Long-Term Operation – Public Draft Alternatives

Appendix D – Seasonal Operations Deconstruction

Central Valley Project, California

Interior Region 10 – California-Great Basin

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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1 Introduction

This seasonal operations deconstruction appendix analyzes potential stressors on aquatic species and their critical habitats from Bureau of Reclamation (Reclamation) and California Department of Water Resources (DWR) actions to store, release, divert, and route flows during the Long-Term Operation (LTO) of the Central Valley Project (CVP) and State Water Project (SWP). Where the Proposed Action may change stressor in intensity or extent with potential adverse effects on listed species, those stressors are identified for consideration of incidental take and conservation measures to limit operations and/or compensate for potential adverse effects.

Appendix A, *Facilities Description*, provides a description of the facilities and the requirements for the CVP and SWP under each respective authorization. Appendix B, *Water Operations and Ecosystem Analyses*, describes the water available for operation of the CVP and SWP with scenarios of: (1) releasing the impaired inflow to reservoirs subject to downstream channel capacities, ("Run of River or EXP 1); (2) operations under Water Right Decision 1641 and other water right requirements, (EXP 3); (3) operations under the 2020 Record of Decision implementing the 2019 Biological Opinions for the CVP and SWP and the 2020 California Incidental Take Permit for the operation of the SWP under the California Endangered Species Act (ESA) ("No Action Alternative"); and (4) the preferred alternative/proposed action, ("Proposed Action"). Appendix C, *Species Spatial and Temporal Domains*, analyzes historical monitoring to describe observations of listed fish species within the Central Valley. This appendix applies consideration for the direction and magnitude of changes to flows and water quality from the operation of the CVP and SWP.

Reclamation considered commonly used published conceptual models where available and made adaptations for species where such models were absent. Conceptual models described hypothesized linkages between the landscape, environmental drivers, habitat, and fish response for different life stages. The conceptual models provide a list of potential stressors. Management actions can change the landscape and environmental drivers to influence these stressors when species may be present. While the Proposed Action and alternatives may result in different magnitudes of flows, the direction of changes are likely to remain similar. Reclamation started from an analysis of changes under the representation of D-1641 and the No Action Analysis, and will refine analyses in developing alternatives and a Proposed Action.

The timing of water operations may vary in any specific year, but generally follows patterns that align with fall, winter, spring, and summer seasonal periods. These months are generally December through February for winter, March through May for spring, June through August for summer, or September through November for fall. Life stages were identified in the dominant season(s) rather than repeated if the leading and trailing months fell within similar operations. Low presence indicates that species have been seen at that time, in some years, but in small numbers. Medium presence indicates observations of species in some years at numbers that warrant potential detailed consideration of the effects of actions. High presence indicates that species are likely present. Thresholds were based on professional opinion and generally represent approximately <1%, <5%, and >5% of the population. For each species, each watershed, each season, and each life stage, Reclamation evaluated each stressor to determine how changes in flows as a result of storing, releasing, diverting, or routing water may increase or reduce each stressor.

Alternatives use modeling to explore potential ranges of water operations, develop conservation measures to address adverse effects, incorporate conservation measures planned to contribute to recovery of species, and evaluate those measures.

2 Winter-Run Chinook Salmon

The federally listed evolutionarily significant unit (ESU) of Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) and designated critical habitat occurs in the action area and may be affected by seasonal operations. Winter-run Chinook salmon exhibit a life-history strategy found nowhere else in the world. Adult winter-run Chinook salmon return to their natal tributary in the winter and spawn during the summer months when air temperatures usually approach their warmest. The last remaining natural spawning area for winter-run Chinook salmon is located on the upper Sacramento River, downstream of Keswick Dam. As a result, the natural population of winter-run Chinook salmon depend entirely upon cold water releases from Shasta Dam to protect incubating eggs from warm ambient conditions.

2.1 Conceptual Lifecycle Models

An action may affect fish when the change in conditions overlap with the location and timing of fish and/or their habitats. The Salmon and Sturgeon Assessment of Indicators by Life stage (SAIL) conceptual model (Windell et al. 2017) describes life stages and geographic locations for winter-run Chinook salmon (Figure).

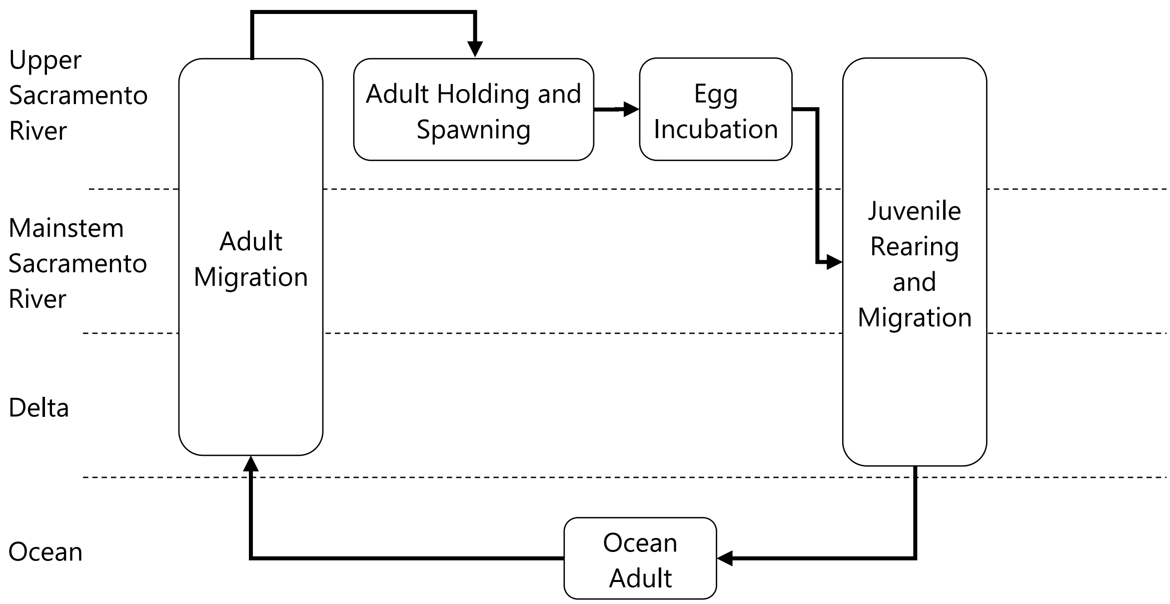

Figure 1. Geographic Life Stage Domains for Winter-Run Chinook Salmon (adapted from Windell et al. 2017, Figure 2)

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
    - H1: In-river fishery and poaching
    - H2: Toxicity from contaminants
    - H3: Stranding risk
    - H6: Water temperature
    - H4: Dissolved oxygen
    - H5: Pathogens
- Adult Holding and Spawning
    - H3: In-river fishery or poaching
    - H1: Toxicity from contaminants
    - H6: Water temperature
    - H7: Pathogens and disease
    - H5: Dissolved oxygen

  - H4: Spawning habitat
  - H2: Competition, introgression, and broodstock removal
- Eggs Incubation to Fry Emergence
  - H1: In-river fishery and trampling
  - H2: Toxicity and contaminants
  - H4: Stranding and dewatering
  - H7: Water temperature
  - H5: Dissolved oxygen
  - H6: Pathogens
  - H8: Sedimentation and gravel quantity
  - H3: Redd quality
  - H9: Predation risk
- Juvenile Rearing to Outmigration
  - H1: Toxicity and contaminants
  - H6: Stranding risk
  - H5: Outmigration cues
  - H7: Water temperature and DO
  - H8: Pathogens and disease
  - H9: Entrainment risk
  - H3: Refuge habitat
  - H4: Food availability and quality
  - H2: Predation and competition

Each deconstruction of the action considers the 31 stressors for the four life stages listed above. Additional and/or alternative conceptual models (e.g., Central Valley Project Improvement Act [CVPIA] Science Integration Team, South Delta Salmonid Research Collaborative) may be incorporated as applicable.

Monitoring data from snorkeling, carcass surveys, redd surveys, rotary screw traps, trawls, and beach seines describe the timing of winter-run presence (Figure 2) (Appendix C).

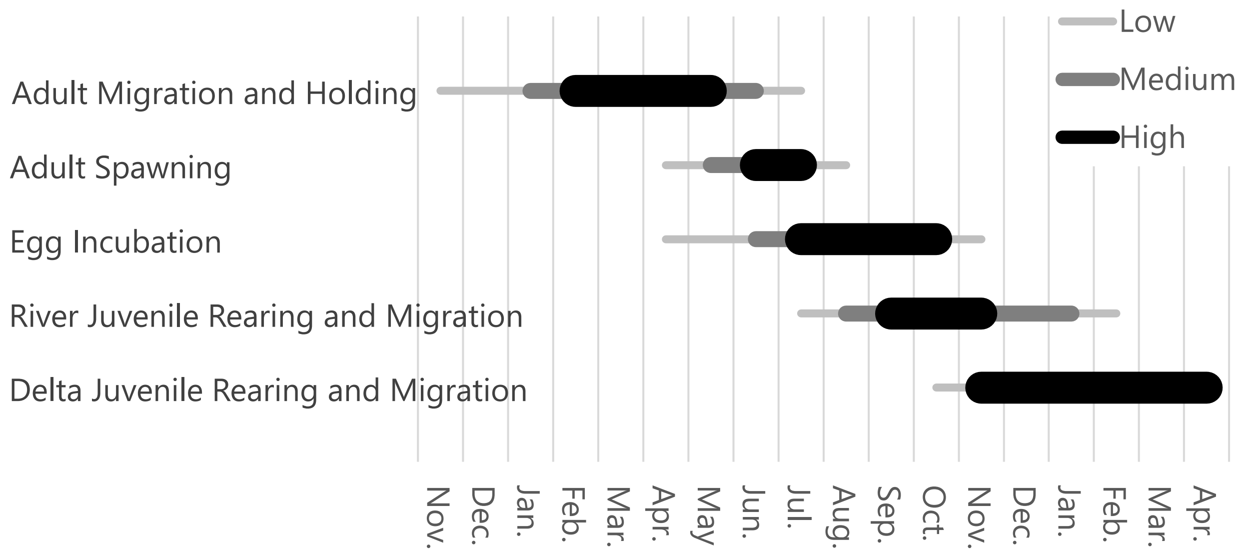

Figure 2. Temporal Life Stage Domains for Winter-Run Chinook Salmon from Appendix C

The two spatial domains defined for winter-run Chinook salmon are the Sacramento River and Bay-Delta. Presence of several life stages in the Central Valley and Bay-Delta (adult migration and holding, juvenile migration) occur over multiple calendar years. The ocean life stage is outside the critical habitat action area determined by the National Marine Fisheries Service (NMFS), and therefore is not shown.

2.2 Species Effects Deconstruction

Winter-run Chinook salmon are anticipated in the Sacramento River and Sacramento–San Joaquin Delta (Delta) and may experience effects from seasonal operations, as described below. The Sacramento River includes migrating, holding, and spawning adults; egg incubation below Keswick Dam; and rearing and migrating juveniles. The Delta includes migrating adults and rearing and migrating juveniles.

2.2.1 Sacramento River

2.2.1.1 Winter

In the winter, the Proposed Action will decrease flows on average in the Sacramento River below Keswick Dam. Decreased flow in the upper Sacramento River may change stressors on winter-run.

2.2.1.1.1 Adults

Adults are migrating in the Sacramento River in the winter, undergoing an energetically taxing salt-to-freshwater transition to spawn. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely insignificant. Maintenance of Shasta Reservoir storage may reduce flows and concentrate contaminants. The timing of snowmelt may also play a role in this stressor though studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017, Chen et al. 2018). However, water quality monitoring has not shown contaminants at levels likely to affect adult salmon and no fish effects have been observed during fish monitoring. Water quality in the Sacramento River and its tributaries within 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 bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. Levels safe for human consumption are assumed not likely to impact fish health and (Murphy et al. 2022) identifies Chinook salmon as safe to eat. Appendix J, *Winter and Spring Pulses and Delta Outflow: Smelt, Chinook Salmon, and Steelhead Migration and Survival*, presents an analysis of this stressor.

Stranding risk stressors are not anticipated to change. Maintenance of Shasta Reservoir storage may reduce flows. Adults use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented within various fishery technical teams in the Upper Sacramento River.

Water temperature stressors are not anticipated to change. Maintenance of Shasta Reservoir storage may result in warmer water temperatures in the winter; however, modeled winter water temperatures are colder than adult migration temperature needs (Appendix B, Section 3.2, *Water Temperatures and Dissolved Oxygen*). Evidence suggests that optimal water temperatures between 37.9°F and 60.8°F for Pacific Northwest Chinook salmon migrating and between 42.8°F and 57.2°F for hatchery Chinook salmon holding (Reiser and Bjornn 1979, McCullough 1999). Studies on Pacific Northwest salmon showed migration being halted and pre-spawn mortality occurring at temperatures greater than 68°F (Goneia et al. 2006, Bowerman et al. 2018).

