stressor. During the kelt emigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. As part of the drought toolkit, Reclamation may operate the TCD to release warmer water temperatures to preserve water for egg incubation later in the year. Warmer water temperatures may increase pathogen virulence and prevalence of disease. Appendices L, M, and N address temperature related effects in the Proposed Action.

The increases in the pathogens and disease stressor are expected to be **sub-lethal** in the Sacramento, American, and Stanislaus rivers. Presence of pathogens and disease may increase stress on steelhead kelts, reducing fitness and impairing emigration. It is uncertain how pathogens and disease may influence rates of anadromy and outmigration cues. Salmonid pathogens and disease can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Seasonal operations that result in decreased flows and increased water temperature, which may increase pathogen concentration and horizontal transmission, while increasing temperature may increase pathogen virulence. Diseases affecting salmonids become highly virulent at temperatures above 59.9°F (McCullough 1999).

The Proposed Action is expected to result in insignificant changes to pathogens and disease in Clear Creek, San Joaquin River, and the Delta. Water temperatures in Clear Creek are below pathogen criteria throughout this period. The Proposed Action is expected to have insignificant changes to water temperature in the Delta and San Joaquin River.

Although the Proposed Action may increase the pathogens and disease stressor in the Sacramento River, pathogens and diseases that may affect kelt emigration 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 (National Marine Fisheries Service 1998).

Natural steelhead 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 steelhead survival. Salmonids are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment (National Marine Fisheries Service 1996, 1998a, 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 steelhead (National Marine Fisheries Service 1996, 1998a, 2009).

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 WTMP 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 water temperature management and peak migration timing. During the kelt emigration period in the Sacramento River, historical daily average water temperatures have been above the virulence threshold of 59.9°F for kelt emigration from April through June. The proportion of kelts in the Sacramento River when water temperatures are above criteria is likely **medium**, as the Sacramento River is a main migratory pathway for other tributaries, but the threshold is not consistently met throughout the emigration period. Historic water temperatures near RBDD indicate the frequency of occurrence is likely **medium**, as the virulence threshold is reached in 16 out of 29 years between April and June (Figure 7-17). Maintenance of Shasta storage may increase the stressor in the spring, and summer releases may decrease the stressor.

Literature on critical water temperatures for pathogens and disease historically identified 59.9°F as the threshold temperature to increase virulence of pathogens.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

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. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed pathogens and disease water temperature criteria obtained from scientific literature.

Results for the exceedance of the 59.9°F pathogen virulence temperature threshold are presented in Table 7-35 for the Sacramento River at Keswick, Table 7-36 for the Sacramento at the RBDD, and Table 7-37 for Clear Creek below Whiskeytown. At Keswick, the percentage of months that exceeded the temperature threshold remained at 0.0% for all water year types under all the phases of the Proposed Action, during the period of February through June.

Table 7-35. Percent of months above the 59.9°F pathogen virulence water temperature threshold for kelt emigration by water year type and for all years combined, Sacramento River at Keswick, February through June.

WYT	**EXP1**	**EXP3**	**NAA**	**Alt2woTUCPwoVA**	**Alt2woTUCPDeltaVA**	**Alt2woTUCPAllVA**
W	12.9	0.0	0.0	0.0	0.0	0.0
AN	18.5	0.0	0.0	0.0	0.0	0.0
BN	27.8	0.0	0.0	0.0	0.0	0.0
D	25.8	0.0	0.0	0.0	0.0	0.0
C	30.0	0.0	0.0	0.0	0.0	0.0
All	22.2	0.0	0.0	0.0	0.0	0.0

At the Sacramento River at the RBDD, the percentage of months that exceeded the temperature threshold ranged from 21.3% for Critical to 14.4% for Below Normal water year types. The Proposed Action phases performed similarly for all water year types, with the percentage of months above the temperature threshold be notably less in Below Normal water year types for the period of February through June.

Table 7-36. Percent of months above the 59.9°F pathogen virulence water temperature threshold for kelt emigration by water year type and for all years combined, Sacramento River at the Red Bluff Diversion Dam, February through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	32.1	32.9	27.1	17.9	17.9	17.9
AN	38.5	33.8	24.6	18.5	18.5	18.5
BN	38.9	28.9	20.0	14.4	14.4	14.4
D	40.8	33.3	24.2	17.5	16.7	20.0
C	50.0	42.5	32.5	21.3	21.3	21.3
All	39.2	33.9	25.7	17.8	17.6	18.4

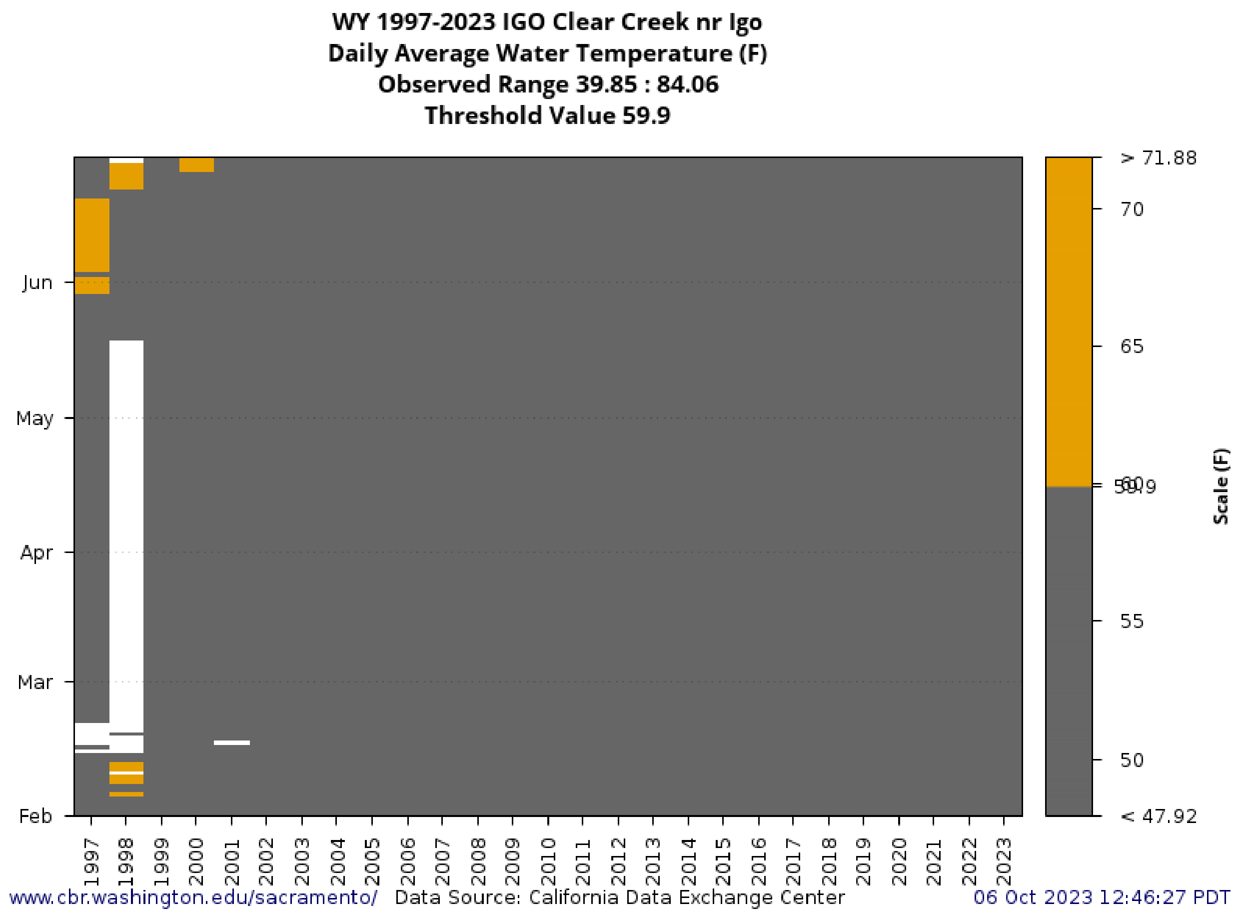
During the kelt emigration period in Clear Creek, historical daily average water temperatures have been above the thermal impairment limit of 59.9°F for kelt emigration in May and June. The **proportion** of adults in Clear Creek when water temperatures are above the virulence threshold is likely **small**, as temperatures exceed the criteria towards the end of kelt emigration, mostly in June.

At Clear Creek below Whiskeytown the percentage of months that exceeded the temperature threshold ranged from 1.3% for Critical to 0.7% for Wet water year types. During Above Normal, Below Normal, and Dry water year types, the percentage of months that exceeded the temperature threshold remained at 0.0% for all phases of the Proposed Action, during the period of February through June.

Table 7-37. Percent of months above the 59.9°F pathogen virulence water temperature threshold for kelt emigration by water year type and for all years combined, Clear Creek below Whiskeytown, February through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	20.0	0.0	0.0	0.7	0.7	0.7
AN	20.0	0.0	0.0	0.0	0.0	0.0
BN	21.1	2.2	0.0	0.0	0.0	0.0
D	21.7	0.8	0.0	0.0	0.0	0.0
C	25.0	3.8	0.0	1.3	1.3	1.3
All	21.4	1.2	0.0	0.4	0.4	0.4

Historical water temperatures near Igo indicate the frequency of occurrence is likely **low**, as the virulence threshold is reached in 3 out of 27 years during this period (Figure 7-65). In the summer, releases of storage are expected to increase flows which may decrease the stressor while storage and reduced lows in the spring may do the opposite.



Source: Columbia Basin Research 2023. Unavailable data depicted in white.

Figure 7-65. Days exceeding water temperatures of 59.9°F in Clear Creek at IgO, 1997 – 2023, February through June.

During the kelt emigration period in the American River, historical daily average water temperatures have been above the virulence threshold of 59.9°F for kelt emigration as early as March and until June. The **proportion** of adults in the American River when water temperatures are above the threshold is likely **medium**, as water temperatures exceed the virulence threshold towards the middle of the emigration season.

Results for the exceedance of the 59.9°F pathogen virulence temperature threshold are presented in Table 7-38 for the American river at Hazel Ave., and Table 7-39 for the American River at Watt Ave. At the American River at Hazel Ave., the percentage of months that exceeded the temperature threshold ranged from 31.3% for Critical to 10.0% for Wet water year types. In general, the percentage of months that exceeded the temperature threshold increased from wetter to drier water year types during the period of February through June, for each phase of the Proposed Action.

Table 7-38. Percent of months above the 59.9°F pathogen virulence water temperature threshold for kelt emigration by water year type and for all years combined, American River at Hazel Ave., February through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	20.0	15.0	10.7	10.7	10.0	10.0
AN	27.7	27.7	16.9	16.9	16.9	16.9
BN	34.4	27.8	25.6	25.6	23.3	24.4
D	34.2	31.7	25.8	28.3	27.5	28.3
C	48.8	38.8	26.3	28.8	30.0	31.3
All	31.7	26.9	20.4	21.4	20.8	21.4

At the American River at Watt Ave., the percentage of months that exceeded the temperature threshold ranged from 52.5% for Critical to 27.1% for Wet water year types. In general, the percentage of months that exceeded the temperature threshold increased from wetter to drier water year types during the period of February through June, for each phase of the Proposed Action.

Table 7-39. Percent of months above the 59.9°F pathogen virulence water temperature threshold for kelt emigration by water year type and for all years combined, American River at Watt Ave., February through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	26.4	27.1	27.1	27.1	27.1	27.1
AN	38.5	38.5	38.5	38.5	38.5	38.5
BN	41.1	37.8	37.8	38.9	40.0	38.9
D	45.0	44.2	42.5	43.3	43.3	43.3
C	56.3	55.0	52.5	48.8	52.5	50.0
All	40.0	39.2	38.4	38.2	39.0	38.4

Historical water temperatures near Watt Ave indicate the frequency of occurrence is likely **high**, as the virulence threshold is reached in 23 out of 25 years during this period. In the summer, releases of storage are expected to increase flows which may decrease the stressor while storage and reduced lows in the spring may do the opposite.

During the kelt emigration period in the Stanislaus River, historical daily average water temperatures have been above the virulence threshold of 59.9°F for kelt emigration as early as March but common in June. The **proportion** of adults in the Stanislaus River when water temperatures are above the virulence threshold is likely **small**, as kelts start migrating in February.

Results for the 59.9°F pathogen virulence threshold are presented in Table 7-40 for Orange Blossom Bridge and Table 7-41 for the confluence. At Orange Blossom Bridge, the percent of months under the Proposed Action phases above the threshold is 11.6 (Table 7-40). Among water year types, the percent of months above the threshold increased from wetter to drier water year types.

At the Stanislaus River at Orange Blossom Bridge, the percentage of months that exceeded the temperature threshold ranged from 20.6% for Critical, to 0.9% for Wet water year types. In general, the percentage of months that exceeded the temperature threshold increased from wetter to drier water year types, during the year-round period, for each phase of the Proposed Action.

Table 7-40. Percent of months above the 59.9°F pathogen virulence water temperature threshold for juvenile steelhead rearing and outmigration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, Year-round.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	11.8	0.0	0.0	0.9	0.9	0.9
AN	20.0	20.0	1.7	1.7	1.7	1.7
BN	22.9	20.0	2.9	5.7	5.7	5.7
D	31.8	23.5	20.0	20.0	20.0	20.0
C	48.5	41.8	22.4	20.6	20.6	20.6
All	30.2	23.5	11.6	11.6	11.6	11.6

At the Stanislaus River above the confluence with San Joaquin, the percentage of months that exceeded the temperature threshold ranged from 69.7% for Critical, to 21.8% for Wet water year types. In general, the percentage of months that exceeded the temperature threshold increased from wetter to drier water year types, during the year-round period, for each phase of the Proposed Action.

Table 7-41. Percent of months above the 59.9°F pathogen virulence water temperature threshold for juvenile steelhead rearing and outmigration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River above confluence with San Joaquin River, Year-round.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	21.8	23.6	22.7	21.8	21.8	21.8
AN	35.0	40.0	25.0	28.3	28.3	28.3
BN	32.9	47.1	28.6	35.7	35.7	35.7
D	48.2	62.4	60.0	58.8	58.8	58.8
C	63.0	75.2	71.5	69.7	69.7	69.7
All	43.5	53.1	46.7	47.1	47.1	47.1

Historical water temperatures near Orange Blossom (Figure 7-29) indicate the frequency of occurrence is likely **medium**, as 15 out 23 years from 2001-2022 have exceeded the virulence threshold. In the summer, releases of storage are expected to increase flows which may decrease the stressor while storage and reduced lows in the spring may do the opposite.

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 steelhead nor to the CVP rivers and tributaries of the Central Valley.

- McCullough (1999) is quantitative, not species-specific, not location specific, published research on virulence temperature thresholds.
- Historical water temperatures are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed from long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- Historical kelt emigration-timing observations are quantitative, species-specific, location-specific, published in technical memos and annual reports from technical teams, not expected to have statistical power.
- HEC-5Q water temperature modeling are quantitative, not species-specific (environmental variable) and location-specific. The model was developed to evaluate reservoir systems using control points, and is widely accepted as the temperature modeling system for use in the upper Central Valley 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

- Clear Creek
    - Water Temperature Management
- American River
    - Water Temperature Management
- Stanislaus River
    - Stepped Release Plan

7.2.4 Egg Incubation and Fry Emergence

Studies on steelhead egg incubation have found that temperatures between 40°F and 55°F are suitable for successful incubation and fry development (Washington State Department of Ecology 2002a). Steelhead egg incubation varies with temperature and requires approximately 490 accumulated temperature units. For example, in 50°F (10°C) water, incubation would end approximately 50 days after incubation starts.

On the American River, egg incubation starts in late December and ends in late May, with peak incubation between February and April (Hannon pers. comm. 2023; Sacramento Water Forum 2015).

Egg incubation timing was not available for the other watersheds so the spawning period for each watershed was used with an addition of 50 days for incubation. In the Sacramento River, timing would be December through June. In Clear Creek, incubation timing would be late-December through late-May. In the Stanislaus River, timing can only be estimated and would be January through late May. There are no reports of steelhead spawning in the San Joaquin River and Delta.

The stressors influencing steelhead egg incubation and fry emergence include predation risk, in-river fishery and trampling, toxicity from contaminants, dissolved oxygen, sedimentation and gravel quantity, redd quality, water temperature, pathogens and disease, and stranding and dewatering and are described in Section 7.1.3, *Limiting Factors, Threats, and Stressors*.

The Proposed Action is not anticipated to change the stressors for *Predation risk* and *In-river fishery and trampling*.

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

- The Proposed Action may increase and decrease the *toxicity from contaminants* stressor. During the egg incubation and fry emergence period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. Reduced flows may concentrate contaminants when present while increased flows may dilute contaminants.

Water quality monitoring 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 and decrease the *dissolved oxygen* stressor depending on the watershed and season. During the egg incubation and fry emergence period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. Releases of reservoir storage may result in cooler water temperatures and higher flows that may provide a higher dissolved oxygen saturation potential. Changing flows with seasonal operations in the spring could result in warmer temperatures and decreased flows (and thus lower oxygen levels).

  Salmonid embryos experience low survival at dissolved oxygen content in the gravel near or below 5 mg/L and increased survival at 8 mg/L (Bjornn and Reiser 1991, Philips and Campbell 1961, Carter 2005). Rombough (1988) proposed maintaining dissolved oxygen levels between 7.5-9.7 mg/L or greater to maximize egg survival. In the Sacramento River below Keswick Dam and Stanislaus River at Ripon, water quality monitoring has not consistently shown dissolved oxygen at levels below 8 mg/L during egg incubation. Dissolved oxygen levels at these two sites occasionally drop below 8 mg/L for short periods towards the end of the incubation period.

  There are no annual dissolved oxygen monitoring stations for Clear Creek and the American River. However, upper Clear Creek is very steep and monitoring shows white water which indicates high levels of gas exchange. Main channels near the rotary screw traps of the lower American river have dissolved oxygen levels above the threshold during egg incubation (Day and Starr 2021). Restoration in the lower American River at Sailor Bar has improved dissolved oxygen levels through gravel augmentation. Prior to gravel additions, the average DO was 4.5 mg/L, and after gravel was added, the average DO was 10.5 mg/L (Redd 2010).

- The Proposed Action may increase the *sedimentation and gravel quantity* stressor. During the egg incubation and fry emergence period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. Decreased flows potentially increase fine sediment deposition, thus increasing the sedimentation and gravel quantity stressor. Deposition of fine sediment has been shown to degrade eggs and alevin essential functions and development (Bennett et al. 2003, Jensen et al. 2009), and build-up of fine sediment can decrease permeability for embryos (Bjornn and Reiser 1991).

Although the Proposed Action will have decreased flows during the egg incubation period, flow rates are still generally higher than other times of the year. The relatively high seasonal flows during the steelhead egg incubation season are likely sufficient to potentially reduce fine sedimentation deposition rates.

- The Proposed Action may increase and/or decrease the *redd quality* stressor. During the egg incubation and fry emergence period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. Build-up of fine sediment can decrease permeability, decrease interstitial flow, and reduce oxygen availability for embryos (Bjornn and Reiser 1991), and increases in flow in the summer may do the opposite.

  Although the Proposed Action will have decreased flows during the egg incubation period, flow rates are still generally higher than other times of the year. The relatively high seasonal flows during the steelhead egg incubation season are likely sufficient to maintain hyporheic connectivity, dissolved oxygen levels, and potentially reduce fine sedimentation deposition rates relative to other seasons, thus improving egg and alevin essential functions and development (Bennett et al. 2003).

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 provided.

7.2.4.1 Water Temperature

The proposed storing and releasing of water may increase the water temperature stressor. During the egg incubation and fry emergence period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. Steelhead eggs require cool water temperature to incubate. Appendices L, M, and N address temperature related effects in the Proposed Action.

Lab-based studies of predominantly rainbow trout, on populations outside of the Central Valley, reported maximum hatching success between 44.6°F and 50°F (Kwain 1975; Washington State Department of Ecology 2002a), with negative thermal effects developing at or near 53.6°F (McCullough 2001) and sharp increases in mortality at 57.2°F or 59°F (Velsen 1987; Rombough 1988).

The increase in the water temperature stressor may be **sub-lethal** in Clear Creek. The increase in water temperature is expected to be **lethal** in the Sacramento River, American River, and Stanislaus River. Steelhead alevin may hatch smaller and less developed at temperatures above 53.6°F and may have sharp increases in egg and alevin mortality in temperatures above 57.2°F.

Although the Proposed Action may increase the water temperature stressor, unsuitable water temperatures for steelhead 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.

Ambient conditions in the Sacramento River during steelhead egg incubation in winter and early spring are generally suitable. In 1997, Reclamation completed the temperature control device at Shasta Reservoir, which can be used to effectively blend water from the warmer upper reservoir levels and, thereby, extend the time-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 temperature control device. Different approaches have targeted different temperatures and locations throughout the years including a warmwater bypasses to conserve limited coldwater pool.

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. 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.

Prior to the construction of Folsom and Nimbus dams, CV steelhead would seek out coldwater refuges in higher elevation habitats of the basin. During the late 1960s, Reclamation designed a modification to the trash rack structures to provide selective withdrawal capability at Folsom Dam through the Folsom Power Plant. The steel trash racks are now equipped with three groups of shutters that can pull water from various elevations, which have different temperatures when the lake is thermally stratified. This allows for limited discretionary temperature management of the lower American River.

In 2009, NMFS issued an RPA that required Reclamation to prepare and implement a TMP by May 15 each year for the American River. Reclamation proposed a similar TMP in 2019. During most years in the spring steelhead incubation season, ambient conditions provide suitable steelhead egg incubation temperatures. Water temperatures in some dry and warm incubation seasons can exceed optimum temperatures. Reclamation implements the flow management standard minimum flows which help to provide suitable steelhead egg incubation temperatures in these types of years.

To reduce the water temperature stressor in the American River, Reclamation recently completed the WTMP effort, which is intended to enhance modeling capabilities to predict summer and fall water temperature through facilities operations, such as the Folsom Dam temperature shutters.

Past operational releases from New Melones Dam have influenced the extent of cool water habitat available below Goodwin Dam. In 2009, NMFS issued an RPA that dictated specific temperature targets for the Stanislaus River to benefit steelhead. Since 2019, Reclamation has implemented an SRP for the Stanislaus River. The SRP does not set water temperature standards for the Stanislaus River, but it does include minimum flow targets that are intended to benefit steelhead, including water temperature benefits. None of the dams on the Stanislaus River have a TCD, so the only mechanism for temperature management on the Stanislaus River is direct flow management. Reclamation currently operates New Melones Dam. Water temperatures in the reach of the Stanislaus where steelhead spawn (Goodwin to ~Orange Blossom) are suitable for steelhead incubation in the winter and early spring incubation season although they can get to the upper optimal limits in some dry and warm years.

The **proportion** of the population affected by the Proposed Action depends on hydrology, meteorology, storage in reservoirs, releases from reservoirs, operation of the TCD, distribution of redds, spawning timing, and duration of egg incubation.

Literature on critical water temperatures historically identified 53.6°F as the threshold temperature to impair egg incubation and fry emergence.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

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. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed water temperature criteria obtained from scientific literature.

In the Sacramento River, the stressor may increase starting in April when historic water temperatures increase above 57.2°F at RBDD (Figure 7-66). The proportion of the population affected by the Proposed Action is likely **small** for Sacramento River, as there is a very small proportion of the population that spawn on the mainstem Sacramento River.

Results for the 45°F to 52°F range are presented in Table 7-42 for the Sacramento River at Keswick, Table 7-43 for the Sacramento River at the RBDD, Table 7-44 for Clear Creek below Whiskeytown, Table 7-45 for the American River at Watt Ave., and Table 7-46 for the American River at Hazel Ave. At Keswick, the percentage of months outside the optimal temperature range was from 50.0% for Dry to 40.2% for Above Normal water year types. Overall, the Proposed Action phases performed similarly for all water year types during the period of December through June.

Table 7-42. Percent of months outside the 45°F to 52°F optimal egg incubation water temperature range steelhead by water year type and for all years combined, Sacramento River at Keswick, December through June.

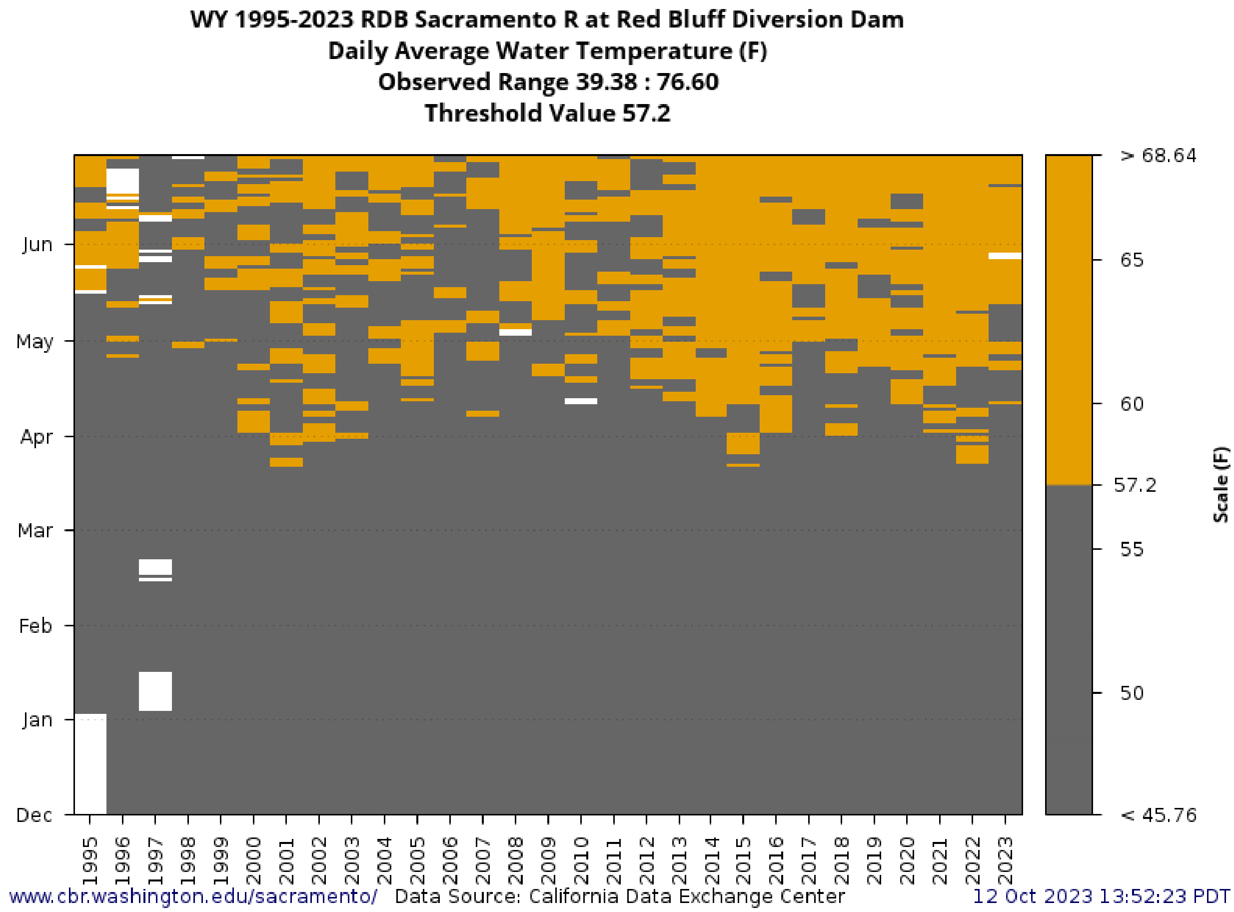
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	66.8	48.5	40.8	44.9	44.4	44.9
AN	72.8	51.1	44.6	42.4	40.2	41.3
BN	77.0	47.6	48.4	47.6	47.6	48.4
D	78.6	53.6	45.2	50.0	48.8	49.4
C	74.8	51.4	47.7	46.8	47.7	45.9
All	73.6	39.1	36.9	34.9	34.3	34.6

At the Sacramento River at the RBDD, the percentage of months outside the 45°F to 52°F range under the Proposed Action phases range from 62.2% during Critical water years to 48.0% of months during Wet water years. Overall, the percentage of months outside the range increased from wetter to drier water year types during the period of December through June.

Table 7-43. Percent of months outside the 45°F to 52°F optimal egg incubation water temperature range steelhead by water year type and for all years combined, Sacramento River at the Red Bluff Diversion Dam, December through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	62.2	51.0	47.4	48.0	48.0	48.0
AN	63.0	53.3	48.9	48.9	48.9	48.9
BN	67.5	56.3	54.8	56.3	56.3	56.3
D	63.7	55.4	56.0	56.0	56.0	56.0
C	64.0	64.9	61.3	62.2	62.2	62.2
All	63.9	55.6	53.2	53.8	53.8	53.8

The **frequency** of occurrence in the Sacramento River is likely **high**. Historic daily average water temperatures in the Sacramento River at RBDD have exceeded the lethal threshold of 57.2°F at least one day during egg incubation April through June, in 29 out of 29 years. Maintenance of Shasta storage may reduce flows in the spring, and subsequently increase the water temperature stressor. Releases of storage in the summer may increase flows which may decrease the stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-66. Days exceeding 57.2°F at Sacramento River at Red Bluff Diversion Dam (RBDD) between December and June, 1995 – 2023.

In Clear Creek, historical water temperatures occasionally reach above the thermal threshold starting in May, and with most redds appearing in January (Figure 7-67), the **proportio**n of the population is likely **small**.

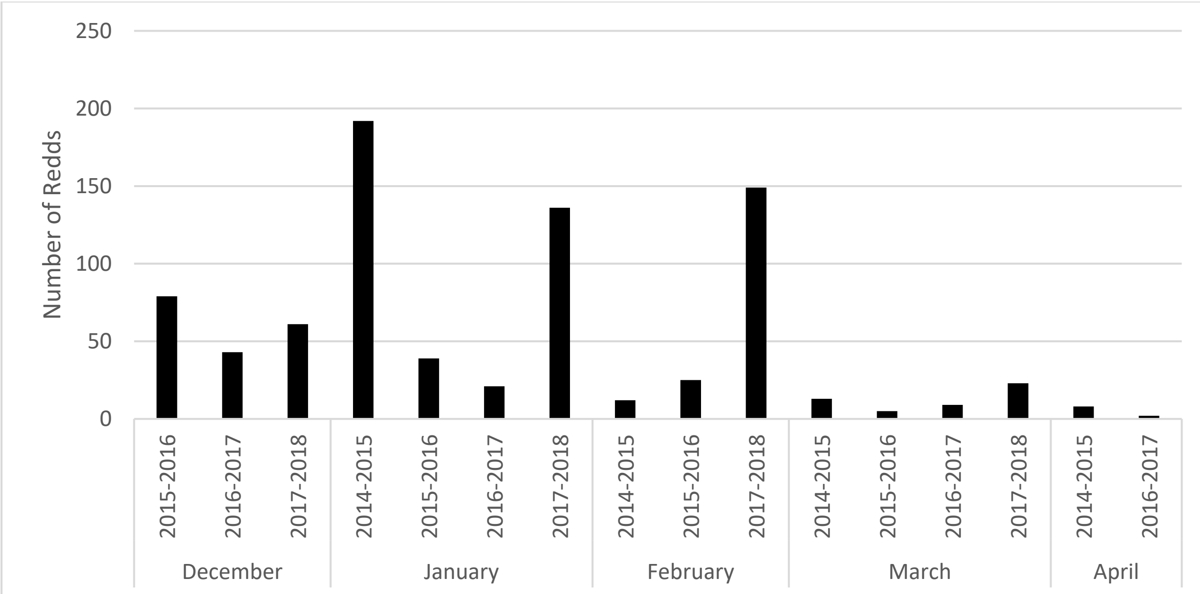


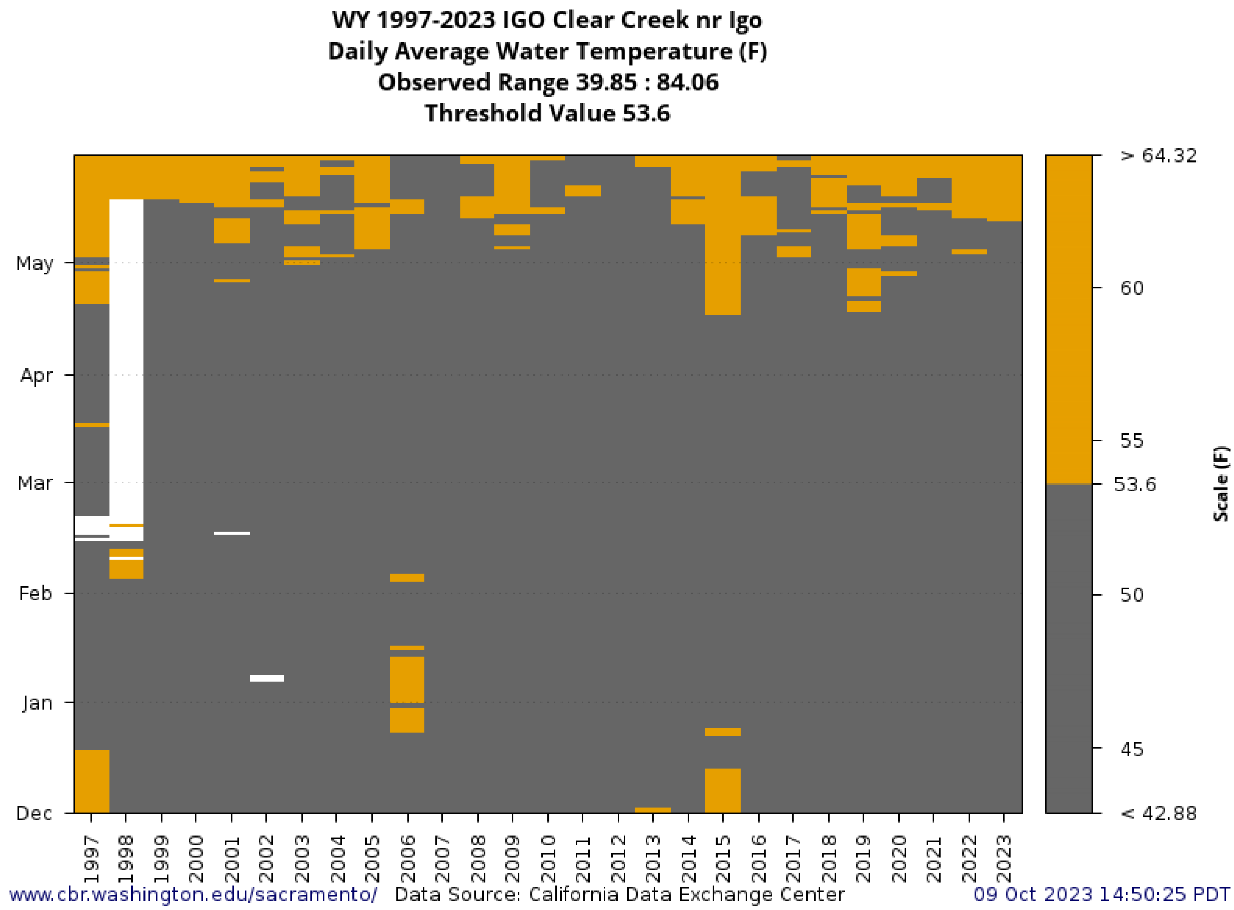
Figure 7-67. Number of redds during monthly redd surveys on Clear Creek, December through April, 2014 – 2018.

At Clear Creek below Whiskeytown, the percentage of months outside the 45°F to 52°F range under the Proposed Action phases ranges from 34.7% during Wet water years to 19.8% of months during Critical water years. Overall, the percentage of months outside the range decreased from wetter to drier water year types during the period of December through June.

Table 7-44. Percent of months outside the 45°F to 52°F optimal egg incubation water temperature range steelhead by water year type and for all years combined, Clear Creek below Whiskeytown, December through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	71.4	26.0	33.7	34.7	34.7	34.7
AN	77.2	20.7	25.0	28.3	29.3	29.3
BN	75.4	31.0	29.4	27.8	27.8	28.6
D	74.4	23.2	21.4	21.4	22.0	21.4
C	73.9	20.7	18.9	19.8	19.8	19.8
All	74.0	11.7	13.1	13.9	14.3	14.3

Historical water temperatures in Clear Creek below Whiskeytown Dam have exceeded 53.6°F at least one day during the egg incubation period, in 25 out of 27 years. The **frequency** of occurrence for a sub-lethal effect in the Clear Creek is likely **high** (Figure 7-68). Maintenance of Whiskeytown storage may reduce flows in the spring, and subsequently increase the water temperature stressor in May. In four of the 27 year historical record, the lethal threshold of 57.2°F was met near Igo in Clear Creek. All instances of daily average water temperature above lethal criteria were prior to 2008.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-68. Days exceeding 53.6°F at Clear Creek near Igo between December and May, 1997 – 2023.

At the American River at Watt Ave., the percentage of months outside the 45°F to 52°F range under the Proposed Action phases range from 69.5% during Critical water years to 45.2% of months during Wet water years. Overall, the percentage of months outside the range increased from wetter to drier water year types during the period of December through May.

Table 7-45. Percent of months outside the 45°F to 52°F optimal egg incubation water temperature range steelhead by water year type and for all years combined, American River at Watt Ave., December through May.

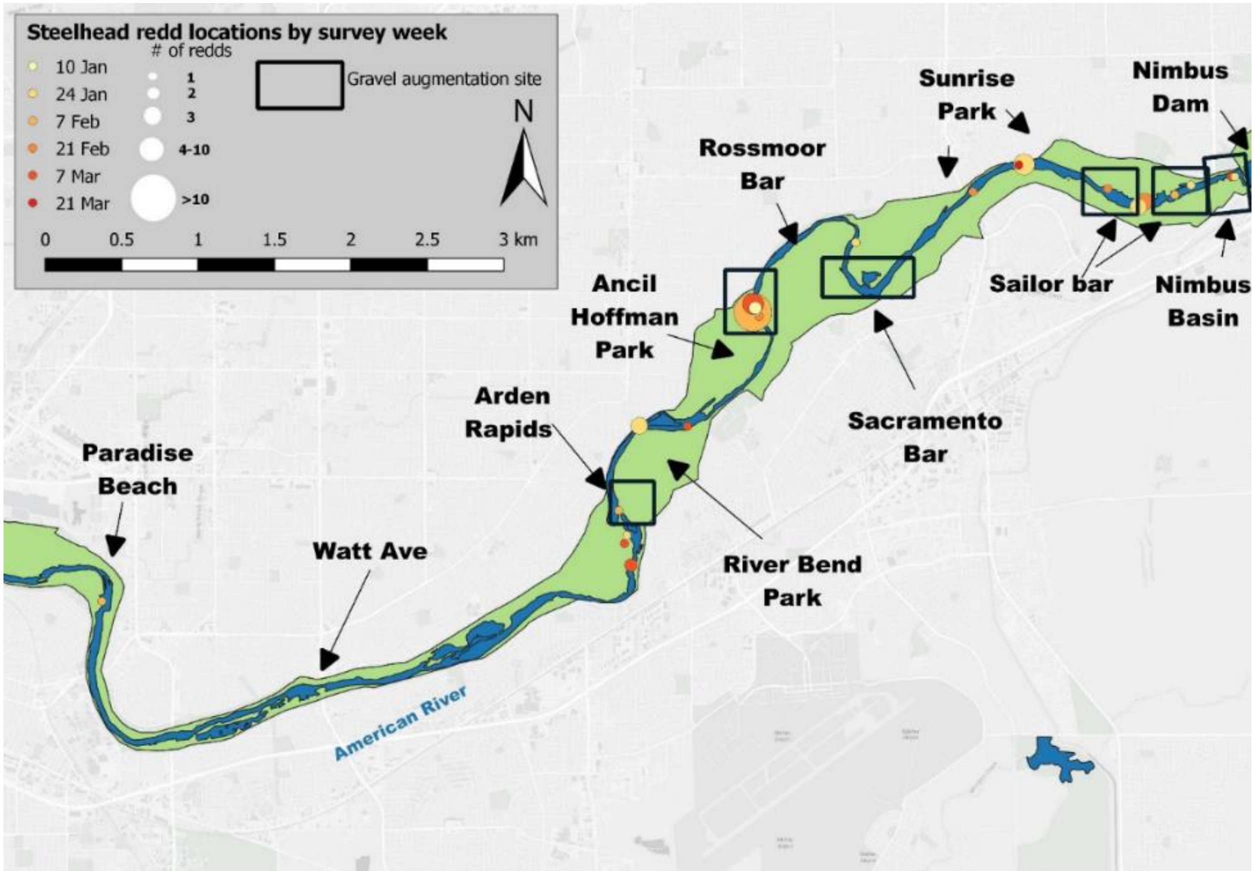
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	47.0	48.2	45.2	44.6	45.2	45.2
AN	48.1	53.2	49.4	48.1	48.1	48.1
BN	53.7	58.3	55.6	57.4	55.6	52.8
D	58.3	63.9	56.9	59.0	59.7	54.9
C	62.1	71.6	67.4	67.4	69.5	67.4
All	53.5	58.2	54.0	54.5	54.9	52.9

At the American River at Hazel Ave., the percentage of months outside the 45°F to 52°F range under the Proposed Action phases ranges from 56.8% during Critical water years to 33.9% of months during Wet water years. Overall, the percentage of months outside the range increased from wetter to drier water year types during the period of December through May.

Table 7-46. Percent of months outside the 45°F to 52°F optimal egg incubation water temperature range steelhead by water year type and for all years combined, American River at Hazel Ave., December through May.