Dissolved oxygen stressors are not anticipated to change. Maintenance of Shasta Reservoir storage may result in warmer water temperature and lower dissolved oxygen. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/l (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below 5.0ml/l in the winter. Dissolved oxygen levels fluctuate daily ranging typically between 10 and 15 mg/l at the Clear Creek gage.

Pathogen stressors are not anticipated to change. Maintenance of Shasta Reservoir storage may result in warmer water temperatures in the winter; however, modeled winter water temperatures (Appendix B, Section 3.2) are colder than those that increase adult susceptibility to pathogen stressors. Water temperature less than 59.9°F occur in the winter, above which temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since it does not remove or introduce winter-run Chinook salmon into the population.

2.2.1.1.2 Eggs

Eggs are not present in the Sacramento River during the winter.

2.2.1.1.3 Juveniles

Juveniles are rearing and migrating downstream in the Sacramento River in the winter. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates dependent on an individual's physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity and contaminants stressors may increase. This increase is likely insignificant. Maintenance of Shasta Reservoir storage may reduce flows concentrating constituents from urban and agricultural land use that affect concentration in juvenile's prey. The timing of snowmelt may also play a role in this stressor though studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017, Chen et al. 2018). Contaminants can cause 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). Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may increase. Maintenance of Shasta Reservoir storage may reduce flows and the increase in the stressor may reduce connectivity, causing stress and mortality of winter-run Chinook salmon. When flows decrease, juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Alternately, stranding risk stressors may decrease from the dampening of flow fluctuations during precipitation events, and would benefit from reduced predation. Appendix L, *Shasta Coldwater Pool Management*, presents an analysis of this stressor.

Outmigration cues stressors may increase. Maintenance of Shasta Reservoir storage may reduce flows and the increase in the stressor may mask the cue to migrate and increase travel time in upper and middle reaches of the Sacramento River. Outmigration cues is 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. Storing water in Shasta Reservoir reduces flow magnitude that juvenile salmon use as cues to continue migration. Winter-run Chinook salmon outmigration cues into the lower Sacramento River increased to more than 5% at the Knights Landing fish monitoring site with daily Wilkin Slough flows of 14,126 cfs (400cms, Del Rosario et al. 2013). Appendix J presents an analysis of this stressor.

Water temperature stressors are not anticipated to change. Maintenance of Shasta Reservoir storage may result in warmer water temperatures in the winter; however, modeled winter water temperatures are colder than juvenile rearing and migration temperature needs (Appendix B, Section 3.2). The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (McCullough 1999).

Dissolved oxygen (DO) stressors are not anticipated to change. Maintenance of Shasta Reservoir storage may reduce flows and result in water water temperatures. Observed swimming performance of Chinook salmon juveniles declined at DO less than 7 mg O_2/l at a temperature of 67.1°F but decreased steadily with DO less than saturation (~10 mg O_2/l) at cooler temperatures (Davis et al. 1963). Water quality monitoring has rarely shown dissolved oxygen at levels below 5mg O_2/l in the winter.

Pathogen and disease stressors may increase. The increase is likely insignificant. Maintenance of Shasta Reservoir storage may decrease flows and may cause crowding into a smaller habitat area and warmer water temperatures. 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 is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Modeled winter water temperatures (Appendix B, Section 3.2) are colder than this threshold. Also, observed winter temperatures have remained below this threshold and pathogen and disease stressors have not been observed in the winter for juvenile winter-run Chinook salmon.

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges (e.g., Glenn-Colusa Irrigation District [GCID], Reclamation District 108 [RD 108]) are screened (see Appendix A).

Refuge habitat stressors may increase. Maintenance of Shasta Reservoir storage may reduce flows and the increase of the stressor may reduce suitable margin and off-channel habitats for juvenile winter-run Chinook salmon. Maintenance of Shasta Reservoir storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for juveniles. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for winter-run Chinook salmon in the winter in the Sacramento River is plotted in Appendix B, Section 3.3, *Suitable Habitat*. Appendix O, *Tributary Habitat Restoration*, defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. Maintenance of Shasta Reservoir storage may reduce flows and the increase of the stressor may result in a change of food web processes and a decrease in quality food available to juvenile winter-run Chinook salmon. Maintenance of Shasta Reservoir storage results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix O presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely insignificant. Maintenance of Shasta Reservoir storage may reduce flows and warm temperatures and the increase of the stressor may result in increased predation. Predation of winter-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of winter-run Chinook salmon. Predation, in this context, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), entrainment risk, and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D, *Seasonal Operations Deconstruction*). Appendix O, Appendix L, Appendix I, *Old and Middle River Flow Management*, and Appendix J present analysis of these stressors using lines of evidence which incorporate indirect predation impacts on salmonids.

2.2.1.2 Spring

In the spring, the Proposed Action will decrease flows on average in the Sacramento River below Keswick Dam. Decreased flow in the upper Sacramento River may change stressors on winter-run Chinook salmon.

2.2.1.2.1 Adults

Adults are migrating, holding, and spawning in the upper Sacramento River in the spring. Adults move into the upper watershed where they hold until ready for spawning. This life-history strategy may leave adults vulnerable to multiple factors that affect survival, timing, and distribution. Additionally, adult body condition upon return to spawning areas can influence effects of stressors on pre-spawn mortality or fecundity. Several stressors have been identified for habitat attributes that affect spawning and holding.

In-river fishery or poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely insignificant. Maintenance of Shasta Reservoir storage may reduce flows and concentrate contaminants. The timing of snowmelt may also play a role in this stressor though studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017, Chen et al. 2018). However, water quality monitoring has not shown contaminants at levels likely to affect adult salmon and fish effects have not been observed during fish monitoring. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. Levels safe for human consumption are assumed not likely to impact fish health and (Murphy et al. 2022) identifies Chinook salmon as safe to eat. Appendix J presents an analysis of this stressor.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented within various fishery technical teams in the Upper Sacramento River.

Water temperature stressors may increase. This increase is likely insignificant. Maintenance of Shasta Reservoir storage may decrease flows which may result in warmer water temperatures in the spring. Modeled spring water temperatures are colder than adult migration temperature needs (Appendix B, Section 3.2). Evidence suggests that optimal water temperatures between 37.9°F and 60.8°F for Pacific Northwest Chinook salmon migrating and between 42.8°F and 57.2°F for hatchery Chinook salmon holding (Reiser and Bjornn 1979, McCullough 1999). Studies on Pacific Northwest salmon showed migration halting and pre-spawn mortality occurring at temperatures greater than 68°F (Goneia et al. 2006, Bowerman et al. 2018).

Dissolved oxygen stressors are not anticipated to change. Maintenance of Shasta Reservoir storage may result in warmer water temperature and lower dissolved oxygen. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/l (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below 5.0 mg/l in the spring.

Pathogens and disease stressors may decrease or increase. This decrease is likely beneficial. Maintenance of Shasta Reservoir storage may result in warmer water temperatures in the spring. Modeled spring water temperature (Appendix B, Section 3.2) are colder than those that increase adult susceptibility to pathogen stressors. Water temperatures less than 59.9°F occur in the spring, above which temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999). However, as part of the drought toolkit, Reclamation may operate the Temperature Control Device (TCD) to release warmer water temperatures during this period to preserve water for egg incubation later in the year. These warmer temperatures associated with exercising the drought toolkit may increase stress on adults taxed from upstream migration and spawning. Appendix L presents analysis of this stressor.

Spawning habitat stressors may increase. The increase is likely discountable. When Shasta Reservoir operations stores water in the spring, decreased flows occur when winter-run Chinook salmon spawning has not started and there is no potential stressor. When Shasta Reservoir operations increases releases in the spring, the increase in the stressor may reduce the quantity and quality of winter-run Chinook salmon spawning habitat. However, early in the spawning period, spawning habitat is not saturated. The U.S. Fish and Wildlife Service (USFWS)(2003) developed habitat suitability curves showing lower flows increased spawning habitat quantity and quality. Since 2003, habitat use and location of spawning has changed and additional spawning habitat restoration has occurred, so there is uncertainty in these relationships. Appendix O presents an analysis of this stressor.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since it does not remove or introduce winter-run Chinook salmon into the population.

2.2.1.2.2 Eggs

Eggs are not present in the Sacramento River in the spring.

2.2.1.2.3 Juveniles

Juveniles are not present in the Sacramento River in the spring.

2.2.1.3 Summer

In the summer, the Proposed Action will increase flows on average in the Sacramento River below Keswick Dam. Increased flow in the upper Sacramento River may change stressors on winter-run Chinook salmon.

2.2.1.3.1 Adults

Adults are migrating, holding, and spawning in the upper Sacramento River in the summer. Adults move into the upper watershed where they hold until ready for spawning. This life-history strategy may leave adults vulnerable to multiple factors that affect survival, timing, and distribution. Additionally, adult body condition upon return to spawning areas can influence effects of stressors on pre-spawn mortality or fecundity. Several stressors have been identified for habitat attributes that affect spawning and holding.

In-river fishery or poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may decrease. This decrease is likely insignificant. Releases of Shasta Reservoir storage may increase flows and dilute constituents. However, increased flows and pulses can mobilize suspended sediments consisting of contaminants in river systems (van Vliet et al. 2023). The timing of snowmelt may also play a role in this stressor though studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017, Chen et al. 2018). However, water quality monitoring has not shown contaminants at levels likely to affect adult salmon and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within the Central Valley is regulated by the US Environmental Protection Agency. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. Levels safe for human consumption are assumed not likely to impact fish health and (Murphy et al. 2022) identifies Chinook salmon as safe to eat. Appendix J presents an analysis of this stressor.

Stranding risk stressors are not anticipated to change. Adult winter-run Chinook salmon use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented within various fishery technical teams in the Upper Sacramento River.

Water temperature stressors may decrease. Releases of Shasta Reservoir storage may increase flows and the decrease is likely beneficial. Although seasonal operations may result in warmer temperatures than 56°F at Red Bluff Diversion Dam, these temperatures are approximately 10°F cooler than other scenarios because the Proposed Action releases water during the summer cooling water temperatures. The frequency of when the Proposed Action would provide benefits to adult winter-run Chinook salmon is high. Historic May through July temperatures on the Sacramento River above Clear Creek (2001 – 2020) were lower than 65°F in all years. Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely insignificant. Releases of Shasta Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential. Winter-run Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/l (Carter 2005) and historical water quality monitoring has not shown summer dissolved oxygen at levels below 5.0 mg/l.

Pathogens and disease stressors may decrease. This decrease is likely beneficial. Releases of Shasta Reservoir storage may result in cooler water temperatures. Historical water temperatures on the Sacramento River above Clear Creek exceeded the 59.9°F threshold for disease virulence one out of 18 years (2021) between 2005 – 2022. Water temperatures less than 59.9°F occur in the summer, above which water temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999). Crowding may be reduced due to increased flows and more holding habitat. Lower densities of holding adults may decrease the potential for lateral transmission of disease.

Spawning habitat stressors may increase. The increase in the stressor may reduce the quantity and quality of winter-run Chinook salmon spawning habitat. Habitat suitability curves show higher flows reduce spawning habitat quantity and quality and there are indications of redd superimposition, where suitable temperature limit spatial extent. Releases of Shasta Reservoir storage may result in cooler water temperatures. Appendix O presents an analysis of this stressor.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since it does not remove or introduce winter-run Chinook salmon into the population.

2.2.1.3.2 Eggs

Eggs are incubating in the Sacramento River streambed in the summer. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, development rate, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity and contaminants stressors may decrease. The decrease is likely insignificant. Releases of Shasta Reservoir storage may increase flows and dilute constituents. However, increased flows and pulses can mobilize suspended sediments consisting of contaminants in river systems (van Vliet et al. 2023). 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.

Stranding and dewatering stressors may decrease. The decrease is likely discountable. Release of Shasta Reservoir storage maintains flows in the summer; however, winter-run Chinook salmon spawn in deeper water and dewatering has not been observed in fish monitoring during the summer (Memeo et al. 2018, 2019; Smith et al. 2020).

Water temperature stressors may decrease or increase. The decrease is likely beneficial. Release of Shasta Reservoir storage maintains flows in the summer. Egg mortality occurs at temperatures above 56°F (McCollough 1999). Although seasonal operations may result in warmer temperatures than 56°F at Red Bluff Diversion Dam, these temperatures are approximately 10°F cooler than other scenarios because the Proposed Action releases water during the summer cooling water temperatures. Temperature conditions upstream of Red Bluff Diversion Dam will likely be cooler than those measured at this location. However, certain temperature management actions may increase this stressor for some individuals. Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely insignificant. Release of Shasta Reservoir storage maintains flows in the summer. Chinook salmon egg and alevin survival decreases when dissolved oxygen is less than 5.5 mg/l (Del Rio et al. 2019), however historical water quality monitoring has not shown summer dissolved oxygen at levels below 5.5 mg/l (California Department of Fish and Wildlife [CDFW] 2014 – 2017 Stressor Monitoring Report, Statewide Drought Response). In addition, releases of Shasta Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogen stressors may decrease. The decrease is likely insignificant. Release of Shasta Reservoir storage maintains flows in the summer. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Seasonal operations result in increased flows and decreased water temperature. Increasing flows may reduce pathogen concentration and horizontal transmission, while decreasing temperature may reduce pathogen virulence. Increased water temperatures have been hypothesized to be one of the factors that contributes to coagulated-yolk disease, or white-spot disease, in both eggs and fry along with other environmental conditions like gas supersaturation and low dissolved oxygen (Mazuranich and Nielson 1959). White Spot Disease has been observed in winter-run Chinook salmon in the Sacramento River (Foott 2016); however, not with high frequency and this disease appears to be more often observed at hatcheries than in rivers.

Predation risk stressors are not anticipated to change. In systems outside the Central Valley, salmon eggs consist of a large portion of the diet of juvenile steelhead, coho salmon, and brook and brown trout (Johnson and Ringler 1979). The metabolism of these predators is driven by water temperatures like other ectothermic animals, and thus predation rates or predator activity are likely positively correlated with temperature. Predator abundance and distribution is not anticipated to change due to operations. Temperature stressors are expected to decrease during this life stage (see water temperature stressor, Appendix D). Specifically, releases of Shasta Reservoir storage may result in 10°F cooler water temperature than other scenarios because the Proposed Action releases water during the summer cooling water temperatures.

Sedimentation and gravel quantity stressors may decrease. This decrease is likely insignificant. Release of Shasta Reservoir storage maintains flows in the summer. Egg and alevin emergence is affected by sedimentation and gravel quantity. Increased flows may remove fine sediment, improving egg and alevin essential functions and development (Bennett et al. 2003). Appendix O presents an analysis of this stressor.

Redd quality stressors may decrease. The decrease is likely beneficial. Release of Shasta Reservoir storage maintains flows in the summer. Egg and alevin emergence is affected by gravel size and interstitial flow. Increased flow may improve hydrologic and biological connectivity within the streambed that improve egg survival and alevin emergence. Appendix O presents an analysis of this stressor.

2.2.1.3.3 Juveniles

Juveniles are rearing and outmigrating in the Sacramento River. The amount of time spent rearing in the upper Sacramento River varies before juveniles migrate into the middle Sacramento River. This habitat is primarily used for rearing and as a migration corridor to the Bay-Delta. Time spent within the Sacramento River and the size distribution of fish both entering and exiting this reach vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and juvenile condition (some affecting several parameters) during the migration.

Toxicity and contaminants stressors may increase. The increase is likely insignificant. Releases of Shasta Reservoir storage may increase flows Increased flows and pulses can mobilize suspended sediments consisting of contaminants in river systems (van Vliet et al. 2023). Water quality monitoring has not shown contaminants at levels likely to affect juvenile growth, condition, or survival and toxicity and contaminant effects have not been observed in fish monitoring. Additionally, tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010)

Stranding risk stressors may increase. Releases of Shasta Reservoir storage may increase flows and the increase in the stressor may reduce connectivity, causing stress and mortality of winter-run Chinook salmon. Fish monitoring during early summer rarely find rearing juvenile winter-run Chinook salmon because they don’t begin to emerge until after mid-July (Memeo et al. 2018; Memeo et al. 2019; Smith et al. 2020). Flows in late summer under the Proposed Action are expected to decline more rapidly and potentially increase stranding risk stressors. Juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Appendix H, *Conservation Measure Deconstruction*, presents an analysis of this stressor.

Outmigration cues stressors are not anticipated to change. Increased releases from Shasta Dam during the summer are less than the outmigration cues from the Sacramento River (Del Rosario et al. 2013; Appendix B, Section 3.1, *Water Operations*). Outmigration cues is 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.

Water temperature may decrease. This decrease is likely beneficial. Releases of Shasta Reservoir storage may increase flows. Seasonal operations result in warmer temperatures than 56°F at Red Bluff Diversion Dam but are cooler than other scenarios because the Proposed Action releases water during the summer cooling water temperatures. (Appendix B, Figure 13). The acceptable range of water temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (McCullough 1999). Appendix L presents an analysis of this stressor.

Dissolved Oxygen stressors may decrease. The decrease is insignificant. Releases of Shasta Reservoir storage may result in cooler water temperatures that may provide a higher dissolved oxygen saturation potential. Historical water quality monitoring has not shown summer dissolved oxygen at levels below 7.0 mg/l, which is when juvenile Chinook salmon swimming performance declines (Davis et al. 1963).

Pathogens and disease stressors may decrease. This decrease is likely insignificant. Releases of Shasta Reservoir storage may result in cooler water temperatures in the summer; and modeled summer water temperatures associated with the Proposed Action (Appendix B, Figure 13) are approximately 57°F to 60°F**.** These temperatures are colder than those that increase juvenile susceptibility to pathogen stressors. Water temperatures greater than 59.9°F result in highly virulent diseases affecting Chinook salmon (McCullough 1999). The influence of the operation of the CVP and SWP on water temperatures potentially influences pathogens; however, effects of pathogens and disease have not been observed in fish monitoring.

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108) (See Appendix A).

Refuge habitat stressors may increase. Releases of Shasta Reservoir storage may increase flows and this increase in the stressor may reduce suitable margin and off-channel habitats for juvenile winter-run Chinook salmon. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for winter-run Chinook salmon in the summer in the Sacramento River is plotted in Section 3.3 of Appendix B. Appendix O presents an analysis of this stressor.

Food availability and quality stressors may increase. Releases of Shasta Reservoir storage may increase flows and the increase in the stressor may result in a change of food web processes and a decrease in quality food available to juvenile winter-run Chinook salmon. Greater food availability may improve the growth and survival of juveniles. 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). Appendix O presents an analysis of this stressor.

Predation and competition stressors may increase or decrease. The increase or decrease are likely insignificant. Releases of Shasta Reservoir storage may increase flows and change water temperatures and the increase of the stressor may result in increased predation. Predation of winter-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of winter-run Chinook salmon. Predation, in this context, is identified at the Delta fish collection facilities and Bay-Delta “hotspots”. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), entrainment risk, and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors using lines of evidence which incorporate indirect predation impacts on salmonids.

2.2.1.4 Fall

In the fall, the Proposed Action will increase flows on average in the Sacramento River below Keswick Dam between September and November. Changes in flows in the upper Sacramento River may affect stressors on winter-run Chinook salmon.

2.2.1.4.1 Adults

Adults are not present in the Sacramento River in the fall.

2.2.1.4.2 Eggs

Eggs are incubating and alevin are emerging in the Sacramento River in October and November. Egg and alevin survival is dependent on a few habitat attributes. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity and contaminants stressors may decrease. The decrease is likely insignificant. Releases of Shasta Reservoir storage may increase flows and dilute contaminants. However, increased flows and pulses can mobilize suspended sediments consisting of contaminants in river systems (van Vliet et al. 2023).Water quality monitoring has not shown contaminants at levels likely to affect eggs and toxicity and contaminant 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.

Stranding and dewatering stressors may increase. Releases of Shasta Reservoir storage may increase flows and the stressor increase may result in dewatering spawning habitat and desiccating eggs, as observed in redd monitoring. Although average flows associated with the Proposed Action are higher than under other operational scenarios and release of Shasta Reservoir storage maintains flows in the fall, historical redd monitoring observed dewatered winter-run Chinook salmon redds that may be due to variation in monthly flow. Appendix L presents an analysis of this stressor.

Water temperature stressors may decrease or increase. The decrease is likely beneficial. Releases of Shasta Reservoir storage may increase flows. Egg mortality occurs at temperatures above 56°F (McCollough 1999). Although seasonal operations may result in warmer temperatures than 56°F at Red Bluff Diversion Dam in early Fall, these water temperatures under the Proposed Action are approximately 10°F cooler than other modeled operational scenarios and temperature conditions upstream of Red Bluff Diversion Dam will likely be cooler than temperatures measured at Red Bluff Diversion Dam. However, certain temperature management actions may increase this stressor for some individuals. Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely insignificant. Releases of Shasta Reservoir storage may increase flows. Chinook salmon egg and alevin survival decreases when dissolved oxygen is less than 5.5 mg/l (Del Rio et al. 2019), however historical water quality monitoring has not shown fall dissolved oxygen at levels below 5.5 mg/l (CDFW 2014 – 2017 Stressor Monitoring Report, Statewide Drought Response). In addition, releases of Shasta Reservoir storage may result in cooler water temperatures that may provide a higher dissolved oxygen saturation potential.

Pathogens stressors may decrease. The decrease is likely insignificant. Releases of Shasta Reservoir storage may increase flows. On average, fall flows are higher under the Proposed Action than other modeled operational scenarios, which may reduce horizontal transmission due to reduced crowding. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Increased water temperatures have been hypothesized to be one of the factors that contributes to coagulated-yolk disease, or white-spot disease, in both eggs and fry along with other environmental conditions like gas supersaturation and low dissolved oxygen (Mazuranich and Nielson 1959). White Spot Disease has been observed in winter-run Chinook salmon in the Sacramento River (Foott 2016); however, not with high frequency, and this disease appears to be more often observed at hatcheries than in rivers.

Sedimentation and gravel quantity stressors may decrease. This decrease is likely insignificant. Releases of Shasta Reservoir storage may increase flows. Egg and alevin emergence is affected by sedimentation and gravel quantity. Increased flows may remove fine sediment and maintain egg and alevin essential functions and development (Bennett et al. 2003). Appendix O presents an analysis of this stressor.

Redd quality stressors may decrease. The decrease is likely beneficial. Releases of Shasta Reservoir storage may increase flows. Egg and alevin emergence is affected by gravel size and interstitial flow. Increased flow may improve hydrologic and biological connectivity within the streambed that improves egg survival and alevin emergence. Appendix O presents an analysis of this stressor.

Predation risk stressors are not anticipated to change. In systems outside the Central Valley, salmon eggs consist of a large portion of the diet of juvenile steelhead, coho salmon, and brook and brown trout (Johnson and Ringler 1979). The metabolism of these predators is driven by water temperatures like other ectothermic animals, and thus predation rates or predator activity are likely positively correlated with temperature. Predator abundance and distribution is not anticipated to change due to operations. Temperature stressors are expected to decrease during this life stage (see water temperature stressor, Appendix D). Specifically, releases of Shasta Reservoir storage associated with the Proposed Action may result in 10°F cooler water temperature relative to other modeled operational scenarios.

2.2.1.4.3 Juveniles

Juveniles are rearing and outmigrating in the middle Sacramento River. The amount of time spent rearing in the upper Sacramento River varies before juveniles migrate into the middle Sacramento River. This habitat is primarily used for rearing and as a through-way to the Bay-Delta. Time spent within and size distribution both entering and exiting the middle Sacramento River vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and juvenile condition (some affecting several parameters) during the migration.

Toxicity and contaminants stressors may increase. The increase is likely insignificant. Releases of Shasta Reservoir storage may increase flows. Increased flows and pulses can mobilize suspended sediments consisting of contaminants in river systems (van Vliet et al. 2023). Water quality monitoring has not shown contaminants at levels likely to affect juvenile growth, condition, or survival and toxicity and contaminants effects have not been observed in fish monitoring. Although operations are not anticipated to increase toxicity and contaminants, weather-driven flooding may result in increased contaminant concentrations in fish tissue. For example, methylmercury tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may increase. Releases of Shasta Reservoir storage may increase flows. The increase in the stressor may reduce connectivity, causing stress and mortality of winter-run Chinook salmon, as observed in historical fish monitoring. Juveniles can become stranded in habitats disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Although average flows are higher under the Proposed Action than other modeled operational scenarios, and release of Shasta Reservoir Storage maintains flows in the fall, historical fish monitoring observed stranded juvenile winter-run Chinook salmon that may be due to variation in monthly flow. Appendix L presents an analysis of this stressor.

Outmigration cues stressors are not anticipated to change. Winter-run Chinook salmon outmigration cues into the lower Sacramento River increases to more than 5% at the Knights

Landing fish monitoring site with daily Wilkins Slough flows of 14,126 cfs (400cms, Del Rosario et al. 2013). Although flows are increasing during this period, average flows are not expected to exceed the 14,126 cfs threshold causing outmigration cues. Outmigration cues is 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. Appendix J presents an analysis of this stressor.

Water temperature stressors may decrease. This decrease is likely beneficial. Releases of Shasta Reservoir storage may increase flows. The Proposed Action results in warmer temperatures than 56°F at Red Bluff Diversion Dam but these temperatures are still cooler than other modeled operational scenarios (Appendix B, Figure 13). The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (McCullough 1999). Appendix L presents an analysis of this stressor.

Dissolved Oxygen stressors may decrease. The decrease is likely insignificant. Releases of Shasta Reservoir storage may result in cooler water temperatures that may provide a higher dissolved oxygen saturation potential. Historical water quality monitoring has not shown fall dissolved oxygen at levels below 7.0 mg/l. Juvenile Chinook salmon swimming performance declines at DO less than 7 mg O_2/l at a temperature at and below 67.1°F (Davis et al. 1963).