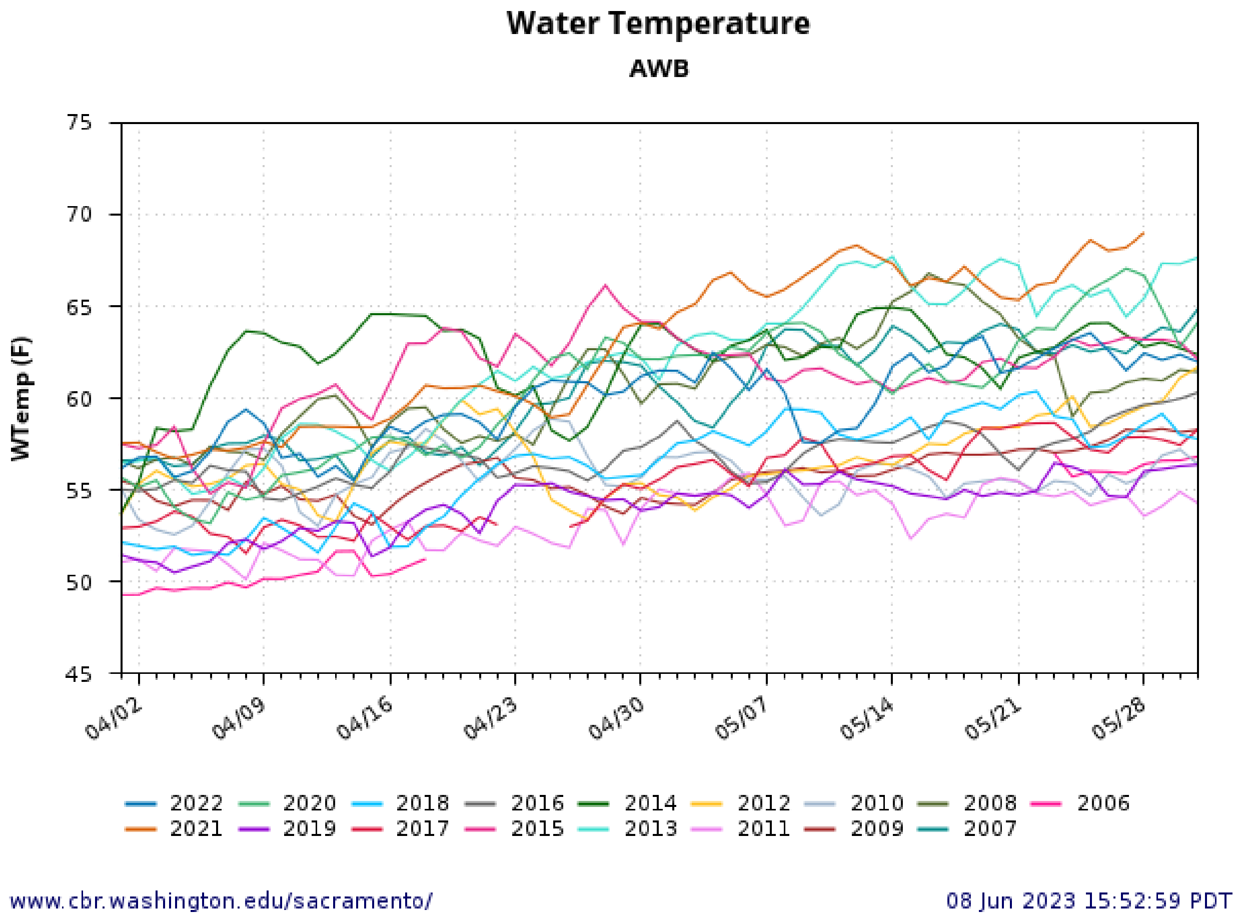
WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	44.6	39.9	34.5	33.9	34.5	33.9
AN	50.6	48.1	40.5	36.7	36.7	38.0
BN	49.1	47.2	41.7	42.6	41.7	40.7
D	56.9	54.9	43.8	48.6	48.6	44.4
C	62.1	63.2	54.7	55.8	56.8	54.7
All	52.0	49.7	42.1	42.9	43.1	41.6

In the American River, the impairment threshold is typically met by March, remains above the impairment threshold throughout the rest of the spawning season, and approaches the lethal limit in April and May (Figure 7-70). The **proportion** of the population affected by the lethal effect of the water temperature stressor is likely **medium**. On the American River, egg incubation starts in late December and ends in May, with peak incubation between February and April (Hannon pers. comm. 2023). Redd distribution during 2022 monitoring season showed peak abundance February through March (Figure 7-69), leading to peak incubation timing from April through May in the latest years of monitoring, when water temperatures occasionally exceed the lethal limit (Figure 7-70 and Figure 7-71).



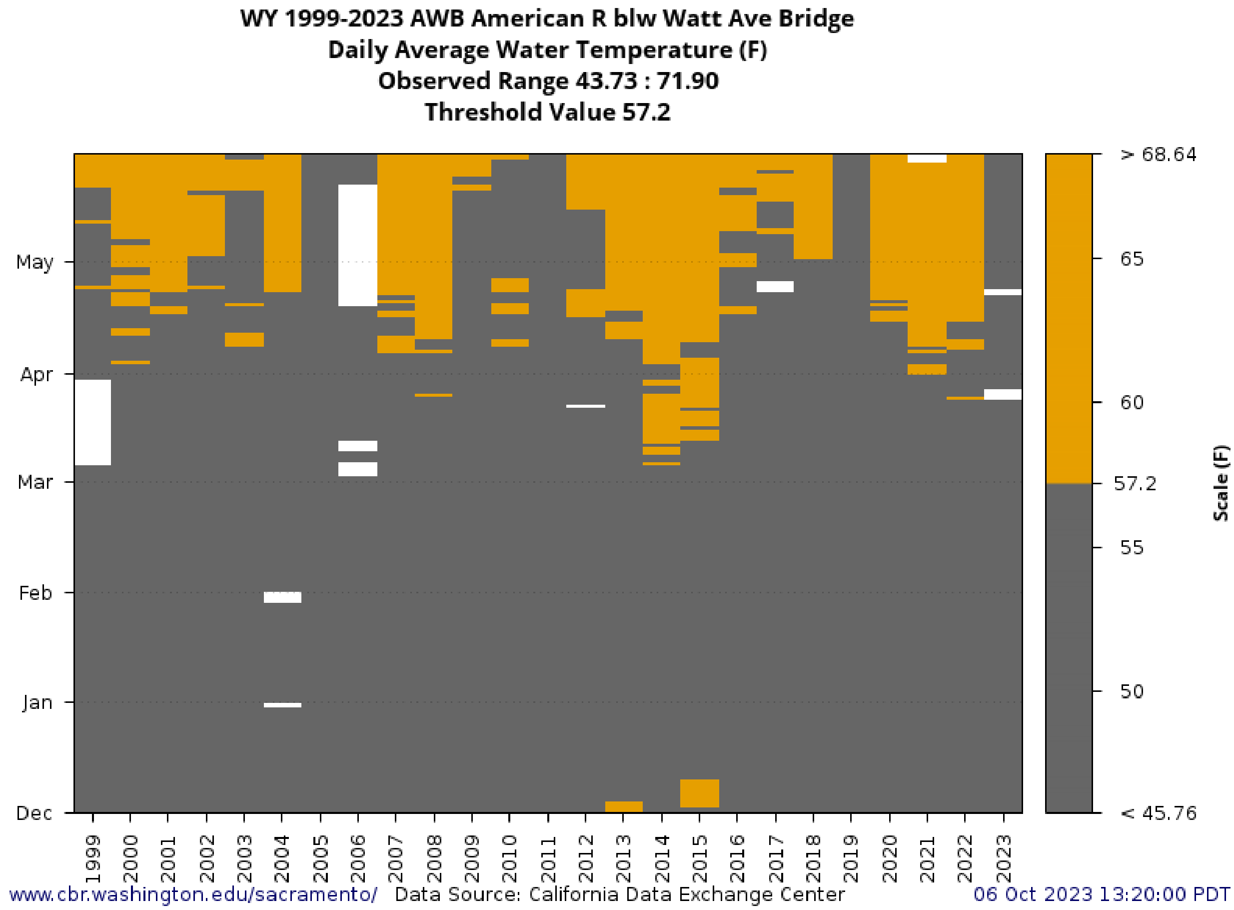
Source: Sweeney et al. 2022.

Figure 7-69. 2022 redd distribution on the American River.



Source: Columbia Basin Research 2023.

Figure 7-70. Water temperature, American River at Watt Avenue, 2006 – 2022, April through May.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-71. Days exceeding 57.2°F at the American River below Watt Ave (AWB) between January and May, 1999 – 2023.

The **frequency** of occurrence in the American River is likely **high**. The water temperature stressor is dependent on coldwater pool availability and is affected primarily by hydrology and meteorology. Historic water temperatures at the American River below Watt Ave have exceeded 57.2°F at least one day during peak passage in 80% of water years in 1999-2023 (Figure 7-71). Maintenance of Folsom storage may reduce flows in the spring, and subsequently increase the water temperature stressor.

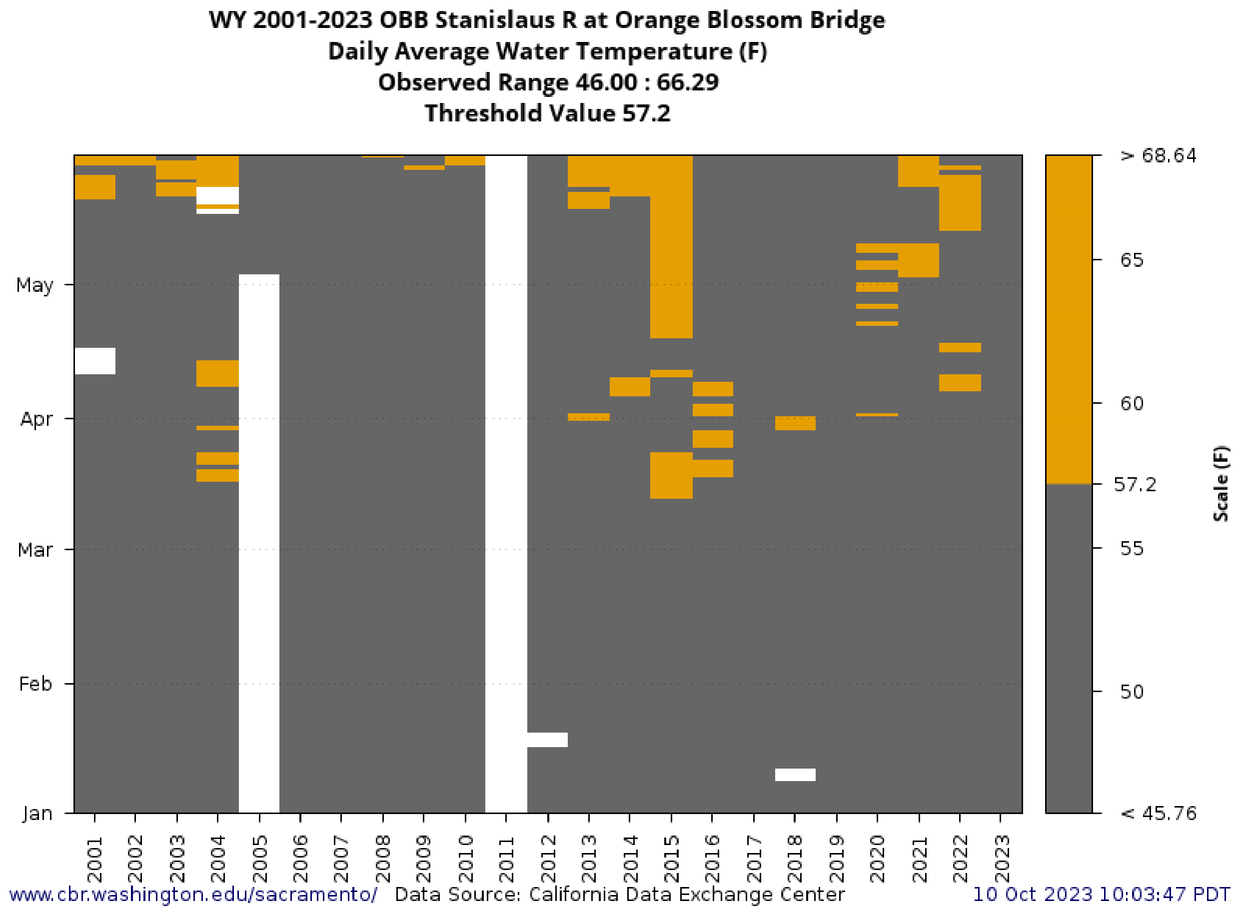
In the Stanislaus River, the impairment threshold is typically met by March, remains above the impairment threshold throughout the rest of the spawning season, and approaches the lethal limit towards the end of the incubation and fry emergence season (Figure 7-29). Historic water temperatures occasionally exceed the lethal limit of 57.2°F in March through May, when the **proportion** of the population is likely **medium**.

Results for the 42.1°F to 55°F range are presented in Table 7-47 for the Stanislaus River at Orange Blossom Bridge. At the Stanislaus at Orange Blossom Bridge, the percentage of months outside the optimal temperature range was from 52.8% for Critical to 6.8% for Wet water year types. Overall, the percentage of months outside of the optimal temperature range increased from wetter to drier water year types for all phases of the Proposed Action during the period of December through July.

Table 7-47. Percent of months outside the 45°F to 52°F optimal egg incubation water temperature range steelhead by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, December through July.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	15.9	6.8	6.1	6.8	6.8	6.8
AN	19.4	15.3	9.7	12.5	12.5	12.5
BN	24.7	22.4	10.6	15.3	15.3	15.3
D	24.5	46.1	40.2	43.1	43.1	43.1
C	39.6	55.3	54.8	52.8	52.8	52.8
All	27.0	33.2	29.4	30.4	30.4	30.4

The **frequency** of occurrence in the Stanislaus River is likely **medium**, as the lethal threshold is met in 14 out of 23 years (Figure 7-72). Maintenance of New Melones storage may reduce flows in the spring, and subsequently increase the water temperature stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-72. Days exceeding 57.2°F at Stanislaus River near Orange Blossom Bridge between January and May, 2001 – 2023.

To evaluate the **weight of evidence** for the water temperature stressor, there are temperature thresholds from several peer reviewed articles and state issued water quality documents that are specific to steelhead but these studies are lab-based and are not specific to the Central Valley. The water quality monitoring data through SacPAS provides quantitative data on each watershed to assess whether a threshold was met (Columbia Basin Research 2023).

- Kwain (1975) is quantitative, species-specific, not specific to anadromy, not location specific, peer reviewed published research for optimal egg incubation water temperatures.
- Washington State Department of Ecology (2002a) is quantitative, species-specific, not location specific, state handbook for water quality criteria and water temperature effects on steelhead.

- McCullough (2001) is quantitative, species-specific, not location specific, federal Environmental Protection Agency handbook for water quality criteria and water temperature effects on steelhead.
- Rombough (1988) is quantitative, species-specific, not location specific, peer reviewed published lab research on growth of steelhead embryos and alevins.
- Historical water temperatures are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed from long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- Historical adult spawning-timing observations are quantitative, species-specific, and location-specific. The observations are published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- HEC-5Q water temperature modeling are quantitative, not species-specific (environmental variable) and location-specific. The model was developed to evaluate reservoir systems using control points, and is widely accepted as the temperature modeling system for use in the upper Central Valley 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
- American River
    - Water Temperature Management
- Stanislaus River
    - Stepped Release Plan

7.2.4.2 Pathogens and Disease

The proposed storing and diverting of water may increase the pathogens and disease stressor. During the egg incubation and fry emergence period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. Warmer water temperatures may increase pathogen virulence and prevalence of disease. Appendices L, M, and N address temperature related effects in the Proposed Action.

The increase in the pathogens and disease stressor is expected to be **sub-lethal** in the Sacramento, American and Stanislaus rivers. Presence of pathogens and disease may impair growth and potentially reduce survival of eggs during incubation and when fry emerge. Seasonal operations result in decreased flows and increased water temperature, which may increase pathogen concentration and horizontal transmission, while increasing temperature may increase pathogen virulence. Water temperatures greater than 59.9°F is the threshold above which diseases affecting Chinook salmon become highly virulent (McCullough 1999).

The Proposed Action is expected to result in insignificant changes to pathogens and disease in Clear Creek. Historical water temperatures in Clear Creek do not exceed the threshold during egg incubation and fry emergence.

Although the Proposed Action may increase the pathogens and disease stressor in the Sacramento, American, and Stanislaus rivers, pathogens and disease that may affect egg incubation and fry emergence 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 (National Marine Fisheries Service 1998).

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 WTMP 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.

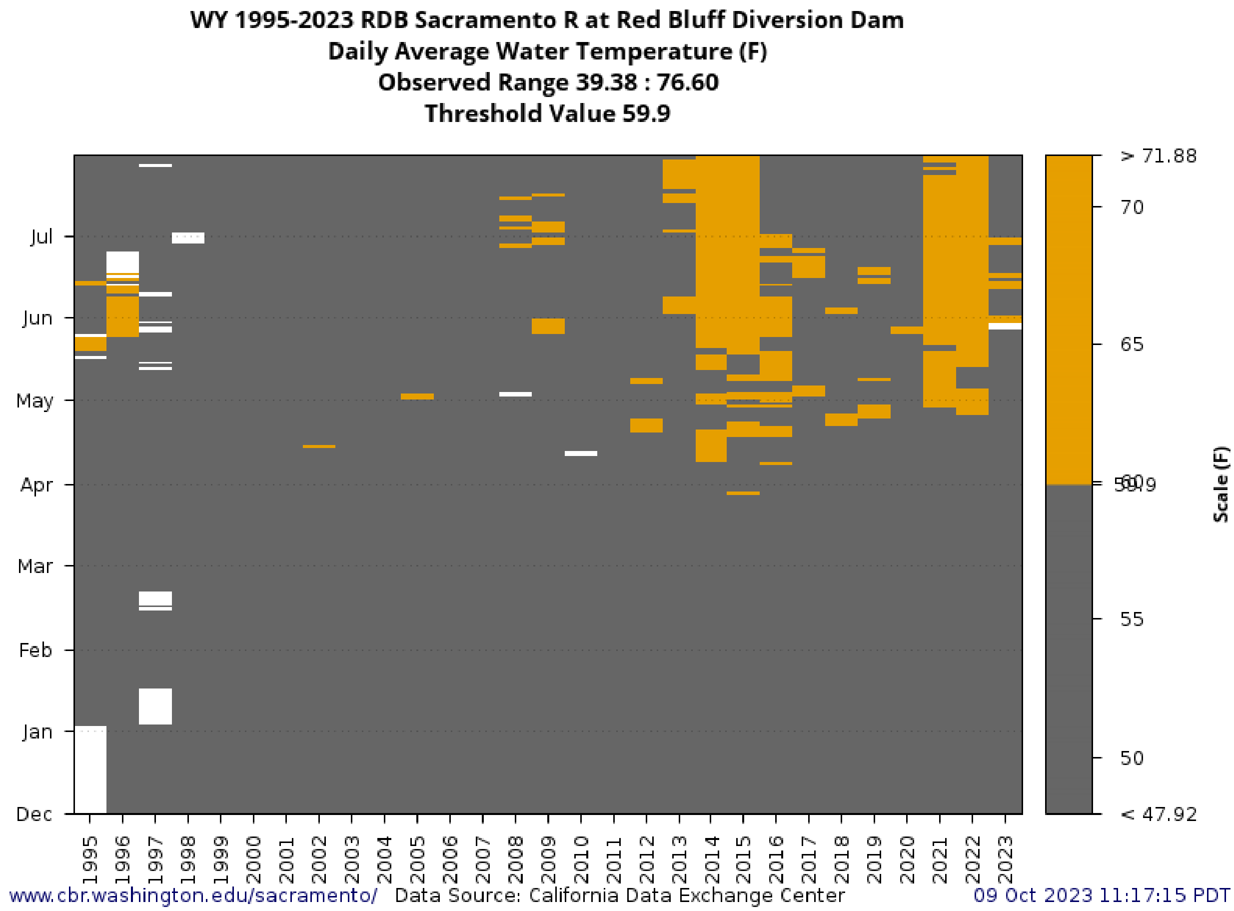
The **proportion** of the population affected by Proposed Action depends on water temperature management and peak migration timing.

Literature on critical water temperatures for pathogens and disease historically identified 59.9°F as the threshold temperature to increase virulence of pathogens.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

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. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed pathogens and disease water temperature criteria obtained from scientific literature.

In the Sacramento River, maintenance of storage from Shasta Reservoir may increase the pathogens and disease stressor during egg incubation and fry emergence. Historical water temperatures occasionally exceed the virulence threshold April through July (Figure 7-73). The **proportion** of the population affected by the Proposed Action is likely **small**, as there is little evidence of spawning on the mainstem Sacramento River.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-73. Days exceeding water temperatures of 59.9°F in the Sacramento River at RBDD, 1999 – 2023, February through June.

Results for the exceedance of the 59.9°F pathogen virulence temperature threshold are presented in Table 7-48 for the Sacramento River at Keswick, Table 7-49 for the Sacramento River at the RBDD, and Table 7-50 for the American River at Hazel Ave., Table 7-51 for the American River at Watt Ave, and Table 7-52 for the Stanislaus River at Orange Blossom Bridge. At Keswick, the percentage of months that exceeded the temperature threshold remained at 0.0% for all phases of the Proposed Action, and all water year types, during the period from December through June.

Table 7-48. Percent of months above the 59.9°F pathogen virulence water temperature threshold for steelhead egg incubation and fry emergence by water year type and for all years combined, Sacramento River at Keswick, December through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	9.2	0.0	0.0	0.0	0.0	0.0
AN	13.0	0.0	0.0	0.0	0.0	0.0
BN	19.8	0.0	0.0	0.0	0.0	0.0
D	18.5	0.0	0.0	0.0	0.0	0.0
C	21.6	0.0	0.0	0.0	0.0	0.0
All	15.9	0.0	0.0	0.0	0.0	0.0

At the Sacramento River at the RBDD, the percentage of months that exceeded the temperature threshold under the Proposed Action phases range from 15.3% during Critical water years to 10.3% of months during Below Normal water year types. Results were similar for all water year types under the Proposed Action phases during the period of December through June.

Table 7-49. Percent of months above the 59.9°F pathogen virulence water temperature threshold for steelhead egg incubation and fry emergence by water year type and for all years combined, Sacramento River at the Red Bluff Diversion Dam, December through June.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	23.0	23.5	19.4	12.8	12.8	12.8
AN	27.2	23.9	17.4	13.0	13.0	13.0
BN	27.8	20.6	14.3	10.3	10.3	10.3
D	29.2	23.8	17.3	12.5	11.9	14.3
C	36.0	30.6	23.4	15.3	15.3	15.3
All	28.0	24.2	18.3	12.7	12.6	13.1

The **frequency** of occurrence is likely **medium**, as the threshold is met in 18 out of 29 years (Figure 7-73).

In Clear Creek, maintenance of storage from Whiskeytown Reservoir in the spring may increase the pathogens and disease stressor during egg incubation and fry emergence, but the effect is likely insignificant. Historical daily average water temperatures have been below the virulence threshold throughout incubation and fry emergence (Figure 7-20).

In the American River, maintenance of storage from Folsom Reservoir in the spring may increase the pathogens and disease stressor during egg incubation and fry emergence. Historical daily average water temperatures exceed the virulence threshold in April and May (Figure 7-26) which may have a compounding effect with lower flows from the Proposed Action. The

proportion of the population affected by the Proposed Action is likely **medium**, as most egg incubation and fry emergence occurs earlier in the season, when the threshold is occasionally met.

At the American River at Hazel Ave., the percentage of months that exceeded the temperature threshold under the Proposed Action phases range from 9.5% during Critical water years to 0.6% of months during Wet water year types. During Above Normal water year types the percentage of months that exceeded the temperature threshold remained at 0.0% for all phases of the Proposed Action, during the period examined from December through May.

Table 7-50. Percent of months above the 59.9°F pathogen virulence water temperature threshold for steelhead egg incubation and fry emergence by water year type and for all years combined, American River at Hazel Ave., December through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	3.0	1.2	0.6	0.6	0.6	0.6
AN	6.3	6.3	0.0	0.0	0.0	0.0
BN	12.0	7.4	5.6	5.6	4.6	4.6
D	11.8	9.7	6.3	7.6	6.9	7.6
C	24.2	15.8	6.3	7.4	8.4	9.5
All	10.6	7.4	3.7	4.2	4.0	4.4

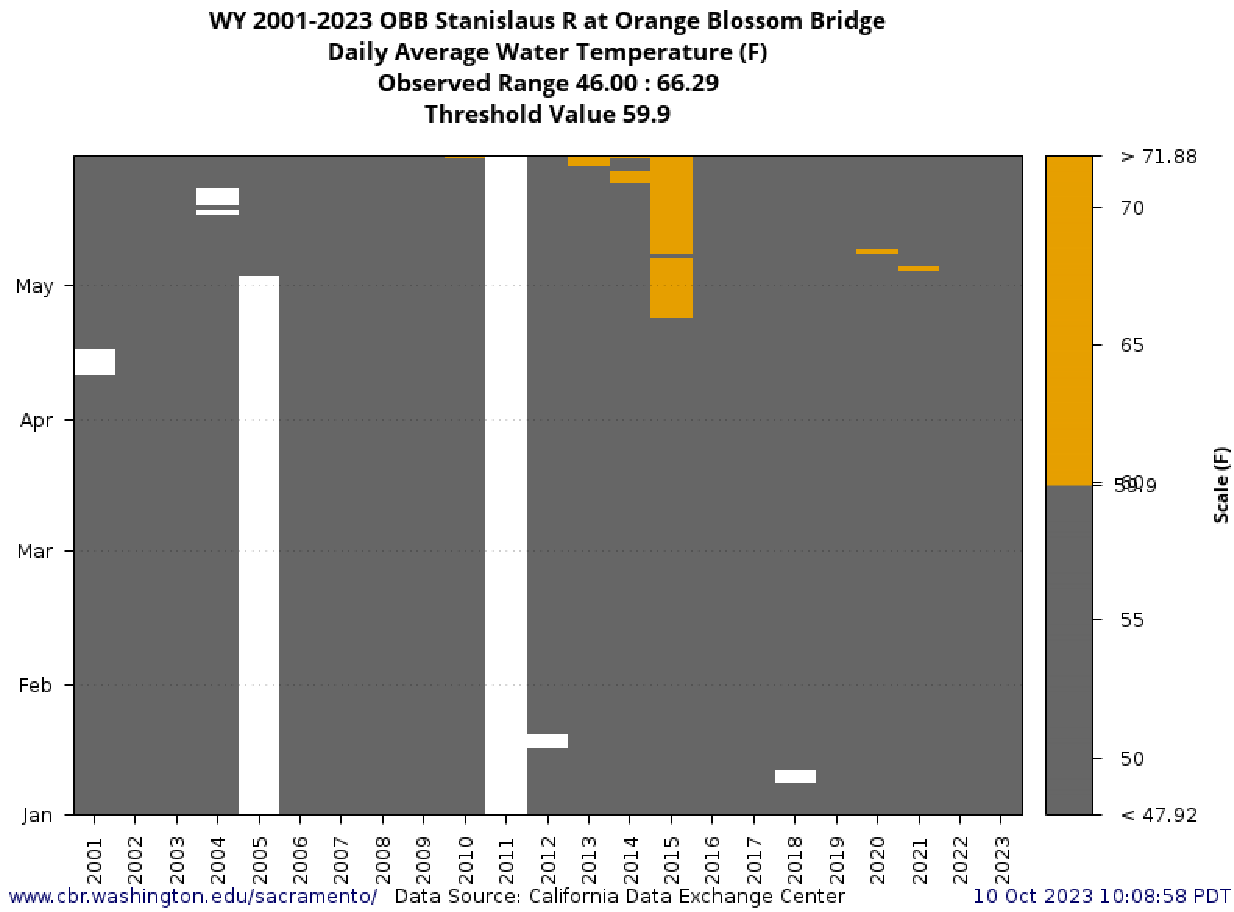
At the American River at Watt Ave., the percentage of months that exceeded the temperature threshold under the Proposed Action phases range from 27.4% during Critical water years to 6.0% of months during Wet water year types. Overall, the percentage of months that exceeded the temperature threshold increased from wetter to drier water year types under the Proposed Action phases during the period of December through May.

Table 7-51. Percent of months above the 59.9°F pathogen virulence water temperature threshold for steelhead egg incubation and fry emergence by water year type and for all years combined, American River at Watt Ave., December through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	5.4	6.0	6.0	6.0	6.0	6.0
AN	15.2	15.2	15.2	15.2	15.2	15.2
BN	17.6	14.8	14.8	15.7	16.7	15.7
D	20.8	20.1	18.8	19.4	19.4	19.4
C	30.5	29.5	27.4	24.2	27.4	25.3
All	16.7	16.0	15.3	15.2	15.8	15.3

The **frequency** of occurrence is likely **medium**, as the daily average water temperatures meet the virulence threshold in 15 out of 25 years.

In the Stanislaus River, maintenance of storage from New Melones Reservoir in the spring may increase the pathogens and disease stressor during egg incubation and fry emergence. Historical daily average water temperatures exceed the virulence threshold occasionally in May (Figure 7-74) which may have a compounding effect with lower flows from the Proposed Action. The **proportion** of the population affected by the Proposed Action is **likely small**, as most egg incubation and fry emergence occurs earlier in the season when the threshold is not met.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-74. Days exceeding water temperatures of 59.9°F in the Stanislaus River at Orange Blossom Bridge, 1999 – 2023, January through May.

At the Stanislaus River at Orange Blossom Bridge, the percentage of months that exceeded the temperature threshold under the Proposed Action phases range from 25.0% during Critical water years to 13.1% of months during Wet water year types. Overall, the percentage of months that exceeded the temperature threshold increased from wetter to drier water year types under the Proposed Action phases during the period of December through July.

Table 7-52. Percent of months above the 59.9°F pathogen virulence water temperature threshold for steelhead egg incubation and fry emergence by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, December through July.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	19.9	12.5	11.9	13.1	13.1	13.1
AN	25.0	25.0	13.5	13.5	13.5	13.5
BN	26.5	24.8	14.2	15.9	15.9	15.9
D	32.4	27.2	25.0	25.0	25.0	25.0
C	43.0	38.8	26.6	24.3	24.3	24.3
All	31.4	27.2	19.6	19.4	19.4	19.4

Similar to the water temperature stressor, the **frequency** of occurrence is likely **low**, as the daily average water temperatures meet the virulence threshold in 5 out of 23 years.

To evaluate the **weight of evidence** for the pathogens and disease stressor, there are water temperature criteria thresholds from published literature for pathogen and disease virulence specific to Chinook salmon. These thresholds, however, are not specific to steelhead nor to the CVP rivers and tributaries of the Central Valley. The water quality monitoring data through SacPAS provides quantitative data on each watershed to assess whether a threshold was met (Columbia Basin Research 2023).

- McCullough (1999) is quantitative, not species-specific, not location specific, published research on virulence water temperature thresholds.
- Historical water temperatures are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed from long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- Historical adult spawning-timing observations are quantitative, species-specific, and location-specific. The observations are published in technical memos and annual reports from technical teams, not expected to have statistical power.
- HEC-5Q water temperature modeling are quantitative, not species-specific (environmental variable) and location-specific. The model was developed to evaluate reservoir systems using control points, and is widely accepted as the temperature modeling system for use in the upper Central Valley 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

- Clear Creek
    - Water Temperature Management
- American River
    - Water Temperature Management
- Stanislaus River
    - Stepped Release Plan

7.2.4.3 Stranding and Dewatering

The proposed storage and release of water may increase the stranding and dewatering stressor on the Sacramento, American and Stanislaus rivers, and decrease the stranding and dewatering stressor on Clear Creek. The release of water from Whiskeytown Reservoir 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 and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. The spring period in the Sacramento, American, and Stanislaus rivers may have some months with a higher rate of flow reduction with the Proposed Action while other months may have a lower rate of flow reduction, causing both an increase and a decrease to the stranding and dewatering stressor during the egg incubation and fry emergence period. Shallow water steelhead redds that are still occupied by incubating eggs may be dewatered. Multiple topic-specific appendices address aspects of redd stranding and dewatering:

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

The increase in stranding and dewatering stressors from the Proposed Action in the Sacramento, American and Stanislaus rivers is expected to be **lethal**. Redds are defined as dewatered when 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 unless the dewatering occurs during a cool weather and flows subsequently rewater the redd before hatch. Currently, steelhead spawn in all four of the aforementioned watersheds, with the majority spawning in the Sacramento River Basin (National Marine Fisheries Service 2019; Eschenroeder et al. 2022). Historically, peak spawning for steelhead occurs from January-March with some portion of the population spawning earlier in December and later in April or May depending on watershed. Eggs are generally estimated to be incubating from January-May, varying by watershed. Winter and spring flow reductions have the potential to expose redds in the American, Stanislaus, and Sacramento rivers. During higher flows, quality spawning gravel is below the water line and accessible to spawning adults.

The decrease in stranding and dewatering from the Proposed Action in Clear Creek is expected to be **beneficial**. In Clear Creek, the rate of flow reduction is low under the Proposed Action throughout the spring period, which may reduce the potential for redd dewatering.

Although the Proposed Action may increase the redd stranding and dewatering stressor in the Sacramento River, steelhead 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, steelhead 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. Steelhead 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 in to Whiskeytown Reservoir.

Reclamation's past operation of Trinity Reservoir has influenced the flow and temperature 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 salmonid redds. The Trinity Reservoir operation allows for Lower Clear Creek to sustain anadromous salmonids. Trinity Reservoir operations provide both the volume and cold water required to keep Clear Creek water hospitable for over summering adult spring run Chinook, steelhead juveniles, and supports all salmonid spawning and incubation.

Reclamation works with the American River group to manage flows to minimize steelhead redd dewatering in the American River to the extent possible while balancing other operational obligations.

The **proportion** of the population affected by the Proposed Actions depends on timing of spawning, depth distribution of redds, duration of embryo incubation, and river stage.

Literature does not uniquely inform the proportion of the population.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

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

[Placeholder: for Sacramento and American rivers redd dewatering model (performance measure is redds dewatered)]

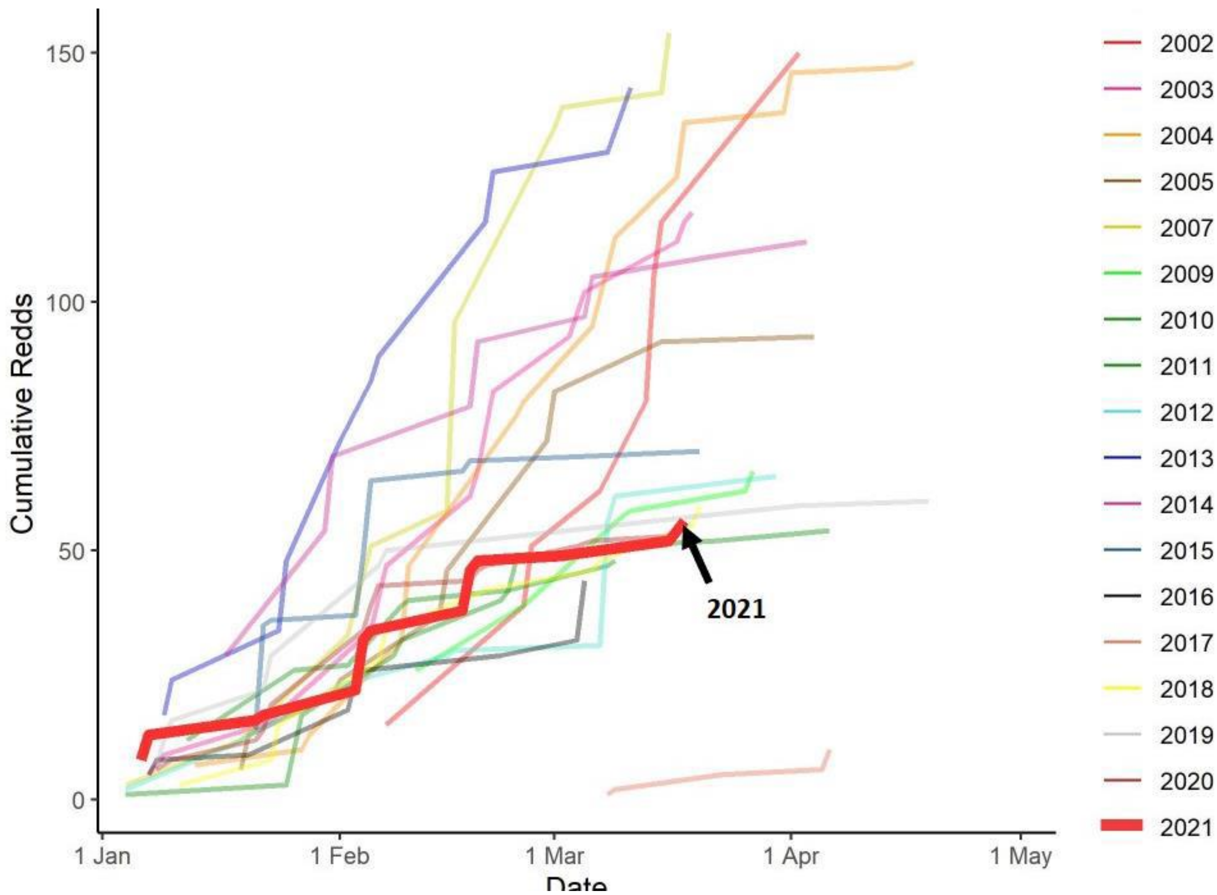
In the Sacramento River, there is a very small proportion of the population that spawn on the mainstem. USFWS counted 2,875 steelhead (rainbow trout over 16") that passed Princeton Ferry on the upper Sacramento River but could not confirm if they were spawning in the Sacramento River or using the mainstem to migrate to other tributaries (Killam 2022). Steelhead spawning and associated data in the Sacramento River is very limited (National Marine Fisheries Service 2009).

The **proportion** of the population affected by the Proposed Action for the stranding and dewatering stressor is likely **small** for Sacramento River. The rate of flow reduction increases between March and April under the Proposed Action. This pattern shifts for the month of May, where releases from Keswick Dam increase during the last month of incubation. The **frequency** of occurrence is likely **high** and may occur on an annual basis.

In Clear Creek, the **proportion** of the population affected is likely **small to medium**. From 2001-2017 an average of 183 redds have been observed in Clear Creek. Since the removal of the Saeltzer Dam in 2000, adult steelhead have had access to more spawning habitat and an upward trend in abundance has been observed since 2006 (National Marine Fisheries Service 2019). The **frequency** of occurrence is likely **high** and may occur on an annual basis. With a lower rate of flow reduction during March, April, and May, the redd dewatering risk decreases. Eggs are generally incubating between December and May in Clear Creek.

In the American River, the rate of flow reduction is higher under the Proposed Action from February to March which may cause redd dewatering. This pattern shifts from April to May, as the rate of flow reduction is lower in the Proposed Action, relative to the rate of decreasing flows for the environmental baseline. As documented in Appendix M, there was historic steelhead redd dewatering in the Sunrise side channel from 2003–2005. Flow management and habitat modification completed in 2008 resolved the dewatering in that location, and dewatering has not been documented on the American River in subsequent reports. The redd dewatering protective adjustment supports fall-run Chinook salmon and address the steelhead stranding and dewatering stressor. In the American River, the **proportion** of the population affected is likely **small to medium**, as redd dewatering has not been reported in the last 15 years and was historically restricted to certain locations.

Steelhead redds are difficult to survey due to turbid water and high flows often encountered during the winter-spring spawning season. Additionally, it is difficult to distinguish between redds made by resident versus anadromous females, and other salmonid species (National Marine Fisheries Service 2019, Eschenroeder et al. 2022). The Lower American River Steelhead Spawning and Stranding Survey in 2021 summarized that 56 steelhead redds were observed in the American River between January and March (Figure 7-75 and Figure 7-76). From 2002-2021 an average of 112 redds were counted on the American River (Figure 7-76).



Source: Sweeney et al. 2021

Figure 7-75. Cumulative Redd Counts in the Lower American River 2002-2021. Note: Date is on the x-axis.

Year	Redd count[1]	Male/Female ratio[2]	Population with 1 redd/female	Population with 2 redd/female	AUC population estimate
2002	159	1.52	401	200	300
2003	215	1.23	479	240	343
2004	197	1.24	441	221	330
2005	155	1.09	324	162	266
2006	Unsuccessful	1.17	n/a	n/a	n/a
2007	178	1.09	372	186	504
2008	Unsuccessful	1.33	n/a	n/a	n/a
2009	96	1.21	212	105	n/a
2010	79	1.08	164	82	n/a
2011	89	0.97	175	88	172
2012	75	0.99	149	75	389
2013	314	0.83	575	287	437
2014	96	1.17	208	104	91
2015	71	2.14	223	111	65
2016	53	1.37	126	63	96
2017	12	1.51	113	56	45
2018	63	1.08	131	66	141
2019	60	1.39	143	72	176
2020	53	1.74	145	73	100
2021	56	1.76	155	77	83[3]

[1] corrected for surveys with low visibility (one survey each of 2004, 2005, and 2007) using non-linear regression. "Unsuccessful" years are due to sustained poor visibility, which prevented redd observations.
[2] from Table 9.
[3] from Table 11.

Source: Sweeney et al. 2022.

Figure 7-76. Steelhead redd counts from 2002-2021 spawning surveys with population estimates.

The American River Redd Dewatering Analysis, Appendix M, Attachment M.1, *American River Redd Dewatering Analysis*, provides context for the dewatering of steelhead redds downstream of Nimbus Dam releases. Steelhead redd dewatering increases substantially from critical to wet water year types (Figure 7-77). This pattern reflects the greater frequency of large flow fluctuations in wetter years. Variations in the percentage of redd dewatered are greater in wetter water year types than in drier years, but are consistent among the different Biological Assessment modeled scenarios (Figure 7-78). The percentage of redds dewatered under the Proposed Action ranges from 0% to 100% for individual months and from 0% to 71% for mean values grouped by water year types.

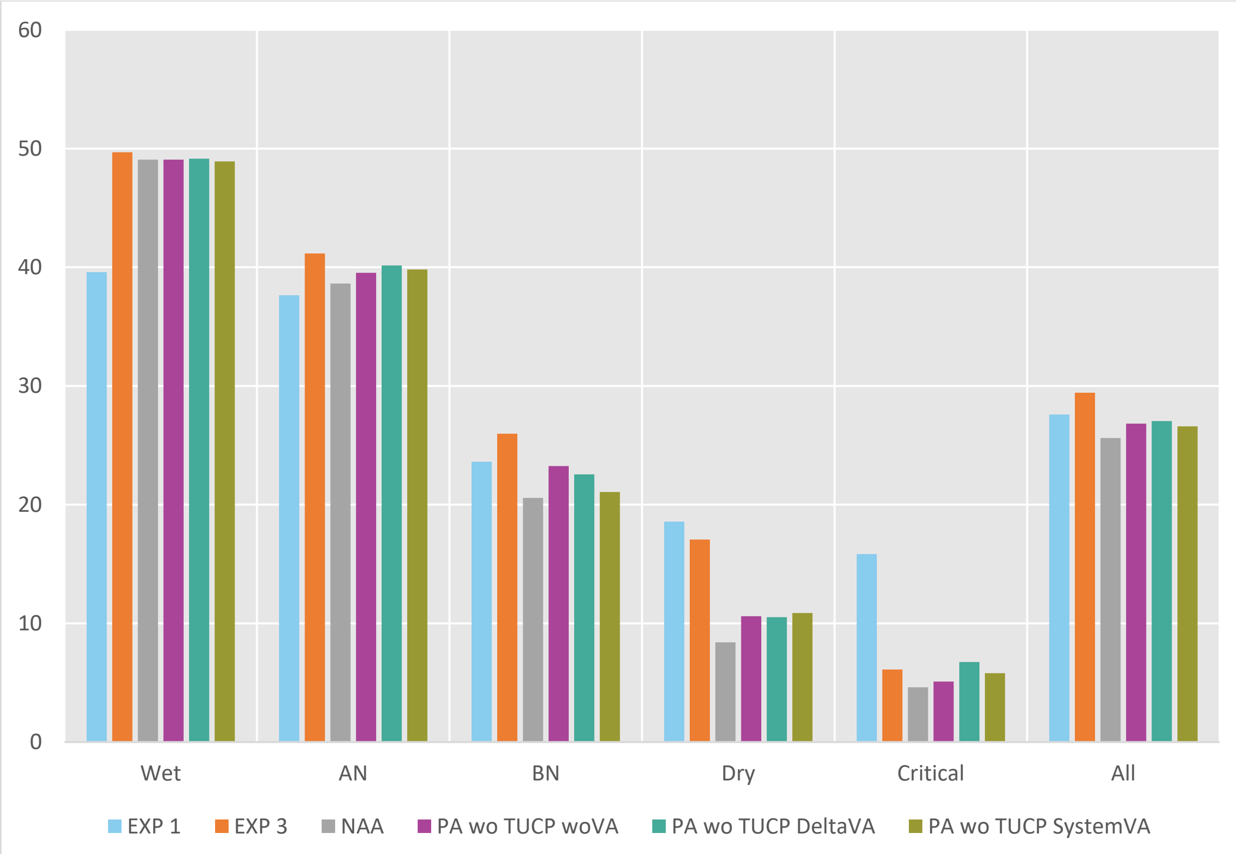


Figure 7-77. Mean Percent of Steelhead Redds Dewatered in the American River Downstream of Nimbus Dam by Water Year Type, Redd Dewatering on the American River

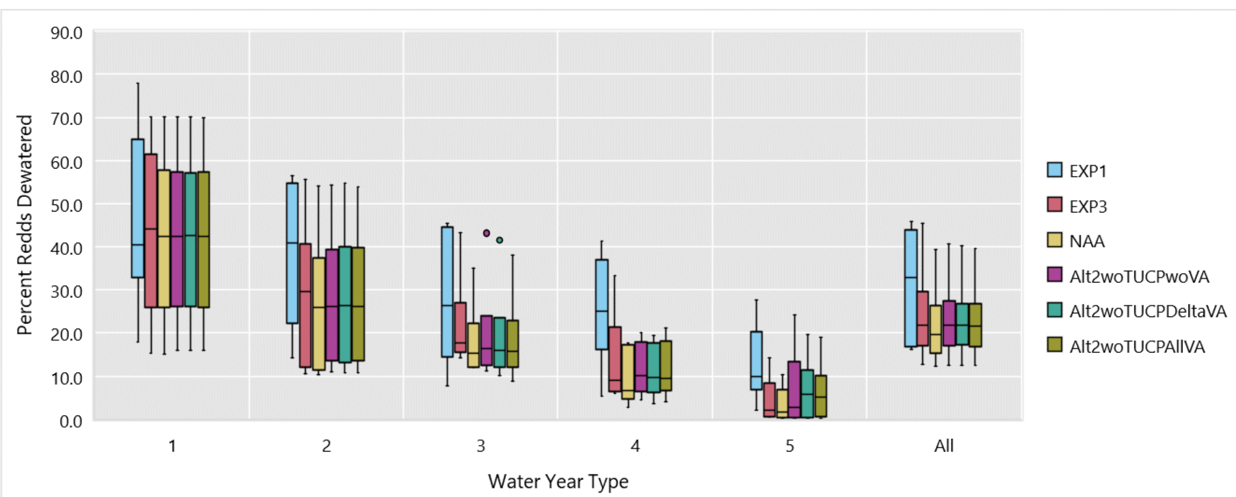
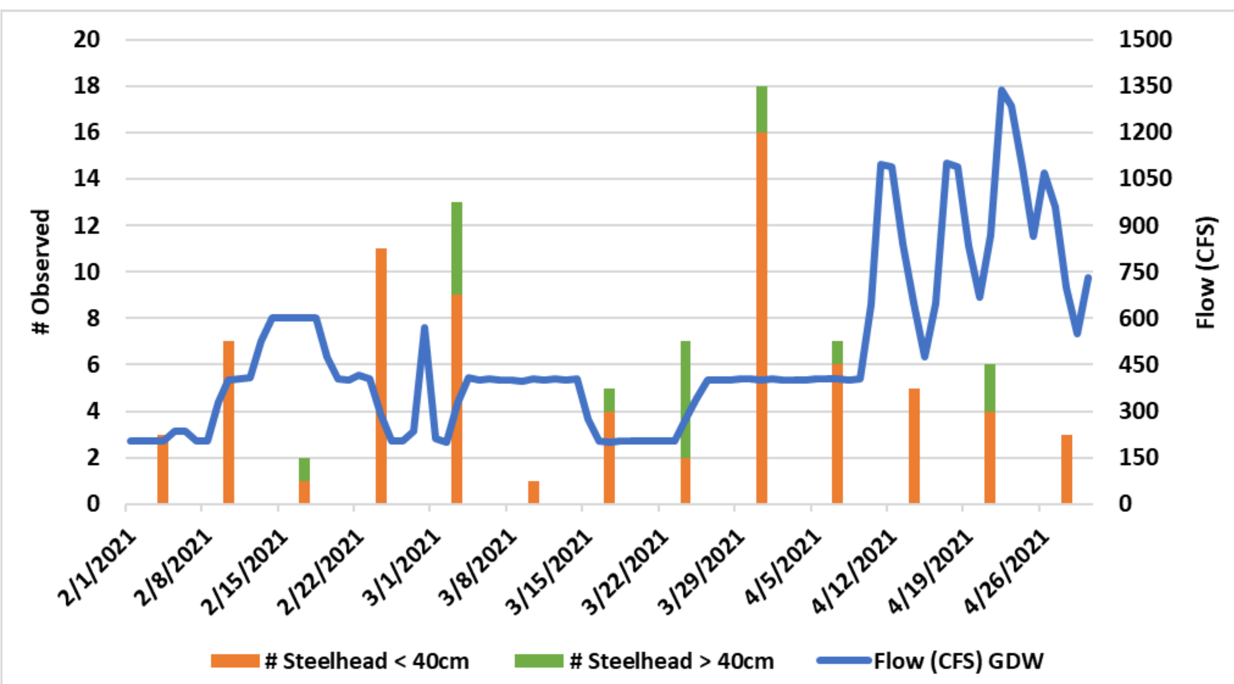


Figure 7-78. Percent of Steelhead Redds Dewatered in the American River Downstream of Nimbus Dam by Water Year Type, Redd Dewatering on the American River

The **frequency** of occurrence in the American River is likely **high** and annual. With decreasing releases and spring pulse flows and an increased rate of flow reduction during the spawning period, there is potential for steelhead to construct their redds during times of high flows in the late winter and early spring. Once flows are subsequently reduced during the incubation period, the result is redds dewatering with some of the eggs still incubating in them. Eggs are generally incubating between late December and May.

In the Stanislaus River, the rate of flow reduction is higher under the Proposed Action from March to April which may cause redd dewatering. The peak flows are lower under the Proposed Action during the egg incubation and fry emergence period, and the rate of flow reduction is lower from April to May, relative to the rate of decreasing flows under the environmental baseline. From 2003-2020, 180 adult steelhead were observed migrating upstream to spawn in the Stanislaus River. Redd surveys were not conducted for steelhead due to the inability to calculate the contribution to the redd abundance that anadromous fish versus resident fish provide. Contemporaneous data on redd stranding and dewatering are limited. CDFW initiated their first redd survey in 2021 on the Stanislaus River, and currently there is only one report available. From this report, it appears peak spawning occurs between February and April (Figure 7-79; Table 7-53). While there have been no reports of redd dewatering or egg stranding on the Stanislaus River, there have been reports of juvenile stranding in April 2016 (California Department of Fish and Wildlife 2023). The **proportion** of the population affected by the stranding and dewatering stressor in the Stanislaus River is likely **small to medium**. Peak spawning may occur during the period of reduced flows but dewatering is limited to certain locations and there have been no reports of steelhead redd dewatering in the Stanislaus River.



Source: Kok and Keller 2023

Figure 7-79. Stanislaus River steelhead observations by size and flow in 2021.

Table 7-53. Stanislaus River steelhead redd counts by sampling week in 2021.

Week	Steelhead Redds
2/1/2021	1
2/8/2021	2
2/15/2021	0
2/22/2021	1
3/1/2021	0
3/8/2021	1
3/15/2021	0
3/22/2021	1
3/29/2021	0
4/5/2021	2
4/12/2021	0
4/19/2021	0
4/26/2021	0

Source: Kok and Keller 2023.

The **frequency** of occurrence for redd dewatering in the Stanislaus River is likely **high**, and may occur on an annual basis.

To evaluate the **weight of evidence** for the redd dewatering stressor, Reclamation's American River Group has a quantitative historical record of steelhead redd monitoring specific to the Lower American River dating back to 2002. The USFWS and Reclamation have quantitative data on adult spawners but not on redd abundance and distribution in the upper Sacramento River. In 2021, CDFW initiated a Stanislaus River redd survey monitoring program to track steelhead spawning, but the data did not span the full spawning season due to COVID restrictions in January 2021. In Clear Creek, USFWS has a quantitative historical record of steelhead redd monitoring specific to Clear Creek (U.S. Fish and Wildlife Service 2008). There is limited data on redd dewatering due in part to the challenges of differentiating steelhead redds from resident rainbow trout redds or other salmonid species and water conditions during the spawning period (National Marine Fisheries Service 2019 BiOp, Eschenroeder et al. 2022).

- Historical stranding and dewatering observations are quantitative, species-specific, and location-specific. The observations are available through multiple sources and QA/QCed from a long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.

- Historical flows associated with stranding and dewatering locations are quantitative, not species-specific (but not expected to be as an environmental variable), and location-specific. The data are available through multiple sources and QA/QCed from a long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- [placeholder] Sacramento River Dewatering modeling are quantitative, species-specific, and location-specific. The analysis uses USRDOM daily flow modeling, which was developed to evaluate flows using multiple inputs and is widely accepted as daily flow modeling system for use in the upper Central Valley watershed].
- American River Dewatering analysis modeling are quantitative, species-specific, and location-specific. The analysis uses CALSIM III daily flow modeling, which was developed to evaluate flows using multiple inputs and is widely accepted as daily flow modeling system for use in the upper Central Valley 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
- Clear Creek
    - Minimum Instream Flows
- American River
    - Minimum Instream Flows
    - Redd Dewatering Adjustment
- Stanislaus River
    - Stepped Release Plan

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 and Redd Maintenance

7.2.5 Juvenile Rearing and Outmigration

Once steelhead embryos emerge out of their redds to become young-of-the-year fry, they rear in freshwater for one to four years before emigrating to the ocean. The timing of juvenile outmigration depends on the watershed and water year.

Upper reaches of the Sacramento River basin appear to have the longest outmigration period detected for juveniles. The rotary screw traps operate year-round at RBDD and from October through June in lower Clear Creek (Table 7-56).

Stationary monitoring systems designed for studying Chinook salmon have low capture efficiencies for collecting juvenile *O. mykiss* smolts, as steelhead will typically outmigrate larger and have stronger swimming abilities when compared to juvenile Chinook salmon (Eschenroeder et al. 2022). Therefore, overall abundance from these surveys should be interpreted with caution. These surveys can be useful for overall juvenile *O. mykiss* outmigration timing, but it is worth noting that most of the RSTs (RBDD is the exception) are not in operation year-round, and often finish in June. Due to limitations with these monitoring strategies, there is a knowledge gap in understanding the overall proportion of the population that adopts anadromy over residency.

While juvenile steelhead can be found in all waterways of the Delta, they are seen more frequently in the main channels to their natal river systems (National Marine Fisheries Service 2009). The San Francisco Estuary is used as a short-term outmigration corridor for juvenile steelhead but the propensity of rearing and timing in the Delta is currently unknown (Hayes and Kocik 2014, Chapman et al. 2015, Buchanan et al. 2021).

The Delta region includes all CVP and non-CVP tributaries and records of observations at the various monitoring sites and fish collection facilities are inclusive of portions of the population that originate outside of CVP-tributaries (e.g., the Feather River, Mokelumne River, Yuba River, and Battle Creek).

Table 7-54. Summary of Juvenile *O. mykiss* Passage in the Bay-Delta by Median Month from U.S. Fish and Wildlife Service Raw Catch Data on SacPAS

Station	**First**	**5% Passing**	**10% Passing**	**90% Passing**	**95% Passing**	**Last**
Sacramento Seines	January	February	February	March	March	March
Sacramento Trawl	February	February	February	May	May	May
Chipps Island	February	February	February	May	May	May
Delta Juvenile	January	February	February	May	May	May
Mossdale Trawl	March	April	April	May	May	May

Source: University of Washington, School of Aquatic and Fishery Science 2022.
Note: Delta juvenile timing is based on the earliest or latest observation of that percentile

Table 7-55. Historical Median Month Cumulative Passage of Unclipped Juvenile *O. mykiss* 2006-2020.

Station	First	5% Passing	10% Passing	90% Passing	95% Passing	Last	Trap Operation
Sacramento River – Red Bluff Diversion (RBDD)	Jan	May	May	Aug	Sept	Dec	Jan – Dec
Sacramento River – Knights Landing (KNL)	Jan	Jan	Feb	April	May	May	Oct – June
San Joaquin River – Mossdale and Stanislaus River	Jan	Jan	Jan	May	May	May	Mossdale: April – June Stanislaus: Jan – June

Table 7-56. Historic Median Month Cumulative Passage of Unclipped Juvenile *O. mykiss* at Rotary Screw Traps on Lower Clear Creek 2011-2018, Lower American River 2013-2021, and Stanislaus River 1996-2021.

Tributary	First	5% Passing	10% Passing	90% Passing	95% Passing	Last	Trap Operation
Lower Clear Creek	Nov	Feb	March	May	June	June	Oct – June
Lower American River	Jan	March	March	May	May	May	Jan – June
Stanislaus River	Jan	Jan	Jan	May	June	June	Jan – June

The stressors influencing juvenile steelhead rearing and outmigration include entrainment risk, toxicity from contaminants, predation and competition, water temperature, pathogens and disease, dissolved oxygen, outmigration cues, stranding risk, refuge habitat, food availability and quality and are described in Section 7.1.3, *Limiting Factors, Threats, and Stressors*.

The Proposed Action is not anticipated to change the stressors for *entrainment risk* on the natal rivers of the CVP.

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

- The Proposed Action may increase and decrease the *toxicity from contaminants stressor* in the Delta and CVP rivers and tributaries. Maintenance of reservoir storage may reduce flows and concentrate constituents from urban and agricultural land use that affect concentration of contaminants in juvenile's prey. Contaminants can cause lethal and sub-lethal effects, may reduce growth and can suppress juveniles' immune system possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). Stormwater runoff from urban roadways contains 6PPD-quinone, a contaminant that originates from tire manufacturing, and may have lethal effects on developing juvenile steelhead depending on duration of exposure (French et al. 2022).

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 Chinook salmon juveniles were reported for 199 samples, and of these only two fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) sampled in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juveniles, as studies have shown that factors that affect growth, body condition, and survival may have disparate influences on rates of anadromy and residency (Kendall et al. 2014, Eschenroeder et al. 2022).

- The Proposed Action may increase the *predation and competition* stressor. During the juvenile rearing and outmigration period, reduced releases from various reservoirs may decrease flows below their respective dams. Indirect effects of predation are described further in Section 7.2.5.3, *Outmigration Cues,* and Section 7.2.5.5, *Refuge Habitat*, below. 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 throughout the Central Valley is ubiquitous. Introduced non-native piscivorous species such as striped and largemouth bass have become well-established predators in the Central Valley system. Juvenile steelhead are preyed upon by aquatic and terrestrial species and this can directly or indirectly influence juveniles' migration, growth, and survival. Certain locations in the Delta (e.g., Clifton Court Forebay, the scour hole at Head of Old River, Delta fish collection facilities, the Delta Cross Channel gates) are considered predator hotspots and operations of these facilities are operating, juvenile steelhead 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 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 provided.

7.2.5.1 Water Temperature and Dissolved Oxygen

The proposed storage, diversion, release and blending of water may increase or decrease water temperature stressor. The proposed storing and diverting of water may increase the dissolved oxygen stressor in the San Joaquin and Stanislaus rivers. During the juvenile rearing and outmigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. In the fall, flows would be increased in the Sacramento River, American River, and Clear Creek, and decreased in the Stanislaus River. Water temperatures reaching the upper temperature limits can add stress to juveniles rearing. Changes in dissolved oxygen can affect the swimming performance of juvenile salmonids. Appendices L, M, and N address temperature related effects in the Proposed Action.

The Proposed Action includes the following components/conservation measures to address water temperature in the lower American River: (1) Reclamation, through Governance, will continue to annually prepare a TMP for the summer through fall. TMP to contains: (a) forecasts of hydrology and storage; and (b) modeling run or runs, using these forecasts, demonstrating what temperature compliance schedule can be attained; (2) Reclamation will plan shutter configurations to attain the best possible (lowest numbered) temperature schedule; (3) Reclamation will implement the ATSP in developing the TMP. For greater than 56°F at Hazel Avenue in November, the TMP will evaluate a power bypass.

The Proposed Action also includes a Stepped Release Plan in the Stanislaus River and Shasta Reservoir Water Temperature and Storage Management for the Sacramento River.

The decrease in the water temperature stressor is expected to be **beneficial** in the American and Stanislaus rivers in the summer. Cooler water temperatures may reduce overall harm to juveniles rearing.

The increase in the dissolved oxygen stressor is expected to be **sub-lethal** in the Stanislaus. Reductions in flow may lead to decreases to dissolved oxygen in rivers with a low historical record, potentially reducing the swimming speed of juvenile *O. mykiss* and increasing their vulnerability to predation and competition. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975) but start to exhibit reduced swimming speeds below this threshold when water temperatures are near 68°F (Dahlberg et al. 1968). Comprehensive literature review by the Washington State Department of Ecology (2002b: 46) determined dissolved oxygen levels below 7 mg/L significantly impacted swimming speed in salmonids. Field studies on salmonids have demonstrated that constant long-term exposure to low dissolved oxygen levels in the range of 3-3.3 mg/L have been lethal, with 50% of juvenile salmonids resulting in mortality (Washington State Department of Ecology 2002b).

Changes to the water temperature stressor are expected to be insignificant in Clear Creek, Delta, and the Sacramento and San Joaquin rivers. During the spring portion of the juvenile rearing and outmigration period, the influence of the operation of the CVP may increase water temperatures in the Delta as diversion decreases Delta inflow. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022) and reservoir operations may influence water temperature to a minimal extent in the lower reaches of the Sacramento River (Daniels and Danner 2020). However, in the Delta water temperature is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). Water temperatures do not exceed the criteria for juvenile growth in Clear Creek and the Sacramento River. Water temperatures in the San Joaquin River near the confluence of the Stanislaus River are anticipated to have minimal changes under the Proposed Action.

Changes in dissolved oxygen are expected to be insignificant for Clear Creek, the Delta, Sacramento and American rivers. Upper Clear Creek is steep and there is often white water, and dissolved oxygen is likely at saturation due to the facilitation of gas exchange in white water conditions. Historical water quality monitoring in the mainstem Sacramento River has rarely shown dissolved oxygen at levels below 7.0 mg/L in the months when juveniles are rearing and outmigrating. There are no annual dissolved oxygen monitoring stations for the lower American River, but stranding surveys from the last five years have indicated there may be occasional effects of flow reductions in the side channel habitats. In March and April, dissolved oxygen levels in the stranding pools were generally within the range that would support juvenile salmonid growth, with occasional decreases in water quality in late April from 2018-2021 (Scriven et al. 2018; Sellheim et al. 2019, 2020; Sweeney et al. 2021). However, in 2017 and 2022 after flow reductions, some isolated pools had dissolved oxygen below 8.0 mg/L in 2022 and below 7.0 mg/L in 2017, which may be considered stressful for juvenile salmonids (Sweeney et al. 2017, 2022). See Section 7.2.5.4, *Stranding Risk*, for more details on stranding in the American River.

There is uncertainty on how these changes in dissolved oxygen may affect occurrence of anadromy among juveniles, as studies have shown that factors that affect growth, body condition, and survival may have disparate influences on rates of anadromy and residency (Kendall et al. 2014, Eschenroeder et al. 2022).

Steelhead rearing occurs year-round in all natal streams (does not include the San Joaquin River), while steelhead outmigration occurs in most streams from February to June but can vary by stream (see Tables above). Optimum temperatures for juvenile steelhead growth, assuming maximum ration levels, occur between 59°F and 66.2°F (Myrick 1998; Myrick and Cech 2001) and preferred temperatures based on behavior trials were between 62.6°F and 66.2°F (Myrick and Cech 2000). The temperature criterion for steelhead smoltification occurs at 57°F 7DADM, with impairment at constant temperatures above 55°F during the outmigration period (U.S. Environmental Protection Agency 2003). For more information on water temperature effects on juvenile outmigration see Section 7.2.5.3, *Outmigration Cues*. There remains a substantial knowledge gap about the effects of water temperature on juvenile steelhead in the Central Valley, but there are some indications that populations from the American River may be more tolerant of warmer water temperatures than populations further north, with optimal growth of hatchery steelhead at 66.2°F (Myrick and Cech 2004; Myrick and Cech 2005).

Furthermore, warmer water temperatures that are optimal for rearing and food availability may have offsetting effects on rates of anadromy, favoring expression of the non-listed rainbow trout life history strategy (Benjamin et al. 2013). Upper temperature limits with a 7-day exposure fall between 73°F and 78.8°F, based on rainbow trout populations outside of the Central Valley (Bidgood and Berst 1969, Threader and Houston 1983, Myrick and Cech 2004). Single daily peak water temperatures above 75.2°F are capable of being lethal to salmonids (Washington State Department of Ecology 2002a).

Although the Proposed Action may, at times, increase the water temperature stressor and the dissolved oxygen stressor, unsuitable water temperatures and changes in dissolved oxygen for steelhead rearing and outmigration 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. Existing facilities, regulatory requirements, and contractual obligations affecting past and present CVP operations on the Stanislaus and San Joaquin rivers and thus, dissolved oxygen in the environmental baseline are detailed in Appendix A, *Facilities Description*.

During the late 1960s, Reclamation designed a modification to the trash rack structures to provide selective withdrawal capability at Folsom Dam through the Folsom Power Plant. The steel trash racks are now equipped with three groups of shutters that can pull water from various elevations, which have different temperatures when the lake is thermally stratified. This allows for limited discretionary temperature management of the lower American River. Different approaches have targeted different temperatures and locations throughout the years including a warmwater bypass to conserve the limited coldwater pool. In 2009, NMFS issued an RPA that required Reclamation to manage Folsom, with certain exceptions, to maintain a daily average water temperature of 65°F or lower at Watt Avenue Bridge from May 15 through October 31, to provide suitable conditions for juvenile steelhead rearing in the lower American River. That same RPA also required Reclamation to prepare and implement a TMP by May 15 each year for the American River. Reclamation proposed a similar TMP in 2019.

To reduce the water temperature stressor in the American River, Reclamation recently completed the WTMP effort, which is intended to enhance modeling capabilities to predict summer and fall water temperature through facilities operations, such as the Folsom Dam temperature shutters. Reclamation modified Nimbus Dam releases to release from the spillway gates in the fall of 2023 to ameliorate low dissolved oxygen in the lower levels of Folsom Reservoir. The coldest water, needed to meet water temperature goals, had low dissolved oxygen and the spillway releases oxygenated the water to suitable levels of greater than 7 mg/l.

On the Stanislaus River, past operational releases from New Melones Dam have influenced the extent of cool water habitat available below Goodwin Dam. Reclamation has operated New Melones Reservoir to meet dissolved oxygen requirements under SWRCB D-1422 and D-1641. In 2009, NMFS issued an RPA that dictated specific temperature targets for the Stanislaus River to benefit steelhead. None of the dams on the Stanislaus River have a temperature control device, so the only mechanism for temperature management on the Stanislaus River is direct flow management.

Since 2019, Reclamation has implemented a Stepped Release Plan for the Stanislaus River. The Stepped Release Plan includes the ability to shape monthly and seasonal flow volumes and are Reclamation's contribution to Vernalis D-1641 standards. The Stepped Release Plan does not set water temperature standards for the Stanislaus River, but it does include minimum flow targets that are intended to benefit steelhead, including water temperature benefits. During the summer, Reclamation is required to maintain applicable dissolved oxygen standards on the lower Stanislaus River for species protection. Reclamation currently operates to a 7 milligrams per liter dissolved oxygen requirement at Ripon from June 1 to September 30. Reclamation moves the compliance location to Orange Blossom Bridge, where the species are primarily located at that time of year.

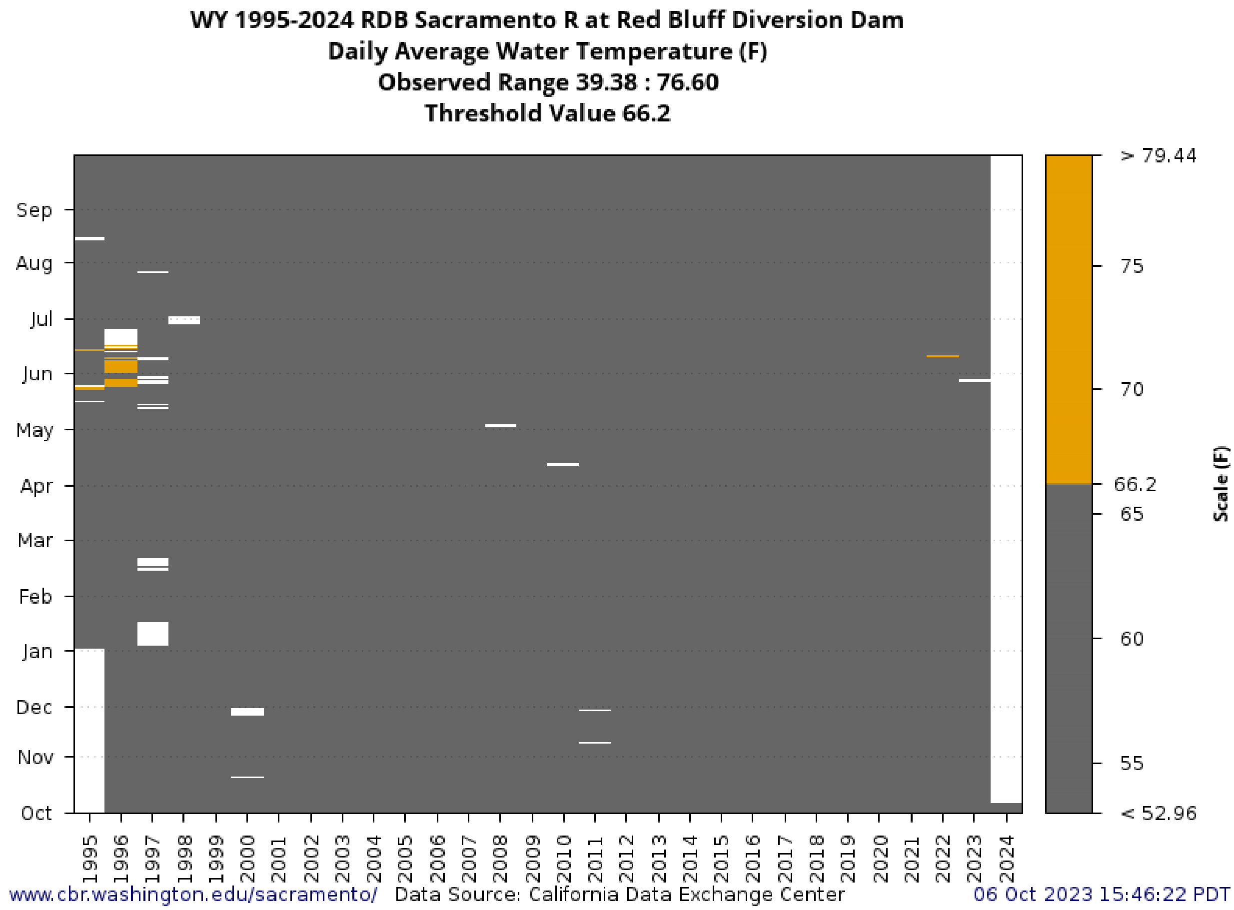
The **proportion** of the population affected by the Proposed Action depends on water temperature management.

Literature on critical water temperatures historically identified 66.2°F as the threshold temperature for optimal juvenile steelhead growth during rearing and dissolved oxygen levels below 7 mg/L as the criteria for swimming performance in salmonids.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

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. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed water temperature criteria obtained from scientific literature.

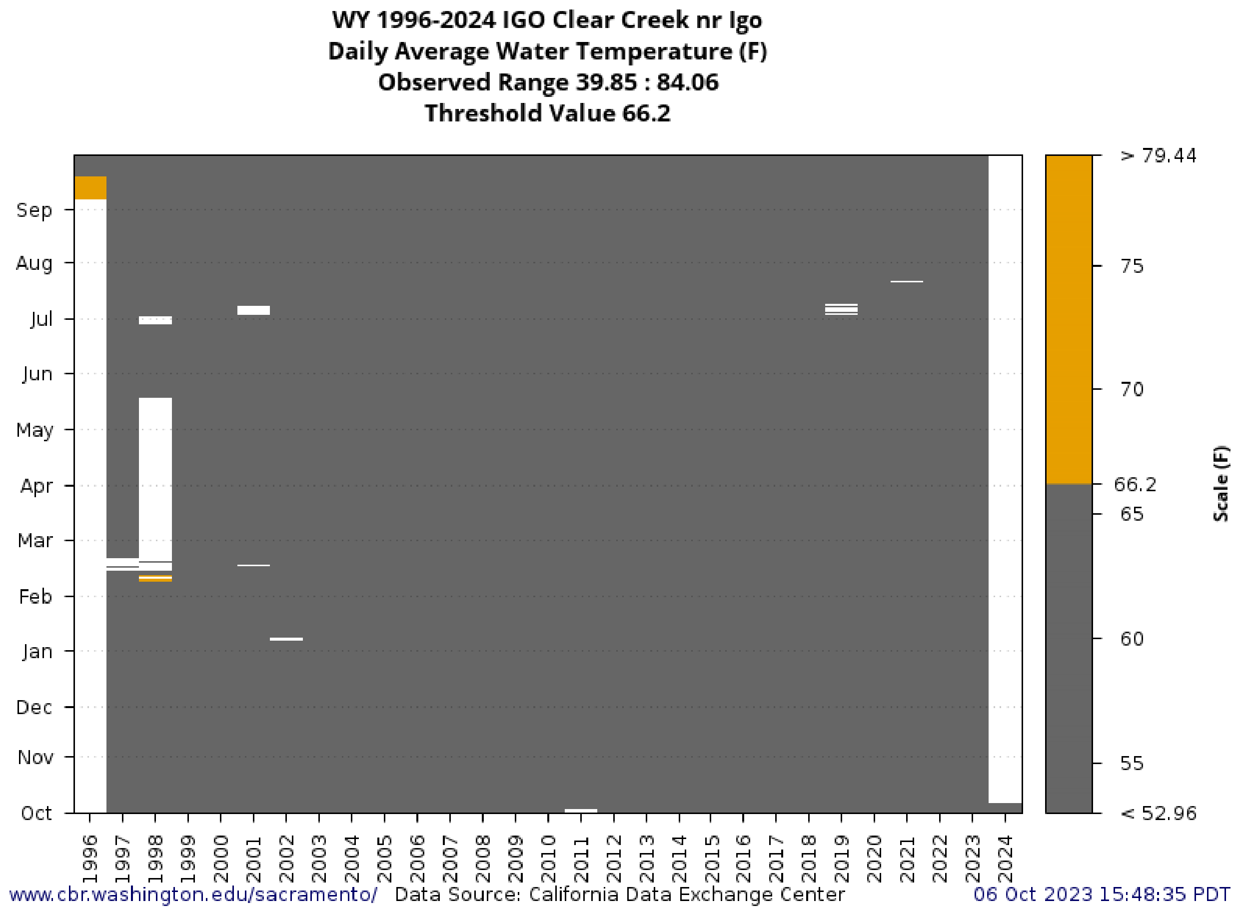
During the juvenile rearing period in the Sacramento River, historical daily average water temperatures have been below the preferred threshold for juvenile growth (Figure 7-80). Changes to water temperature during juvenile rearing are likely insignificant in the Sacramento River.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-80. Days exceeding 66.2°F in the Sacramento River at RBDD between October and September 1995 – 2023.

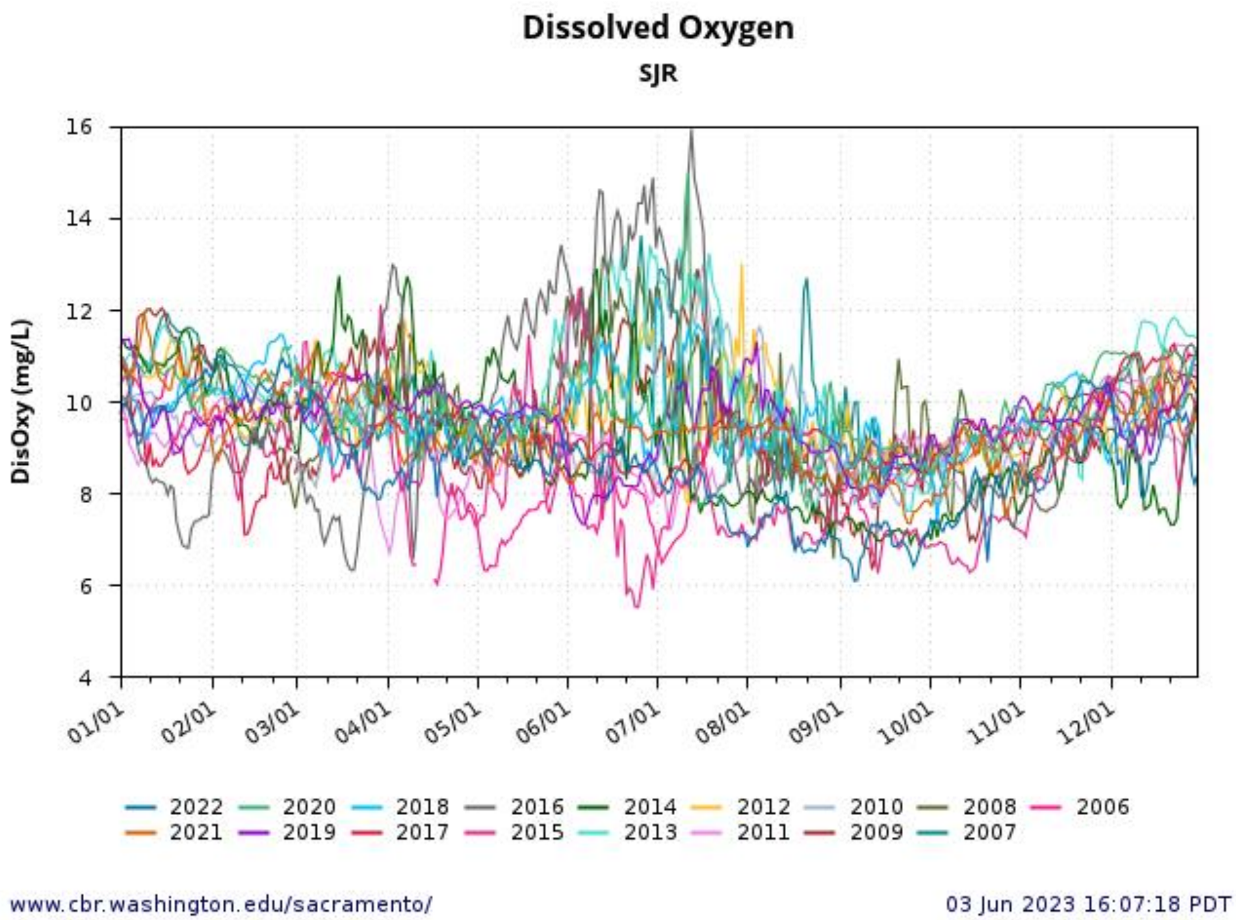
During the juvenile rearing period in Clear Creek, historical daily average water temperatures have been below the preferred threshold for juvenile growth (Figure 7-81). Changes to water temperature during juvenile rearing are likely insignificant in Clear Creek.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

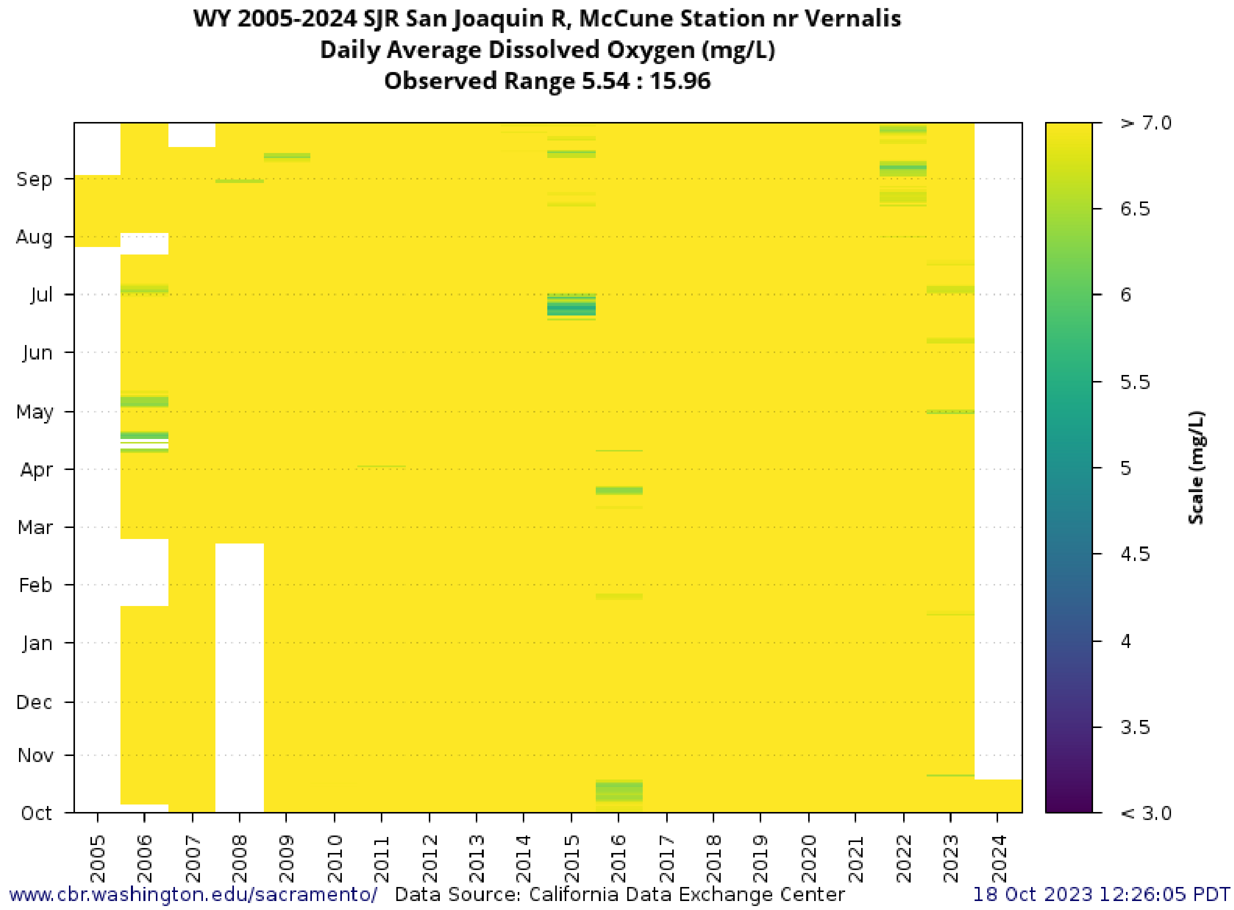
Figure 7-81. Days exceeding 66.2°F in Clear Creek at IgO between October and September 1996 – 2023.