Pathogens and disease stressors may decrease. The decrease is likely insignificant. During the juvenile rearing and outmigration period, releases of Shasta Reservoir storage may result in cooler water temperatures and higher flows in the Sacramento River while operations will decrease flows in the Delta. The influence of the operation of the CVP and SWP on water temperatures potentially influences pathogens; however, effects of pathogens and disease have not been observed in fish monitoring.

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108).

Refuge habitat stressors may increase. Releases of Shasta Reservoir storage may increase flows and the increase of the stressor may reduce suitable margin and off-channel habitats for juvenile winter-run Chinook salmon. An increase in flows may increase access to high quality refuge habitat. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for winter-run Chinook salmon in the fall in the Sacramento River is plotted in Appendix B, Section 3.3. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may decrease. The decrease is likely insignificant. Releases of Shasta Reservoir storage may increase flows which may result in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of juveniles. 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). Appendix O presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely insignificant. Releases of Shasta Reservoir storage may increase flows and change water temperatures and the increase of the stressor may result in increased predation. Predation of winter-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of winter-run Chinook salmon**.** Predation, in this context, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), entrainment risk, and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors using lines of evidence which incorporate indirect predation impacts on salmonids.

2.2.2 Bay-Delta

2.2.2.1 Winter

In the winter, the Proposed Action will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on winter-run Chinook salmon.

2.2.2.1.1 Adults

Adults are migrating in the Delta. Adults are undergoing an energetically taxing salt-to-freshwater transition to spawn. Several stressors have been identified to possibly delay adult migration, decrease adult survival during migration, or increase energy necessary to undergo the transition.

In-river fishery and poaching stressors are not anticipated to change. Chinook salmon fishing is not allowed in the Delta during the winter. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely insignificant. The Proposed Action decreases Delta inflow and outflow, thereby potentially concentrating contaminant constituents. The timing of snowmelt may also play a role in this stressor though studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017, Chen et al. 2018).During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. A 0.2 mg/kg threshold for methylmercury is protective of both juvenile and adult fish (Beckvar et al. 2005). Water quality monitoring has not shown contaminants at levels likely to affect adult salmon and toxicity effects have not been observed in fish monitoring. Levels safe for human consumption are assumed not likely to impact fish health and (Murphy et al. 2022) identifies Chinook salmon as safe to eat.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented by the various fishery technical teams in the Bay-Delta.

Water temperature stressors are not anticipated to change. The Proposed Action decreases Delta inflow and outflow. Although Delta water temperature is positively correlated with Delta inflow in the winter (Bashevkin and Mahardja 2022) and CVP and SWP storage and diversion decreases Delta inflow and outflow, Bay-Delta water temperature is mainly driven by air temperature, solar radiation, and meteorology (Vroom et al. 2017, Daniels and Danner 2020). Moreover, it is unlikely that flow alterations from Keswick will influence water temperature in the lower Sacramento River and north Delta (Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures measured at Prisoners Point rarely exceed 56°F in the winter.

Dissolved oxygen stressors are not anticipated to change. The Proposed Action decreases Delta inflow and outflow. Dissolved oxygen less than 5.0mg/L may affect migration (Carter 2005). However, water quality monitoring has not shown dissolved oxygen at levels below this in the winter.

Pathogens stressors are not anticipated to change. The Proposed Action decreases Delta inflow and outflow and may increase water temperatures. Water temperatures above 59.9°F result in highly virulent diseases affecting Chinook salmon. (McCullough 1999). However, water quality monitoring has not shown water temperatures greater than this in the winter.

2.2.2.1.2 Eggs and Alevin

Eggs are not present in the Delta.

2.2.2.1.3 Juveniles

Juveniles are migrating, foraging, and sheltering in the Delta. Juvenile use of the Bay-Delta varies both within and among years. During the winter months, some early migrants can leave the Delta, though migration can occur through May. A large storm pulse during the winter may cue juveniles rearing in the middle Sacramento River to migrate into the Bay-Delta, but in years without a storm pulse or pulses, juveniles historically migrate in a single pulse during late winter. Several stressors have been identified to possibly affect survival, residence time and migration, and physical condition. Habitat attributes may have compounding effects; it is important to not consider a single stressor alone.

Toxicity and contaminants stressors may increase. The increase is likely insignificant. Exposure to contaminants can lead to reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). The Proposed Action decreases Delta inflow and outflow concentrating constituents. The timing of snowmelt may also play a role in this stressor though studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017, Chen et al. 2018). Historical fisheries monitoring has not reported large-scale evidence of toxicity and contaminants in Bay-Delta fishes. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005).

Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors are not anticipated to change from decreased Delta inflow and outflow. Juvenile stranding has not been observed during fish monitoring in the Bay-Delta.

Outmigration cues stressors may increase. The Proposed Action decreases Delta inflow and outflow and this increase in the stressor may mask the cue to migrate and increase travel time in the Delta, which may reduce outmigration survival. Outmigration cues is 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. Appendix I presents analysis on this stressor.

Water temperature stressors are not anticipated to change. Although Delta water temperature is positively correlated with Delta inflow in the winter (Bashevkin and Mahardja 2022) and CVP and SWP storage and diversion decreases Delta inflow and outflow, Bay-Delta water temperature is mainly driven by air temperature, solar radiation, and meteorology (Vroom et al. 2017, Daniels and Danner 2020). Moreover, it is unlikely that flow alterations from Keswick will influence water temperature in the lower Sacramento River and north Delta (Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures measured at Prisoners Point do not exceed suitable temperatures in the winter (60°F; EPA 2001).

Dissolved Oxygen are not anticipated to change. The Proposed Action decreases Delta inflow and outflow. Dissolved oxygen less than 5.0mg/L may affect migration (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below 5.0 mg/Lin the winter.

Pathogens and disease stressors are not anticipated to change. The Proposed Action decreases Delta inflow and outflow. Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Water quality monitoring has not shown water temperatures greater than 59.9F in the winter.

Entrainment risk stressors may increase. The Proposed Action decreases Delta inflow and outflow and the increase in the stressor may result in higher levels of entrainment and loss of juvenile winter-run Chinook salmon. The Proposed Action will result in entrainment at the Skinner and Tracy fish facilities. Entrainment is defined in two ways: (1) fish routed through specific migratory pathways in the Delta (Delta route-specific travel time and survival); and (2) fish encountering CVP facilities where they may be pulled into diversions or the export facilities. In both definitions of entrainment risk, outmigrating juveniles may be exposed to predation in different locations within the Delta. Appendix I presents the analysis on this stressor.

Refuge habitat stressors are not anticipated to change. All juveniles outmigrating from the Sacramento River must pass through the Delta on the way to the Pacific Ocean. The Delta is tidally influenced. As such, the effect of Proposed Action storage of water on available shallow-water refuge habitat would be within the daily tidal range near the seaward end of the Delta. Tidal influence dissipated toward the landward edges of the Delta and effects of Proposed Action storage of water would be more similar to that described for the mainstem Sacramento River above. In the Delta, winter-run Chinook salmon utilize side channel and inundated floodplain habitat in the tidal shoreline of the Delta for foraging and growth. The tidal habitat of the Delta also serves the critical role as a physiological transition zone before saltwater entry, with juveniles residing in the Delta for an average of three months (del Rosario et al. 2013). However, only a small fraction of the wetland rearing habitat is still accessible to fish, and much of the modern Delta and bays have been converted to serve agriculture and human population growth (SFEI-ASC 2014). The loss of tidal marshes and historical floodplain wetlands have resulted in a loss of refuge habitat for winter-run Chinook salmon. In addition, there are 200 miles of exterior levees in Suisun Marsh, twenty of those miles are along Suisun, Grizzly, and Honker Bays (SMP 2013). Levee construction involves the removal and loss of riparian vegetation (Anderson and Sedell 1979; Pusey and Arthington 2003). There is no known relationship between flows and refuge habitat availability similar to those for the Sacramento River (Gard 2005), inter-annual variation in flows at Freeport during the rearing and outmigration period is greater than at Keswick; thus, flow-dependent refuge habitat is likely limiting less often in the Delta than in the Sacramento River. Suitable habitat for winter-run Chinook salmon in the winter in the Bay Delta is plotted in Appendix B, Section 8.3, *Suitable Habitat*). Appendix P, *Delta Habitat*, defines refuge habitat and presents analyzes on this stressor.

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

Appendix P presents analyzes on this stressor.

Predation and competition stressors may increase. The increase is likely insignificant. The Proposed Action will reduce flow and warm temperatures and the increase of the stressor may result in increased predation. Predation of winter-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of winter-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in juvenile winter-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), entrainment risk, and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix I presents analysis of these stressors using lines of evidence which incorporate indirect predation impacts on salmonids.

2.2.2.2 Spring

In the spring, the Proposed Action will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on winter-run Chinook salmon.

2.2.2.2.1 Adults

Adults are migrating in the Delta. Adults move through the Bay-Delta into reaches of the middle and upper Sacramento River, where they hold until ready for spawning. This life-history strategy may leave adults vulnerable to multiple factors that affect survival, timing, and distribution. Additionally, adult body condition upon return to spawning areas can influence effects of stressors on pre-spawn mortality or fecundity. Several stressors have been identified for habitat attributes that affect spawning and holding.

In-river fishery and poaching stressors are not anticipated to change. There is no Chinook salmon fishing permitted in the Delta in the spring. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely insignificant. The Proposed Action decreases Delta inflow and outflow, thereby potentially concentrating contaminant constituents. The timing of snowmelt may also play a role in this stressor though studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017, Chen et al. 2018).During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. A 0.2 mg/kg threshold for methylmercury is protective of both juvenile and adult fish (Beckvar et al. 2005). Water quality monitoring has not shown contaminants at levels likely to affect adult salmon and toxicity effects have not been observed in fish monitoring. Levels safe for human consumption are assumed not likely to impact fish health and (Murphy et al. 2022) identifies Chinook salmon as safe to eat.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented by the various fishery technical teams in the Bay-Delta.

Water temperature stressors may increase. The increase is likely insignificant. The Proposed Action decreases Delta inflow and outflow. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022). Reservoir operations may influence water temperature to a minimal extent in the lower reaches of the Sacramento River (Daniels and Danner 2020). The historical record of temperatures in the Delta at Prisoner's Point shows water temperatures greater than 68°F within the Delta in May. There is uncertainty about whether the decreased inflow from reservoir operations is a cause for increased Delta water temperatures. The range of potential reservoir operations is unlikely to have a measurable effect on Delta water temperatures. 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). 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.

Dissolved oxygen stressors are not anticipated to change. Dissolved oxygen less than 5.0mg/L may affect migration (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below this in the spring.

Pathogens stressors may increase. This increase is likely insignificant. The Proposed Action decreases Delta inflow and outflow and may increase water temperatures. Water temperatures greater than 59.9°F do occur in the spring, and this is the threshold when diseases affecting Chinook salmon become highly virulent (McCullough 1999). On average, Prisoner Point water temperature has been lower than 59.9°F in early spring, but higher in late spring (Appendix B, Section 8.2, *Water Temperatures and Dissolved Oxygen*). There is uncertainty about whether the decreased spring outflow is a cause for changes in Delta water temperatures. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin et al. 2022); however, this relationship is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature and meteorology (Vroom et al. 2017). Decreased spring flow outside of flood control is unlikely to influence Delta water temperatures.

2.2.2.2.2 Eggs and Alevin

Eggs and alevin are not present in the Delta.

2.2.2.2.3 Juveniles

Juveniles rear and migrate in the Delta. Juvenile use of the Bay-Delta varies both within and among years. During the spring months, some early migrants can leave the Delta, though migration can occur through May. A large storm pulse during the winter may cue juveniles rearing in the middle Sacramento River to migrate into the Bay-Delta, with a second pulse between February and March. The majority of the population is present within the Bay-Delta during the spring. Several stressors have been identified to possibly affect survival, residence time and migration, and physical condition. Habitat attributes may have compounding effects; it is important to not consider a single stressor alone.

Toxicity and contaminants stressors may increase. The increase is likely insignificant. The Proposed Action decreases Delta inflow and outflow concentrating constituents. The timing of snowmelt may also play a role in this stressor though studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017, Chen et al. 2018). Exposure to contaminants can lead to reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). Moreover, historical fisheries monitoring has not reported large-scale evidence of toxicity and contaminants in Bay-Delta fishes.

Stranding risk stressors are not anticipated to change from decreased Delta inflow and outflow. Juvenile stranding has not been observed in fish monitoring in the Bay-Delta.

Outmigration cues stressors may increase. The Proposed Action decreases Delta inflow and outflow and this increase in the stressor may mask the cue to migrate and increase travel time in the Delta, which may reduce outmigration survival. Outmigration cues is 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. Appendix I presents analysis on this stressor.

Water temperature stressor may increase. The increase is likely insignificant. The Proposed Action decreases Delta inflow and outflow. Although Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022) and CVP and SWP storage and diversion decreases Delta inflow and outflow, Bay-Delta water temperature is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature, solar radiation, and meteorology (Vroom et al. 2017, Daniels and Danner 2020). Moreover, it is unlikely that flow alterations from Keswick will influence water temperature in the lower Sacramento River and north Delta (Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures measured at Prisoners Point rarely exceed suitable temperatures in the spring (60°F; EPA 2001).