The **proportion** of the population affected by the dissolved oxygen stressor under the Proposed Action depends on flow management and peak outmigration timing. During the spring portion of juvenile rearing and outmigration in the San Joaquin River, the Proposed Action may increase the dissolved oxygen stressor. Historical water quality monitoring near Vernalis has shown dissolved oxygen levels can vary below 7 mg/L in the spring, but has not fallen below 6 mg/L (Figure 7-82; Columbia Basin Research, University of Washington 2023). Changing flows associated with seasonal operations may result in warmer water temperatures and decreased flows throughout the juvenile rearing and outmigration period on the San Joaquin River. The **proportion** of the population affected is likely **medium**, as juvenile *O. mykiss* outmigration typically occurs between January and May, with peak outmigration between April and May. There are no reports of juvenile rearing in the San Joquin River so the **proportion** of the juvenile rearing population is likely **small**. The **frequency** of occurrence for juvenile outmigration is likely **low**, as 4 out of 18 years have DO below 7 mg/L during the outmigration period (Figure 7-83) and is likely **medium** for juvenile rearing as the criteria is met in 7 out of 18 years.



Source: Columbia Basin Research 2023.

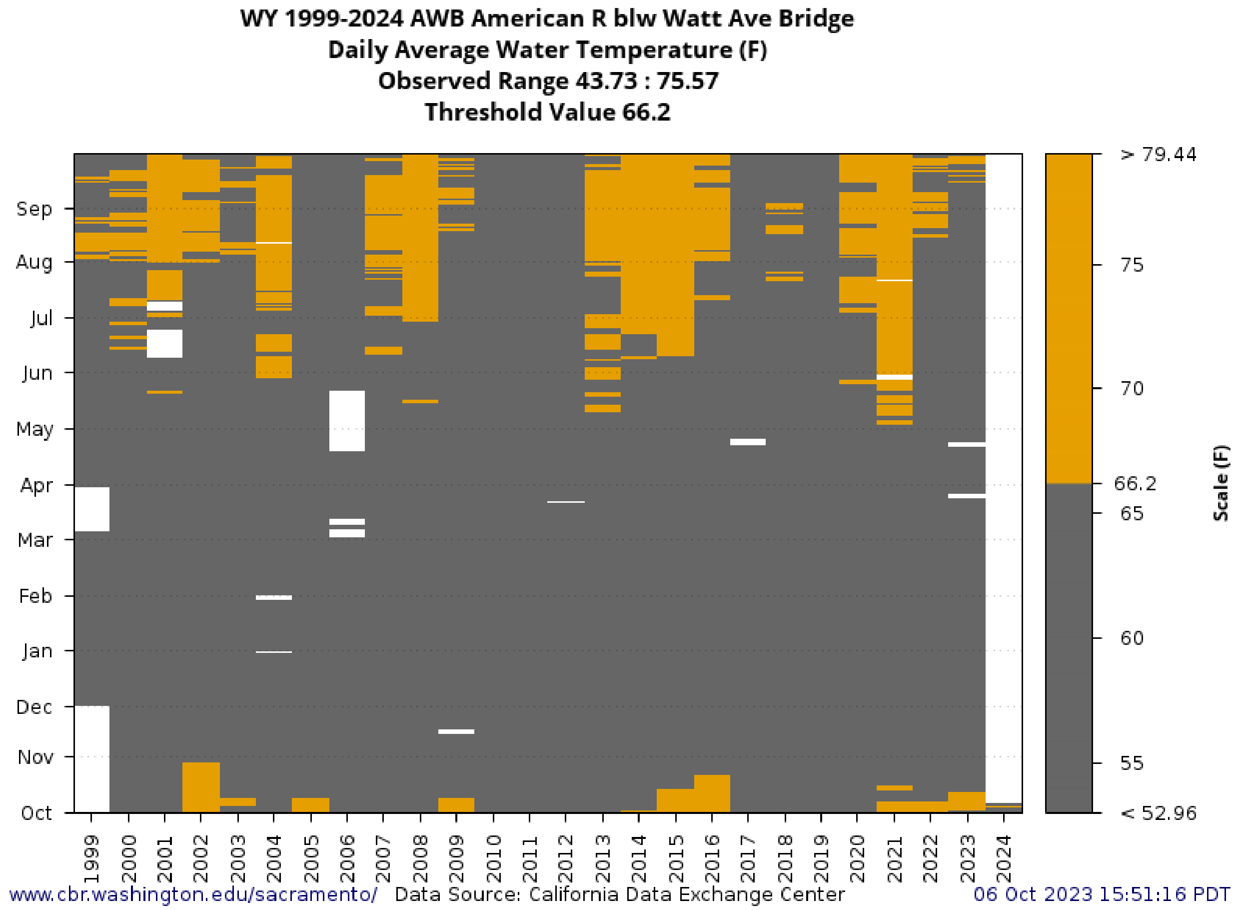
Figure 7-82. SJR San Joaquin River Dissolved Oxygen 2006-2022 at McCune Station near Vernalis.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-83. San Joaquin River Dissolved Oxygen 2005-2023 at McCune Station near Vernalis.

During the juvenile rearing period in the American River, historical daily average water temperatures have been above the preferred threshold for juvenile growth (Figure 7-84). Releases of storage in the summer may increase flows which may decrease the stressor from June through August. Water temperatures changes, as a result of the Proposed Action in the winter, fall, and spring are either insignificant or below the criteria of 66.2°F. The **proportion** of juvenile steelhead rearing in the American River when water temperatures are above criteria is likely **large**, as juveniles are rearing year-round. While there remains a substantial knowledge gap about the effects of water temperature on juvenile steelhead, there are some indications that populations from the American River may be more tolerant than populations further north (Myrick and Cech 2004). Historical water temperatures at Watt Ave indicate the frequency of occurrence is likely **medium**, as the criteria is met in 18 out of 25 years.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-84. Days exceeding 66.2°F in the American River below Watt Ave between October and September 1999 – 2023.

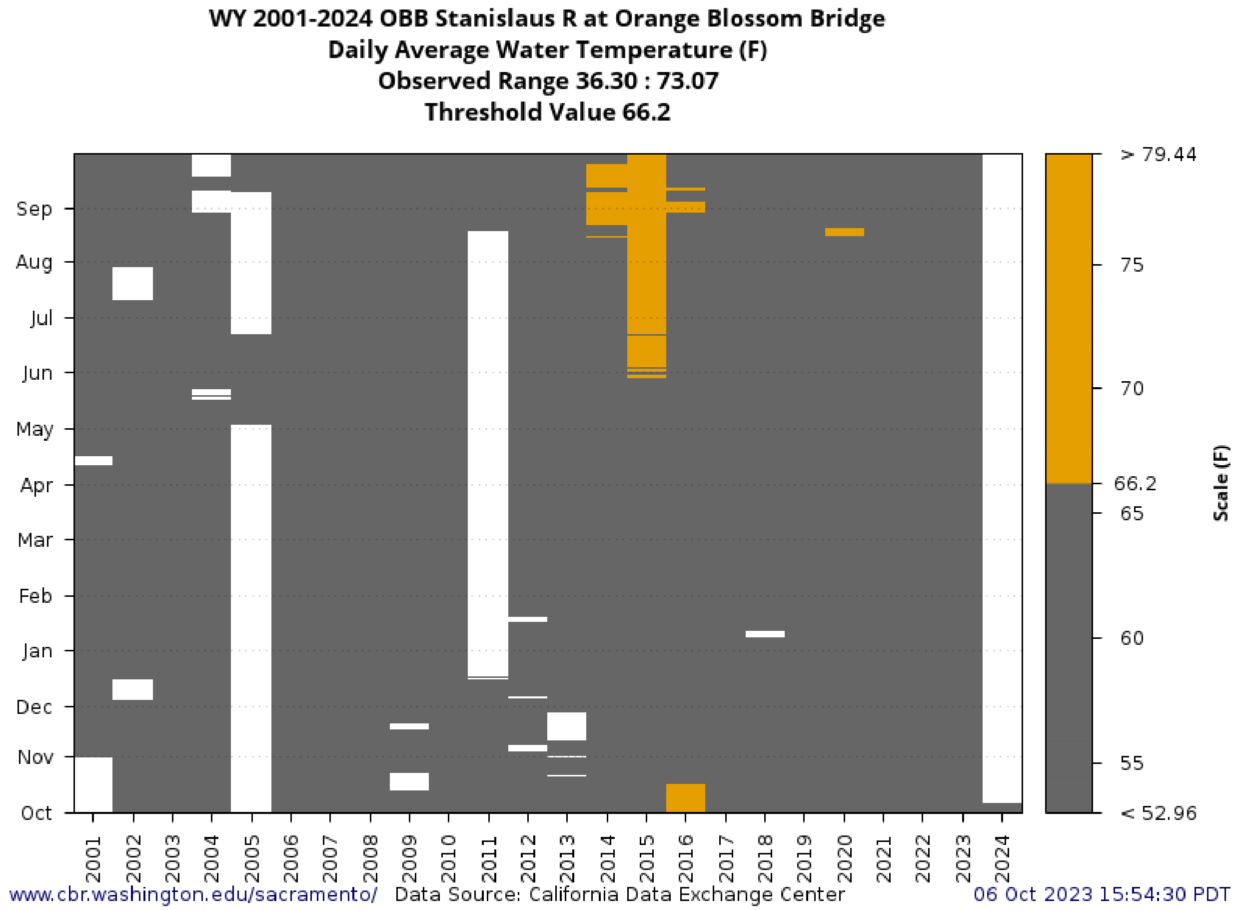
During the juvenile rearing period in the Stanislaus River, historical daily average water temperatures have been above the preferred threshold for juvenile growth. Historical data suggests water temperatures can increase above the thermal limit for juvenile steelhead rearing June through October (Figure 7-29).

Results for the 66.2°F range are presented in Table 7-57 for the Stanislaus River at Orange Blossom Bridge. At the Stanislaus at Orange Blossom Bridge, the percent of months that exceeded the temperature threshold ranged from 2.0% for Critical to 0.6% for Below Normal water year types. For Wet, Above Normal, and Dry water year types, the percentage of months above the temperature threshold remained at 0.0% for all phases of the Proposed Action during the year-round period.

Table 7-57. Percent of months above the 66.2°F water temperature threshold for successful juvenile steelhead rearing by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, Year-round.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	27.7	8.3	0.0	0.0	0.0	0.0
AN	35.4	14.6	0.0	0.0	0.0	0.0
BN	35.3	14.1	0.0	0.6	0.6	0.6
D	40.7	14.2	0.0	0.0	0.0	0.0
C	43.0	10.9	1.8	2.0	2.0	1.8
All	37.1	11.8	0.6	0.8	0.8	0.7

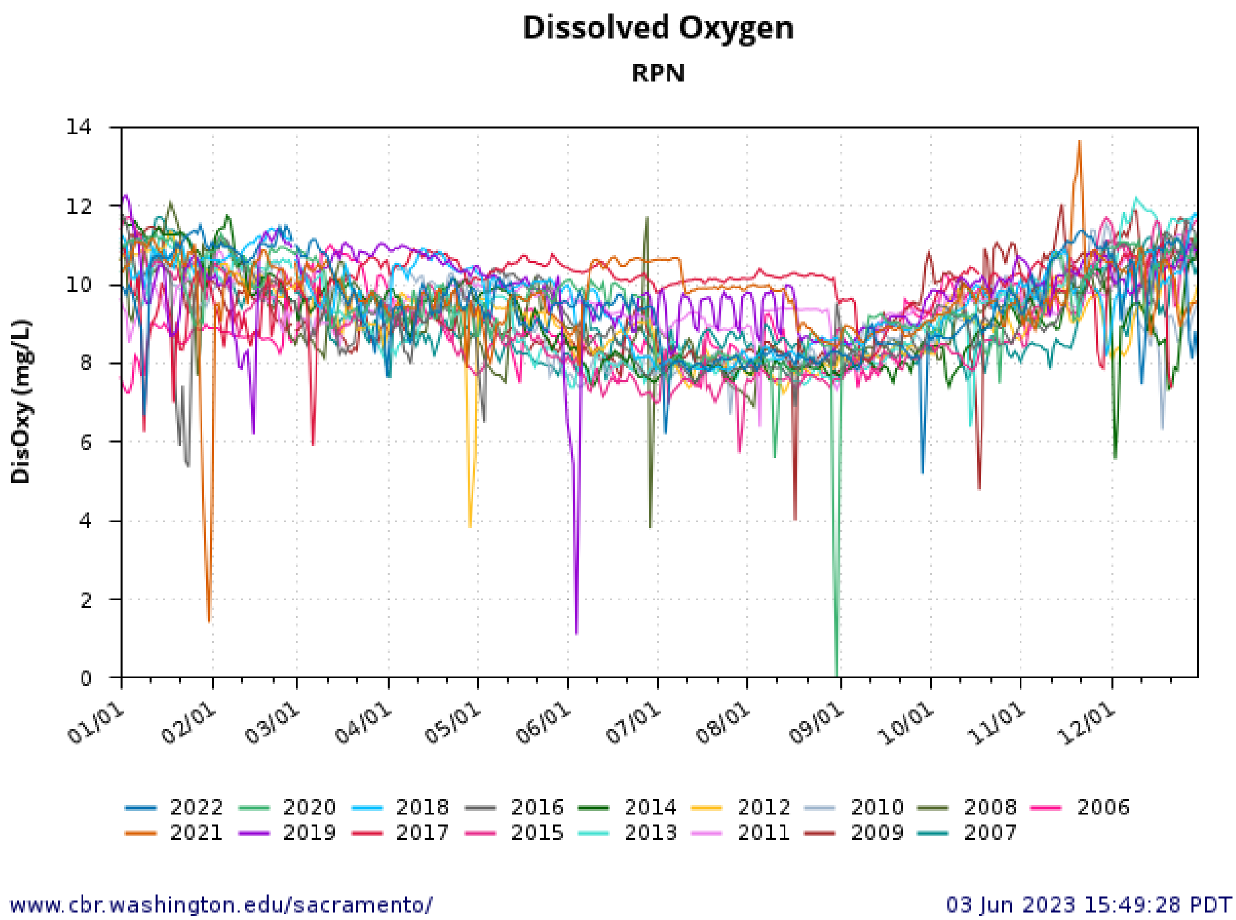
The **proportion** of juvenile steelhead rearing in the Stanislaus River when water temperatures are above criteria is likely **large**, as juveniles are rearing year-round. Historic water temperatures near Orange Blossom (Figure 7-85) indicate the frequency of occurrence is likely **low** (criteria is met in 4 of 23 years). Maintenance of New Melones storage may reduce flows in the spring and fall, and subsequently increase the water temperature stressor. Releases of storage in the summer may increase flows which may decrease the stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

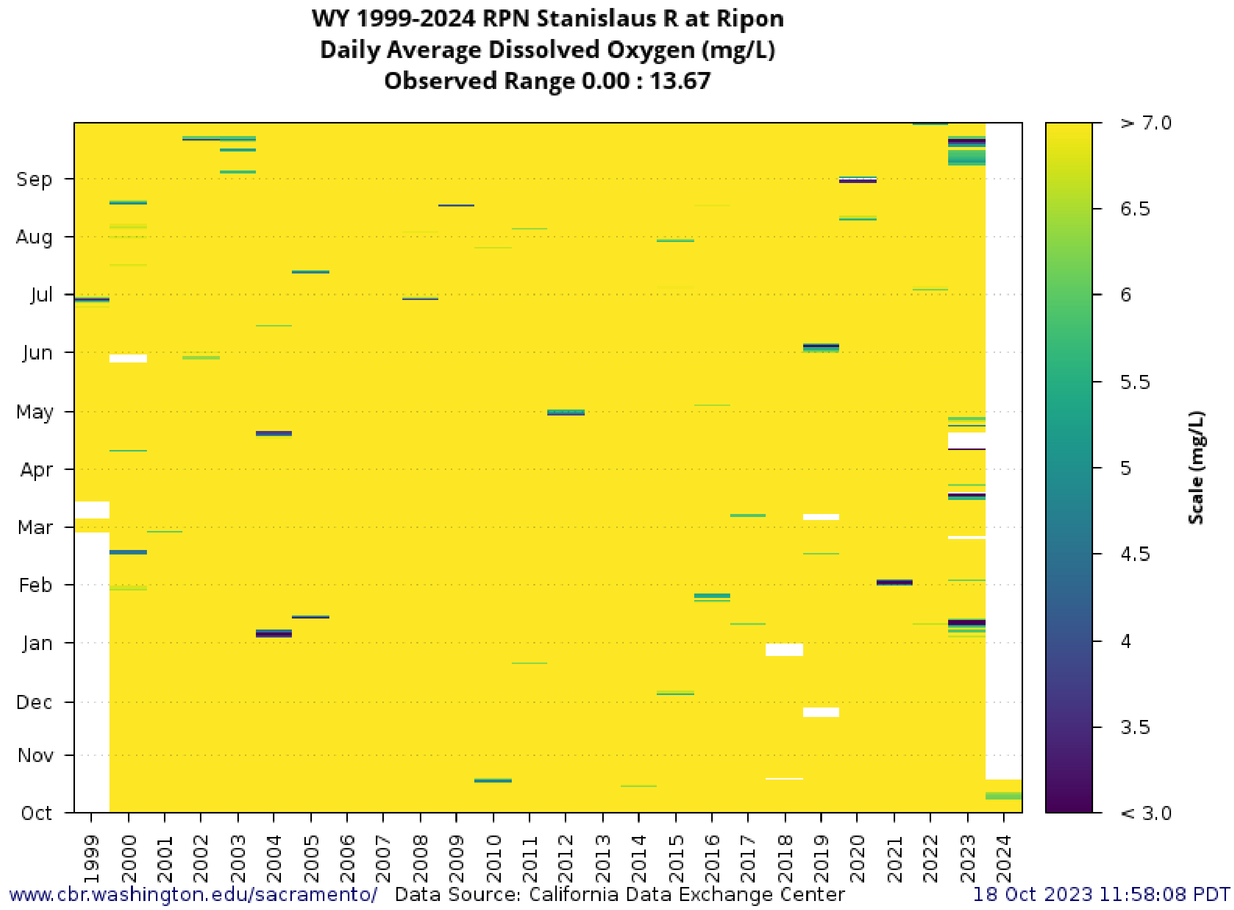
Figure 7-85. Days exceeding 66.2°F in the Stanislaus River at Orange Blossom Bridge between October and September 2001 – 2023.

During juvenile rearing and outmigration in the Stanislaus River, the dissolved oxygen stressor may increase. Historical water quality monitoring near Ripon has shown dissolved oxygen levels can vary below 7 mg/L in the spring and summer, and have fallen below 4 mg/L in the short-term (Figure 7-86; Columbia Basin Research, University of Washington 2023). Juvenile *O. mykiss* outmigration typically occurs between January and June, with peak outmigration between April and May. The **proportion** of the juvenile outmigrating population affected by the dissolved oxygen stressor is likely **medium**, as the 7mg/L threshold is occasionally met during peak outmigration and throughout the outmigration period. The proportion of the juvenile rearing population affected by the dissolved oxygen stressor is likely **large**, as rearing is year round. The **frequency** of occurrence is likely **medium** for juvenile outmigration (criteria is met in 11 out of 25 years) and likely **high** for juvenile (criteria is met in 21 out of 25 years).



Source: Columbia Basin Research 2023.

Figure 7-86. Stanislaus River Dissolved Oxygen 2006-2022 at Ripon.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-87. Stanislaus River Dissolved Oxygen 1999-2023 at Ripon.

To evaluate the **weight of evidence** for the water temperature stressor and the dissolved oxygen stressor, there are temperature and dissolved oxygen thresholds from several peer reviewed articles and state issued water quality documents that are specific to steelhead but these studies are not specific to the Central Valley. The water quality monitoring data through SacPAS provides quantitative data on each watershed to assess whether a threshold was met (Columbia Basin Research 2023).

- Myrick (1998), Myrick and Cech (2000), and Myrick and Cech (2001) are quantitative, species-specific and include some Central Valley strains of rainbow trout but are not specific to anadromous populations in CVP rivers and tributaries. These reports are peer reviewed and provide guidance on water quality standards for salmonids using both field based and lab-based studies.

- Washington State Department of Ecology (2002a) is quantitative, species-specific (but not necessarily to anadromy), and is not location specific. The document is a comprehensive published report for guidance on water quality standards for the salmonids using both field based and lab-based studies.
- Davis (1975) is a quantitative, species-specific (but not necessarily to anadromy), not location-specific, scientific review of minimal oxygen requirements.
- Washington State Department of Ecology (2002b) is a quantitative, not species-specific, not location specific, comprehensive published report for guidance on water quality standards for the salmonids using both field based and lab-based studies.
- Historical water temperatures are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed from long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- Historical dissolved oxygen is quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources, but may have variation in their data quality. They are not expected to have statistical power.
- Historical juvenile outmigration-timing observations are quantitative, species-specific, and location-specific. The observations are published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- HEC-5Q water temperature modeling are quantitative, not species-specific (environmental variable) and location-specific. The model was developed to evaluate reservoir systems using control points, and is widely accepted as the temperature modeling system for use in the upper Central Valley 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
    - Shasta Reservoir Water Temperature and Storage Management
- Clear Creek
    - Minimum Instream Flows
    - Water Temperature Management
- American River
    - Minimum Instream Flows
    - Water Temperature Management
- Stanislaus River
    - Stepped Release Plan

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 too cold too early and exhausting cold water pool)
- American River
  - Fall and Winter Base Flows for Shasta Reservoir Refill and Redd Maintenance
  - Rebalancing between other CVP Reservoirs for Shasta Reservoir End of September Storage
  - Reduced Wilkins Slough Minimum Flows for Shasta Reservoir End of September Storage
- Drought Actions

7.2.5.2 Pathogens and Disease

The proposed storing and diverting of water may increase or decrease the pathogens and disease stressor. During the juvenile rearing and outmigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. In the San Joaquin River, operations of storage and releases of water would result in decreased flows throughout the year. In the fall, flows would increase in the Sacramento River, American River, and Clear Creek, and decrease in the Stanislaus River. As part of the drought toolkit, Reclamation may operate the TCD to release warmer water temperatures to preserve water for egg incubation later in the year. Maintenance of reservoir storage may decrease flows and cause crowding into a smaller habitat area. Decreased flows may also increase water temperatures to cause an increase in pathogen virulence and prevalence of disease. Appendices L, M, and N address temperature related effects in the Proposed Action.

The increase in the pathogens and disease stressor in the spring is expected to be **sub-lethal** in Clear Creek, the Sacramento, American, and Stanislaus rivers. 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 2011; Nekouei et al. 2019). Juvenile survival of salmonids is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting salmonids become highly virulent at temperatures above 59.9°F (McCullough 1999). Since 2004 in the American River, there has been persistence of a disease commonly referred to as “rosy anus,” which arises through bacterial inflammation of the anal vent in juvenile steelhead (Bratovich et al. 2005). CDFW pathologists have found that immune responses in juveniles peak at about 60°F, and then sharply drops at water temperatures increase (Bratovich et al. 2005). There is also uncertainty on how changes in pathogen and disease stressors may affect occurrence of anadromy among juveniles, as studies have shown that factors that affect growth, body condition, and survival may have disparate influences on rates of anadromy and residency (Kendall et al. 2014, Eschenroeder et al. 2022).

The decrease in the pathogens and disease stressor in the summer and fall are expected to be **beneficial** in Clear Creek, the Sacramento, American, and Stanislaus rivers. Reductions water temperature and the prevalence of pathogens and disease may decrease stress on juvenile steelhead, improving growth and outmigration.

Changes to the water temperature stressor are expected to be insignificant in the San Joaquin River and the Delta. The Proposed Action is expected to have insignificant changes to water temperature in the San Joaquin River (see Chapter 4, Figure 4-53). 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). 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 is a cause for increased 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.

Although the Proposed Action may, at times, increase the pathogens and disease stressor in the Sacramento River, pathogens and diseases that may affect steelhead rearing and outmigration 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 (National Marine Fisheries Service 1998).

Natural steelhead may contract diseases that are spread through the water column (i.e., waterborne pathogens) (Buchanan et al. 1983). Infectious diseases and pathogens naturally affect juvenile steelhead survival. Juveniles are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment (National Marine Fisheries Service 1996, 1998a, 2009). Specific diseases such as bacterial kidney disease, *Ceratomyxosis shasta*, columnaris, furunculosis, infectious hematopoietic necrosis, redmouth and black spot disease, rosy anus, whirling disease, and erythrocytic inclusion body syndrome are known, among others, to affect steelhead (National Marine Fisheries Service 1996, 1998a, 2009, Bratovich et al. 2005).

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 WTMP 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 temperature management and peak migration timing.

Literature on critical water temperatures for pathogens and disease historically identified 59.9°F as the threshold temperature to increase virulence of pathogens.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

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. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed pathogens and disease water temperature criteria obtained from scientific literature.

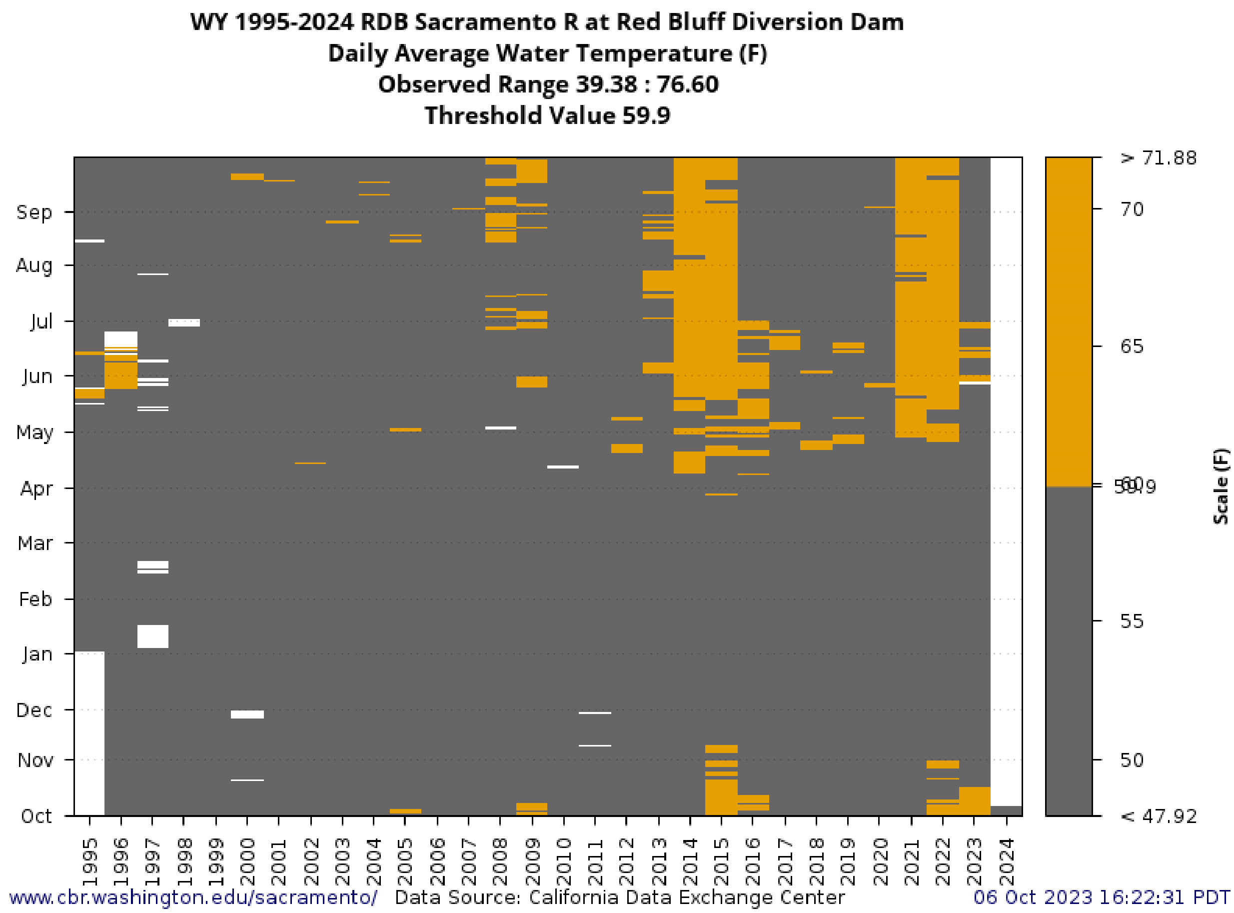
In the spring (April and May) during juvenile rearing and outmigration in the Sacramento River, historical daily average water temperatures have been above the virulence threshold.

Results for the exceedance of the 59.9°F pathogen virulence water temperature threshold are presented in Table 7-58 for the Sacramento River at Keswick, Table 7-59 for the Sacramento River at the RBDD, and Table 7-60 for Clear Creek below Whiskeytown. At Keswick Reservoir, only the Critically dry water year types had months that exceeded the temperature threshold with 10.1% for all phases of the Proposed Action. In Wet, Above Normal, Below Normal, and Dry water year types, percentages outside the range were 0% throughout the year-round period under the Proposed Action phases.

Table 7-58. Percent of months above the 59.9°F pathogen virulence water temperature threshold for juvenile steelhead rearing and outmigration by water year type and for all years combined, Sacramento River at Keswick, Year-round.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	35.1	0.0	0.0	0.0	0.0	0.0
AN	35.4	0.0	0.0	0.0	0.0	0.0
BN	39.4	0.0	0.0	0.0	0.0	0.0
D	36.8	0.0	0.0	0.0	0.0	0.0
C	41.8	3.2	9.0	10.1	10.1	10.1
All	37.4	0.5	1.4	1.6	1.6	1.6

The **proportion** of juveniles rearing in the Sacramento River when water temperatures are above the virulence threshold is likely **medium**, as juveniles are rearing year-round but likely rearing in natal tributaries. Peak outmigration at the KNL traps occurs in March and April, therefore the **proportion** of the population that is outmigrating when water temperatures are above the threshold is likely in April and May on the Sacramento River is likely **small**. Water temperature management occurs in all years and water temperatures downstream of Shasta Reservoir are dependent on hydrology and meteorology. Historical water temperatures for RBDD (Figure 7-88) indicate the **frequency** of occurrence is likely **medium** for rearing and outmigration (occurs in 15 out of 29 years). In the winter and spring, storage may reduce flows which may increase the stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-88. Days exceeding 59.9°F in the Sacramento River at RBDD between October and September 1995 – 2023.

In the summer and fall, during juvenile rearing and outmigration in the Sacramento River, historical daily average water temperatures have been above the virulence threshold.

At the Sacramento River at the RBDD results for the exceedance of the 59.9°F pathogen virulence temperature threshold under the Proposed Action phases ranged from 34.9% during Critical water years to 7.6% of months during Above Normal water years. Overall, the percent of months outside the range increased from wetter to drier water year types under all phases of the Proposed Action, throughout the year-round period.

Table 7-59. Percent of months above the 59.9°F pathogen virulence water temperature threshold for juvenile steelhead rearing and outmigration by water year type and for all years combined, Sacramento River at the Red Bluff Diversion Dam, Year-round.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	45.8	27.1	13.4	8.9	8.9	8.9
AN	47.5	22.2	10.1	7.6	7.6	7.6
BN	47.2	21.3	14.8	9.3	9.7	10.2
D	48.3	20.1	16.3	11.1	10.8	12.8
C	54.5	41.3	40.2	34.9	33.9	32.8
All	48.3	25.9	18.2	13.5	13.3	13.7

The **proportion** of juveniles rearing in the Sacramento River when water temperatures are above the virulence threshold in the summer and fall is likely **medium**, as juveniles are rearing year-round but likely rearing in natal tributaries. Juvenile outmigration typically occurs between January and May, therefore the **proportion** of the population that is outmigrating when water temperatures are above the threshold in the summer and fall months is **small**. Historical water temperatures for RBDD (Figure 7-88) indicate the **frequency** of occurrence is likely **medium** for rearing and outmigration (occurs in 15 out of 29 years). In the summer and fall, releases may increase flows which may decrease the stressor.

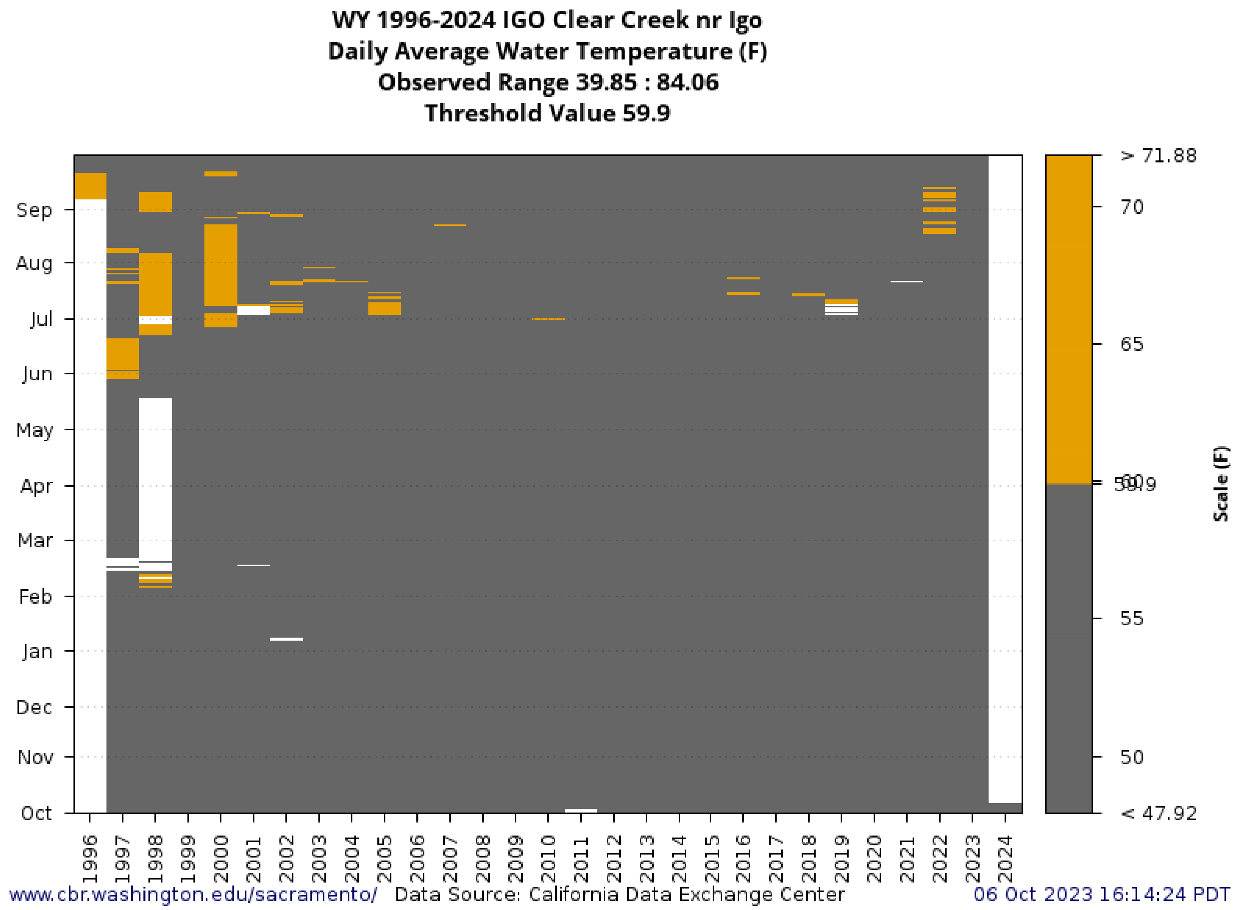
During the juvenile rearing and outmigration period in Clear Creek, historical daily average water temperatures can exceed the threshold during rearing and outmigration. Water temperatures are within the preferred temperatures for juvenile steelhead outmigration for most of the period but exceed the threshold in June (Figure 7-89).

At Clear Creek below Whiskeytown, results for the exceedance of the 59.9°F pathogen virulence temperature threshold under the Proposed Action phases range from 6.9% during Critical water years to 0.3% of months during Wet water years. During Above Normal, and Dry water year types, the percentage of months above the temperature threshold remained at 0% for all phases of the Proposed Action during the year-round period.

Table 7-60. Percent of months above the 59.9°F pathogen virulence water temperature threshold for juvenile steelhead rearing and outmigration by water year type and for all years combined, Clear Creek below Whiskeytown, Year-round.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	35.4	0.0	0.0	0.3	0.3	0.6
AN	33.5	0.0	0.0	0.0	0.0	0.0
BN	38.9	4.2	0.5	0.9	0.9	0.9
D	40.3	11.5	0.0	0.0	0.0	0.0
C	43.4	14.3	1.6	7.4	6.9	6.9
All	38.2	5.8	0.3	1.4	1.3	1.4

The **proportion** of juvenile steelhead rearing in Clear Creek when water temperatures are virulent is likely **medium**, as juveniles are rearing year-round and water temperatures are not consistently above the virulence threshold. Table 7-56 shows a summary of cumulative historical passage at rotary screw traps for the lower Clear Creek for juvenile unclipped *O. mykiss*. Based on outmigration timing from traps on lower Clear Creek, peak outmigration occurs March through late May, when temperatures rarely exceed the threshold for short periods of time. Therefore, the **proportion** of the population that is outmigrating during the warmer water temperatures on lower Clear Creek is likely **small**. Historical water temperatures at Clear Creek near Igo indicate the frequency of occurrence is likely **medium** for rearing and likely **low** for outmigration (Figure 7-89). In the winter and spring, storage may reduce flows, which may increase the stressor. In the summer and fall, releases may increase flows, which may decrease the stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-89. Days exceeding 59.9°F in Clear Creek near IgO between October and September 1996 – 2023.

During the juvenile rearing and outmigration period in the American River, historical daily average water temperatures have reached the virulence threshold. Water temperatures occasionally exceed the virulence threshold as early as March and through November during juvenile rearing (Figure 7-90). Juveniles with the bacterial disease “rosy anus” have been observed in the American River in summer and fall (Bratovich et al. 2005).

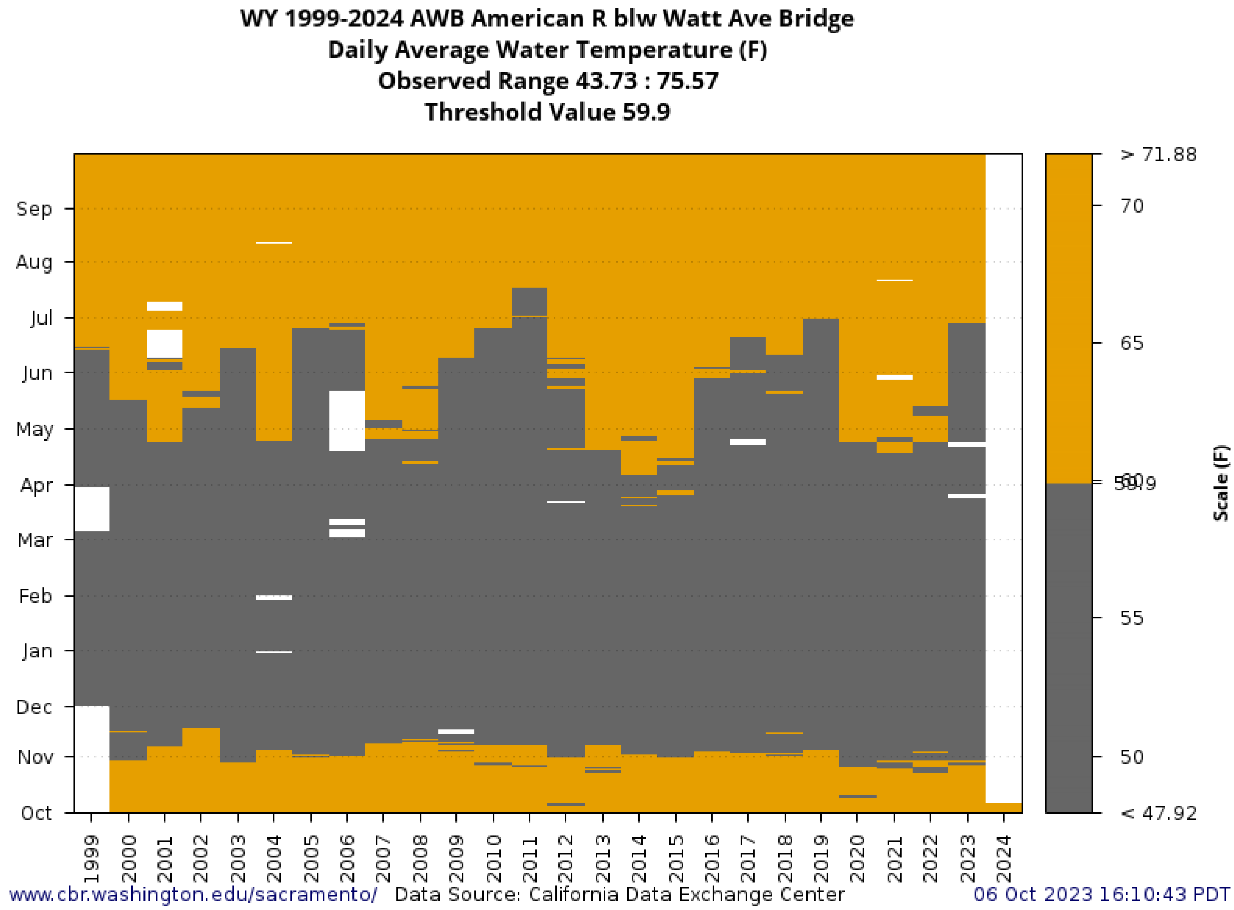
Table 7-61. Percent of months above the 59.9°F pathogen virulence water temperature threshold for juvenile steelhead rearing and outmigration by water year type and for all years combined, American River at Hazel Ave., Year-round.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	41.4	42.6	37.8	38.1	37.8	38.1
AN	44.3	46.8	38.6	38.6	39.2	39.2
BN	47.2	49.5	42.6	42.1	41.7	42.1
D	47.6	51.0	44.1	45.1	45.1	45.1
C	56.6	56.1	48.1	49.7	49.7	49.2
All	46.8	48.6	42.0	42.5	42.4	42.5

Table 7-62. Percent of months above the 59.9°F pathogen virulence water temperature threshold for juvenile steelhead rearing and outmigration by water year type and for all years combined, American River at Watt Ave., Year-round.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	44.0	48.2	44.9	45.2	44.9	45.2
AN	48.7	50.6	48.7	48.7	49.4	49.4
BN	51.4	53.7	49.1	49.5	50.0	49.5
D	52.8	55.9	51.4	51.7	52.4	51.7
C	59.3	61.4	59.8	57.7	58.7	57.1
All	50.5	53.5	50.1	50.0	50.5	50.0

The **proportion** of juvenile steelhead rearing in the American River when water temperatures are warmer is likely **large**, as juveniles are rearing year-round. Table 7-56 shows a summary of cumulative historical passage at rotary screw traps for the lower American River for juvenile unclipped *O. mykiss*. Based on migration timing from traps on the lower American, peak outmigration occurs April through early May. Therefore, the **proportion** of the population that is outmigrating during the virulent temperatures on the lower American River is likely **small**. Historical water temperatures at Watt Ave indicate the frequency of occurrence is likely **high** for rearing and **medium** for outmigration (criteria is met in 13 out of 25 years during the outmigration period). In the winter and spring, storage may reduce flows which may increase the stressor. In the summer and fall, releases may increase flows which may decrease the stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-90. Days exceeding 59.9°F in the American River below Watt Ave between October and September 1999 – 2023.