Dissolved Oxygen stressors are not anticipated to change. The Proposed Action decreases Delta inflow and outflow. Dissolved oxygen less than 5.0mg/L may affect migration (Carter 2005). However, water quality monitoring has not shown dissolved oxygen at levels below 5.0 mg/L in the spring.

Pathogens and disease stressors may increase. This increase is likely insignificant. The Proposed Action decreases Delta inflow and outflow. Water temperatures greater than 59.9°F are reported to promote conditions in where diseases affecting Chinook salmon become highly virulent (McCullough 1999). On average, Prisoner Point water temperatures have been lower than 59.9°F occur in March, but higher in April and May (Appendix B, Section 8.2). There is uncertainty about whether the decreased spring outflow is a cause for changes in Delta water temperatures. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin et al. 2022); however, this relationship is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature and meteorology (Vroom et al. 2017).

Entrainment risk stressors may increase. The Proposed Action decreases Delta inflow and outflow and the increase in the stressor may result in higher levels of entrainment and loss of juvenile winter-run Chinook salmon. CVP and SWP storage and diversions result in entrainment at the Skinner and Tracy fish facilities. Entrainment is defined in two ways: (1) fish routed through specific migratory pathways in the Delta (Delta route-specific travel time and survival); and (2) fish encountering CVP facilities where they may be pulled into diversions or the export facilities. In both definitions of entrainment risk, outmigrating juveniles may be exposed to predation in different locations within the Delta. Appendix I presents the analysis on this stressor.

Refuge habitat stressors are not anticipated to change. All juveniles outmigrating from the Sacramento River must pass through the Delta on the way to the Pacific Ocean. The Delta is tidally influenced. As such, the effect of Proposed Action storage of water on available shallow-water refuge habitat would be within the daily tidal range near the seaward end of the Delta. Tidal influence dissipated toward the landward edges of the Delta and effects of Proposed Action storage of water would be more similar to that described for the mainstem Sacramento River above. In the Delta, winter-run Chinook salmon utilize side channel and inundated floodplain habitat in the tidal shoreline of the Delta for foraging and growth. The tidal habitat of the Delta also serves the critical role as a physiological transition zone before saltwater entry, with juveniles residing in the Delta for an average of three months (del Rosario et al. 2013). However, only a small fraction of the wetland rearing habitat is still accessible to fish, and much of the modern Delta and bays have been converted to serve agriculture and human population growth (SFEI-ASC 2014). The loss of tidal marshes and historical floodplain wetlands have resulted in a loss of refuge habitat for winter-run Chinook salmon. In addition, there are 200 miles of exterior levees in Suisun Marsh, twenty of those miles are along Suisun, Grizzly, and Honker Bays (SMP 2013). Levee construction involves the removal and loss of riparian vegetation (Anderson and Sedell 1979; Pusey and Arthington 2003). There is no known relationship between flows and refuge habitat availability similar to those for the Sacramento River (Gard 2005), inter-annual variation in flows at Freeport during the rearing and outmigration period is greater than at Keswick; thus, flow-dependent refuge habitat is likely limiting less often in the Delta than in the Sacramento River. Suitable habitat for winter-run Chinook salmon in the winter in the Bay Delta is plotted in Section 8.3 of Appendix B). Appendix P defines refuge habitat and presents analyzes on this stressor.

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

Predation and competition stressors may increase. The increase is likely insignificant. The Proposed Action will reduce flow and warm temperatures and the increase of the stressor may result in increased predation. Predation, in this context, is identified at the Delta fish collection facilities and Bay-Delta “hotspots”. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), entrainment risk, and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix I presents analysis of these stressors using lines of evidence which incorporate indirect predation impacts on salmonids.

2.2.2.3 Summer

In the summer, the Proposed Action will decrease Delta outflow on average through CVP and SWP diversions.

2.2.2.3.1 Adults

Adults are not present in the Delta in the summer.

2.2.2.3.2 Eggs and Alevin

Eggs are not present in the Delta.

2.2.2.3.3 Juveniles

Juveniles are not present in the Delta in the summer.

2.2.2.4 Fall

In the fall, the Proposed Action will decrease Delta outflow on average through CVP and SWP diversions. Decreased outflow in the Bay-Delta may change stressors on winter-run Chinook salmon.

2.2.2.4.1 Adults

Adults are not present in the Delta.

2.2.2.4.2 Eggs and Alevin

Eggs are not present in the Delta.

2.2.2.4.3 Juveniles

Juveniles are rearing and outmigrating from the Sacramento River to the Delta. Juvenile use of the Bay-Delta varies both within and among years. The historic distribution of juveniles present in the Bay-Delta in the fall is low. Several stressors have been identified to possibly affect survival, residence time and migration, and condition.

Toxicity and contaminants stressors may increase. The increase is likely insignificant. The Proposed Action decreases Delta inflow and outflow concentrating constituents. The timing of snowmelt may also play a role in this stressor though studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017, Chen et al.

2018). Exposure can lead to reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). Historical fisheries monitoring has not reported large-scale evidence of toxicity and contaminants in Bay-Delta fishes. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors are not anticipated to change from decreased Delta inflow and outflow associated with the Proposed Action. Juvenile stranding has not been observed during fish monitoring in the Bay-Delta

Outmigration cues stressors may increase. The Proposed Action decreases Delta inflow and outflow and this increase in the stressor may mask the cue to migrate and increase travel time in the Delta, which may reduce outmigration survival. Outmigration cues is 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. Appendix I presents analysis on this stressor.

Water temperature stressor may increase or decrease. The increase or decrease is likely discountable. CVP and SWP storage and diversion associated with the Proposed Action decreases Delta outflow in the fall. Delta water temperature is negatively correlated with Delta inflow in the fall (Bashevkin et al. 2022); however, this relationship is mainly driven by air temperature and meteorology (Vroom et al. 2017) and therefore, the Proposed Action is unlikely to significantly influence water temperatures in the Delta.

Dissolved Oxygen stressors are not anticipated to change. The Proposed Action decreases Delta inflow and outflow. Dissolved oxygen less than 5.0mg/L may affect migration (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below 5.0 mg/L in the fall.

Pathogens and disease stressors may increase. This increase is likely insignificant. The Proposed Action decreases Delta inflow and outflow. Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Though a decrease in flows may influence pathogen and disease exposure, including increased transfer from hatchery fish to natural-origin juveniles; transmission directionality is difficult to track and evidence of transfer is lacking (Naish et al. 2007; Kent 2013; Nekouei et al. 2019). McCollough (1999) reported a 59.9°F water temperature threshold as the threshold above which diseases affecting Chinook salmon become highly virulent. Water temperatures greater than 59.9°F occur during the fall (Appendix B, Section 8.2). Above this threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999). There is uncertainty about whether the decreased outflow is a cause for changes in Delta water temperatures. Delta water temperature is negatively correlated with Delta inflow in the fall (Bashevkin et al. 2022); however, this relationship is mainly driven by air temperature and meteorology (Vroom et al. 2017). Historic water temperatures in the Bay-Delta (Prisoner's Point) during juvenile outmigration exceed 59.9°F. However, the volumes of water required to overcome ambient air temperatures make the operation of the CVP and SWP unlikely to influence water temperatures in the Delta.

Entrainment risk stressors may increase. CVP and SWP storage and diversions associated with the Proposed Action result in entrainment at the Skinner and Tracy fish facilities. The increase may result in higher levels of entrainment and loss of juvenile winter-run Chinook salmon. Entrainment is defined in two ways: (1) fish routed through specific migratory pathways in the Delta (Delta route-specific travel time and survival); and (2) fish encountering CVP facilities where they may be pulled into diversions or the export facilities. In both, outmigrating juveniles may be exposed to predation in different locations within the Delta. Appendix I presents the analysis on this stressor.

Refuge habitat stressors are not anticipated to change. All juveniles outmigrating from the Sacramento River must pass through the Delta on the way to the Pacific Ocean. The Delta is tidally influenced. As such, the effect of Proposed Action storage of water on available shallow-water refuge habitat would be within the daily tidal range near the seaward end of the Delta. Tidal influence dissipated toward the landward edges of the Delta and effects of Proposed Action storage of water would be more similar to that described for the mainstem Sacramento River above. In the Delta, winter-run Chinook salmon utilize side channel and inundated floodplain habitat in the tidal shoreline of the Delta for foraging and growth. The tidal habitat of the Delta also serves the critical role as a physiological transition zone before saltwater entry, with juveniles residing in the Delta for an average of three months (del Rosario et al. 2013). However, only a small fraction of the wetland rearing habitat is still accessible to fish, and much of the modern Delta and bays have been converted to serve agriculture and human population growth (SFEI-ASC 2014). The loss of tidal marshes and historical floodplain wetlands have resulted in a loss of refuge habitat for winter-run Chinook salmon. In addition, there are 200 miles of exterior levees in Suisun Marsh, twenty of those miles are along Suisun, Grizzly, and Honker Bays (SMP 2013). Levee construction involves the removal and loss of riparian vegetation (Anderson and Sedell 1979; Pusey and Arthington 2003). There is no known relationship between flows and refuge habitat availability similar to those for the Sacramento River (Gard 2005), inter-annual variation in flows at Freeport during the rearing and outmigration period is greater than at Keswick; thus, flow-dependent refuge habitat is likely limiting less often in the Delta than in the Sacramento River. Suitable habitat for winter-run Chinook salmon in the winter in the Bay Delta is plotted in Section 8.3 of Appendix B). Appendix P defines refuge habitat and presents analyzes on this stressor.

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

Predation and competition stressors may increase. The increase is likely insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures and the increase of the stressor may result in increased predation. Predation of winter-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of winter-run Chinook salmon, Predation, in this context, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), entrainment risk, and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix I presents analysis of these stressors using lines of evidence which incorporate indirect predation impacts on salmonids.

2.3 Critical Habitat Physical and Biological Features

The critical habitat designation for winter-run Chinook salmon includes: The Sacramento River from Keswick Dam; Shasta County (River Mile 302) to Chipps Island (River Mile 0) at the westward margin of the Sacramento-San Joaquin Delta; all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge.[1]

Within the Sacramento River, the designation includes the river water, river bottom (including those areas and associated gravel used by winter-run Chinook salmon as spawning substrate), and adjacent riparian zone used by fry and juveniles for rearing. Also, in the areas westward from Sherman Island to Chipps Island, it includes Kimball Island, Winter Island, and Browns Island. In the areas westward from Chipps Island, including San Francisco Bay to the Golden Gate Bridge, it includes the estuarine water column and essential foraging habitat and food resources used by winter-run as part of their juvenile outmigration or adult spawning migration. Critical habitat does not include the open ocean habitat used by winter-run because NMFS determined this area does not appear to be in need of special management consideration, and degradation of this portion of the species' habitat, and other factors associated with the open ocean such as commercial and recreational fishing, do not appear to be significant factors in the

[1] NMFS designated critical habitat for Sacramento River winter-run Chinook salmon on June 16, 1993 (58 FR 33212).

decline of the species. NMFS determined existing laws appeared adequate to protect these areas, and special management of this habitat was not considered necessary. The designation does not include any estuarine sloughs within San Francisco Bay or San Pablo Bay. NMFS concluded that proper management of the existing habitat is sufficient to provide for the survival and recovery of this species.

The action area encompasses the entire range-wide riverine and estuarine critical habitat physical and biological features for Sacramento River winter-run Chinook salmon. Physical and biological features that are essential for the conservation of winter-run, based on the best available information, are discussed below.

2.3.1 Adult Passage

Access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River is essential for the conservation of winter-run Chinook salmon.

The species effect determination found related potential stressors of:

- Stranding that may be minimized through a conservation measure of minimum instream flows

There are no additional Proposed Action effects on adult passage when species are not present.

2.3.2 Spawning Substrate

The availability of clean gravel for spawning substrate is essential for the conservation of winter-run Chinook salmon and is necessary for the population to successfully spawn and produce offspring.

The species effect determination found related potential stressors of:

- Spawning habitat quality that may be compensated for and enhanced by the maintenance and construction of spawning habitat

There are no additional operations effects on spawning substrate when species are not present.

2.3.3 Adequate Flows

Adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles are essential for the conservation of winter-run Chinook salmon.

The species effect determination found related potential stressors of:

- Stranding that may be minimized through a conservation measure for ramping rates
- Juvenile outmigration cues that may be minimized through a conservation measure for minimum instream flows
- Pathogens and disease that may be minimized through a conservation measure for minimum instream flows

There are no additional operations effects on adequate flows when species are not present.

2.3.4 Water Temperatures

Water temperatures between 42.5°F and 57.5°F (5.8°C and 14.1°C) for successful spawning, egg incubation, and fry development are essential for the conservation of winter-run.

The species effect determination found related potential stressors of:

- Adult holding that may be minimized or enhanced through a conservation measure for water temperature management
- Egg incubation that may be minimized or enhanced through a conservation measure for water temperature management
- Juvenile rearing that may be minimized or enhanced through a conservation measure for water temperature management

There are no additional operation effects on water temperatures when species are not present.

2.3.5 Uncontaminated Habitat Areas and Prey

Habitat areas and adequate prey that are not contaminated are essential for the conservation of winter-run.

The species effect determination found related potential stressors of:

- Food availability and quality that may be compensated or enhanced through rearing habitat construction

There are no additional operation effects on uncontaminated habitat areas and prey when species are not present.

2.3.6 Juvenile Riparian Habitat

Riparian habitat that provides for successful juvenile development and survival are essential for the conservation of winter-run.

The species effect determination found related potential stressors of:

- Refuge habitat that may be compensated or enhanced through construction of rearing habitat
- Food availability and quality that may be compensated or enhanced through construction of rearing habitat

There are no additional operation effects on juvenile riparian habitat when species are not present.

2.3.7 Juvenile Passage

Access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean.

The species effect determination found related stressors of:

- Entrainment risk that may be minimized or compensated by several conservation measures that may include Delta Cross Channel Gate closures, a Georgiana Slough Barrier, Old and Middle River flow management, and salvage before the export facilities

There are no additional operation effects on juvenile passage when species are not present.

3 Spring-Run Chinook Salmon

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

3.1 Conceptual Lifecycle Models

An action may affect fish when the change in conditions overlap with the location and timing of fish and/or their habitats. The SAIL winter-run Chinook salmon conceptual model (Windell et al. 2017) has been adapted for spring-run Chinook salmon by generalizing to natal tributaries and with the addition of yearling life history diversity to describe life stages and geographic locations for this effects analyses (Figure).

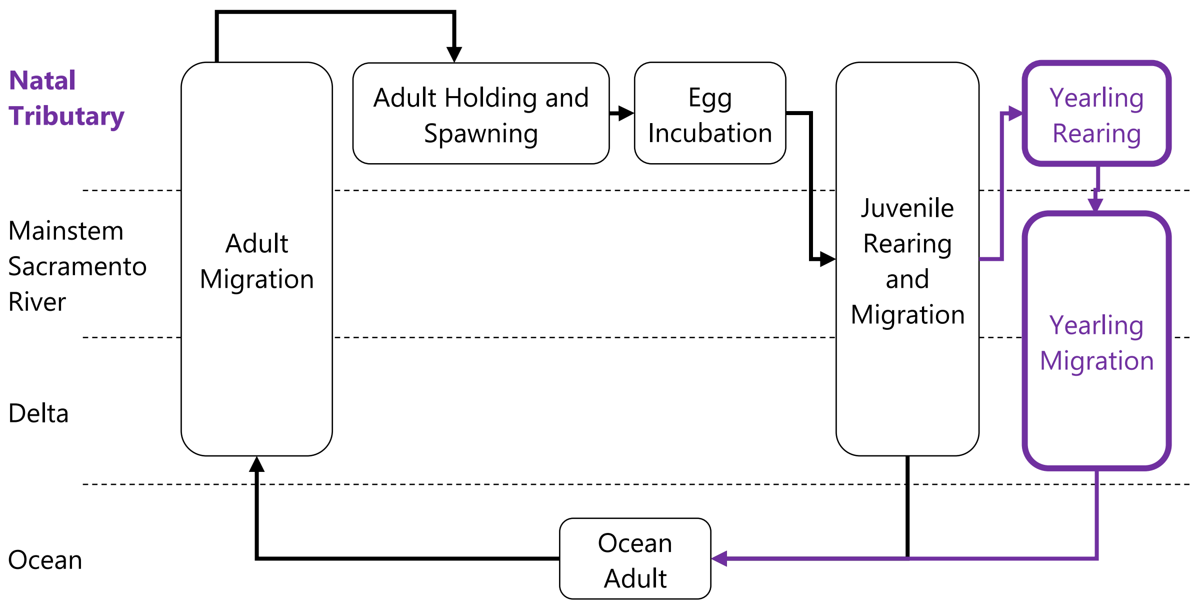

Figure 3. Geographic Life Stage Domains for Spring-Run Chinook Salmon (adapted from Windell et al. 2017, Figure 2)

- In addition to the winter-run Chinook salmon life stages and stressors, the proposed conceptual lifecycle framework for spring-run considers two additional life stages that include stressors from the winter-run Chinook salmon Juvenile Rearing to Outmigration hypotheses:
- Yearling Rearing
    - H1: Toxicity and contaminants
    - H6: Stranding risk
    - H5: Outmigration cues
    - H7: Water temperature and DO
    - H8: Pathogens and disease
    - H9: Entrainment risk
    - H3: Refuge habitat
    - H4: Food availability and quality
    - H2: Predation and competition
- Yearling Migration
    - H1: Toxicity and contaminants

- H6: Stranding risk
- H5: Outmigration cues
- H7: Water temperature and DO
- H8: Pathogens and disease
- H9: Entrainment risk
- H3: Refuge habitat
- H4: Food availability and quality
- H2: Predation and competition

Each deconstruction of the action considers the stressors for the winter-run Chinook salmon life stages and the additional two spring-run Chinook salmon life stages. Additional and/or alternative conceptual models (e.g., CVPIA Science Integration Team, South Delta Salmonid Research Collaborative) may be incorporated as applicable.

Monitoring data from snorkeling, carcass surveys, redd surveys, rotary screw traps, trawls, and beach seines describe the timing of spring-run Chinook salmon presence (Figure 4) (Appendix C).

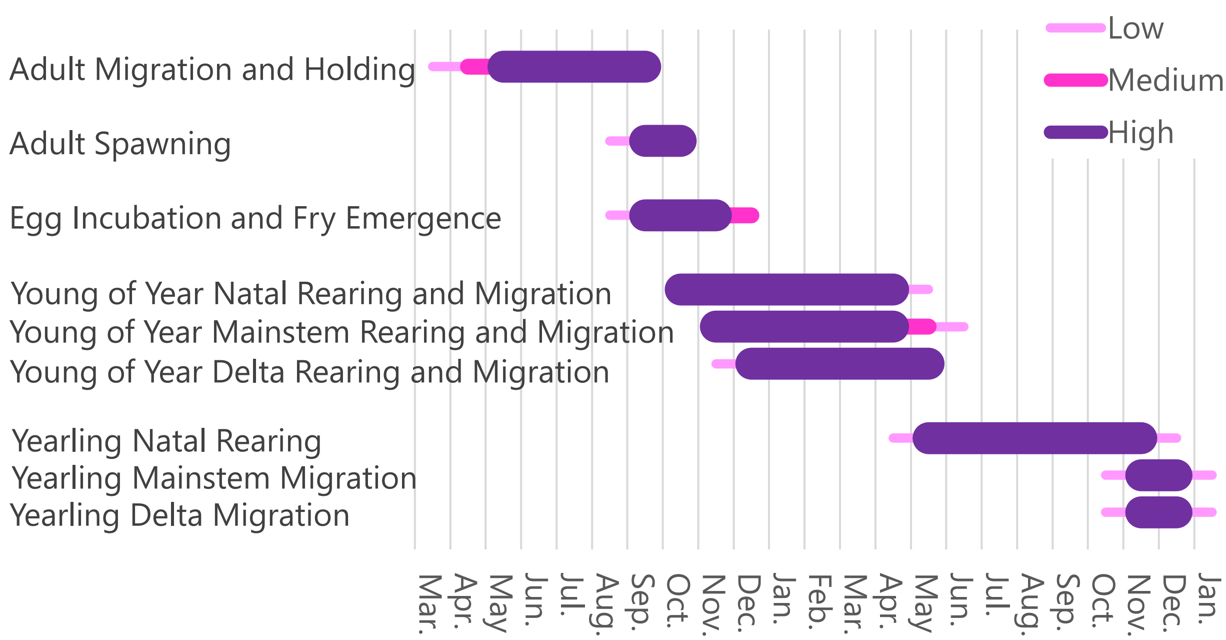

Figure 4. Temporal Life Stage Domains for Spring-Run Chinook Salmon from Appendix C

The three spatial domains defined for spring-run Chinook salmon are the Sacramento River, Clear Creek, and the Bay-Delta Central Valley and Bay-Delta presence for young of year and yearling rearing span more than one year. The ocean life stage is outside the action area determined by NMFS, and therefore is not shown.

3.2 Species Effects Deconstruction

Spring-run Chinook salmon are primarily anticipated in the Sacramento River, Clear Creek, and the Delta, and may experience effects from components of seasonal operations as described below. The Sacramento River includes migrating, holding, and spawning adults; egg incubation below Keswick Dam; and rearing and migrating juveniles and yearlings. Clear Creek includes migrating, holding, and spawning adults; egg incubation; and rearing and migrating juveniles and yearlings. The Bay-Delta includes migrating adults, rearing and migrating juveniles, and migrating yearlings.

3.2.1 Sacramento River

3.2.1.1 Winter

In the winter, the Proposed Action proposed storage of water will decrease flows on average in the Sacramento River below Keswick Dam. Decreased flows in the upper Sacramento River may change stressors on spring-run Chinook salmon.

3.2.1.1.1 Adults

Adults are not present in the upper Sacramento River in the winter.

3.2.1.1.2 Eggs

Eggs are present in the upper Sacramento River in the winter. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity and contaminants stressors may decrease. The decrease is likely insignificant. During the egg incubation and fry emergence period, the Proposed Action will release water increasing flows in the Sacramento River below Keswick Dam and in Clear Creek below Whiskeytown. Water. Water quality monitoring has not shown contaminants at levels likely to affect eggs and contaminant 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.

Stranding and dewatering stressors may increase. The increase is expected to be lethal as during part of the egg incubation and fry emergence period, the Proposed Action will store water from Shasta Reservoir resulting in lower flows on the Sacramento River. High elevation spring-run Chinook salmon redds that are still occupied by incubating eggs may be dewatered. Appendix L presents an analysis of this stressor.

Water temperature stressors may increase or decrease. The proposed release and blending of water from Shasta Dam may increase or decrease the water temperature stressor. Releases are expected to be **beneficial** overall; however, certain temperature management actions may be **lethal** to some individuals. Spring-run Chinook salmon eggs require cool water temperatures to incubate. Appendix L presents an analysis of this stressor.

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

Pathogens and disease stressors may increase or decrease. The increase or decrease is likely insignificant. During the egg incubation and fry emergence period, the Proposed Action will release water and increase flows in the Sacramento River below Keswick Dam and in Clear Creek below Whiskeytown and potentially influence pathogen and disease presence and virulence. Increased water temperatures have been hypothesized to be one of the factors that contributes to coagulated-yolk disease, or white-spot disease, in both eggs and fry along with other environmental conditions like gas supersaturation and low dissolved oxygen (Mazuranich and Nielson 1959). Monitoring in Clear Creek that not shown incidence of White Spot Disease in spring-run Chinook salmon. White Spot Disease has been observed in winter-run Chinook salmon in the Sacramento River (Foott 2016); however, not with high frequency, and not in spring-run Chinook salmon. There has been no evidence of White Spot Disease in the Sacramento River and this disease appears to be more often observed at hatcheries than in rivers.

Sedimentation and gravel quantity stressors may decrease. The decrease is likely discountable and/or insignificant. During the egg incubation and fry emergence period, the Proposed Action will release water and increase flows in the Sacramento River below Keswick Dam. Increased flows may provide environmental conditions favorable to redds and developing embryos. Increased surface flows may reduce sedimentation in the Sacramento River. Build-up of fine sediment can decrease permeability for embryos (Bjornn and Reiser 1991). Gravel quantity is addressed in the “Spawning Habitat” stressor of the “Adult holding and Spawning” section. Appendix O presents an analysis of this stressor.

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

Predation risk stressors are not anticipated to change. Temperature stressors are expected to decrease with the Proposed Action during this life stage (see water temperature stressor, Appendix D). The metabolism of these predators is driven by water temperatures like other ectothermic animals, and thus predation rates or predator activity are likely positively correlated with temperature. Predator abundance and distribution is not anticipated to change due to operations.

3.2.1.1.3 Young-of-Year Juveniles

Juveniles are rearing and migrating in the upper Sacramento River in the winter. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates dependent on an individual's physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity and contaminants stressors may increase. This increase is likely insignificant. Maintenance of Shasta Reservoir storage associated with the Proposed Action may reduce flows concentrating constituents from urban and agricultural land use that affect concentration in juvenile's prey. Contaminants can cause sub-lethal effects, may reduce growth and can suppress juvenile's immune system possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may increase. During the juvenile rearing and outmigration period, reducing flows by reducing releases from Shasta Reservoir under the Proposed Action can trap juveniles in habitat disconnected from the main channel. The increase may reduce connectivity, causing stress and mortality of spring-run Chinook salmon. When flows decrease, juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Alternately, stranding risk stressors may decrease from the dampening of flow fluctuations during precipitation events and would benefit from reduced predation. Appendix L presents an analysis of this stressor.