During the juvenile rearing and outmigration period in the Stanislaus River, historical daily average water temperatures can exceed the threshold during rearing and outmigration. Water temperatures are within the preferred temperatures for juvenile steelhead outmigration for most of the period but exceed the threshold in June (Figure 7-91).

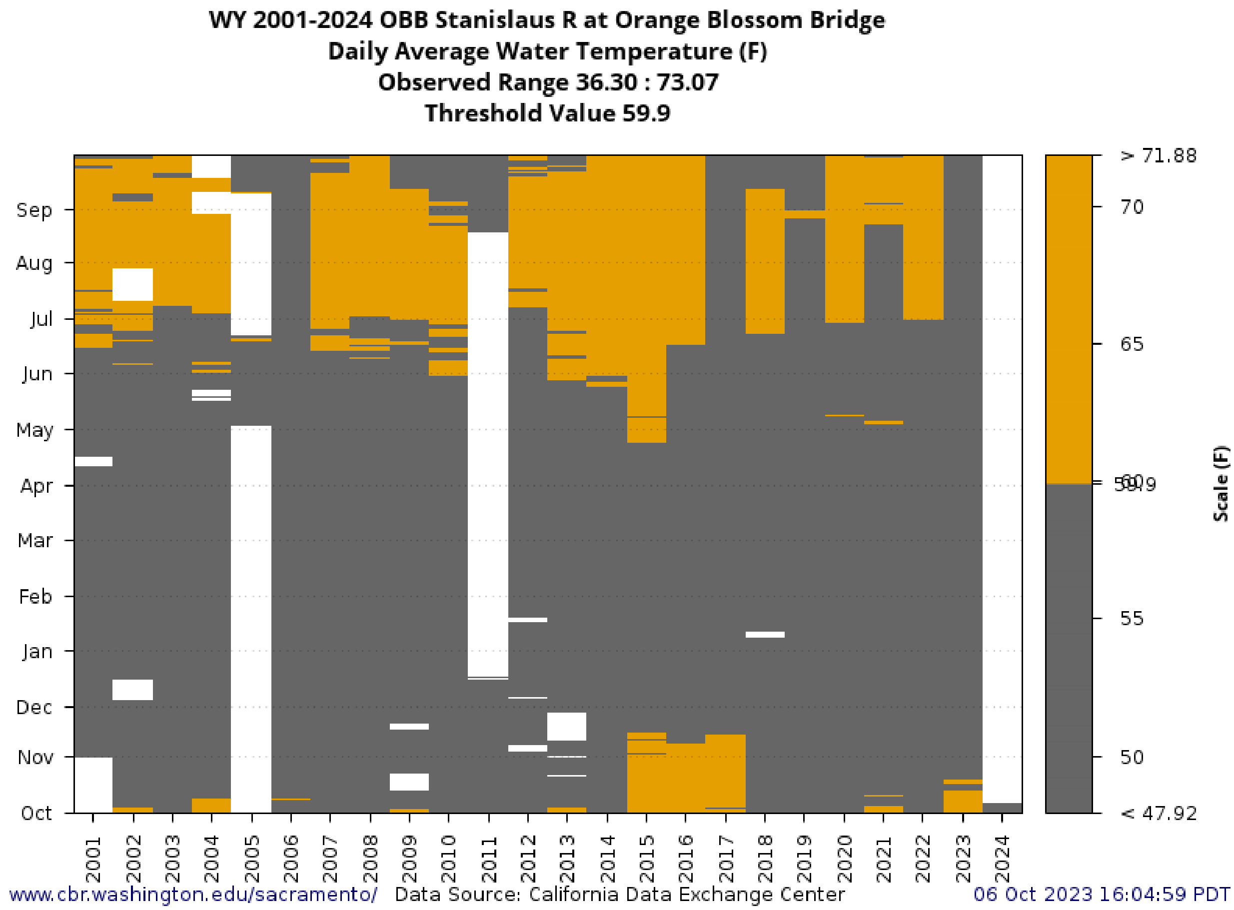
Table 7-63. Percent of months above the 59.9°F pathogen virulence water temperature threshold for juvenile steelhead rearing and outmigration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River at Orange Blossom Bridge, Year-round.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	39.4	12.5	12.9	13.6	13.6	13.6
AN	41.7	28.5	22.9	22.9	22.9	22.9
BN	43.5	30.6	21.8	22.9	22.9	22.9
D	47.1	34.3	31.9	31.9	31.9	31.9
C	56.0	43.0	35.4	33.1	33.1	33.1
All	47.1	31.1	26.2	25.8	25.8	25.8

Table 7-64. Percent of months above the 59.9°F pathogen virulence water temperature threshold for juvenile steelhead rearing and outmigration by water year type (San Joaquin Valley Index) and for all years combined, Stanislaus River above confluence, Year-round.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	43.9	33.0	35.2	35.2	35.2	35.2
AN	47.9	45.1	39.6	41.7	41.7	41.7
BN	47.1	50.6	40.6	43.5	43.5	43.5
D	54.9	59.8	57.4	57.4	57.4	57.4
C	60.3	65.1	63.9	62.8	62.8	62.8
All	52.3	52.4	50.0	50.3	50.3	50.3

The **proportion** of juvenile steelhead rearing in the Stanislaus River when water temperatures are virulent is likely **large**, as juveniles are rearing year-round and water temperatures are consistently above the threshold June through September. Table 7-56 shows a summary of cumulative historical passage at RSTs for the Stanislaus River for juvenile unclipped *O. mykiss*. Based on migration timing from traps, peak outmigration occurs March through May. Therefore, the **proportion** of the population that is outmigrating during water temperatures above the virulence threshold in the Stanislaus River is likely **small**. Historical water temperatures at Orange Blossom Bridge indicate the frequency of occurrence is likely **high** for rearing and likely **low** for outmigration (criteria is frequently met in 3 out of 23 years). In the fall, winter, and spring, storage may reduce flows which may increase the stressor. In the summer releases may increase flows which may decrease the stressor.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-91. Days exceeding 59.9°F in the Stanislaus River at OBB between October and September 2001 – 2023.

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 steelhead nor to the Sacramento River. There is also uncertainty on how changes in pathogens and disease stressors may affect occurrence of anadromy among juveniles, as studies have shown that factors that affect growth, body condition, and survival may have disparate influences on rates of anadromy and residency (Kendall et al. 2014, Eschenroeder et al. 2022).

- McCullough (1999) is quantitative, not species-specific, not location specific, published research on virulence temperature thresholds.
- Historical water temperatures are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed data from long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.

- Historical juvenile outmigration-timing observations are quantitative, species-specific, and location-specific. The observations are published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- HEC-5Q water temperature modeling are quantitative, not species-specific (environmental variable) and location-specific. The model was developed to evaluate reservoir systems using control points, and is widely accepted as the temperature modeling system for use in the upper Central Valley 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
- Clear Creek
    - Water Temperature Management
- American River
    - Water Temperature Management
- Stanislaus River
    - Stepped Release Plan

7.2.5.3 Outmigration Cues

The proposed storage of water may increase the outmigration cue stressor. During the juvenile rearing and outmigration period, the Proposed Action will provide stable flows relative to natural hydrology in the rivers below their respective dams. Research over the last decade has identified that rivers and streams with high, stable flows tend to favor residency (Courter et al. 2009; Kendall et al. 2014), but no flow thresholds have been established due to significant variations in geomorphology across steelhead populations and habitat. Water temperature within ranges associated with smoltification may be essential for cueing outmigration in juvenile steelhead. Warmer water temperatures with high food resources may lead to lower rates of smoltification and fewer life history trajectories expressed (Benjamin et al. 2013). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation.

- Appendix L – analyzes Sacramento River and Clear Creek smoltification water temperature criteria
- Appendix M – analyzes American River smoltification water temperature criteria
- Appendix N – analyzes Stanislaus River smoltification water temperature criteria
- Appendix H – presents analysis on the “Minimum Flows” conservation measure

Steelhead successfully undergo smoltification at water temperatures between 43.7°F and 53.4°F, and show little adaptation to high levels of salinity at water temperatures above 59°F (Myrick and Cech 2001). Cooler temperatures below 50°F tend to increase their seawater adaptation. The temperature criterion for steelhead smoltification occurs at 57°F 7DADM, with impairment at constant temperatures above 55°F during the outmigration period (U.S. Environmental Protection Agency 2003). Steelhead outmigration is likely triggered by a complex interaction of flow, food availability, water temperature, and turbidity, and can't be linked to a single threshold for any of these factors. Steelhead smolts may alter their outmigration rhythms depending on water temperatures, with hatchery smolt diurnal detections increasing with water temperature, making them more susceptible to predation during the day (Chapman et al. 2012; Ibbotson et al. 2006). Cooler water temperatures are also critical for the smoltification and outmigration process (Washington State Department of Ecology 2002a). There is also uncertainty on how changes in these factors may affect occurrence of anadromy among juveniles, as studies have shown that factors that affect growth, body condition, and survival may have disparate influences on rates of anadromy and residency (Kendall et al. 2014, Eschenroeder et al. 2022). Outmigrating juvenile *O. mykiss* abundance in Clear Creek has been negatively correlated with water temperatures in June and July and increased flows as fry (He and Marcinkevage 2017).

The outmigration cues stressor is expected to be **sub-lethal** in Clear Creek, the Sacramento, American, and Stanislaus rivers. Water temperatures above criteria may change juvenile steelhead behavior and alter the smoltification process for individuals preparing for outmigration. If juvenile *O. mykiss* stay in their natal rivers and tributaries longer, since they are not cued to outmigrate, this delay may encourage residency and lower the rate of anadromous individuals in the population. The impact of outmigration cues is not independent from these other stressors such as refuge habitat, food availability and quality, entrainment risk, predation, and competition. Outmigration cues may be masked by the Proposed Action in the Delta, increase travel time, and potentially reduce outmigration survival. Outmigration cues are defined as fish outmigration behavior impacted by variation and volume of flows and fish travel times being affected and increasing juveniles' exposure to predators and poor environmental conditions.

Changes to the outmigration cues stressor are expected to be insignificant in the Delta and San Joaquin River. The Proposed Action is expected to have insignificant changes to water temperature and, therefore, smoltification in the Delta and San Joaquin River. Furthermore, juvenile steelhead are not known for rearing at these locations and are likely cued for outmigration in their natal rivers and tributaries.

Although the Proposed Action may increase the outmigration cues stressor, changes in outmigration cues that affect steelhead exist in the **environmental baseline** (without the Proposed Action). Generally, natural flows in Central Valley rivers and tributaries 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 Sacramento River. In addition, other facilities owned by senior water users affect flows. Climate affects reservoir storage, which influences reservoir releases and flows below dams, along with releases for authorized purposes. The resulting flows influence steelhead outmigration behavior, which may expose steelhead to predators often near existing structures and poor environmental conditions from past and present human impacts.

The **proportion** of the population affected by the Proposed Action depends on water temperature management and peak outmigration timing.

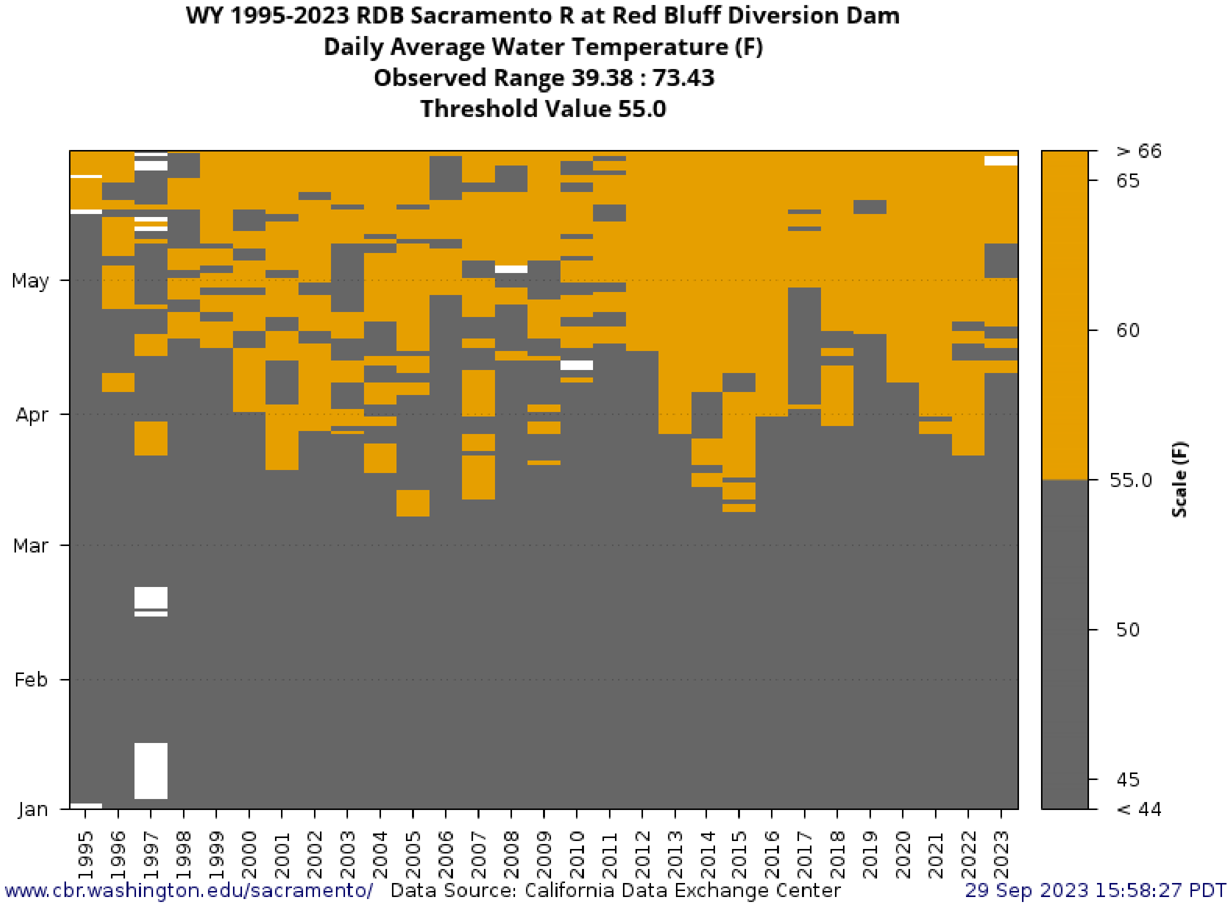
Literature on critical water temperatures for smoltification historically identified 54°F as the threshold temperature to outmigration.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

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. HEC-5Q modeling analysis enumerates the frequency at which mean monthly simulated water temperatures exceed water temperature criteria obtained from scientific literature.

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 of Chinook salmon 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. Survival of juvenile steelhead in the southern Sacramento-San Joaquin River Delta has been associated with river discharge in the upstream reaches, while survival in the lower reaches has been associated with the migration route (Buchanan et al. 2021). As inflow declines and tidal influence moves upstream, travel time and distance of outmigrating juveniles may increase leading to higher exposure to predators.

During the juvenile outmigration period in the Sacramento River, historical water temperatures have been above the smoltification criteria (Figure 7-92). The Sacramento River is the main migratory pathway for the Central Valley and peak outmigration at the KNL traps occurs in March and April when water temperatures are above the criteria. In the Delta, the Proposed Action is unlikely to significantly impact water temperatures. Therefore, the **proportion** of the population affected by the increase to the outmigration cue stressor is likely **large**, as the Sacramento River and the Delta are major migratory pathways for CV steelhead.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-92. Days exceeding 55°F in the Sacramento River at RBDD between January and May 1995 – 2023.

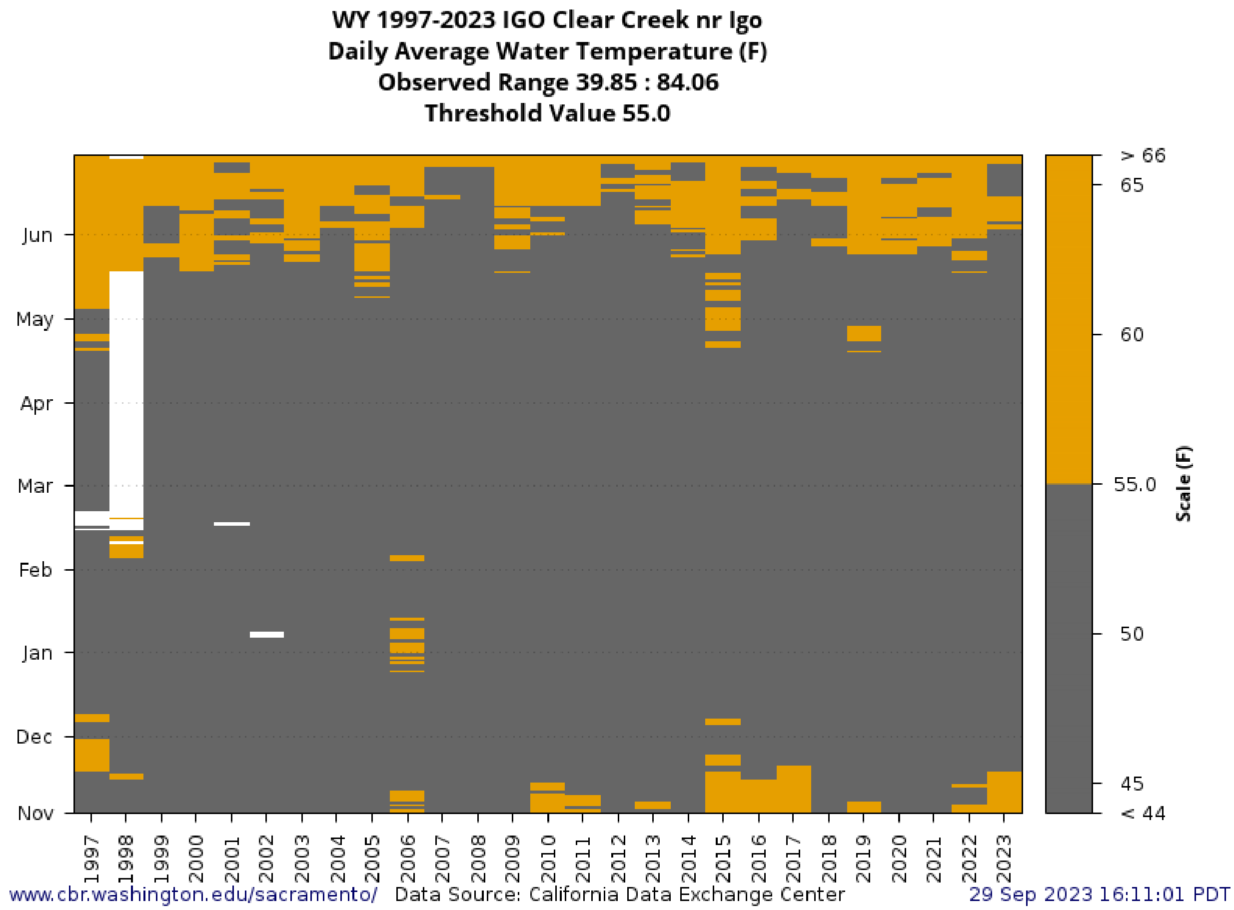
Results for the 55°F temperature threshold for the steelhead outmigration cue are presented in Table 7-65 for the Sacramento River at the RBDD and Table 7-66 for Clear Creek below Whiskeytown. At the RBDD, the percentage of months that exceeded the temperature threshold range from 47.5% in Critical to 36.4% in Wet water year types. Overall, the percentage of months that exceed the temperature threshold increased from wetter to drier water year types, with the Dry water years performing similarly to Above Normal water year types for all phases of the Proposed Action during the period of January through May.

Table 7-65. Percent of months above the 55°F water temperature threshold for the juvenile steelhead outmigration cue by water year type and for all years combined, Sacramento River at the Red Bluff Diversion Dam, January through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	25.7	35.7	36.4	36.4	36.4	36.4
AN	35.4	40.0	40.0	40.0	40.0	40.0
BN	36.7	44.4	42.2	42.2	42.2	42.2
D	39.2	45.0	40.0	40.8	41.7	41.7
C	45.0	52.5	50.0	47.5	47.5	47.5
All	35.4	42.8	41.0	40.8	41.0	41.0

The **frequency** of occurrence in the upstream reaches may depend on hydrology and meteorology while the lower reaches may depend on routing as indicated by the study in the south Delta. Water temperature management occurs in all years and water temperatures downstream of Shasta Reservoir are dependent on hydrology and meteorology. Historical water temperatures at RBDD (Figure 7-80) go above the criteria in 28 out of 29 years during peak migration, when flows are reduced under the Proposed Action. Therefore, the frequency of occurrence may range from **low** to **high**, depending on routing as indicated by Buchanan et al. (2021).

During the juvenile outmigration period in Clear Creek, historical water temperatures have been above the smoltification criteria (Figure 7-93). Table 7-56 shows a summary of cumulative historical passage at RSTs for the lower Clear Creek for juvenile unclipped *O. mykiss*. The traps are operational from October through June. Based on migration timing from traps on lower Clear Creek, peak outmigration occurs March through late May. Therefore, the **proportion** of the population that is outmigrating during the water temperatures above the smoltification criteria on lower Clear Creek is likely **small**.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-93. Days exceeding 55°F in Clear Creek at IgO between November and June 1996 – 2023.

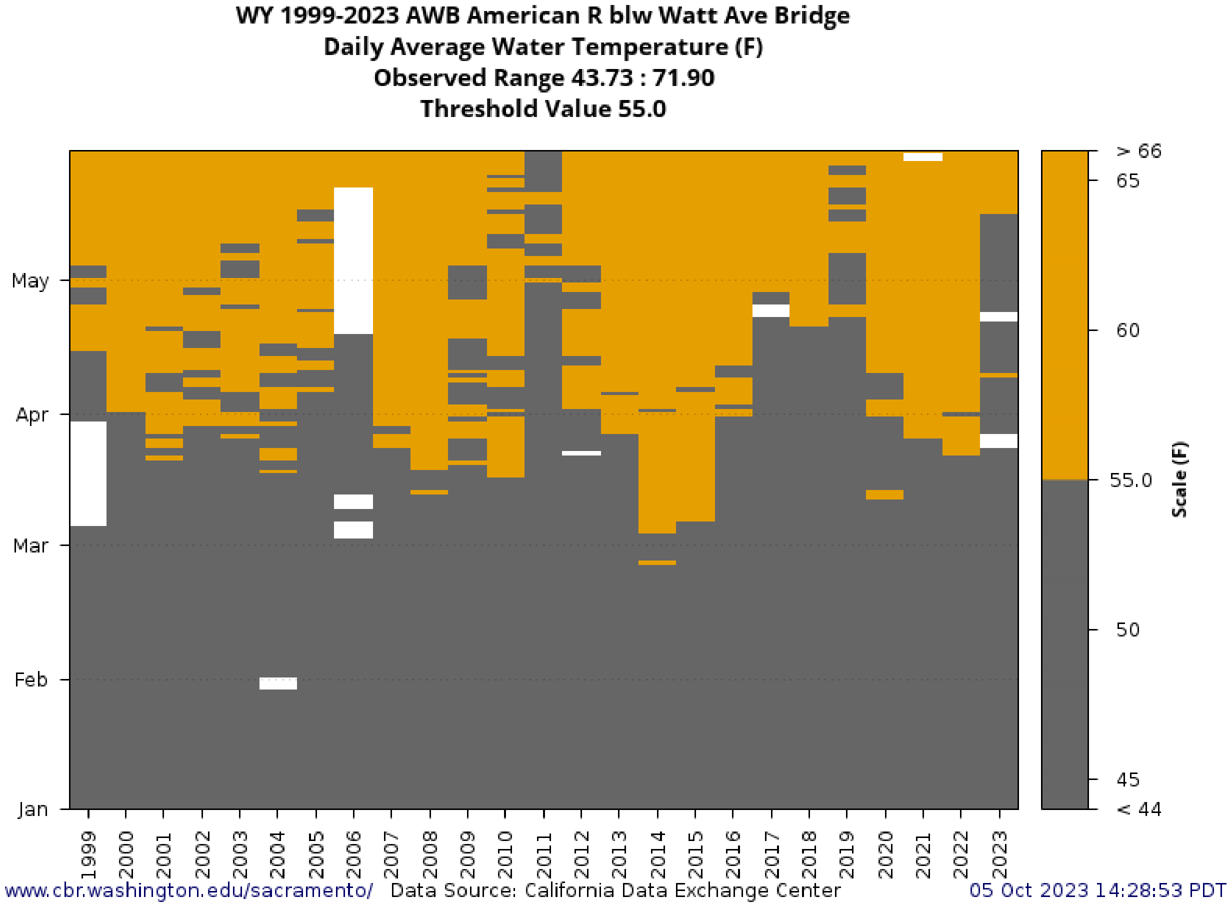
At Clear Creek below Whiskeytown, the percentage of months that exceed the 55°F temperature threshold under the Proposed Action phases remained at 0.0% for all water year types during the period of January through May.

Table 7-66. Percent of months above the 55°F water temperature threshold for the juvenile steelhead outmigration cue by water year type and for all years combined, Clear Creek below Whiskeytown, January through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	20.0	0.0	0.0	0.0	0.0	0.0
AN	20.0	0.0	0.0	0.0	0.0	0.0
BN	21.1	2.2	0.0	0.0	0.0	0.0
D	20.0	0.0	0.0	0.0	0.0	0.0
C	21.3	1.3	0.0	0.0	0.0	0.0
All	20.4	0.6	0.0	0.0	0.0	0.0

Historical water temperatures at Clear Creek near IGO indicate the frequency of occurrence is likely **high** (the criteria is met in all 27 years).

During the juvenile outmigration period in the American River, historical water temperatures have been above smoltification criteria (Figure 7-94). Table 7-56 shows a summary of cumulative historical passage at RSTs for the lower American River for juvenile unclipped *O. mykiss*. The traps are operational from January through June. Based on outmigration timing from traps on the lower American, peak outmigration occurs April through early May. Therefore, the **proportion** of the population that is outmigrating during the sublethal water temperatures on the lower American River is likely **large**, as temperatures often exceed the criteria between April and early May.



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-94. Days exceeding 55°F in the American River below Watt Ave between February and May 1999 – 2023.

Results for the 55°F temperature threshold for the steelhead outmigration cue are presented in Table 7-67 for the American River at Hazel Ave., Table 7-68 for the American River at Watt Ave., Table 7-69 for the Stanislaus River at Orange Blossom Bridge, and Table 7-70 for the Stanislaus River above the confluence with the San Joaquin. At the American River at Hazel Ave., the percentage of months that exceeded the temperature threshold range from 30.0% in Critical to 17.9% in Wet water year types. Overall, the percentage of months that exceed the temperature threshold were similar for each phase of the Proposed Action and across water year types. During Critical water year types the percentage of months above the threshold were notably higher for all phases of the Proposed Action during the period of January through May.

Table 7-67. Percent of months above the 55°F water temperature threshold for the juvenile steelhead outmigration cue by water year type and for all years combined, American River at Hazel Ave., January through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	14.3	19.3	17.9	18.6	18.6	17.9
AN	24.6	20.0	20.0	20.0	20.0	20.0
BN	26.7	20.0	20.0	20.0	20.0	20.0
D	34.2	20.8	20.0	20.0	20.0	20.0
C	45.0	28.8	26.3	25.0	30.0	25.0
All	27.7	21.4	20.4	20.4	21.2	20.2

On the American River at Watt Ave., the percentage of months that exceed the 55°F temperature threshold under the Proposed Action phases ranged from 62.5% in Critical to 26.4% in Wet water year types. In general, the percentage of months that exceeded the temperature threshold increased from wetter to drier water year types, for all phases of the Proposed Action during the period of January through May.

Table 7-68. Percent of months above the 55°F water temperature threshold for the juvenile steelhead outmigration cue by water year type and for all years combined, American River at Watt Ave., January through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	23.6	27.9	26.4	26.4	26.4	26.4
AN	30.8	40.0	40.0	40.0	40.0	40.0
BN	32.2	45.6	42.2	42.2	43.3	43.3
D	44.2	49.2	45.8	46.7	47.5	46.7
C	56.3	60.0	58.8	60.0	62.5	61.3
All	36.4	43.0	41.0	41.4	42.2	41.8

Historical water temperatures at Watt Ave indicate the **frequency** of occurrence is likely **high** (occurs in all 25 years).

During the juvenile outmigration period in the Stanislaus River, historical water temperatures have been above the smoltification criteria. Table 7-56 shows a summary of cumulative historical passage at the Stanislaus River Caswell RSTs for juvenile unclipped *O. mykiss*. The traps are operational from October through June. Based on outmigration timing from the trap, peak outmigration occurs March through May. Therefore, the **proportion** of the population that is outmigrating during the water temperatures above the criteria is likely **large**.

On the Stanislaus River at Orange Blossom Bridge, the percentage of months that exceed the 55°F temperature threshold under the Proposed Action phases ranged from 53.3% in Critical to 1.7% in Above Normal water year types. With the exception of Above Normal water years, the percentage of months that exceeded the threshold increased from wetter to drier water year types, with Dry and Critically dry water years having significantly higher percentage of months compared to the other water year types during the period of January through May.

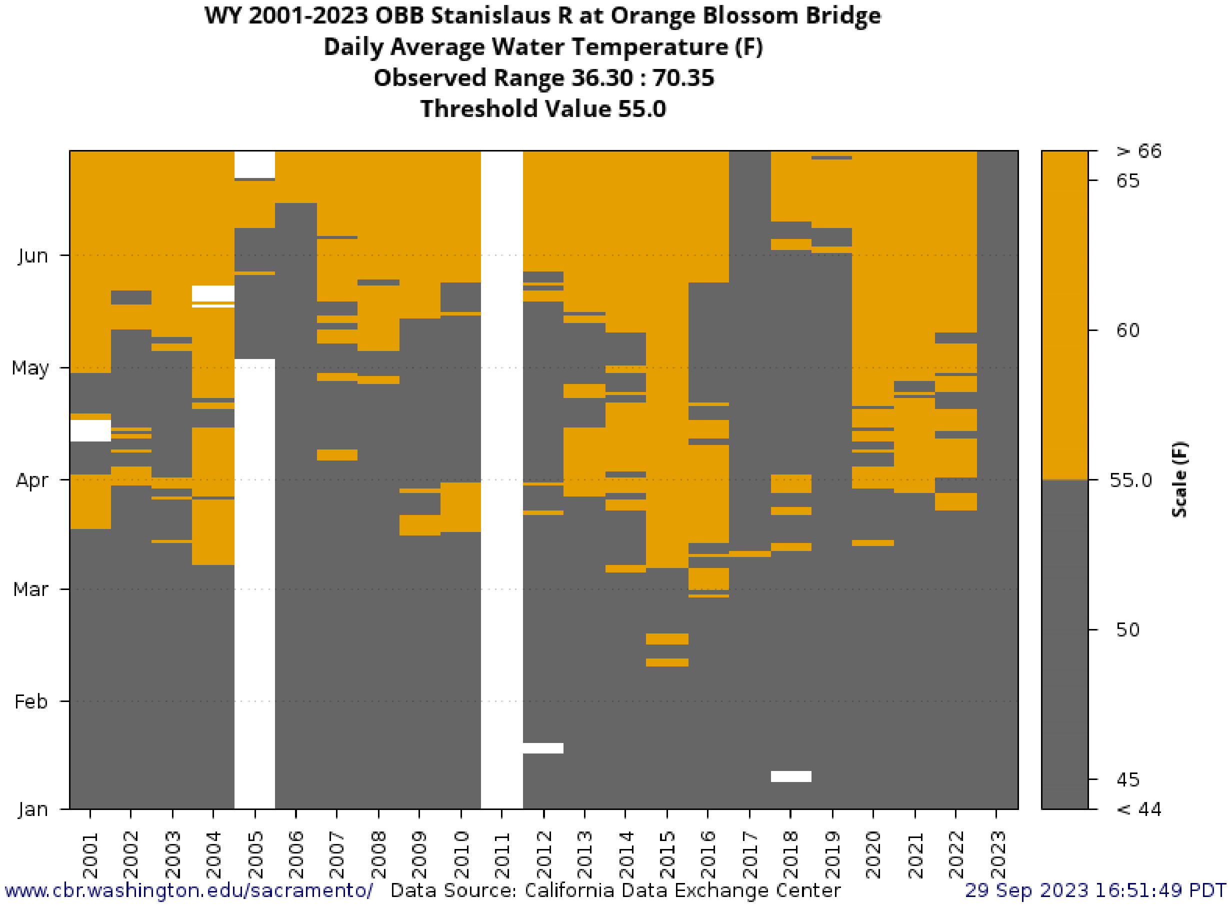
Table 7-69. Percent of months above the 55°F water temperature threshold for the juvenile steelhead outmigration cue by water year type (San Joaquin index) and for all years combined, Stanislaus River at Orange Blossom Bridge, January through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	8.2	4.5	3.6	2.7	3.6	3.6
AN	18.3	5.0	3.3	1.7	1.7	1.7
BN	18.6	14.3	4.3	5.7	5.7	5.7
D	24.7	47.1	36.5	41.2	41.2	41.2
C	43.0	59.4	51.5	53.3	53.3	53.3
All	25.5	31.8	25.5	26.7	26.9	26.9

At the Stanislaus River above the confluence with the San Joaquin, the percentage of months that exceed the 55°F temperature threshold under the Proposed Action phases ranged from 64.8% in Critical to 41.8% in Wet water year types. Overall, the percentage of months that exceeded the threshold increased from wetter to drier water year types, for all phases of the Proposed Action during the period of January through May.

Table 7-70. Percent of months above the 55°F water temperature threshold for the juvenile steelhead outmigration cue by water year type (San Joaquin index) and for all years combined, Stanislaus River above confluence with San Joaquin, January through May.

WYT	EXP1	EXP3	NAA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA
W	24.5	37.3	42.7	41.8	41.8	41.8
AN	31.7	48.3	48.3	48.3	48.3	48.3
BN	37.1	54.3	54.3	54.3	54.3	54.3
D	42.4	62.4	62.4	61.2	61.2	61.2
C	60.0	67.3	66.7	64.8	64.8	64.8
All	42.2	55.5	56.5	55.5	55.5	55.5



Source: Columbia Basin Research 2023.
Unavailable data depicted in white.

Figure 7-95. Days exceeding 55°F in the Stanislaus River below Watt Ave between January and June 2001 – 2023.

Historical water temperatures near Orange Blossom (Figure 7-95) indicate the **frequency** of occurrence is likely **high** (criteria is frequency exceeded in 20 out of 22 years).

To evaluate the **weight of evidence** for the outmigration cues stressor, there are smoltification temperature thresholds from several peer reviewed articles and state issued water quality documents that are specific to steelhead but these studies are not specific to the Central Valley. The water quality monitoring data through SacPAS provides quantitative data on each watershed to assess whether a threshold was met (Columbia Basin Research 2023).

- Historical water temperatures are quantitative, not species-specific (environmental variable), and location-specific. The data are available through multiple sources and QA/QCed data from long time-series, published in technical memos and annual reports from technical teams, and not expected to have statistical power.

- Historical juvenile outmigration-timing observations are quantitative, species-specific, and location-specific. The observations are published in technical memos and annual reports from technical teams, not expected to have statistical power.
- HEC-5Q water temperature modeling are quantitative, not species-specific (environmental variable) and location-specific. The model was developed to evaluate reservoir systems using control points, and is widely accepted as the temperature modeling system for use in the upper Central Valley 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
    - Spring Pulse Flows
- Clear Creek
    - Minimum Instream Flows
    - Spring Pulse Flows
- American River
    - Minimum Instream Flows
    - Spring Pulse Flows
- Stanislaus River
    - Stepped Release Plan

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 and Redd Maintenance
- American River
    - Reduced Wilkins Slough Minimum Flows for Shasta Reservoir End of September Storage
    - Rebalancing between other CVP Reservoirs for Shasta Reservoir End of September Storage
- Drought Actions

7.2.5.4 Stranding Risk

The proposed storage and diversion of water may increase the stranding risk stressor in all five steelhead bearing natal rivers and tributaries of the CVP and may decrease depending seasonality in the Sacramento, American and Stanislaus rivers. During the juvenile rearing (year-round) and outmigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. In the San Joaquin River, operations of storage and releases of water would result in decreased flows throughout the year. In the fall, flows would be increased in the Sacramento River, American River, and Clear Creek, and decreased in the Stanislaus River. Decreased flows may result in fish trapped in isolated pools or shallow areas off the mainstem. Appendices L, M, and H will address the stranding risk stressor through the “Minimum Instream Flows” and “Ramping Rates” conservation measures.

The increase in stranding risk stressors during the winter and spring 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. As water temperatures increase, these isolated pools may also have low dissolved oxygen and poor water quality.

A decrease in the stranding risk stressor from the Proposed Action in the summer and fall is potentially **beneficial**. Increased releases below Folsom, Keswick, and New Melones reservoirs may result in more inundated habitats for juvenile steelhead, reducing the stranding risk.

The stranding risk stressor is not anticipated to change in the Delta. Juvenile steelhead stranding has not been observed in fish monitoring in the Delta.

Although the Proposed Action may, at times increase the stranding risk stressor, stranding of juvenile steelhead 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 stranding. Flow fluctuations from past have contributed to steelhead 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.

The **proportion** of the population affected by the Proposed Action depends on presence of juveniles and hydrology. Juveniles are present year-round in the Sacramento River and are most vulnerable to stranding when they are young of the year and rearing in shallow water.

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

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models. Using minimum flows and ramping rates resulted in an average of 660 steelhead per year stranded between 2013 – 2021 (minimum: 153 fish; maximum: 2,043 fish). This was between 0.09 % and 7.24 % of the estimated juvenile population estimate at RBDD RST (Table 7-71).

Table 7-71. *O. mykiss* Passage Index with lower and upper 90% confidence intervals (CI) by brood year for Red Bluff Diversion Dam rotary screw traps between July 2002 and June 2020.

Brood Year	**Passage Index**	**Lower 90% CI**	**Upper 90% CI**	**Direct Count of *O. mykiss* Stranded (WY)**	**Percentage of *O. mykiss* population affected**	**Effort (*n* surveys)**
2002	124,436	27,224	244,701	Not available	Not available	NA
2003	139,008	54,885	243,927	Not available	Not available	NA
2004	151,694	86,857	218,132	Not available	Not available	NA
2005	85,614	32,251	152,568	Not available	Not available	NA
2006	83,801	20,603	169,712	Not available	Not available	NA
2007	139,424	73,827	205,647	Not available	Not available	NA
2008	131,013	69,331	193,584	Not available	Not available	NA
2009	129,581	62,350	197,795	Not available	Not available	NA
2010	100,997	47,050	155,692	Not available	Not available	NA
2011	56,798	23,494	89,369	Not available	Not available	NA
2012	136,621	78,804	194,892	Not available	Not available	27
2013	163,030	91,269	234,791	153	0.09%	70
2014	61,552	21,730	101,374	515	0.84%	76
2015	16,511	7,134	25,888	15	0.09%	75
2016	28,133	9,234	47,032	372	1.32%	103
2017	10,159	-468	20,785	857	8.44%	42
2018	28,227	10,386	46,069	2,043	7.24%	83
2019	24,472	5,950	42,995	Not available	Not available	30

Source: Passage Estimates from U.S. Fish and Wildlife Service RBDD rotary screw trap reports 2002-2019* and Stranding Reports from Revnak and Killam 2013; Jarrett and Killam 2014, 2015; Revnak et al. 2017; Memeo et al. 2018, 2019; Smith et al. 2021.
*Efficiency trials for the RBDD rotary screw traps were performed with chinook salmon, and were not done with steelhead. Recorded catch of juvenile *O. mykiss* does not distinguish between life stages or life history type.
The direct count of stranded juveniles is recorded by Water Year and a subsequent calculated percentage of *O. mykiss* population stranded using the passage index.

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

[Placeholder: for Sacramento River juvenile stranding model (performance measure is juveniles stranded)]

During the juvenile rearing and outmigration period on the Sacramento River, the Proposed Action will reduce releases from Shasta Reservoir and decrease flows below Keswick Dam. This storage decreases in August and September, and December through April during juvenile outmigration and rearing. Annual total stranding of steelhead was monitored by Pacific States Marine Fisheries Commission and CDFW in the Sacramento River during field seasons from 2012-2013 to 2020-2021 (Table 7-71) and results are reported in annual reports (Revnak and Killam 2013; Jarrett and Killam 2014, 2015; Revnak et al. 2017; Memeo et al. 2018, 2019; Smith et al. 2021).

During juvenile outmigration and rearing in the Sacramento River, the proportion of the population affected by the increase to the stranding risk stressor is likely **small** to **medium** if flow reductions begin in November. Historically, peak passage of steelhead juveniles at RBDD occurs between May and September (95% passage at RBDD RST occurred before October 2nd; Table 7-55). After November, when flow reduction starts in the Proposed Action, a portion of the current brood year steelhead are potentially at risk of stranding. Seasonal operations on the Sacramento River from Keswick Dam may increase flows May through July. The proportion of the **population** affected by the decrease to the stranding risk stressor is likely **medium** for rearing juveniles when there is sufficient storage and **small** when the storage is limited.

Use of Minimum Flows defines a floor, or flow threshold below which habitat can become disconnected allowing an area to remain viable for steelhead juveniles. Additionally, ramping rates provide cues through changes in flows, generating time needed by some juvenile steelhead to exit areas that may become disconnected.

The **frequency** of occurrence for both the increase and decrease to the stressor is **high** as it likely to occur annually in the Proposed Action. 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.

In Clear Creek, relative stable flow for seasonal operations may increase the stranding risk stressor in November. Historically, USFWS monitoring in Clear Creek for steelhead have not produced numbers on stranding in their annual reports, and there are currently no stranding reports. Therefore, the proportion of the juvenile population affected by stranding can only be estimated based on modeling of the Proposed Action flows. Flows are expected to decrease during the start of outmigration, therefore the **proportion** of the juvenile population affected is likely **small**. The **frequency** of occurrence is **high**, since it is likely to occur annually in the Proposed Action.

In the San Joaquin River, flows may decrease between April and May under the Proposed Action, which can lead to juvenile stranding during outmigration. Historically, monitoring on the San Joaquin River for steelhead has been limited, and there are no stranding reports of juvenile steelhead. Flows are expected to decrease during peak outmigration; however, juveniles are not known to rear in the mainstem, and may outmigrate at a relatively fast rate through the San Joaquin River. In a study by Buchanan et al. (2021), juvenile steelhead migration timing through the South Delta from the head of Old River past Chipps Island varied depending on the route, but the median travel time was 5.6 days. The **proportion** of the juvenile population affected in the San Joaquin River is likely **small to medium**. The **frequency** of occurrence is **high**, since it is likely to occur annually in the Proposed Action.

In the American River, flows are expected to decrease in the late winter and early spring under the Proposed Action which may lead to an increase in the stranding risk stressor. Juvenile stranding surveys were conducted in the American River and the results are covered in annual reports in 2015 – 2022 (Sellheim 2015, 2016, 2019, 2020; Sweeney 2017, 2021, 2022; Scrivin 2018). Assistance from CDFW started in 2017 to rescue stranded fish and move them into the main channel. Results from the stranding surveys are documented in Table 7-72. Peak passage for juveniles outmigrating is in April and May, when the rate of flow reductions is low. Historically, monitoring from these stranding surveys have shown stranded fish in March and April (Sellheim et al. 2020, Sweeney et al. 2021, Sweeney et al. 2022). The **proportion** of the juvenile population affected is likely **small to medium** (depending on the timing of flow reductions). The **frequency** of occurrence is **high**, since it is likely to occur annually in the Proposed Action. There may be a decrease in the stressor in the summer period for rearing juveniles as the Proposed Action may increase flows from June to July.

Table 7-72. Juvenile Salmonid Stranding Survey Results in the American River 2015-2022.

Year	Species	Stranding events	Effort (survey days)	Stranding mortalities	Rescued	Notes
2022	Steelhead	1	6	233	8,164	
2021	Steelhead	2	4		25	
2020	Steelhead	2	5		35	
2019	Steelhead	5	9	1	273	
2018	Steelhead	6	8		370	
2017	Steelhead	7	14		22	
2016	Salmonids	3	5	1,595		mortalities not specified - no fish salvage attempts
2015	Salmonids	3	4	4,226		mortalities not specified - no fish salvage attempts

In the American River, the Proposed Action is expected to increase releases below Folsom Reservoir from June through September and the risk of juvenile stranding in disconnected habitat would be decreased. The proportion of the population of juveniles rearing that would benefit from the decrease in the stressor would be **medium** when there is sufficient storage and **small** when the storage is limited. The **frequency** of occurrence is **high**, since it is likely to occur annually in the Proposed Action.

In the Stanislaus River, operations may decrease flows in the late winter early spring, but the rate of flow reduction may be lower under the Proposed Action. Historically, monitoring on the Stanislaus River has shown some stranded juvenile steelhead in April (California Department of Fish and Wildlife 2023) during peak outmigration, but available data on a juvenile population and frequency of stranding is limited. The **proportion** of the juvenile population affected by stranding is likely **small to medium** (dependent on the timing of flow reductions). The **frequency** of occurrence is **high**, since it is likely to occur annually in the Proposed Action.

In the Stanislaus River, operations may increase the flows between July and September. The proportion of the juvenile steelhead population rearing in the Stanislaus River that would benefit from the decrease in the stressor would be **medium** when there is sufficient storage and **small** when the storage is limited. The **frequency** of occurrence is **high** since it is likely to occur annually in the Proposed Action.

To evaluate the **weight of evidence** for the stranding risk stressor, there is a twenty-year quantitative historical record of *O. mykiss* stranding monitoring and releases specific to the Sacramento River, however, some years are missing stranding data and there are reports of steelhead trap avoidance. In the American River, there are five years of quantitative data on stranding, but a juvenile population estimate is not available. In the Stanislaus River, there are observations of juvenile *O. mykiss* stranded from CDFW but no quantitative reports. In Clear Creek and the San Joaquin River, there are no reports of juvenile stranding and estimates can only be estimated based on modeling of the Proposed Action flows.

Historical stranding observations are quantitative, species-specific, and location-specific. The observations are available through multiple sources and QA/QCed, long time-series and not expected to have statistical power.

[placeholder] Sacramento River juvenile stranding modeling are quantitative, species-specific, and location-specific. The analysis uses USRDOM daily flow modeling, which was developed to evaluate flows using multiple inputs and is widely accepted as daily flow modeling system for use in the upper Central Valley watershed.

Historical flows are quantitative, not species-specific (environmental variable), location-specific, and QA/QCed from a long time-series. The values are published in technical memos and annual reports from technical teams, and not expected to have statistical power.

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
- American River
    - Minimum Instream Flows
    - Ramping Rates
- Stanislaus River
    - Stepped Release Plan

7.2.5.5 Refuge Habitat

The proposed storage and release of water may increase and decrease the refuge habitat stressor depending on seasonality and watershed. During the juvenile rearing and outmigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam and the Delta, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. In the San Joaquin River, operations of storage and releases of water would result in decreased flows throughout the year. In the fall, flows would be increased in the Sacramento River, American River, and Clear Creek, and decreased in the Stanislaus River. A decrease in flows can reduce suitable margin and off-channel habitats available as refuge habitat for juveniles, while an increase in flows may do the opposite. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles. Appendix O defines refuge habitat and analyzes this stressor.

In the Delta, operations are not expected to increase the refuge habitat stressor for rearing and outmigrating juvenile steelhead. All juveniles outmigrating from the Sacramento and San Joaquin rivers 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. There are no documented studies of juvenile steelhead rearing in the Delta, but they may utilize side channel and inundated floodplain habitat in the tidal shoreline of the Delta during their outmigration. The tidal habitat of the Delta also serves the critical role as a physiological transition zone before saltwater entry. 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 salmonids. 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 outmigration period is frequently greater than at 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** in Clear Creek and the Sacramento, American Stanislaus and San Joaquin rivers in the winter and spring. 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 steelhead 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.

The decrease in the refuge habitat stressors during the summer and fall when the Proposed Action will release stored water and increase flows is expected to be **beneficial**. During the summer, the Proposed Action will increase flows in the Sacramento River below Keswick Dam, American River below Folsom Dam, and Stanislaus River below New Melones Dam. The increase in flows may increase access to high quality refuge habitat.

Although the Proposed Action may, at times, increase the refuge habitat stressor, changes in refuge habitat of juvenile steelhead 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; Whipple 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.

Restoration projects implemented by Reclamation have reduced the refuge habitat stressor on juvenile steelhead. 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 steelhead. Operation of the project is expected to provide improved habitat connectivity for 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.

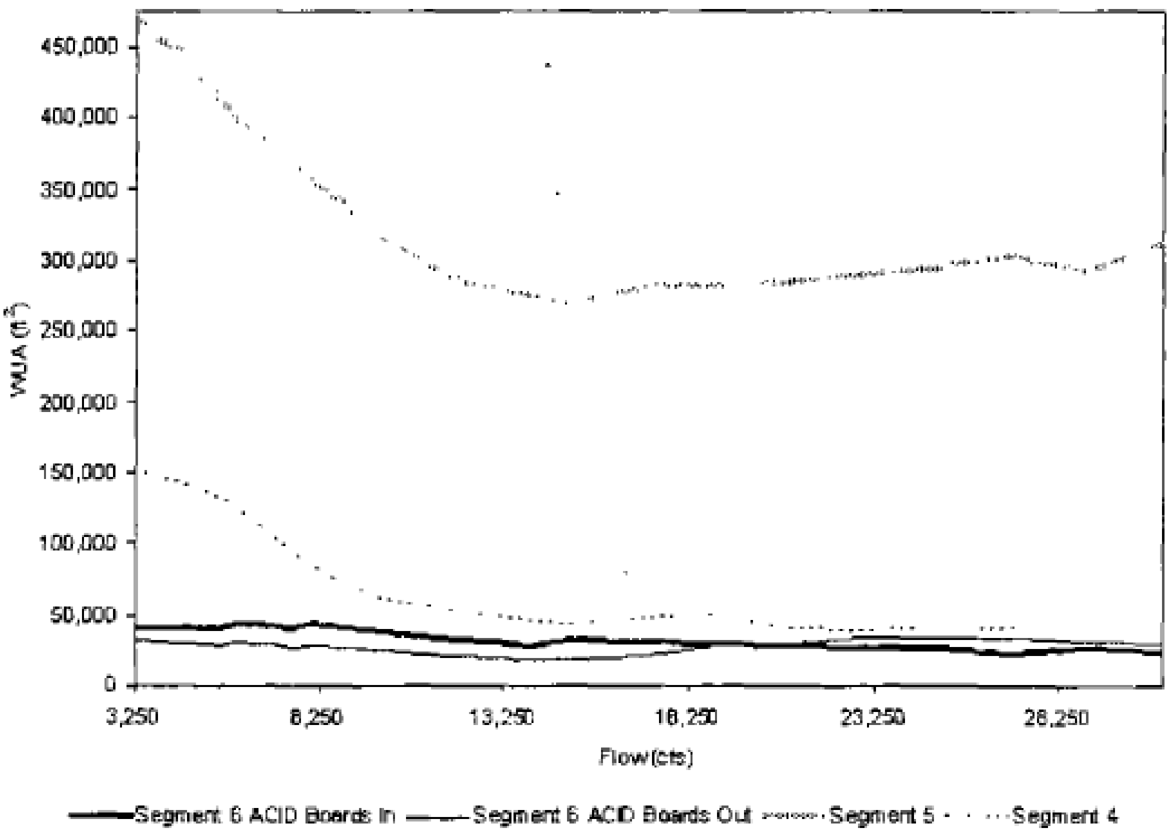
The **proportion** of the population affected by decreased refuge habitat depends on bathymetry, use of the coldwater pool, and peak outmigration timing.

Literature does not uniquely inform the proportion of the population.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

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 rearing habitat available. The WUA analyses are 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 steelhead rearing habitat in all CVP tributaries.

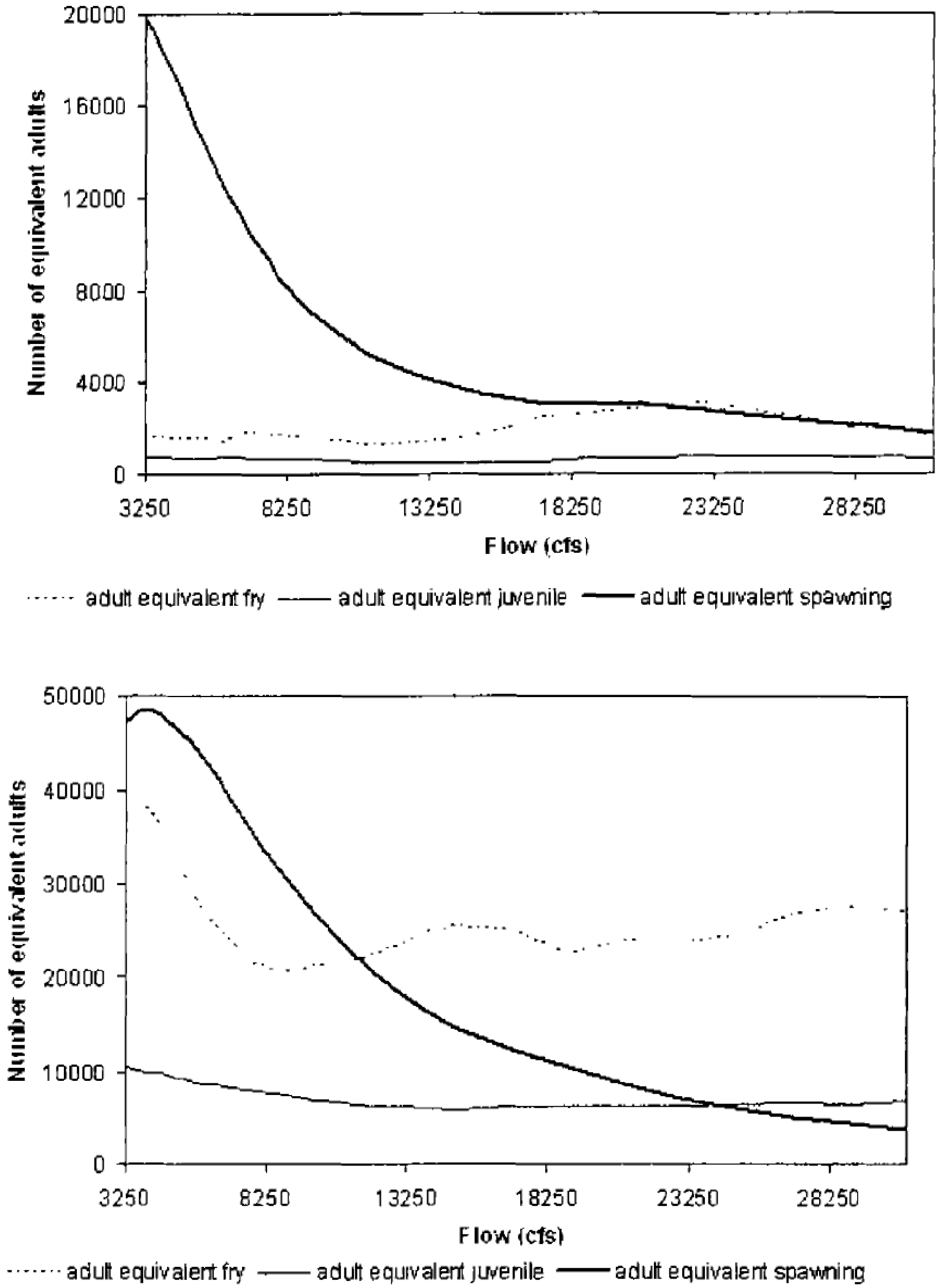
Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2019). Habitat restoration programs aim to provide benefits to native salmonids (quality habitat, increased food availability, refuge) but these efforts also provide benefits to non-native and native predators possibly increasing predation rates. Reduced releases decrease potential refuge habitat for steelhead by removing access to side-channels, access to refuge, and changing geomorphic processes. The relationships are observable in the figures below show flow-habitat relationships (Figure 7-96) and limiting life stage analyses for juvenile fall-run Chinook salmon (as a surrogate for steelhead because no such relationships have been determined) by Sacramento River segment 6 (ACID to Keswick Dam, Figure 7-97a-b). Analyses of segments 4 (Battle Creek to Cow Creek) and 5 (Cow Creek to Anderson-Cottonwood Irrigation District, ACID) show a similar trend. There are no flow-habitat relationships developed for Clear Creek or the San Joaquin River. Flow-habitat relationships for juvenile rearing habitat in the American River are outdated or unreliable (Sites Project Authority and Bureau of Reclamation. 2021.). For these rivers, Sacramento River relationships were used. Using surrogate species and rivers for flow-habitat relationships for steelhead creates high uncertainty in how WUA changes with varying flows.



Source: Gard 2005

Figure 7-96. Juvenile late fall-run Chinook salmon (as a surrogate for steelhead) rearing flow-habitat relationships for segments 4 through 6 (ACID boards in and out).

(a)



Source: Gard 2005.

Adult equivalent juvenile is represented by the thin solid black line.

Figure 7-97a-b. Limiting life stage analysis for late fall-run Chinook salmon (as a surrogate for steelhead) in (a) segment 6 (ACID to Keswick Dam, ACID boards out) and (b) segment 5 (Cow Creek to Anderson-Cottonwood Irrigation District, ACID).

The Sacramento River Weighted Usable Area Analysis, Appendix O, Attachment O.3, provides context for the weighted usable area available for steelhead fry and juvenile rearing downstream of Keswick releases. Late fall-run Chinook salmon rearing WUA habitat values are used as proxies for Sacramento River steelhead rearing WUA. The late fall-run Chinook salmon WUA habitat values for both fry and juveniles peak at the minimum flow (3,250 cfs). The WUA habitat value under the Proposed Action phases ranges from 368,182 to 415,011 for fry (Figure 7-98) and from 652,251 to 816,218 for juveniles (Figure 7-99). Overall, these WUA habitat values are lowest in wet and above normal water years and successively increase in the drier water year types. This pattern of variation is attributable to the low flows at which steelhead rearing WUA habitat values peak in the Sacramento River.

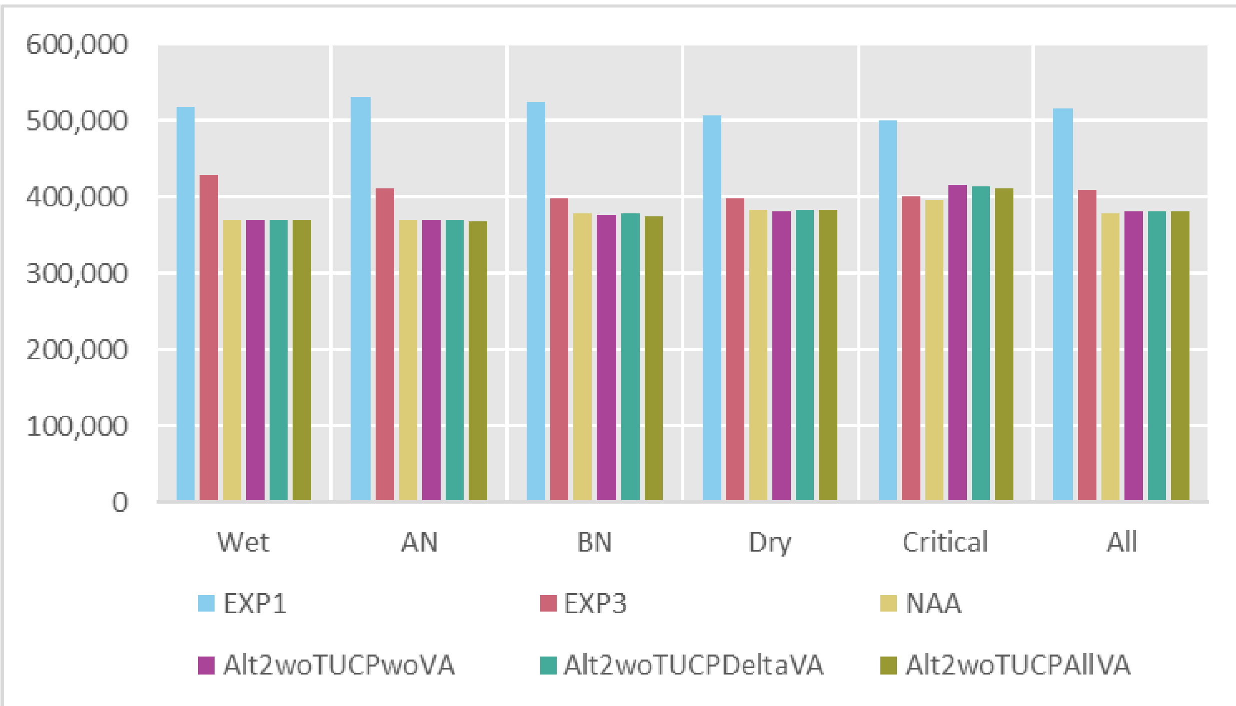


Figure 7-98. Mean Weighted Usable Area for Segments 4-6 by Water Year Type, Steelhead Fry Rearing the Sacramento River

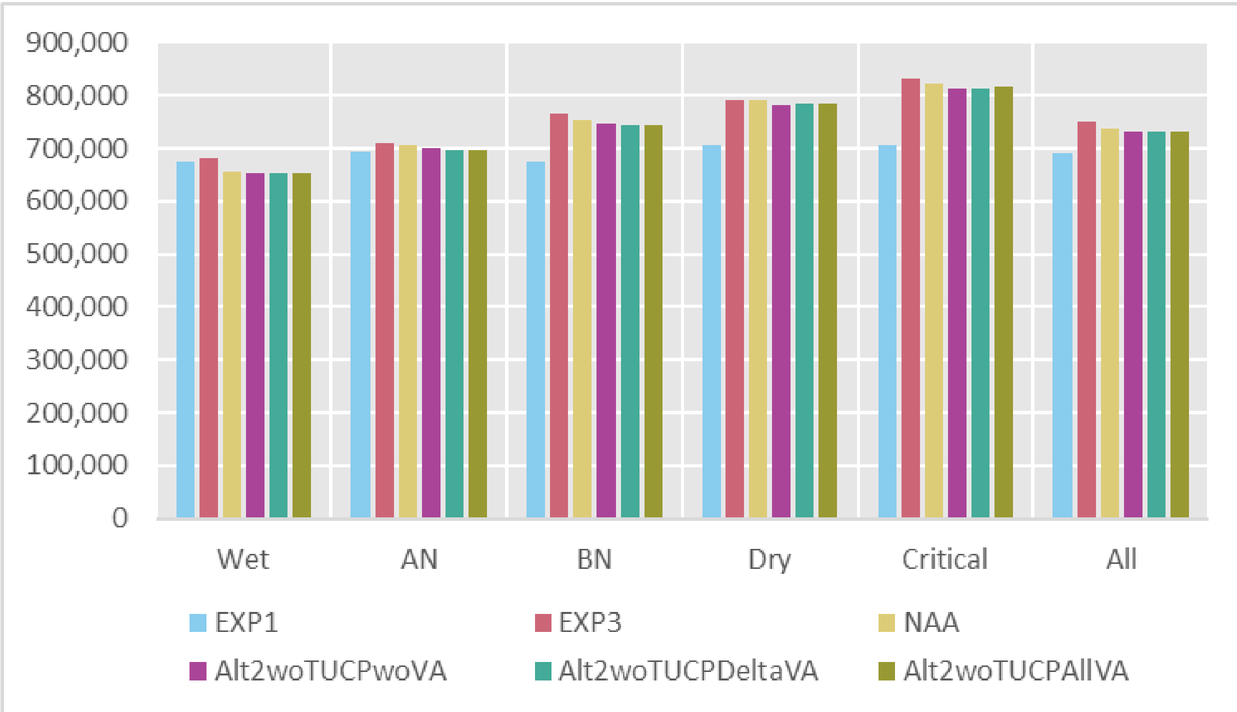
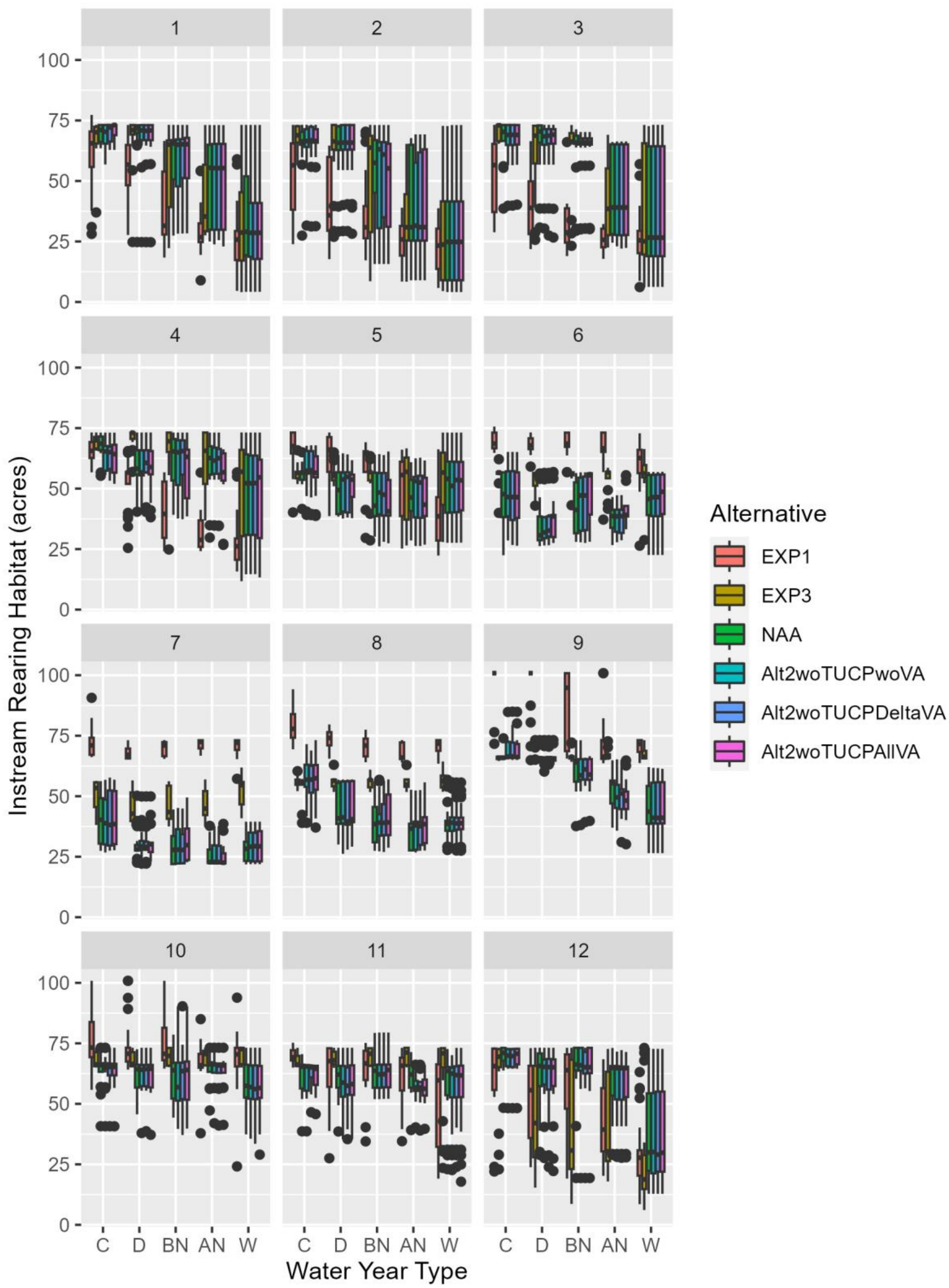


Figure 7-99. Mean Weighted Usable Area for Segments 4-6 by Water Year Type, Steelhead Juvenile Rearing the Sacramento River

In most cases, limiting life stage analyses indicated that juvenile habitat for late fall-run Chinook salmon, a surrogate for steelhead, is limiting (Gard 2005). In the Sacramento River, peak outmigration occurs between February and May, as flows are decreasing under the Proposed Action. When there are sufficient flows from the coldwater pool, the proportion is likely **small**, and when flows below Keswick Dam are limited, the **proportion** is likely **medium** for juveniles rearing and outmigrating.

The SIT LCM Habitat Estimates, Tributary Habitat, Appendix O, Attachment O.2, provides context for the instream and floodplain rearing habitat area available for steelhead juveniles in the upper Sacramento River, Clear Creek, American River, and Stanislaus River for all calendar months.

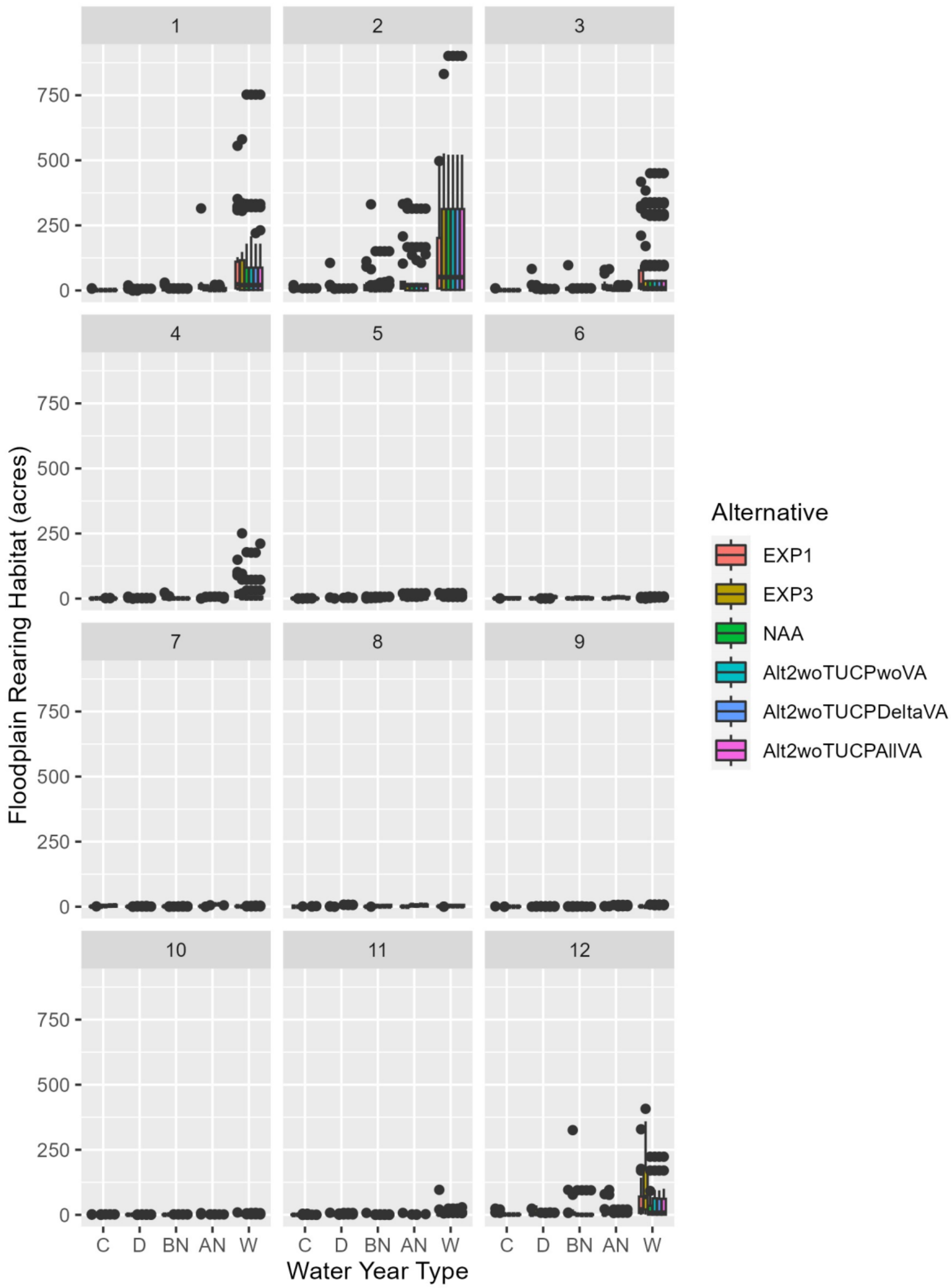
For instream rearing habitat in the Upper Sacramento River, the monthly habitat values under the Proposed Action phases range from a low of approximately five acres to a high of approximately 100 acres (Figure 7-100). Available instream rearing habitat for steelhead juveniles peaks at low flows and decreases with increasing flows in the upper Sacramento River. Overall, the habitat values do not vary much among months, but the lowest habitat values generally occurred in Proposed Action phases in July. Habitat values do vary by water year type, with less instream rearing habitat available in increasingly wet water year types.



Variability within months (facets; January-December) reflects variation across CalSim WYs.

Figure 7-100. Estimated instream rearing habitat for steelhead juveniles in the Upper Sacramento River.

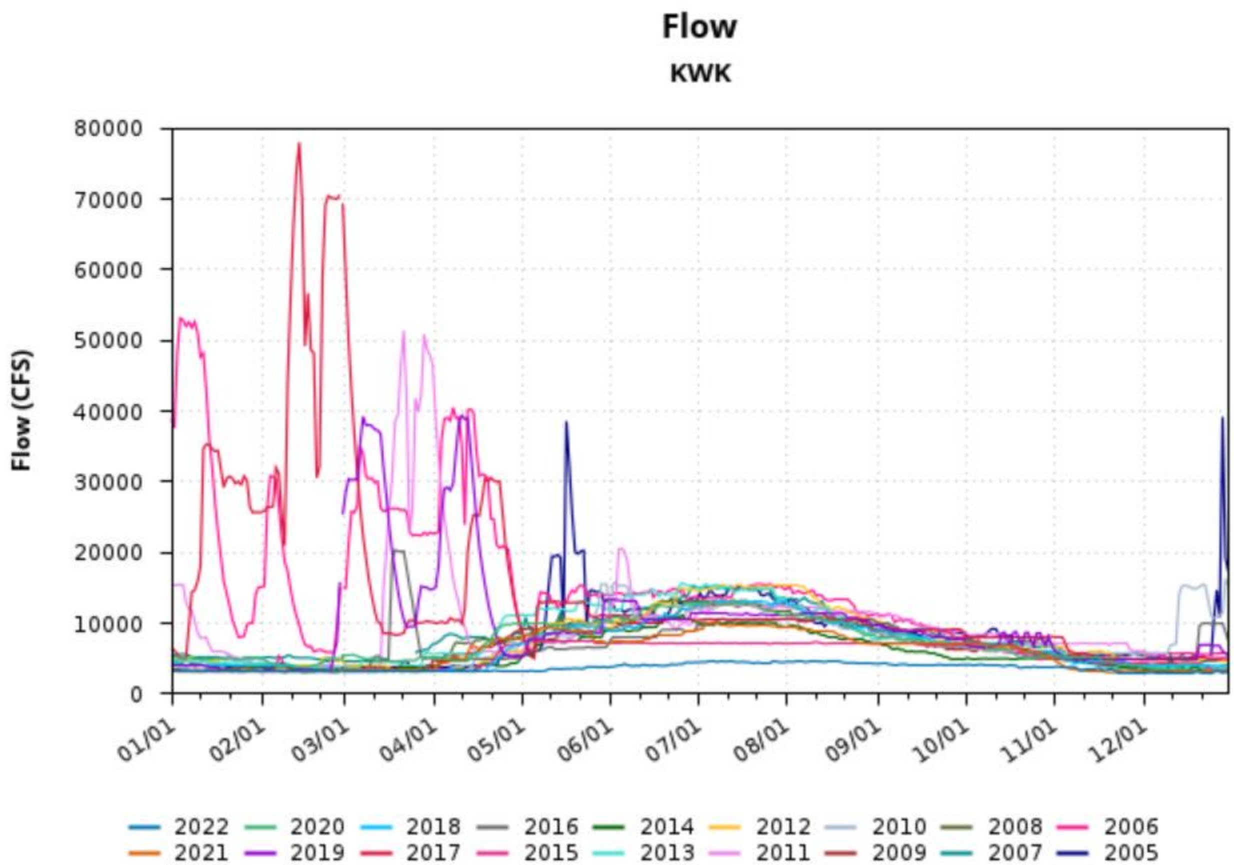
For floodplain rearing habitat in the upper Sacramento River, the monthly habitat values under the Proposed Action phases range widely from a low of approximately 0 acres to a high of approximately 875 acres (Figure 7-101). Available floodplain rearing habitat for steelhead juveniles only increases at flows greater than 25,000 cfs and peaks at flows of approximately 175,000 cfs. Habitat values do vary under the Proposed Action phases in response to the combination of both month and water year type. Floodplain rearing habitat availability peaks in December through February in only Above Normal and Wet water year types.



Variability within months (facets; January-December) reflects variation across CalSim WYs.

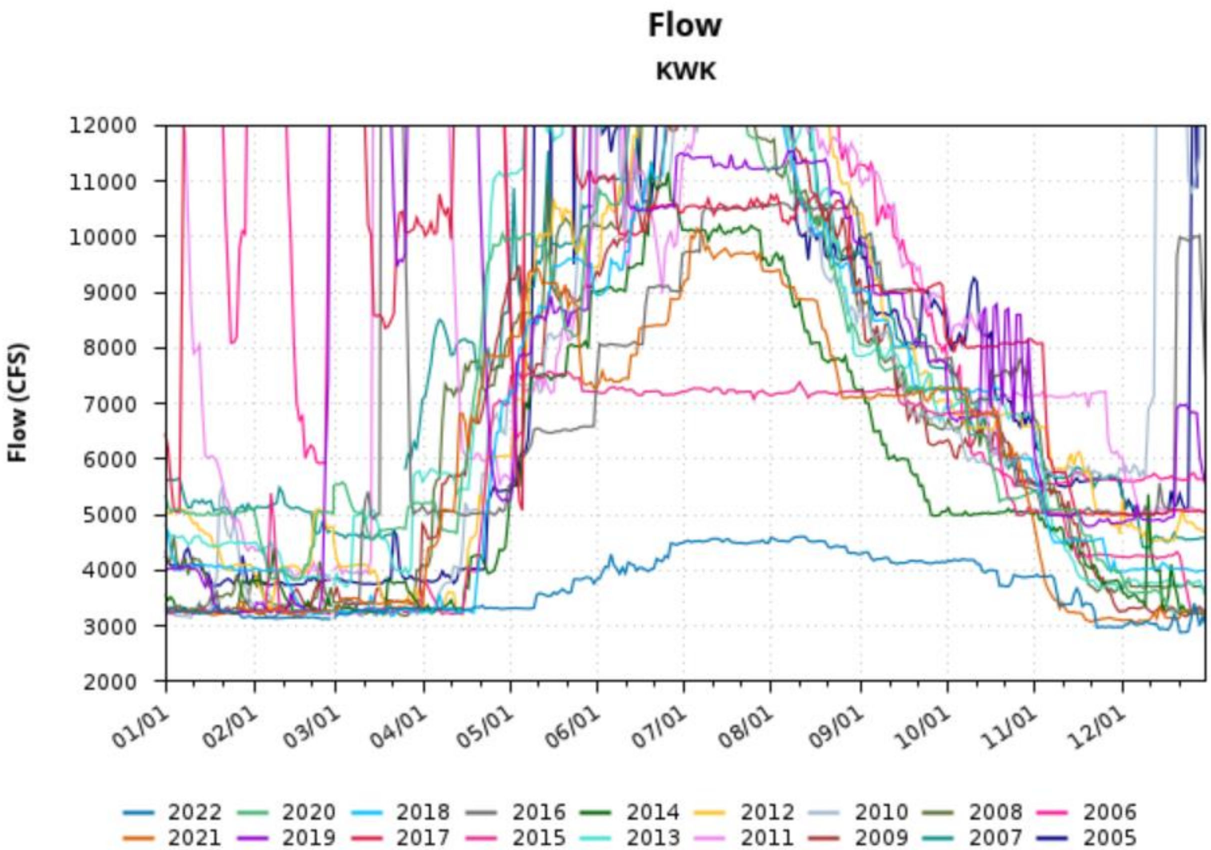
Figure 7-101. Estimated floodplain rearing habitat for steelhead juveniles in the Upper Sacramento River.

The **frequency** of occurrence is annual and depends primarily on hydrology and is likely **medium** on the Sacramento River. Between the fall and winter months, flows below Keswick Dam generally decrease, with the exception of wet and above normal water year types (e.g., 2005, 2006, 2010, 2011, 2017, 2019, Figure 7-102 and Figure 7-103). 6 out of 18 years (33%, 2005 – 2022) were wet or above normal water year types (Sacramento Valley Index) and maximum flows between December and April were greater than 15,000 cfs. Limiting life stage analysis for late fall-run Chinook salmon shows that flows in Segment 6 do not appear limiting.



Source: Columbia Basin Research 2023.

Figure 7-102. Sacramento River below Keswick flows, 2005 – 2022.