Outmigration cues stressors may increase. The increase may mask the cue to migrate and increase travel time in upper and middle reaches of the Sacramento River. Storing water in Shasta Reservoir associated with the Proposed Action reduces flow magnitude, that juvenile salmon use as cues to continue migration. Spring-run Chinook salmon use flows for cues to begin and continue migration, and outmigration cues may be changed due to a decrease in flows. Appendix J presents an analysis of this stressor.

Water temperature stressors may increase increase or decrease. The increase or decrease is insignificant. Maintenance of Shasta Reservoir storage associated with the Proposed Action may result in warmer water temperatures in the winter; however, modeled winter water temperatures are colder than juvenile rearing and migration temperature needs (Appendix B, Section 3.2). The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001).

Dissolved oxygen stressors may increase or decrease. The increase or decrease is expected to be insignificant. Reduced releases from Shasta Reservoir will decrease flows in the Sacramento River below Keswick in the winter. Releases of storage may result in cooler water temperatures and higher flows that may provide a higher dissolved oxygen saturation potential and decreased water temperatures while storing water may do the opposite. Observed swimming performance of Chinook salmon juveniles declined at DO less than 7 mg O_2/l at a temperature of 67.1°F but decreased steadily with DO less than saturation (~10 mg O_2/l) at cooler temperatures (Davis et al. 1963). Water quality monitoring has rarely shown dissolved oxygen at levels below 5 mg O_2/l in the winter.

Pathogens and disease stressors may increase. This increase is likely to be discountable Maintenance of Shasta Reservoir storage associated with the Proposed Action may decrease flows and may cause crowding into a smaller habitat area and warmer water temperatures. 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 is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Modeled winter water temperatures (Appendix B, Section 3.2) are colder than this threshold. Also, observed winter temperatures have remained below this threshold and pathogen and disease stressors have not been observed in the winter for juvenile spring-run Chinook salmon.

Entrainment risk stressor may increase. The increase is to be lethal. During the juvenile rearing and outmigration period, the proposed diversion of water associated with the Proposed Action alters hydrodynamic conditions in the Sacramento River. This hydrodynamic alteration may influence fish travel time and migration routing in the Sacramento River mainstem.

Refuge habitat stressors may increase. Maintenance of Shasta Reservoir storage associated with the Proposed Action decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for juveniles. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the winter on the Sacramento River is plotted in Section 3.3 of Appendix B. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. Maintenance of Shasta Reservoir storage associated with the Proposed Action results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix O defines refuge habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. CVP and SWP operations associated with the Proposed Action to store water will reduce flow and warm temperatures. Predation by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon. Predation, in this context, is identified at the Delta fish collection facilities and Bay-Delta “hotspots”. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.1.1.4 Yearling Juveniles

Yearlings are rearing and migrating in the upper Sacramento River. The amount of time spent rearing in the upper Sacramento River varies before yearlings migrate into the middle Sacramento River. This habitat is primarily used for rearing and as a through-way to the Bay-Delta. Time spent within and size distribution both entering and exiting the upper Sacramento River varies among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and condition (some affecting several parameters) during the migration.

Toxicity and contaminants stressors may increase or decrease. The increase or decrease is expected to be insignificant. During the yearling outmigration period, the Proposed Action will release water increasing flows and then store water decreasing flows on the Sacramento River below Keswick Dam. Exposure to contaminants can result in sub-lethal effects such as reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). From historic monitoring efforts, there is no evidence of effects of contaminants on yearlings in the Sacramento River.

Stranding risk stressors may increase or decrease. During the yearling outmigration period, the Proposed Action will store water decreasing flows on the Sacramento River and Delta outflow. Reducing releases and the storage of water reduces flows. Yearlings can become stranded in habitat disconnected from the main channel. The increase may reduce connectivity, causing stress and mortality of spring-run Chinook salmon. When flows decrease, yearlings can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Alternately, stranding risk stressors may decrease from the dampening of flow fluctuations associated with the Proposed Action during precipitation events and would benefit from reduced predation. Appendix L presents an analysis of this stressor.

Outmigration cues stressors may increase. Storing water in Shasta Reservoir associated with the Proposed Action reduces flow magnitude, that yearling salmon use as cues to continue migration. Thus, the Proposed Action may mask the cue to migrate and increase travel time in upper and middle reaches of the Sacramento River. Appendix J presents an analysis of this stressor.

Water temperature stressors may increase or decrease. The increase or decrease is expected to be insignificant. Reduced releases from Shasta Reservoir will decrease flows in the Sacramento River below Keswick and Delta inflow and outflow in the winter and spring. Releases of storage may result in cooler water temperatures and higher flows that may provide a higher dissolved oxygen saturation potential and decreased water temperatures while storing water may do the opposite. The acceptable range of water temperatures for growth of Chinook salmonids gathered from a synthesis of evidence is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001).

Dissolved oxygen stressors may increase or decrease. The increase or decrease is expected to be insignificant. Reduced releases from Shasta Reservoir will decrease flows in the Sacramento River below Keswick and Delta inflow and outflow in the winter and spring. Releases of storage may result in cooler water temperatures and higher flows that may provide a higher dissolved oxygen saturation potential and decreased water temperatures while storing water may do the opposite. The acceptable range of water temperatures for growth of Chinook salmonids gathered from a synthesis of evidence is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001).

Pathogens and disease stressors may decrease or may increase. The increase or decrease is expected to be insignificant. During the yearling outmigration period, the Proposed Action will release water increasing flows and then store water decreasing flows on the Sacramento River below Keswick Dam. A release of water from Shasta Reservoir may result in cooler water temperatures while storage of water may decrease flows resulting in increased water temperatures. Juvenile survival is influenced by specific diseases (e.g., Ceratomyxa shasta, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Reduced releases from Shasta Reservoir will decrease flows in the Sacramento River below Keswick in the winter. A decrease in flows may influence pathogen and disease exposure, including increased transfer from hatchery fish to natural-origin yearlings; however, transmission directionality is difficult to track and evidence of transfer is lacking (Naish et al. 2007; Kent 2011; Nekouei et al. 2019). Yearling survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999).

Entrainment risk stressors may increase. The increase is expected to be lethal. During the juvenile rearing and outmigration period, the proposed diversion of water associated with the Proposed Action alters hydrodynamic conditions in the Sacramento River. This hydrodynamic alteration may influence fish travel time and migration routing in the Sacramento River mainstem.

Refuge habitat stressors may increase. The increase may reduce suitable margin and off-channel habitats for yearling spring-run Chinook salmon. Maintenance of Shasta Reservoir storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for yearlings. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the winter on the Sacramento River is plotted in Section 3.3 of Appendix B. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. The increase may result in a change of food web processes and a decrease in quality food available to yearling spring-run Chinook salmon. Maintenance of Shasta Reservoir storage results in less inundated habitats. 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 yearlings (Jeffres et al. 2008, 2020; Goertler et al. 2018). Appendix O defines refuge habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in spring-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.1.2 Spring

In the spring, Reclamation and DWR's proposed storage of water will decrease flows on average in the Sacramento River below Keswick Dam. Decreased flows in the upper Sacramento River may change stressors on spring-run.

3.2.1.2.1 Adults

Adults are migrating and holding in the upper Sacramento River in the spring. Adults move into the upper watershed where they hold until ready for spawning, undergoing an energetically taxing salt-to-freshwater transition. This life-history strategy may leave adults vulnerable to multiple factors that affect survival, timing, and distribution. Additionally, adult body condition upon return to spawning areas can influence effects of stressors on pre-spawn mortality or fecundity. Several stressors have been identified for habitat attributes that affect spawning and holding.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may decrease or increase. The decrease or increase is likely discountable and/or insignificant. During the adult migration period, the Proposed Action will release water resulting in increased flows in the Sacramento River below Keswick Dam Appendix J presents an analysis of this stressor. Increased flows may dilute contaminants if, and when contaminants are present while decreased inflow may concentrate contaminants. However, increased flows and pulses can mobilize suspended sediments consisting of contaminants in river systems (van Vliet et al. 2023). The timing of snowmelt may also play a role in this stressor though studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017, Chen et al. 2018). Water quality in the Central Valley is regulated by the U.S. Environmental Protection Agency. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below the bankfull flows that would mobilize these contaminants. During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. Monitoring has not shown fish kills that may be indicative of contaminants at levels likely to affect adult salmon. Levels safe for human consumption are assumed not likely to impact fish health and (Murphy et al. 2022) identifies Chinook salmon as safe to eat.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented within various fishery technical teams in the Upper Sacramento River.

Water temperature stressors may decrease. The decrease is likely discountable and/or insignificant. Maintenance of Shasta storage may result in warmer water temperatures in the spring; however, modeled spring water temperatures are colder than adult migration temperature needs (Appendix B, Section 3.2). Evidence suggests that optimal water temperatures between 37.9°F and 60.8°F for Pacific Northwest Chinook salmon migrating and between 42.8°F and 57.2°F for hatchery Chinook salmon holding (Reiser and Bjornn 1979, McCullough 1999). Studies on Pacific Northwest salmon showed migration halting and pre-spawn mortality occurring at temperatures greater than 68°F (Goneia et al. 2006, Bowerman et al. 2018). Shasta Coldwater Pool (Appendix L) analyzes this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/l (Carter 2005). Maintenance of Shasta Storage may result in warmer water temperature and lower dissolved oxygen in March and cooler water temperature and higher dissolved oxygen in May; however, water quality monitoring has not shown dissolved oxygen at levels below this in the spring.

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

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since it does not remove or introduce spring-run Chinook salmon into the population. Additionally, there is no spring-run Chinook salmon hatchery in the upper Sacramento River, so genetic introgression is not a stressor.

3.2.1.2.2 Eggs

Eggs are not present in the upper Sacramento River in the spring.

3.2.1.2.3 Young-of-Year Juveniles

Juveniles are rearing and migrating in the upper Sacramento River in the spring After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates depending on an individual's physiological stage and condition and hydrologic conditions. Historically peak juvenile abundance occurs in the winter; however, migration can occur through May, especially during dry water years. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity and contaminants stressors may increase. This increase is likely discountable and/or insignificant. Maintenance of Shasta Reservoir storage may reduce flows concentrating constituents from urban and agricultural land use that affect concentration in juvenile's prey. Contaminants can cause sub-lethal effects and 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). Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may increase. The increase may reduce connectivity, causing stress and mortality of spring-run Chinook salmon. When flows decrease, juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Alternately, stranding risk stressors may decrease from the dampening of flow fluctuations during precipitation events and would benefit from reduced predation. Appendix L presents an analysis of this stressor.

Outmigration cues stressors may increase. The increase may mask the cue to migrate and increase travel time in upper and middle reaches of the Sacramento River. Storing water in Shasta Reservoir reduces flow magnitude, that juvenile salmon use as cues to continue migration. Spring-run Chinook salmon use flows for cues to begin and continue migration, and outmigration cues may be changed due to a decrease in flows. Appendix J presents an analysis of this stressor.

Water temperature stressors may increase or decrease. The increase or decrease is likely to be insignificant. Reduced releases from Shasta Reservoir will decrease flows in the Sacramento River below Keswick and Delta inflow and outflow in the winter and spring. Releases of storage may result in cooler water temperatures and higher flows that may provide a higher dissolved oxygen saturation potential and decreased water temperatures while storing water may do the opposite. The acceptable range of water temperatures for growth of Chinook salmonids gathered from a synthesis of evidence is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001).

Dissolved oxygen stressors may increase or decrease. The increase or decrease is likely to be insignificant. Reduced releases from Shasta Reservoir will decrease flows in the Sacramento River below Keswick and Delta inflow and outflow in the winter and spring. Releases of storage may result in cooler water temperatures and higher flows that may provide a higher dissolved oxygen saturation potential and decreased water temperatures while storing water may do the opposite. The acceptable range of water temperatures for growth of Chinook salmonids gathered from a synthesis of evidence is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001).

Pathogens and disease stressors may increase. The increase is likely to be discountable and/or insignificant. Reduced releases from Shasta Reservoir will decrease flows in the Sacramento River below Keswick and Delta inflow and outflow in the winter and spring. A decrease in flows may influence pathogen and disease exposure, including increased transfer from hatchery fish to natural-origin juveniles; however, transmission directionality is difficult to track and evidence of transfer is lacking (Naish et al. 2007; Kent 2013; Nekouei et al. 2019). The influence of the operation of the CVP and SWP on water temperatures potentially influences pathogens; however, effects of pathogens and disease have not been observed in fish monitoring.

Entrainment risk stressors may increase. During the juvenile rearing and outmigration period, the proposed diversion of water associated with the Proposed Action alters hydrodynamic conditions in the Sacramento River. This hydrodynamic alteration may influence fish travel time and migration routing in the Sacramento River mainstem.