Source: Columbia Basin Research 2023.

Figure 7-103. Sacramento River below Keswick flows, 2005 – 2022, scaled to a maximum of 12,000 cfs.

In Clear Creek, low flows December through May can increase the refuge habitat stressor by reducing the availability of rearing habitat (U.S. Fish and Wildlife Service 2015). The **proportion** of the population affected by the increase in the refuge habitat stressor in Clear Creek is likely **large**, as juveniles are rearing year-round and peak outmigration occurs during this period.

The Clear Creek Weighted Usable Area Analysis, Appendix O, Attachment O.1, provides context for the weighted usable area available for steelhead rearing downstream of Whiskeytown Reservoir releases. Fry and juvenile rearing weighted usable area for steelhead peaks at approximately 600 - 900 cfs. The mean WUA habitat value under the Proposed Action phases ranges from 87,375 in critical water years to 88,538 in wet years (Figure 7-104 and Figure 7-105). Overall, these WUA habitat values do not vary much among Proposed Action phases and water year types. This suggests the summer flow ranges in the Proposed Action provide stable rearing habitats.

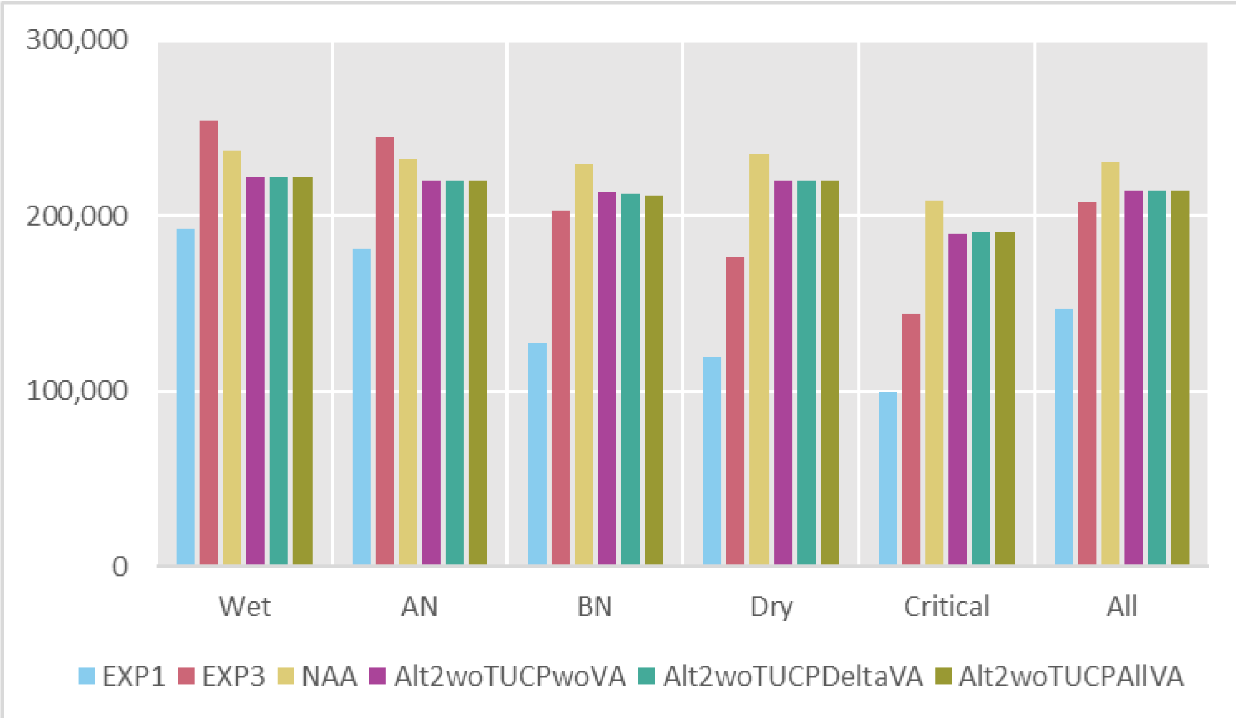


Figure 7-104. Mean Weighted Usable Area for Combined Lower Alluvial, Upper Alluvial and Canyon Segments by Water Year Type, Steelhead Fry Rearing in Clear Creek

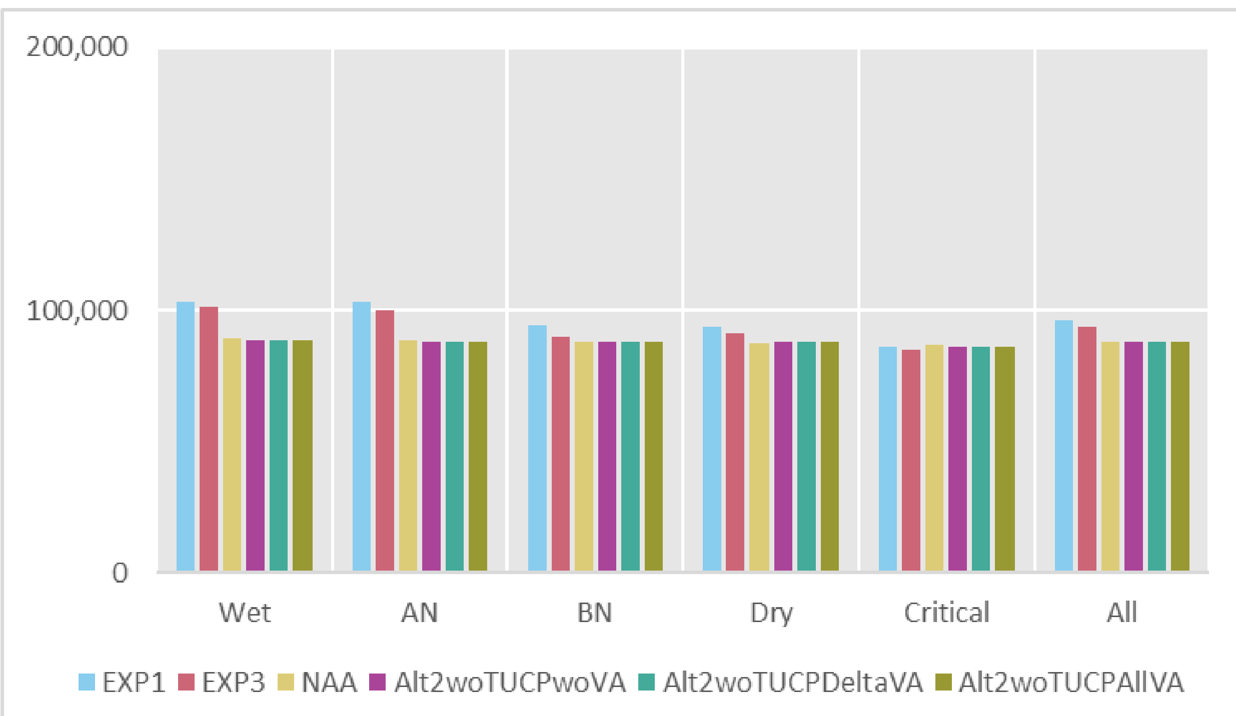
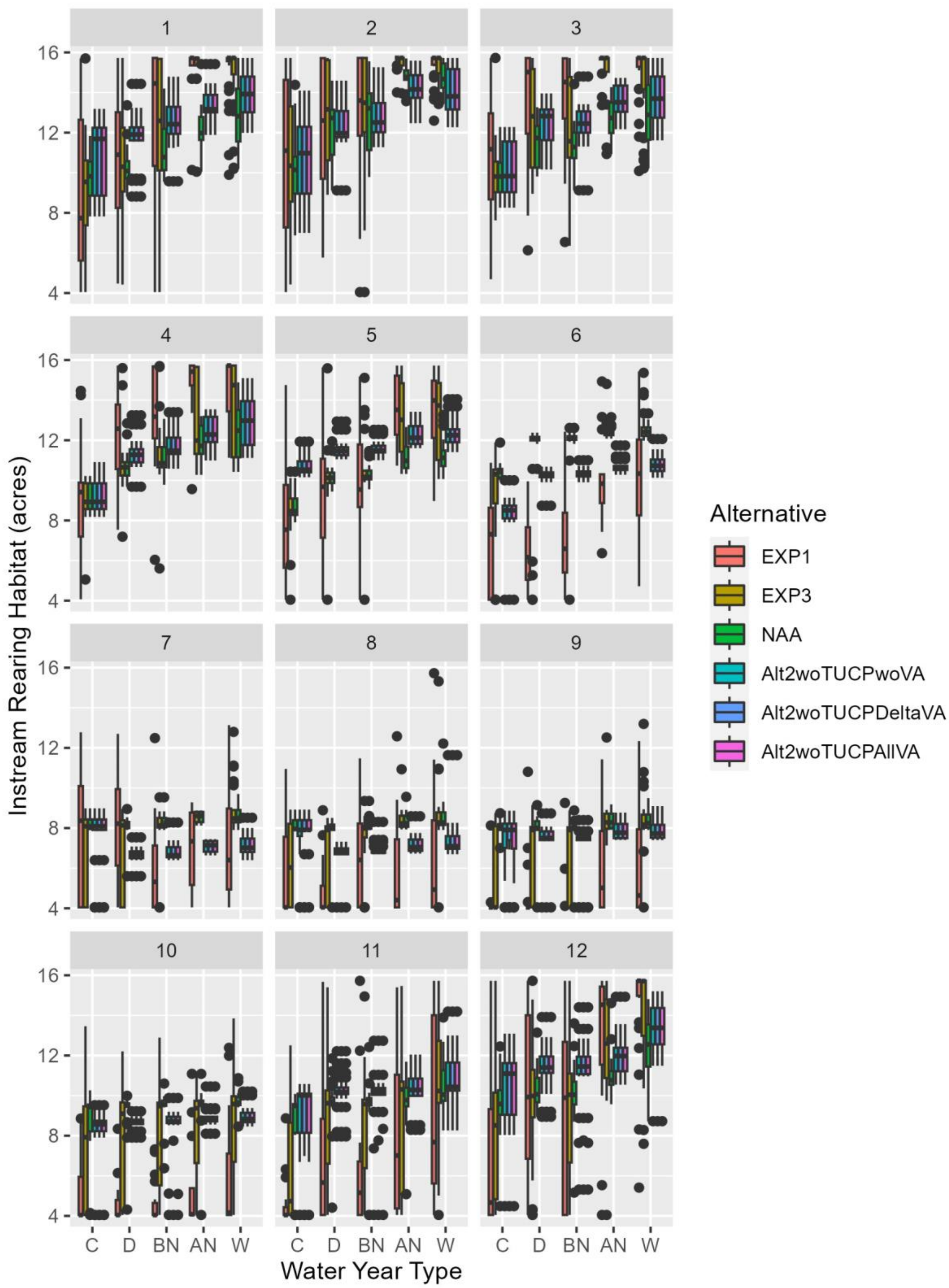


Figure 7-105. Mean Weighted Usable Area for Combined Lower Alluvial, Upper Alluvial and Canyon Segments by Water Year Type, Steelhead Juvenile Rearing in Clear Creek

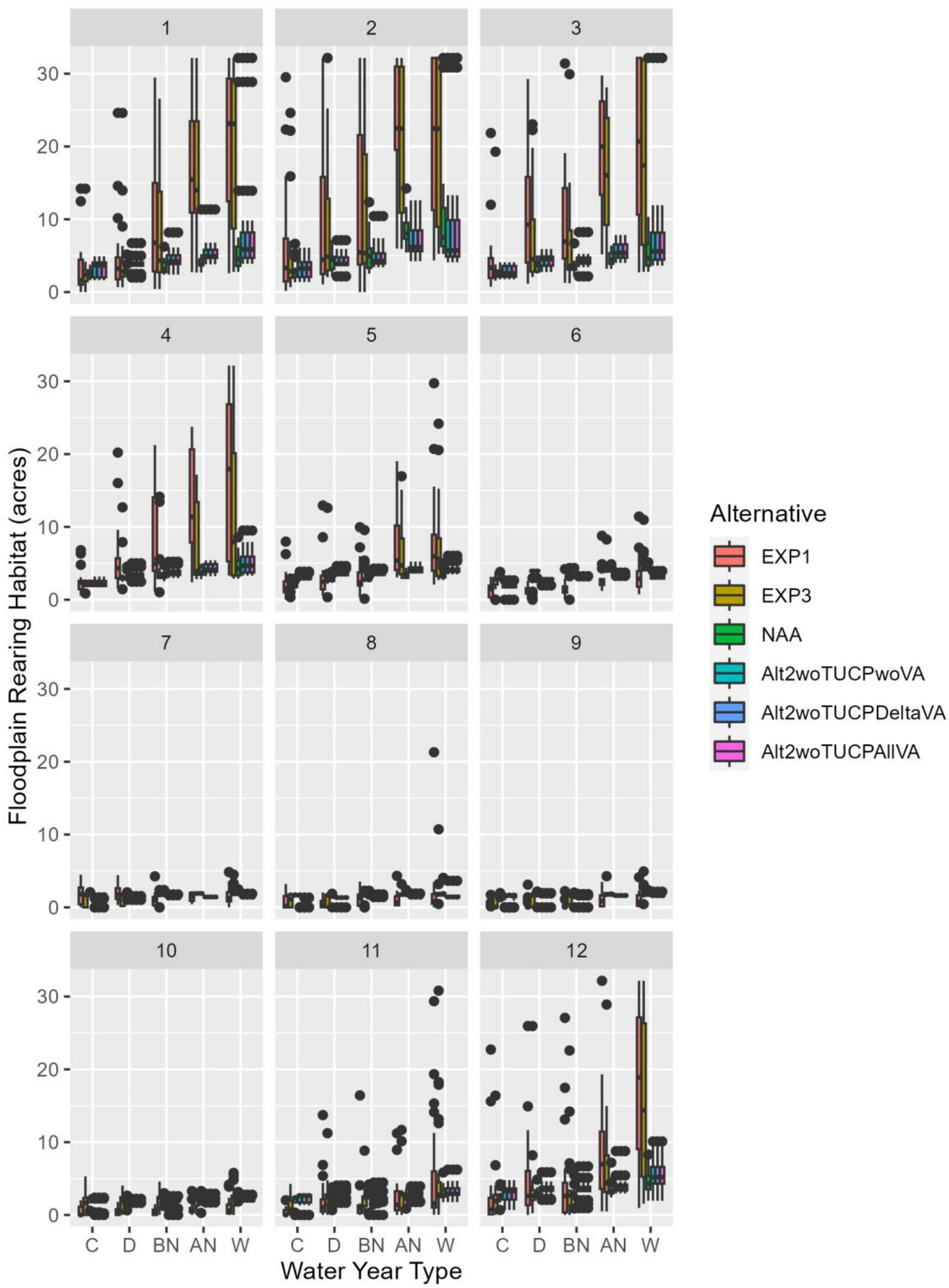
For instream rearing habitat in Clear Creek, the monthly habitat values under the Proposed Action phases range from a low of approximately 4 acres to a high of approximately 16 acres (Figure 7-106). Available instream rearing habitat for steelhead juveniles increases asymptotically with increasing flow in Clear Creek, up to 875 cfs. The habitat values vary among months under the Proposed Action phases, with the lowest habitat values generally occurring in July through October. Habitat values do vary by water year type, with increased instream rearing habitat available in increasing wet water year types.



Variability within months (facets; January-December) reflects variation across CalSim WYs.

Figure 7-106. Estimated instream rearing habitat for steelhead juveniles in Clear Creek.

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 32 acres (Figure 7-107). Available floodplain rearing habitat for steelhead juveniles increases asymptotically with increasing flow through flows as high as 2000 cfs. Habitat values do vary under the Proposed Action phases in response to both month and water year type. Floodplain rearing habitat availability peaks in December through April across water year types and increases with increasingly wet water year types.



Variability within months (facets; January-December) reflects variation across CalSim WYs.

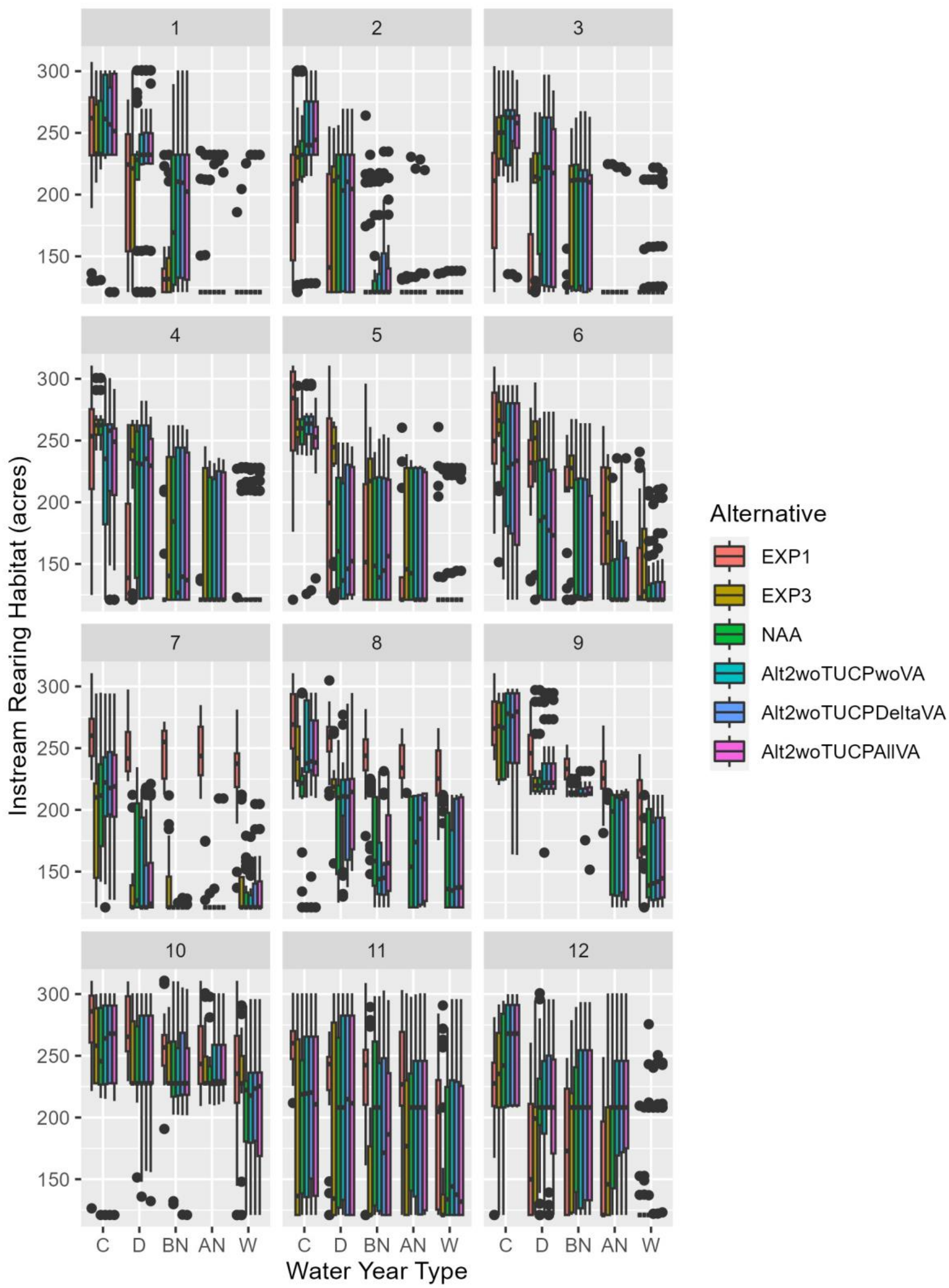
Figure 7-107. Estimated floodplain rearing habitat for steelhead juveniles in Clear Creek.

The **frequency** of occurrence is likely **medium**, but there are no reliable limiting life stage analysis relationships developed for Clear Creek, leading to uncertainty in how abundance by life stage changes with varying flows for stretches along Clear Creek.

In the San Joaquin River, decreases in flow throughout the year may increase this stressor. The **proportion** of the population affected by the increase in the refuge habitat stressor in the is likely **small to medium** as juveniles are not known to use the San Joaquin River for rearing habitat. The effect is expected year-round and the **frequency** is likely **high** as it may occur on an annual basis. There are no reliable limiting life stage analysis relationships developed for the San Joaquin River so there is a lot of uncertainty in these estimates.

In the American River, decreases in flow from Folsom Dam between February and March and low flows in April may reduce the availability of refuge habit for juveniles. Increases in flow in the summer and fall period may provide an increase to available habitat and be **beneficial** to juvenile steelhead for rearing. The **proportion** of the population affected by the increase in the refuge habitat stressor in the American River is likely **large**, as juveniles are rearing year-round and peak outmigration occurs during this period. The **proportion** of the population affected by the decrease in the refuge habitat stressor in the summer and fall period is likely **large** for juveniles rearing but **small** for juveniles out-migrating during this period.

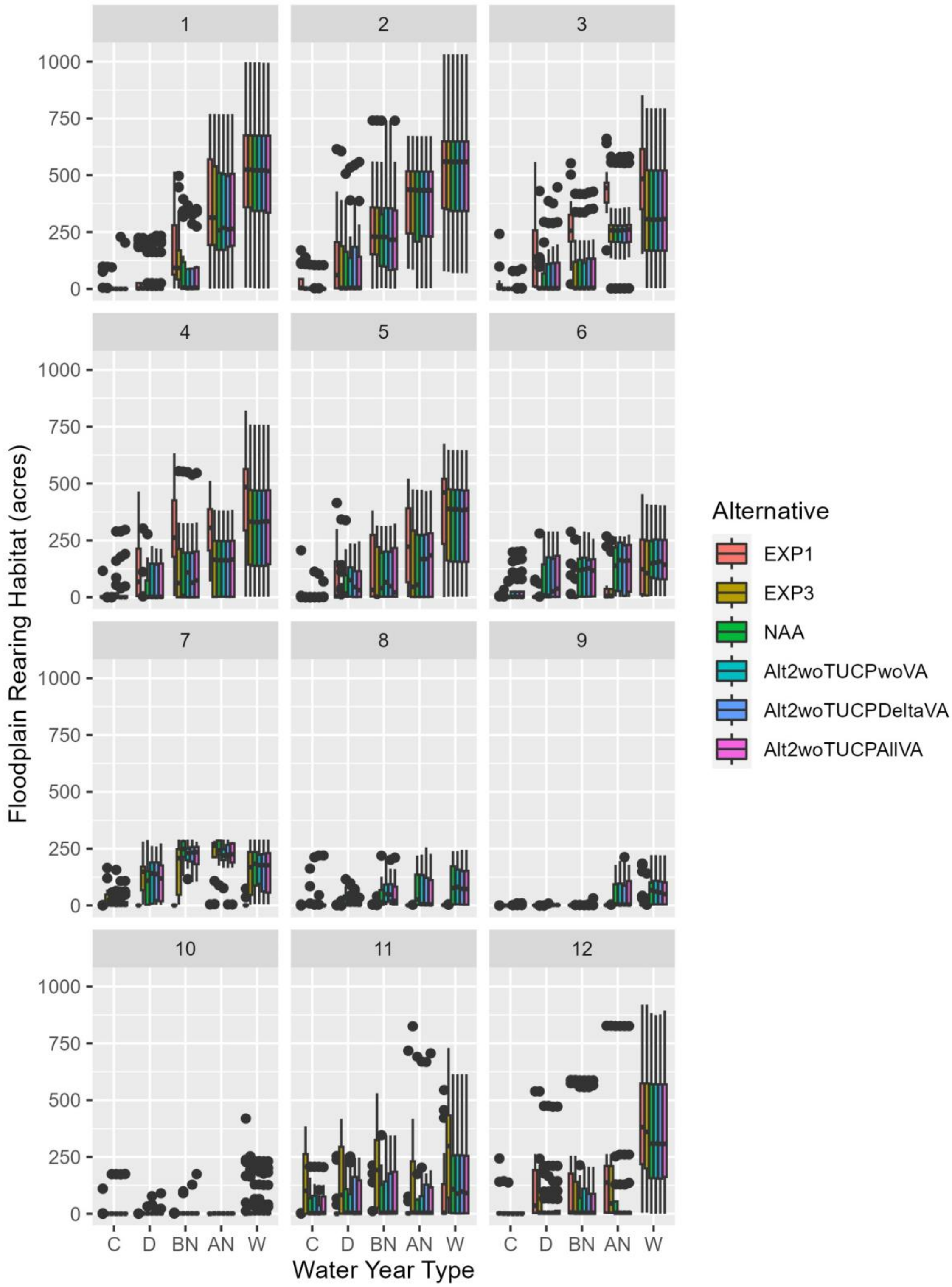
For instream rearing habitat in the American River, the monthly habitat values under the Proposed Action phases range from a low of approximately 125 acres to a high of approximately 300 acres (Figure 7-108). Available instream rearing habitat for steelhead juveniles peaks at low flows and decreases with increasing flows. Habitat values vary among months under the Proposed Action phases, with the greatest values generally occurring in August and September, and vary by water year type, with less instream rearing habitat available in increasingly wet water year types.



Variability within months (facets; January-December) reflects variation across CalSim WYs.

Figure 7-108. Estimated instream rearing habitat for steelhead juveniles in the American River.

For floodplain rearing habitat in the American River, the monthly habitat values under the Proposed Action phases range from a low of approximately 0 acres to a high of approximately 1,000 acres (Figure 7-109). Available floodplain rearing habitat for steelhead juveniles increases asymptotically with increasing flow through flows as high as 30,000 cfs. Habitat values vary among months and water year type under the Proposed Action phases, with the greatest values occurring in December through May and values increasing with increasingly wet water year types.



Variability within months (facets; January-December) reflects variation across CalSim WYs.

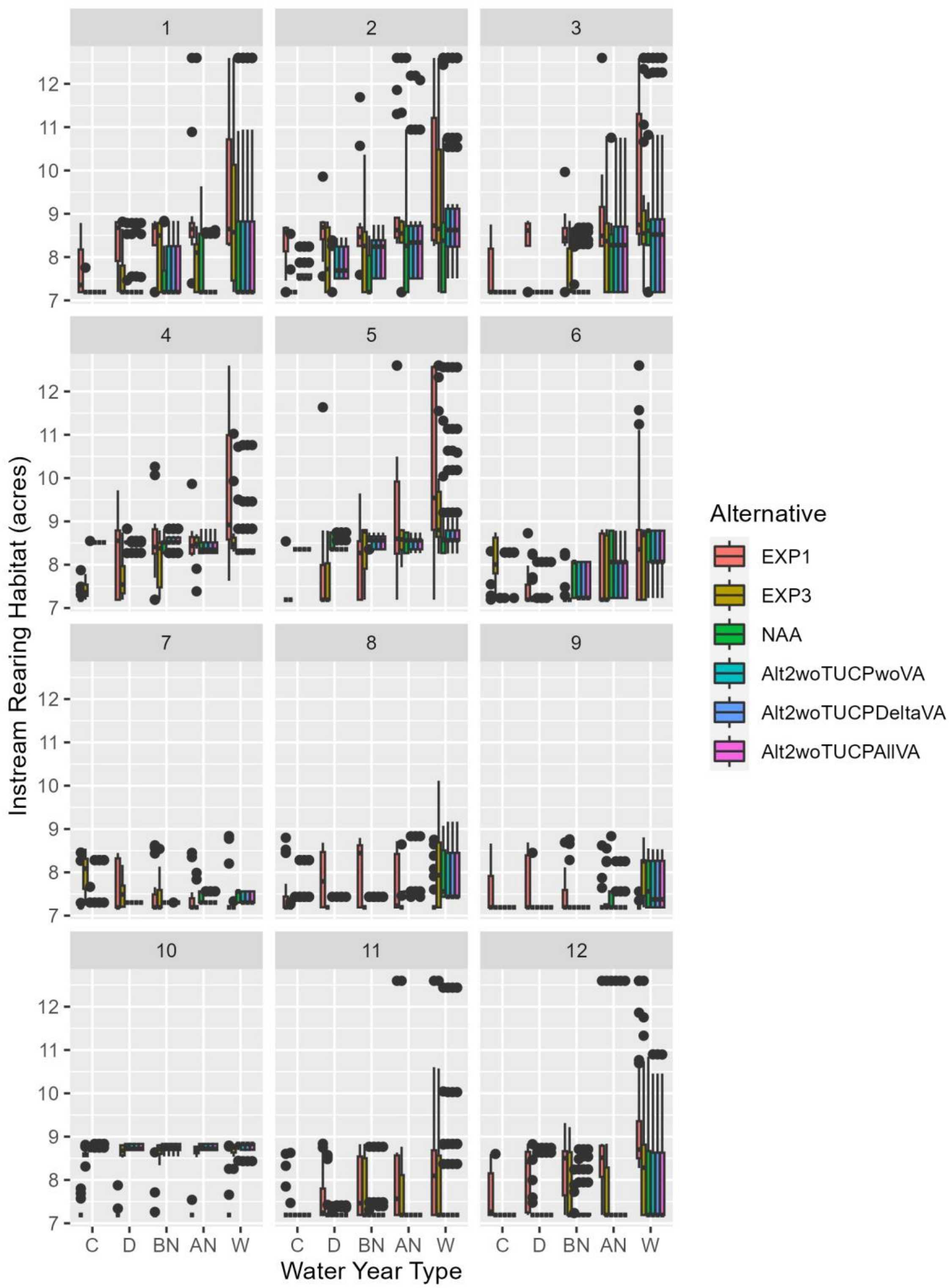
Figure 7-109. Estimated floodplain rearing habitat for steelhead juveniles in the American River.

The **frequency** of occurrence is likely **medium** for both directions (beneficial and sub-lethal) in the American River.

In the Stanislaus River, decreases in flow from Goodwin Dam in the winter and spring may increase this stressor. Increases in flow in the late summer and early fall period may provide an increase to available habitat and be beneficial to juvenile steelhead for rearing. The **proportion** of the population affected by the increase in the refuge habitat stressor in the Stanislaus River is likely **large**, as juveniles are rearing year-round and peak outmigration occurs during this period. The **proportion** of the population affected by the decrease in the refuge habitat stressor in the summer and fall period is likely **large** for juveniles rearing but **small** for juveniles out-migrating during this period.

[placeholder: Stanislaus River rearing WUA analysis]

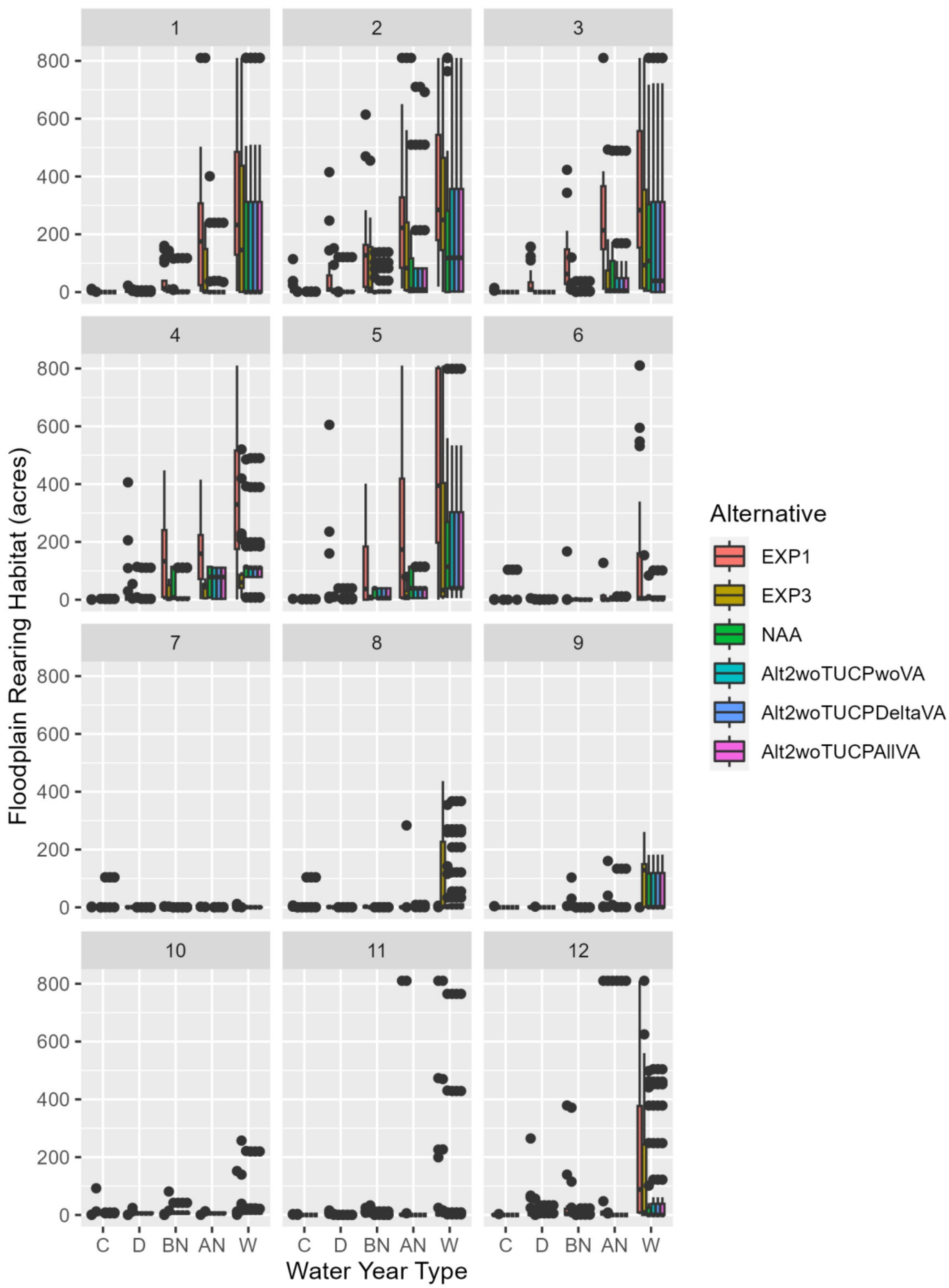
For instream rearing habitat in the Stanislaus River, the monthly habitat values under the Proposed Action phases range from a low of approximately 7 acres to a high of approximately 12.5 acres (Figure 7-110). Available instream rearing habitat for steelhead juveniles increases asymptotically with increasing flow up to 750 cfs, decreases slightly with increasing flow up to 1500 cfs, and then increases steadily through flows as high as 5000 cfs. Habitat values vary among months under the Proposed Action phases, with the greatest values generally occurring in February and March, and vary by water year type, with increasing instream rearing habitat available in increasingly wet water year types.



Variability within months (facets; January-December) reflects variation across CalSim WYs.

Figure 7-110. Estimated instream rearing habitat for steelhead juveniles in the Stanislaus River.

For floodplain rearing habitat in the Stanislaus River, the monthly habitat values under the Proposed Action phases range from a low of approximately 0 acres to a high of approximately 800 acres (Figure 7-111). Available floodplain rearing habitat for steelhead juveniles increases generally linearly with increasing flow through flows as high as 5,000 cfs. Habitat values vary in response to the combination of month and water year type, with floodplain rearing habitat availability peaking in January through May in only Below Normal, Above Normal, and Wet water year types.



Variability within months (facets; January-December) reflects variation across CalSim WYs

Figure 7-111. Estimated floodplain rearing habitat for steelhead juveniles in the Stanislaus River.

The **frequency** of occurrence is likely **medium** for both directions both directions (beneficial and sub-lethal) in the Stanislaus River.

To evaluate the **weight of evidence** for refuge habitat stressor, there are limited published location-specific to the Sacramento River only and no species-specific (late fall-run Chinook salmon and not steelhead) literature available: flow-habitat relationships and limiting life stage analyses (Gard 2005).

- Historical flows are quantitative, not species-specific (environmental variable), location-specific, and QA/QCed from a long time-series. The values are published in technical memos and annual reports from technical teams, and 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 rearing WUA analysis is quantitative and location-specific to the Sacramento River but not species specific. Steelhead rearing WUA curves have not been developed in the USFWS studies, therefore late fall-run Chinook salmon were used as a surrogate. WUA analyses are widely used and recognized analytical tools for assessing effects of flow on fish populations (Reiser and Hilgert 2018).
- Clear Creek rearing 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
- American River
    - Minimum Instream Flows
- Stanislaus River
    - Stepped Release Plan

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 and Redd Maintenance

7.2.5.6 Food Availability and Quality

The proposed storage and release of water may increase or decrease the food availability and quality stressor depending on seasonality. During the juvenile rearing and outmigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam and the Delta, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. In the San Joaquin River, operations of storage and releases of water would result in decreased flows throughout the year. In the fall, flows would be increased in the Sacramento River, American River, and Clear Creek, and decreased in the Stanislaus River. Changing operations result in decreased flows and less inundated habitats. These changes may modify food web processes and cause a decrease in quality food available to juvenile steelhead. However, juvenile growth can be dependent on the interaction between food availability and higher water temperatures, which may increase the food supply (Brett et al. 1969; Sogard and Olla 2001). Appendix O analyzes this stressor.

The increase in food availability and quality stressor is expected to be **sublethal** in Clear Creek and the Sacramento, San Joaquin, American, and Stanislaus rivers during the winter and spring. A decrease in quality and quantity of food for foraging steelhead will impact growth rates. Changes in food availability may also affect occurrence of anadromy among juveniles, as studies have shown that factors that affect food availability and growth may have disparate influences on rates of anadromy (Kendall et al. 2014, Benjamin et al. 2013; Eschenroeder et al. 2022). Additionally, food limitation can weaken juvenile steelhead, leading to extremes such as starvation, and alter behavior resulting in predation risk.

The decrease in food availability and quality stressor when the Proposed Action releases water in the summer and fall is expected to be **beneficial** in Clear Creek and the Sacramento, American, and Stanislaus rivers. An increase in flows may provide more suitable habitat that increases the quality and quantity of food for rearing and outmigrating steelhead, which may impact growth rates.

Food availability and quantity is not independent of refuge habitat, another sublethal stressor discussed above.

In the Delta, operations are not expected to increase the food availability and quality stressor for juvenile steelhead. During the juvenile rearing and outmigration period, the Proposed Action reduces Delta inflow and outflow, which may alter hydrodynamic conditions in the Sacramento River and Delta. As noted in the refuge habitat stressor above, juvenile steelhead do not appear to rear in the Delta, but may utilize side channel and inundated floodplain habitat in the tidal shoreline of the Delta during outmigration. There are no known relationships between Delta outflow and salmonid food availability and quality similar to those for Delta smelt or for salmonids in the Sacramento River (Gard 2006). Inter-annual variation in flows at Freeport during the outmigration period is frequently greater than at Keswick; thus, flow-dependent refuge habitat is likely limiting less often in the Delta than in the Sacramento River.

Although the Proposed Action may, at times, increase the food availability and quality stressor, changes in food availability and quality for steelhead 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, which aquatic and terrestrial invertebrates depend upon. A significant portion of juvenile steelhead's diet is composed of terrestrial insects, particularly aphids which are dependent on riparian habitat (National Marine Fisheries Service 1997). 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.

Reclamation funded and cooperatively constructed annual side channel juvenile rearing habitat projects in the Sacramento River beginning in 2016 and these are continuing into the future. Reclamation funded spawning and rearing habitat projects in the American River and cooperatively constructed them with the Sacramento Water Forum annually since 2008 and these are continuing into the future. Reclamation places gravel in the Goodwin Canyon area of the Stanislaus River in most years and continuing into the future. The gravel provides both spawning and rearing habitat for steelhead in the area of the river with most suitable temperatures for steelhead.

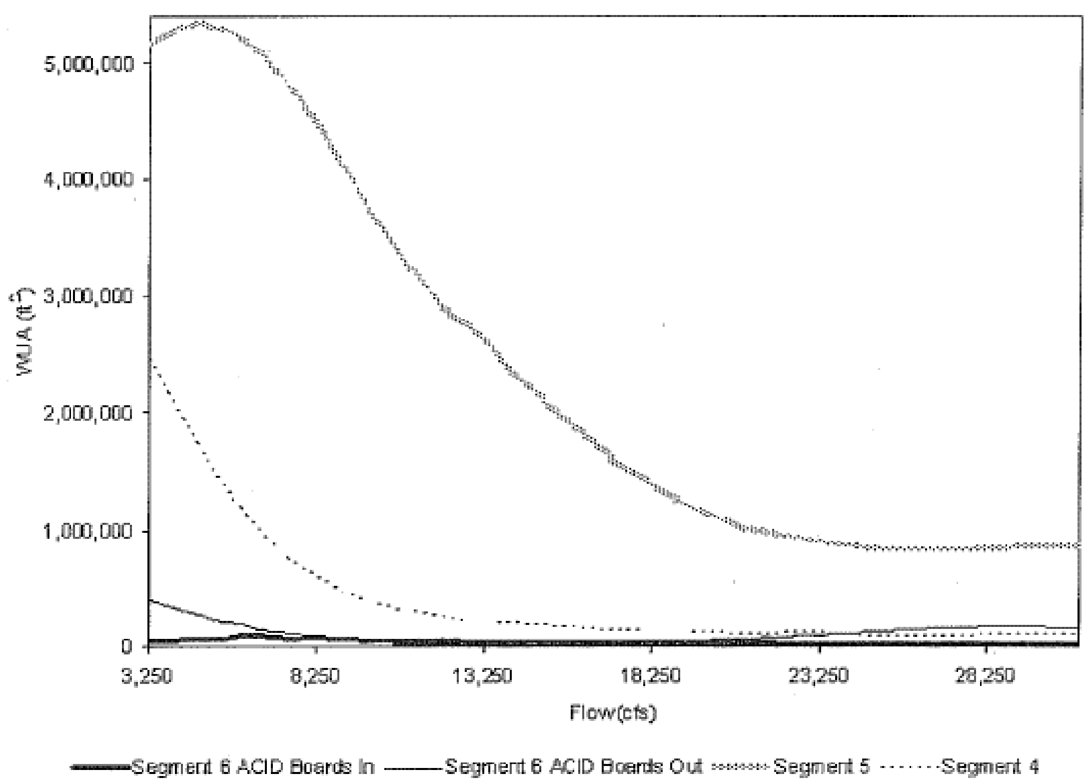
The **proportion** of the population affected by decreased food availability and quality depends on bathymetry and hydrology.

The literature demonstrates flow-habitat relationship metrics for juvenile salmonid food supply developed for the Sacramento River, between Keswick Dam and Battle Creek (Gard 2006). Optimal flows for the macroinvertebrate index varied by reach and ranged from 3,250 cfs to 6,000 cfs (Figure 7-112, 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 salmonids removing access to side-channels, access to refuge, and changing geomorphic processes. See Figure 7-96 and Figure 7-97 in Section 7.2.5.5, *Refuge Habitat*, for juvenile salmonid flow-habitat relationships and limiting life stage analyses.

Datasets use historical conditions and observation to inform how steelhead may respond to the Proposed Action. Historical monitoring may support or refute hypotheses and informs the reasonableness of information generated by models.

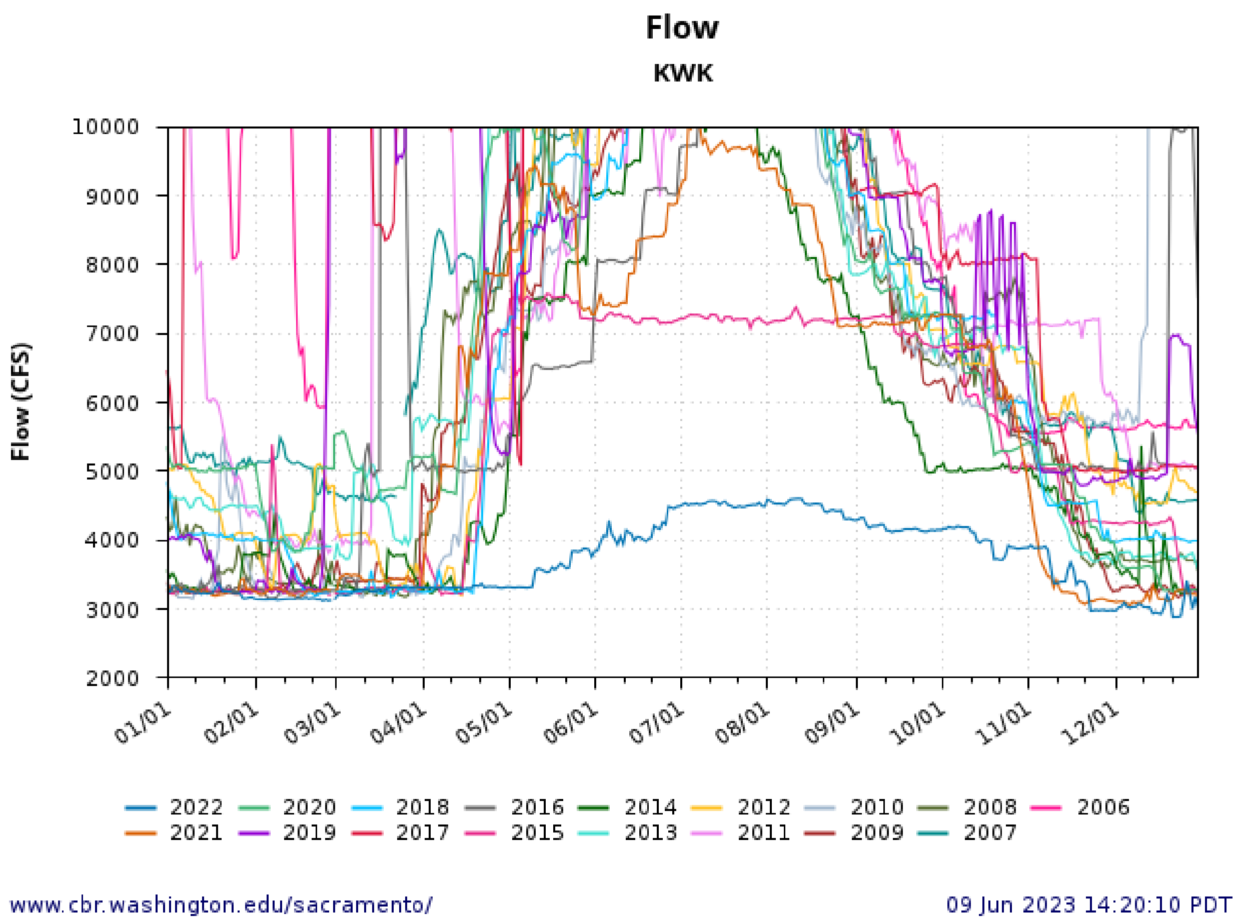
Models do not uniquely inform the proportion of the population affected.

During the winter and early spring portion of juvenile rearing and outmigration in the Sacramento River, Stanislaus River, American River, and Clear Creek, the Proposed Action may increase the food availability and quality stressor. The **proportion** of the population affected by the increase to the stressor is likely **large** in all four watersheds as juveniles are present year-round and have peak outmigration during this period. The **frequency** of occurrence is annual and depends primarily on hydrology and is likely **medium** for the Sacramento River. Flow with the maximum total ash-free dry weight of total macroinvertebrates habitat varies with reach in the upper Sacramento, and ranges from 3,250 cfs to 6,000 cfs in the Sacramento River below Keswick Dam (Gard 2006; Figure 7-112). In 6 out of 17 years in the winter and early spring period, the flows below Keswick Dam exceed 6,000 cfs (Figure 7-113). There are no WUA analyses in relation to macroinvertebrate food supply for the other watersheds. The frequency of occurrence is likely **medium** for Clear Creek, **low to medium** for the American River, and **low to medium** for the Stanislaus River.



Source: Gard 2006.

Figure 7-112. Flow-habitat relationship by reach for juvenile chinook salmon food supply (biomass of Baetids, Chironomids, and Hydropsychids).



Source: Columbia Basin Research 2023.

Figure 7-113. Sacramento River below Keswick Dam flows, 2006 – 2022.

In the San Joaquin River, the food availability and quality stressor may increase throughout the entire year. The proportion of the juvenile population is likely **small to medium** as juveniles typically use the San Joaquin River as an outmigration corridor and may have a relatively fast outmigration rate through the San Joaquin River into the south Delta (Buchanan et al. 2021). The **frequency** of occurrence is annual and depends primarily on hydrology and is likely **high** for the San Joaquin River.

The **proportion** of the population affected when the food availability and quality stressor may decrease in the Sacramento River, American River, and Clear Creek is likely **large** for juveniles rearing and likely **small to medium** for juveniles outmigrating, as juveniles typically finish outmigration in early May.

To evaluate the **weight of evidence** for the food availability and quality stressor, a study by Gard 2006 was used to assess the relationship of flow to food quality in the upper Sacramento River and was a quantitative agency report from USFWS. However, this study was not species specific and the same flow-relationships could not be applied to the other watersheds due to differences in a multitude of factors, including bathymetry and hydrology.

- Historical flows are quantitative, not species-specific (environmental variable), location-specific, and QA/QCed from a long time-series. The values are published in technical memos and annual reports from technical teams, and not expected to have statistical power.
- Gard 2006 WUA flow-habitat relationships modeling is quantitative, species-specific, and location-specific to the Sacramento River only. The flow-habitat relationships were 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
- American River
  - Minimum Instream Flows
- Stanislaus River
  - Stepped Release Plan

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 and Redd Maintenance

7.2.5.7 Entrainment

The proposed diversion of water may increase the entrainment risk stressor. During juvenile rearing and outmigration in the Delta, the entrainment stressor may increase in the winter and spring. During this period, the Proposed Action reduces Delta inflow and outflow, which may alter hydrodynamic conditions in the Sacramento River and Delta. This influences 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. When juvenile steelhead 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 juveniles. Appendix I, *Old and Middle River Flow Management*, presents analysis of this stressor, results are summarized here. Appendix J, *Winter and Spring Pulses and Delta Outflow: Smelt, Chinook Salmon, and Steelhead Migration and Survival*, presents analysis of the effects of spring Delta outflow on juvenile survival with a focus on route-specific travel time and survival. *Appendix G* including sections for *"Tracy Fish Collection Facility"* and *"Skinner Fish Delta Fish Protective Facility."* Appendix H describes the *"Old and Middle River Management"* and *"Delta Cross Channel Closure"* conservation measures. Appendix Q, *Georgiana Slough Barrier*, describes the operation of the Georgiana Slough Non-Physical Barrier, one measure that can be taken to prevent juvenile steelhead from traveling through Georgiana Slough into the central Delta.

Under the Proposed Action, Reclamation would operate the Delta Cross Channel Gates to reduce juvenile salmonid entrainment risk beyond actions described in D-1641, consistent with Delta water quality requirements in D-1641. Reclamation and California Department of Water Resources (DWR) will also operate the Fish Salvage facilities in the Delta. The Proposed Action also includes Old and Middle River (OMR) management to minimize entrainment.

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 salvage facilities.

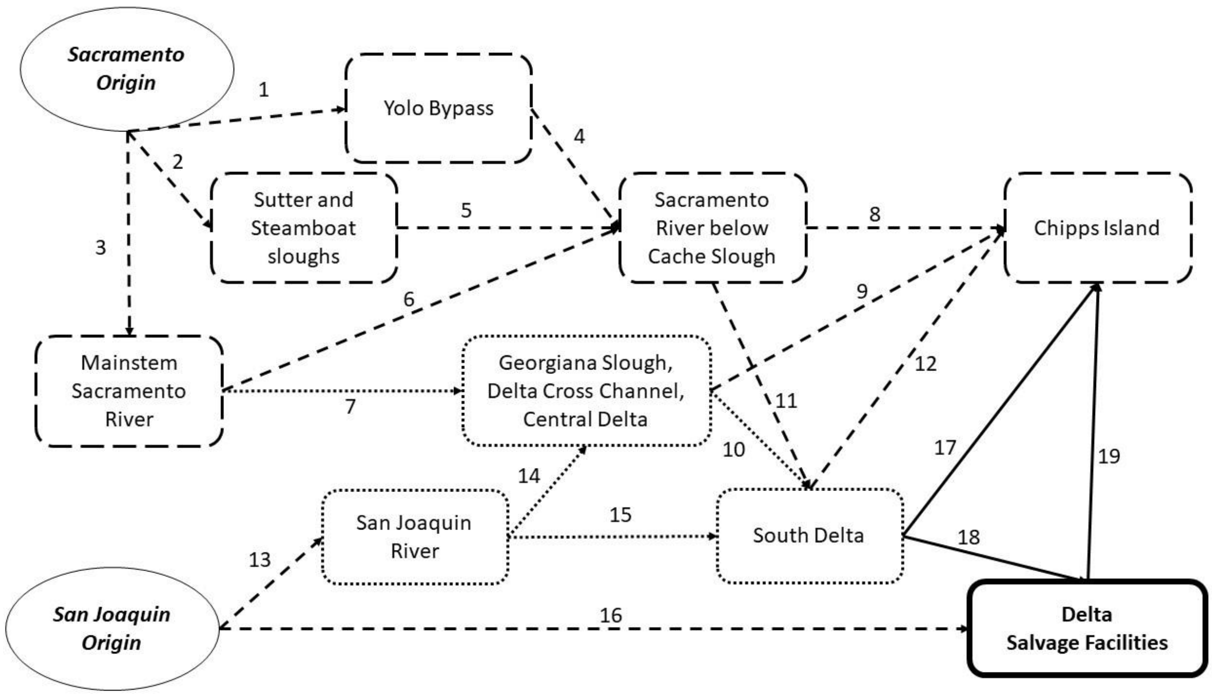
Although the Proposed Action may increase the entrainment risk stressor, entrainment of rearing and outmigrating steelhead exists in the environmental baseline (without the Proposed Action). Proximity to irrigation diversion operations drives the entrainment stressor (Windell et al. 2017). These diversions 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 also is influenced by non-CVP and non-SWP diversions in the Delta. Most of the 370 water diversions operating in Suisun Marsh are unscreened (Herren and Kawasaki 2001).

Reclamation’s past operation of the Delta Cross Channel 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 Delta Cross Channel Gates; and (2) controlled the net negative flows toward the export pumps in OMRs to reduce the likelihood that fish would be diverted from the San Joaquin or Sacramento River into the southern or central Delta.

The **proportion** of the population affected by the Proposed Action varies annually and depends upon flow routing, hydrology, and export rates and is likely **small** (since 2010, 2010 – 2022) to **medium** (prior to 2010, 1993 – 2009). In 14 out of 30 years (47%, 1993 – 2022), the early season annual loss threshold was exceeded (Table 7-73). In 8 out of 30 years (27%, 1993 – 2022), the late season annual threshold was exceeded (Table 7-73). However, steelhead loss in years after 2010 are more representative of current OMR management and the Proposed Action. Many of the years when annual loss thresholds were exceeded occurred in the late 1990s and early 2000s.

Steelhead 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. For example, a fish observed salvage could have arrived via one of two pathways: San Joaquin Origin via the San Joaquin River or San Joaquin or Sacramento Origin via the South Delta (Figure 7-114). If a proportion of flows is higher down a migratory pathway documented as a route with higher survival rates for juvenile steelhead 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 Delta Cross Channel or Georgiana Slough).



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.

Figure 7-114. Conceptual Model of Delta Regions and Routing symbolized by fish fate.

The proportion is quantified by through-Delta survival and the detection of steelhead in salvage as an annual and weekly percent of the steelhead juvenile population estimate. The knowledge base paper, solicited literature, datasets, and models were used to analyze entrainment.

Literature for steelhead 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, Delta Cross Channel 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.

Reclamation considered historical salvage and literature on routing and entrainment and to estimate the proportion of the population affected by an increase in the entrainment risk stressor. In addition to observations, proportion was informed by the resulting distribution of modeled estimates of particles inserted at certain locations in the Delta using a Particle Tracking Model (PTM) and particle behavior using Ecological Particle Tracking Model (ECO-PTM). PTM and ECO-PTM current modeling results can be used to inform entrainment risk on Sacramento River origin steelhead but not San Joaquin River origin steelhead.

Historical records of salvage and loss of steelhead at the CVP and SWP Delta fish collection facilities (1993 – 2022) show loss varies annually (Table 7-73). These loss records represent steelhead from both CVP and non-CVP tributaries. There is currently not a juvenile production estimate developed for steelhead; however, in the previous Proposed Action there were early season and late season annual loss thresholds. The early season threshold includes loss occurring between December 1 and March 31 (1,414 individuals) and the late season threshold includes loss occurring between April 1 and June 15 (1,552 individuals). These thresholds were developed to capture the temporal variability of steelhead outmigrating from the Sacramento River (early) and San Joaquin River (late).

Table 7-73. Juvenile unclipped *O. mykiss* loss at the CVP and SWP Delta fish collection facilities (1993 – 2022), Sacramento Valley Index Water Year Type (WYT), Early Season loss, percent of Early Season annual threshold (1,414 individuals) Late Season loss, and percent of Late Season annual threshold (1,552 individuals).

Water Year	Total Loss	WYT	Dec – Mar Early Loss	Percent of Early Season threshold	Apr – Jun Late Loss	Percent of Late Season threshold
1993	46,595.41	Above Normal	43,767.61	3095	2,827.8	182
1994	2,096.05	Critical	1,700.47	120	386.92	25
1995	5,107.53	Wet	3,811.54	270	1,140.61	73
1996	14,539.55	Wet	12,778.75	904	1,743.48	112
1997	1,382.52	Wet	406.85	29	814.29	52
1998	468.96	Wet	318.08	22	91.26	6
1999	4,868.49	Wet	1,149.62	81	3,654.42	235
2000	10,553.06	Above Normal	9,029.07	639	1,296.5	84
2001	13,895	Dry	12,057.25	853	1,319.15	85
2002	3,566.21	Dry	2,867.81	203	637.78	41
2003	6,087.52	Above Normal	4,896.11	346	1,126.46	73
2004	4,692.25	Below Normal	4,376.15	309	255.98	16
2005	3,915.33	Above Normal	1,853.59	131	1,863.56	120
2006	4,421.13	Wet	2,289.24	162	2,123.73	137
2007	5,342.87	Dry	3,393.02	240	1,923.87	124
2008	3,132.31	Critical	2,597.89	184	517.1	33

Water Year	Total Loss	WYT	Dec – Mar Early Loss	Percent of Early Season threshold	Apr – Jun Late Loss	Percent of Late Season threshold
2009	877.23	Dry	655.06	46	204.85	13
2010	2,163.71	Below Normal	1,553.83	110	592.56	38
2011	2,614.93	Wet	921.04	65	1,639.21	106
2012	1,112.37	Below Normal	723.24	51	371.81	24
2013	2,263.04	Dry	953.08	67	1,214.52	78
2014	260.51	Critical	201.69	14	58.82	4
2015	156.99	Critical	77.94	6	61.73	4
2016	292.62	Below Normal	245.92	17	46.7	3
2017	193.85	Wet	57.4	4	116.41	8
2018	2,851.65	Below Normal	1,127.01	80	1,724.64	111
2019	1,479.51	Wet	978.48	69	483.71	31
2020	728.67	Dry	401.98	28	323.97	21
2021	91.04	Critical	41.19	3	49.85	3
2022	238.66	Critical	75.44	5	154.38	10

Good et al. (2005) estimated the steelhead population at approximately 94,000 – 336,000 juveniles. Nobriga and Cadrett (2001) put that estimate at 413,069 – 658,453 juveniles. Using annual combined loss from CVP and SWP facilities as a percentage of the lowest and highest juvenile population estimates, the **proportion** of the population affected is likely **small to medium** (Table 7-74). However, since annual loss is correlated with population size, an average loss rate likely underestimates the proportion of the population affected in high abundance years and overestimates the proportion of the population affected in low abundance years.

Table 7-74. Total annual juvenile steelhead loss and facilities loss as a proportion of low and high estimates of juveniles in the population.

Water Year	Total Loss	Loss as Percent of Juvenile Population Estimate (Low)	Loss as Percent of Juvenile Population Estimate (High)
1993	46595.41	49.6	7.1
1994	2096.05	2.2	0.3
1995	5107.53	5.4	0.8
1996	14539.55	15.5	2.2
1997	1382.52	1.5	0.2
1998	468.96	0.5	0.1
1999	4868.49	5.2	0.7
2000	10553.06	11.2	1.6
2001	13895	14.8	2.1

Water Year	Total Loss	Loss as Percent of Juvenile Population Estimate (Low)	Loss as Percent of Juvenile Population Estimate (High)
2002	3566.21	3.8	0.5
2003	6087.52	6.5	0.9
2004	4692.25	5.0	0.7
2005	3915.33	4.2	0.6
2006	4421.13	4.7	0.7
2007	5342.87	5.7	0.8
2008	3132.31	3.3	0.5
2009	877.23	0.9	0.1
2010	2163.71	2.3	0.3
2011	2614.93	2.8	0.4
2012	1112.37	1.2	0.2
2013	2263.04	2.4	0.3
2014	260.51	0.3	0.0
2015	156.99	0.2	0.0
2016	292.62	0.3	0.0
2017	193.85	0.2	0.0
2018	2851.65	3.0	0.4
2019	1479.51	1.6	0.2
2020	728.67	0.8	0.1
2021	91.04	0.1	0.0
2022	238.66	0.3	0.0

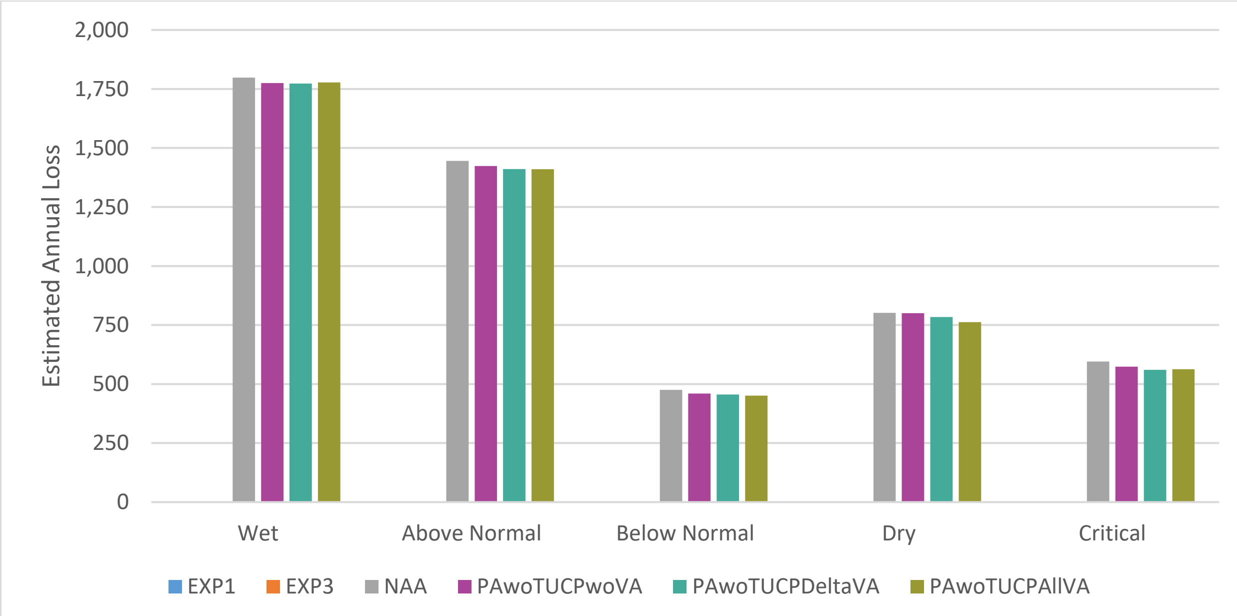
Steelhead are exposed to effects of the CVP and SWP in the Delta through specific migratory pathways, and the proportion of the population affected by these routes can be described based on published literatures and modeling. It is hypothesized that the small proportion of juvenile steelhead that are counted at the CVP and SWP fish collection facilities is representative of a larger proportion of the population and this proportion can be reduced by reducing negative net flows in the OMR corridor.

San Joaquin Origin: Empirical estimates of tagged juvenile steelhead released at Mossdale on the San Joaquin River entering Old River at HOR was 0.84 (SE = 0.02) to 0.92 (SE = 0.02) between March and May of 2013, with an overall average of 0.88 (SE = 0.01) (Bureau of Reclamation 2018). The authors developed a model which showed the effect of both river flow and stage on the probability of entering Old River; fish arriving at higher flow or stage were less likely to enter Old River compared with those arriving at lower flow or stage. Incoming tide was associated with entry to Turner Cut; however, 17 tags were available for analysis at this junction, too few to test significance. As fish migrate past Mossdale, similar to fish in the Sacramento River, they encounter junctions into routes which may lead to decreased survival. Steelhead survival through the Delta appears to be highly variable both within and among years; survival of fish released at Mossdale to Chipps Island in 2011 through 2016 ranged from 0.06 to 0.69; Buchanan et al. 2021). For the same years, survival of fish from the junction of the San Joaquin River at Old River head to Chipps Island ranged from 0 to 0.71 (Buchanan et al. 2021). Buchanan et al. (2021) found a strong survival difference between survival in the mainstem San Joaquin River compared with the interior Delta route from Turner Cut. Other studies reported similar findings using fall-run Chinook salmon and steelhead migrating in the mainstem Sacramento compared with interior Delta routes (Perry et al. 2010, Singer et al. 2013).

Sacramento Origin: Empirical estimates of tagged wild steelhead released in Deer Creek and Mill Creek between March and May of 2020 experienced a routing probability into Georgiana Slough (condition on fish arrival at the junction) of 27.7% (SE = 8.9) (CalFishTrack online, water year 2020 archived study). Wild steelhead released in Deer Creek between April and June of 2019 experienced a routing probability into Georgiana Slough of 22.7% (SE = 8.9) (CalFishTrack online, water year 2019 archived study). In 2019, there were two pulse flows that occurred in mid-March and mid-April which would have impacted fish migrating downstream through the Sacramento River while flows remained more muted in 2020. Using tagged Chinook which take the same migratory routes as Sacramento River origin steelhead, 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 water year type 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 in other water year types (Interior Delta, Georgiana Slough), survival is generally lower than in higher flow years and other routes (mainstem Sacramento, Sutter and Steamboat sloughs). Routing estimates from tagged Chinook salmon 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. Studies of tagged Chinook 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.

Results from “Volumetric Influence”, “Zone of Influence”, “Flow into Junctions”, “Particle Tracking Models”, and ECO-PTM are available in the Winter-Run Chinook Salmon chapter (Chapter 5). Steelhead species-specific results from the salvage density model and the negative binomial loss model follow.

The Salvage Density Analysis, Appendix I, Attachment I.2, *OMR Salvage-Density Model Loss*, provides context for steelhead at the export facilities. This analysis weighs south Delta exports at the export facilities by historical salvage per unit volume. Predicted annual loss of steelhead at the facilities under the Proposed Action components ranges from 451 to 1,778 (Figure 7-115). The lowest predicted loss occurred in Proposed Action phases for below normal water year types. The highest predicted loss occurred in Proposed Action phases for wet water year types. Loss of steelhead at the facilities in the Proposed Action phases range over an order of magnitude among water year types, which is similar to historically observed salvage in the recent past.



Under EXP1 and EXP3 exports are set at 0 resulting in a predicted loss of 0.

Figure 7-115. Estimated cumulative annual loss of Sacramento River origin steelhead at the export facilities by WYT based on salvage-density method.

Negative Binomial Loss model (Appendix I, Attachment I.1, *Negative Binomial Salvage Model*) provides context for estimated salvage of steelhead at the Delta Fish Collection Facilities, combined. The analysis assumes the Proposed Action may change the presence of steelhead 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 steelhead included month and combined exports from CVP and SWP through a model selection process.

Predicted annual cumulative salvage of steelhead at the facilities under the Proposed Action phases ranges from 190 to 4,286 (Figure 7-116). Overall, predicted salvage varies among water year types. The highest predicted salvage occurred in Proposed Action phases for wet water year types. Salvage of steelhead at the facilities in the Proposed Action phases range over an order of magnitude among water year types, particularly between wet water year type and the other four water year types, which is similar to historically observed salvage in the recent past.

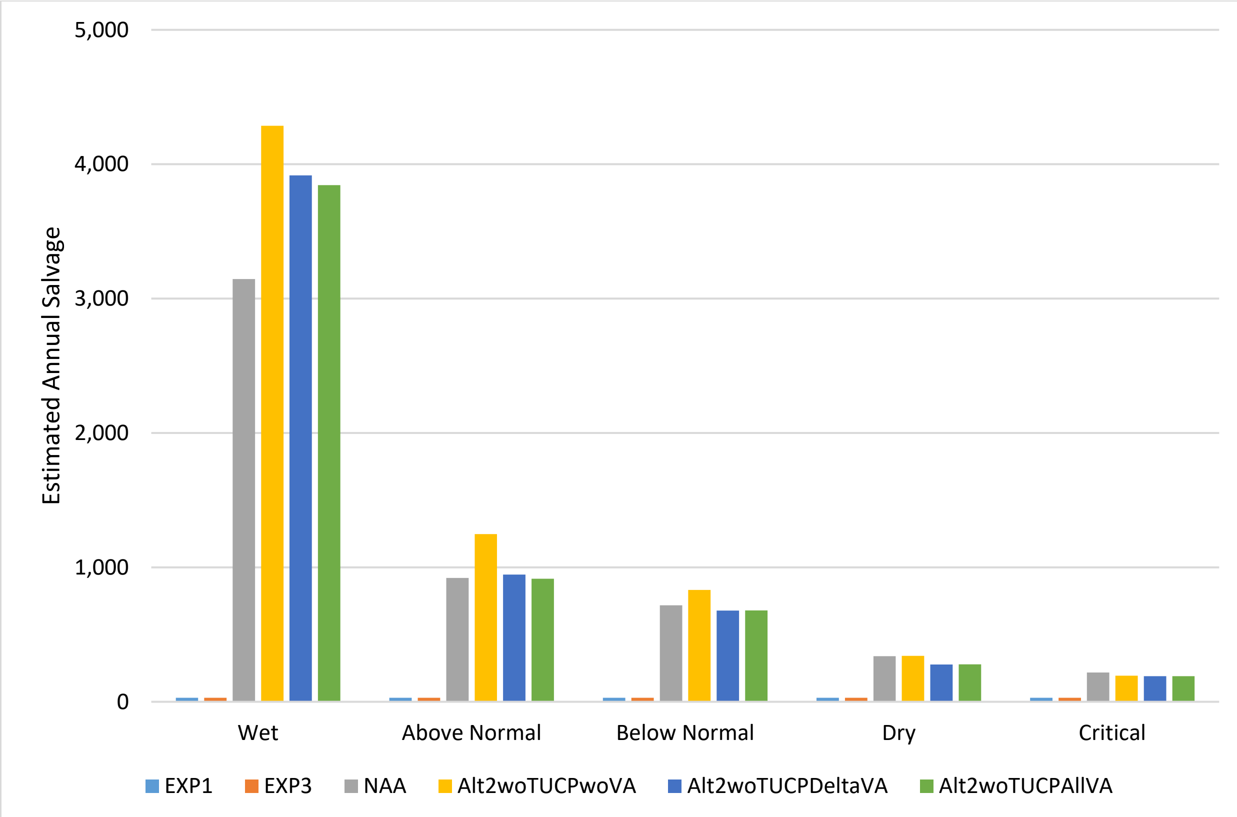


Figure 7-116. Estimated mean annual salvage of Sacramento River origin steelhead at the export facilities by WYT based on negative binomial salvage method.

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 loss threshold, etc.). The **frequency** of occurrence is **high** and likely to occur annually as the CVP and SWP will not surpass -5000 cfs (i.e., -6000 cfs).

The **weight of evidence** for entrainment risk includes empirical species- and route-specific entrainment estimates from acoustically tagged steelhead, decades of OMR flow data, 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.

- Historical migration timing is quantitative, species-specific, and location-specific. The data are available through multiple sources and QA/QCed, long time-series and not expected to have statistical power.
- Historical salvage observations are quantitative, species-specific, and location-specific. The observations are available through multiple sources and QA/QCed, long time-series and not expected to have statistical power.
- Salvage Density modeling is quantitative, species-specific, and location-specific. The model is widely accepted and historically used as a salvage / loss estimation tool, with a single covariate.

- Negative Binomial modeling is quantitative, species-specific, and location-specific. The model is newly developed unpublished method for estimating loss specific to salmonids, final covariates unique to each species from model selection process.
- [placeholder] Bulk flow modeling [placeholder] is quantitative, not species-specific (but not expected to be, environmental variable), and location-specific. The models are not published, and are simplified representation of the Bay-Delta (proportion of Sacramento inflow exported).
- [placeholder] ZOI modeling is quantitative, not species-specific (but not expected to be, environmental variable), and location-specific. The models are not published, but are a widely accepted method for evaluating spatial extent of varying levels of exports within the Bay-Delta.
- [placeholder] PTM modeling is quantitative, not species-specific (but not expected to be, environmental variable), and location-specific. The models are used in multiple peer-reviewed publications. PTM is a widely accepted method to estimate particle movement and can be evaluated with covariates.
- [placeholder] ECO-PTM modeling is quantitative, species-specific (model developed with tagged Chinook salmon), and location-specific. The model is under development with the U.S. Geological Survey and DWR, and has been presented at conferences / meetings. The model has also been used by inter-agency working groups (e.g., Georgiana Slough SDM group), and is an individual-based model combining PTM and swimming behavior from tagged salmonids calibrated and validated with field data.

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

- Delta Cross Channel Gate Closure
- First Flush and Start of OMR Management
- January 1 and Start of OMR Management
- Steelhead Weekly Thresholds
- Winter and Spring and 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

7.3 Critical Habitat Analysis

Critical habitat for steelhead was designated on September 2, 2005 (70 FR 52488). The geographical extent of designated critical habitat includes, but is not limited to, the following: Sacramento, Feather, and Yuba rivers; Clear, Deer, Mill, Battle, and Antelope creeks in the Sacramento River basin; the San Joaquin River, including its tributaries; and the waterways of the Delta. The critical habitat designation for steelhead 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.

7.3.1 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 draw information from multiple sections. For spawning, incubation, fry development, and fry emergence flows, Section 7.2.2, *Adult Spawning*, the spawning habitat stressor discussion presents habitat suitability curves for spawning habitat quantity and quality. Section 7.2.4.3, *Stranding and Dewatering*, analyzes the maintenance of flows and potential for dewatering. Section 7.2.2.1, *Water Temperature*, and Section 7.2.4.1, *Water Temperature*, addresses water temperature management.

Adult steelhead are known to spawn in the Sacramento River from Keswick Dam downstream to Red Bluff, Clear Creek, American River, and the Stanislaus River. No spawning has been reported in the Delta or San Joaquin River. Spawning in these areas has been affected by the presence of dams. In 2000, Reclamation removed the McKormick-Saeltzer Dam, which opened approximately 12 miles of lower Clear Creek to salmon and steelhead spawning. Since 2009, Reclamation has provided channel maintenance flows on Clear Creek, which are intended to increase the amount of spawning habitat available to steelhead. Gravel augmentations on Clear Creek have occurred in most years since 1996.

The proposed storing and diverting of water under the Proposed Action may actually decrease the spawning habitat stressor by decreasing flows that provide more suitable water velocities for spawning. Increases in the available spawning habitat through suitable flows may increase spawning success. Habitat suitability curves show lower flows increase steelhead spawning habitat quantity and quality in the Sacramento River (U.S. Fish and Wildlife Service 2003). Decreased flows under seasonal operations will increase the available spawning habitat, but spawning habitat is not a limiting resource. The proposed storing and releasing of water may generally increase the water temperature stressor during the adult spawning period in the Sacramento River, Clear Creek, American River, and Stanislaus River.

During the egg incubation and fry emergence period, the proposed storage and release of water may increase the stranding and dewatering stressor on the Sacramento, American and Stanislaus rivers, and decrease the stranding and dewatering stressor on Clear Creek. The release of water from Whiskeytown Reservoir results in higher flows in Clear Creek during the redd construction season. During the egg incubation and fry emergence period, the Sacramento, American, and Stanislaus rivers may have some months with a higher rate of flow reduction with the Proposed Action while other months may have a lower rate of flow reduction, causing both an increase and a decrease to the stranding and dewatering stressor.

To reduce the water temperature stressor in the American River, Reclamation recently completed the WTMP effort, which is intended to enhance modeling capabilities to predict summer and fall water temperature through facilities operations, including the Folsom Dam Temperature Shutters.

7.3.2 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. For juvenile rearing and outmigration, Section 7.2.5.1, *Water Temperature and Dissolved Oxygen*, Section 7.2.5.4, *Stranding Risk*, Section 7.2.5.5, *Refuge Habitat*, and Section 7.2.5.6, *Food Availability and Quality*, address this physical and biological feature.

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 food web processes, and slowed regeneration of riparian vegetation. Some complex, productive habitats with floodplains remain in the system. Outside of this consultation, Reclamation has completed many side-channel restoration projects that provide refuge habitat for juveniles and yearlings.

On the Stanislaus River, the proposed storage, diversion and blending of water will result in a reduction in water flows in winter and spring and an increase in water flows in summer and fall. The storage of water in the winter and spring will increase the water temperature stressor, dissolved oxygen stressor, stranding risk stressor, refuge habitat stressor, and the food availability stressor. The release of water in summer will decrease water temperature stressor, stranding risk stressor, refuge habitat stressor, and the food availability stressor.

On the American River the proposed storage, diversion and blending of water will result in a reduction in water flows in winter and spring and an increase in water flows in summer and fall. The storage of water in the winter and spring will increase water temperature stressor, stranding risk stressor, refuge habitat stressor, and the food availability stressor. The release of water in summer and fall will decrease water temperature stressor, stranding risk stressor, refuge habitat stressor, and the food availability stressor.

On the Sacramento River the proposed storage, diversion and blending of water in winter and spring will result in increased stranding risk stressor, refuge habitat stressor, and the food availability stressor. The release of water in summer and fall will decrease stranding risk stressor, refuge habitat stressor, and the food availability stressor.

On the Clear Creek the proposed storage, diversion and blending of water in winter and spring will result in increased stranding risk stressor, refuge habitat stressor, and the food availability stressor. The release of water in summer and fall will decrease stranding risk stressor, refuge habitat stressor, and the food availability stressor.

7.3.3 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 draw information from multiple sections. For juvenile rearing and outmigration, Section 7.2.5.3, *Outmigration Cues*, Section 7.2.5.5, *Refuge Habitat*, Section 7.2.5.6, *Food Availability and Quality*, and Section 7.2.5.7, *Entrainment*; For adults migrating, Section 7.2.1.1, *Water Temperature*, and Section 7.2.1.2, *Pathogens and Disease*.

The proposed storage, diversion, release and blending of water may increase or decrease water temperature, pathogens and disease, stranding risk, refuge habitat, and food availability and quality stressors. The proposed storing and diverting of water may increase the dissolved oxygen stressor in the San Joaquin and Stanislaus rivers. During the juvenile rearing and outmigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. In the fall, flows would be increased in the Sacramento River, American River, and Clear Creek, and decreased in the Stanislaus River. Water temperatures reaching the upper temperature limits can add stress to juveniles rearing. Changes in dissolved oxygen can affect the swimming performance of juvenile salmonids.

The proposed storing and diverting of water may generally decrease the water temperature stressor on adults migrating. During the adult migration and holding period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer and fall resulting in increased flows.

The proposed storing and diverting of water may increase or decrease the pathogens and disease stressor. During the juvenile rearing and outmigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. In the San Joaquin River, operations of storage and releases of water would result in decreased flows throughout the year. In the fall, flows would increase in the Sacramento River, American River, and Clear Creek, and decrease in the Stanislaus River. As part of the drought toolkit, Reclamation may operate the TCD to release warmer water temperatures to preserve water for egg incubation later in the year. Maintenance of reservoir storage may decrease flows and cause crowding into a smaller habitat area. Decreased flows may also increase water temperatures to cause an increase in pathogen virulence and prevalence of disease.

The proposed storing, diverting and releasing of water may decrease the pathogens and disease stressor for adults. Water temperatures below the criteria may decrease pathogen virulence and prevalence of disease. During the adult migration and holding period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring. The Proposed Action will release storage in those locations in the summer resulting in increased flows. The Proposed Action may result in decreased flows in the fall in the Stanislaus River below Goodwin Dam.

The proposed storage and diversion of water may increase the stranding risk stressor in all five steelhead bearing natal rivers and tributaries of the CVP and may decrease depending seasonality in the Sacramento, American and Stanislaus rivers. During the juvenile rearing (year-round) and outmigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. In the San Joaquin River, operations of storage and releases of water would result in decreased flows throughout the year. In the fall, flows would be increased in the Sacramento River, American River, and Clear Creek, and decreased in the Stanislaus River. Decreased flows may result in fish trapped in isolated pools or shallow areas off the mainstem.

The proposed storage and release of water may increase and decrease the refuge habitat stressor depending on seasonality and watershed. During the juvenile rearing and outmigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam and the Delta, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. In the San Joaquin River, operations of storage and releases of water would result in decreased flows throughout the year. In the fall, flows would be increased in the Sacramento River, American River, and Clear Creek, and decreased in the Stanislaus River. A decrease in flows can reduce suitable margin and off-channel habitats available as refuge habitat for juveniles, while an increase in flows may do the opposite.

The proposed storage and release of water may increase or decrease the food availability and quality stressor depending on seasonality. During the juvenile rearing and outmigration period, the Proposed Action will store and divert water resulting in decreased flows in the Sacramento River below Keswick Dam and the Delta, Clear Creek below Whiskeytown Dam, American River below Folsom Dam, and Stanislaus River below Goodwin Dam in the winter and spring, and release storage in the summer resulting in increased flows. In the San Joaquin River, operations of storage and releases of water would result in decreased flows throughout the year. In the fall, flows would be increased in the Sacramento River, American River, and Clear Creek, and decreased in the Stanislaus River. Changing operations result in decreased flows and less inundated habitats. These changes may modify food web processes and cause a decrease in quality food available to juvenile steelhead. However, juvenile growth can be dependent on the interaction between food availability and higher water temperatures, which may increase the food supply (Brett et al. 1969; Sogard and Olla 2001).

The Proposed Action may result in entrainment risks for juveniles 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.

Changes to the water temperature stressor are expected to be insignificant in the San Joaquin River and the Delta. In the Delta, operations are not expected to increase the stranding risk, refuge habitat, and food availability and quality stressor for rearing and outmigrating juvenile and migrating adult steelhead.

7.3.4 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.

Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022) and reservoir operations may influence water temperature to a minimal extent in the lower reaches of the Sacramento River (Daniels and Danner 2020). However, in the Delta water temperature is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020).

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. The Proposed Action is expected to result in insignificant changes to water temperature in the Sacramento River and San Joaquin River, and the Delta. Water temperatures in the Delta and Sacramento River are below juvenile and adult migration and holding criteria throughout this period. The Proposed Action is expected to have insignificant changes to water temperature in the San Joaquin River. Exports of water from the south Delta would continue to entrain some steelhead, affecting migratory conditions through the Delta.

7.4 Lifecycle Analysis

Literature, datasets, and models do not uniquely inform a life cycle analysis of CV steelhead.

7.5 References

7.5.1 Printed References

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7.5.2 Personal Communications

Hannon, John. Fisheries Biologist. Mid-Pacific Regional Office. Bureau of Reclamation. Sacramento, CA. MONTH DATE—Emails containing Egg Incubation Timing for Lower American River sent to XXX, Sacramento, CA.