Refuge habitat stressors may increase. The increase may reduce suitable margin and off-channel habitats for juvenile spring-run Chinook salmon. Maintenance of Shasta Reservoir storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for juveniles. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the spring on the Sacramento River is plotted in Section 3.3 of Appendix B. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. The increase may result in a change of food web processes and a decrease in quality food available to juvenile spring-run Chinook salmon. Maintenance of Shasta Reservoir storage results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix O defines refuge habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in juvenile winter-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.1.2.4 Yearling Juveniles

Yearlings are rearing in the upper Sacramento River in the spring. The amount of time spent rearing in the upper Sacramento River varies before yearlings migrate into the middle Sacramento River. This habitat is primarily used for rearing and as a through-way to the Bay-Delta. Time spent within and size distribution both entering and exiting the upper Sacramento River vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and condition (some affecting several parameters) during the migration.

Toxicity and contaminants stressors may increase or decrease. This increase is likely discountable and/or insignificant. Maintenance of Shasta Reservoir storage may reduce flows concentrating constituents from urban and agricultural land use that affect concentration in yearlings' prey. Contaminants can cause sub-lethal effects and may reduce growth and can suppress yearlings' immune system possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may decrease. Stranding risk stressors may decrease from the dampening of flow fluctuations during precipitation events and would benefit from reduced predation. Appendix L presents an analysis of this stressor.

Outmigration cues stressors may increase. The increase may mask the cue to migrate and increase travel time in upper and middle reaches of the Sacramento River. Storing water in Shasta Reservoir reduces flow magnitude, that yearlings use as cues to continue migration. Spring-run Chinook salmon use flows for cues to begin and continue migration, and outmigration cues may be changed due to a decrease in flows. Appendix J presents an analysis of this stressor.

Water temperature stressors may decrease. The decrease is expected to be beneficial. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring. Spring-run chinook salmon require cool water temperature for optimal growth. Additionally, cooler water temperatures may reduce overall harm to yearlings spending time in Clear Creek before outmigrating through the Sacramento River and the Delta. Appendix L addresses temperature related effects.

Dissolved oxygen stressors may decrease. The decrease is expected to be beneficial. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring. Spring-run chinook salmon require cool water temperature for optimal growth. Additionally, cooler water temperatures may reduce overall harm to yearlings spending time in Clear Creek before outmigrating through the Sacramento River and the Delta. Appendix L addresses temperature related effects.

Pathogens and disease stressors may decrease. The decrease is likely to be discountable and/or insignificant. Releases of water from Shasta Reservoir may result in cooler water temperatures while storage of water may decrease flows resulting in increased water temperatures. Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999).

Entrainment risk stressors may increase. During the yearling outmigration period, the Proposed Action will store water decreasing flows on the Sacramento River. This influences fish travel time and routing migrating in the Sacramento River mainstem.

Refuge habitat stressors may increase. The increase may reduce suitable margin and off-channel habitats for yearling spring-run Chinook salmon. Maintenance of Shasta Reservoir storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for yearlings. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the spring on the Sacramento River is plotted in Section 3.3 of Appendix B. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. The increase may result in a change of food web processes and a decrease in quality food available to yearling spring-run Chinook salmon. Maintenance of Shasta Reservoir storage results in less inundated habitats. 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 yearlings (Jeffres et al. 2008, 2020; Goertler et al. 2018). Appendix O defines refuge habitat and presents an analysis of this stressor.

Predation and competition may increase. The increase is likely to be insignificant and/or discountable. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.1.3 Summer

In the summer, Reclamation and DWR's proposed release of water will increase flows on average in the Sacramento River below Keswick Dam. Increased flows in the upper Sacramento River may change stressors on spring-run.

3.2.1.3.1 Adults

Adults are migrating and holding in the upper Sacramento River. Adults move into the upper watershed where they hold until ready for spawning. This life-history strategy may leave adults vulnerable to multiple factors that affect survival, timing, and distribution. Additionally, adult body condition upon return to spawning areas can influence effects of stressors on pre-spawn mortality or fecundity. Several stressors have been identified for habitat attributes that affect spawning and holding.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity and contaminants may increase or decrease. This decrease is likely discountable and/or insignificant. Releases of Shasta Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmon and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within 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 bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. Levels safe for human consumption are assumed not likely to impact fish health and Murphy et al. (2022) identifies Chinook salmon as safe to eat. Appendix J presents an analysis of this stressor.

Stranding risk stressors are not anticipated to change. Adult spring-run Chinook salmon use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented within various fishery technical teams in the Upper Sacramento River.

Water temperature stressors may decrease. The decrease is likely beneficial. Although seasonal operations may result in warmer temperatures than 56°F at Red Bluff Diversion Dam, these temperatures are approximately 10°F cooler than environmental baseline. Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/l (Carter 2005) and historical water quality monitoring has not shown summer dissolved oxygen at levels below 5.0 mg/l. Releases of Shasta Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogen stressors may decrease. This decrease is likely beneficial. Releases of Shasta Reservoir storage may result in cooler water temperatures in the summer than environmental baseline; and modeled summer water temperatures (Appendix B, Section 3.2) are colder than those that increase adult susceptibility to pathogen stressors. Water temperatures less than 59.9°F occur in the summer, above which temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999). Crowding may be reduced due to increased flows and more holding habitat. Lower densities of holding adults may decrease the potential for lateral transmission of disease.

Spawning habitat stressors may increase. The increase in the stressor may reduce the quantity and quality of spring-run Chinook salmon spawning habitat. Habitat suitability curves show higher flows reduce spawning habitat quality and quantity and there are indications of redd superimposition, where suitable temperatures limit spatial extent. Appendix O presents an analysis of this stressor.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since it does not remove or introduce spring-run Chinook salmon into the population.

3.2.1.3.2 Eggs

Eggs are not present in the upper Sacramento River in the summer.

3.2.1.3.3 Juveniles

Juveniles are not present in the upper Sacramento River in the summer.

3.2.1.3.4 Yearlings

Yearlings are rearing in the upper Sacramento River in the summer. The amount of time spent rearing in the upper Sacramento River varies before yearlings migrate into the middle Sacramento River. This habitat is primarily used for rearing and as a through-way to the Bay-Delta. Time spent within and size distribution both entering and exiting the upper Sacramento River vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and condition (some affecting several parameters) during the migration.

Toxicity and contaminants stressors may increase. The increase is likely discountable and/or insignificant. The Proposed Action will release water increasing flows and then store water decreasing flows on the Sacramento River below Keswick Dam. Exposure to contaminants can result in sub-lethal effects such as reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). From historic monitoring efforts, there is no evidence of effects of contaminants on yearlings in the Sacramento River.

Stranding risk stressors may decrease. the Proposed Action will store water decreasing flows on the Sacramento River. Reducing releases and the storage of water reduces flows. Yearlings can become stranded in habitat disconnected from the main channel. Appendix O presents analysis of this stressor. Appendix H presents an analysis of this stressor.

Outmigration cues stressors may increase. During this period, the Proposed Action will store water decreasing flows on the Sacramento River. These changes may affect yearlings' cue to migrate and their outmigration travel rates. If fish stay in the upper Sacramento River longer because they are not cued to outmigrate, the risk of exposure to sources of mortality increases (e.g., higher exposure to predation).

Water temperature stressors may decrease. This decrease is likely beneficial. Seasonal operations result in warmer summer temperatures than 56°F at Red Bluff Diversion Dam but are cooler than environmental baseline (Appendix B, Figure 13). The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (McCullough 1999). Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. This decrease is likely discountable and/or insignificant. Yearling Chinook salmon swimming performance declines at DO less than 9 mg O_2/l at a temperature of 52.7°F and decreases more severely with DO less than 5 mg O_2/l (Davis et al. 1963). Historical water quality monitoring has not shown summer dissolved oxygen levels at below 7 mg/l. Releases of Shasta Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogens and disease stressors may decrease. This decrease is likely beneficial. Releases of Shasta Reservoir storage may result in cooler water temperatures in the summer and modeled summer water temperatures Environmental baseline(Appendix B, Figure 13) are approximately 57°F to 60°F, colder than those that would increase salmonid susceptibility to pathogen stressors. Water temperatures less than 59.9°F occur in the summer, above which temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Entrainment risk stressors may increase. During the yearling outmigration period, the Proposed Action will store water decreasing flows on the Sacramento River. This influences fish travel time and routing migrating in the Sacramento River mainstem.

Refuge habitat stressors may decrease. This decrease is likely beneficial. An increase in flows may increase access to high quality refuge habitat. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run in the summer in the Upper Sacramento River is plotted in Section 3.3 of Appendix B. Appendix O presents an analysis of this stressor.

Food availability and quality stressors may decrease. This decrease is likely beneficial. An increase in flows results in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of yearlings. 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 yearlings (Jeffres et al. 2008, 2020; Goertler et al. 2018, Steel et al. 2017; Bellido-Veiva et al. 2021). Appendix O presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/pr insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in spring-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.1.4 Fall

In the fall, Reclamation and DWR's proposed release of water will increase flows on average in the Sacramento River below Keswick Dam. Increased flows in the upper Sacramento River may change stressors on spring-run.

3.2.1.4.1 Adults

Adults are migrating, holding, and spawning in the upper Sacramento River in the fall. Adults move into the upper watershed where they hold until ready for spawning. This life-history strategy may leave adults vulnerable to multiple factors that affect survival, timing, and distribution. Additionally, adult body condition upon return to spawning areas can influence effects of stressors on pre-spawn mortality or fecundity. Several stressors have been identified for habitat attributes that affect spawning and holding.

In-river fishery or poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may decrease. This decrease is likely discountable and/or insignificant. Releases of Shasta Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmon and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within 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 bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. Levels safe for human consumption are assumed not likely to impact fish health and Murphy et al. (2022) identifies Chinook salmon as safe to eat. Appendix J presents an analysis of this stressor.

Stranding Risk stressors are not anticipated to change. Adult spring-run Chinook salmon use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented within various fishery technical teams in the Upper Sacramento River.

Water temperature stressors may decrease. This decrease is likely beneficial. Although seasonal operations may result in warmer temperatures than 56°F at Red Bluff Diversion Dam, these temperatures are approximately 10°F cooler than environmental baseline in early fall. Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/l (Carter 2005) and historic water quality monitoring rarely shows fall dissolved oxygen levels at levels below 5.0 mg/l. Releases of Shasta Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogen and disease stressors may decrease. The decrease is likely beneficial. Releases of Shasta Reservoir storage may result in cooler water temperatures in the fall than environmental baseline; and modeled fall water temperatures (Appendix B, Section 3.2) are colder than those that increase adult susceptibility to pathogen stressors. Water temperatures are almost always less than 59.9°F during the fall, which is below the temperature threshold when diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Spawning habitat stressors may increase. The increase in the stressor may reduce the quantity and quality of spring-run Chinook salmon spawning habitat. Habitat suitability curves show higher flows reduce spawning habitat quality and quantity and there are indications of redd superimposition, where suitable temperatures limit spatial extent. Appendix O presents an analysis of this stressor.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since it does not remove or introduce spring-run Chinook salmon into the population.

3.2.1.4.2 Eggs

Eggs are present in the upper Sacramento River in the fall. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity and contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Releases of Shasta Reservoir storage may increase flows and dilute contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect eggs and toxicity and contaminant 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.

Stranding and dewater stressors may increase. The increase may result in dewatering spawning habitat and desiccating eggs, as observed in redd monitoring. Although average flows are higher than under environmental baseline condition and release of Shasta Reservoir storage maintains flows in the fall, historical redd monitoring observed dewatered spring-run Chinook salmon redds that may be due to variation in monthly flow. Appendix L presents an analysis of this stressor.

Water temperature stressors may increase. The increase may be lethal to some individuals, suitable water temperatures are required for egg incubation and development. Egg mortality occurs at temperatures above 56°F (McCollough 1999). Historic water temperatures at Sacramento River above Clear Creek have exceeded a mean daily temperature of 53.5°F at least one day between September and November 100% of years 2005 – 2022 and have exceeded 56°F at least one day 50% of years during the same months 2005 – 2022. Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Chinook salmon egg survival decreases when dissolved oxygen is less than 5.5 mg/l (Del Rio et al. 2019); however, historic water quality monitoring has not shown fall dissolved oxygen at levels below 5.5 mg/l (e.g., Mill Creek pool habitat; CDFW 2014 – 2017 Stressor Monitoring Report, Statewide Drought Response). In addition, releases of Shasta Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogens and disease stressors may decrease. The decrease is likely discountable and/or insignificant. On average, fall flows are higher than environmental baseline, which may reduce horizontal transmission due to reduced overcrowding. Moreover, water temperatures are almost always less than 59.9°F during the fall, which is below the temperature threshold when diseases affecting Chinook salmon become highly virulent (McCullough 1999). Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992).

Sedimentation and gravel quantity stressors may decrease. This decrease is likely discountable and/or insignificant. Egg and alevin emergence is affected by sedimentation and gravel quantity. Increased flows may remove fine sediment, improving egg and alevin essential functions and development (Bennett et al. 2003). Increased surface flows may reduce sedimentation. Build-up of fine sediment can decrease permeability for embryos (Bjornn and Reiser 1991). Gravel quantity is addressed in the "Spawning Habitat" stressor of the "Adult holding and Spawning" section. Appendix O presents an analysis of this stressor.

Redd quality stressors may decrease. The decrease is likely beneficial. Egg and alevin emergence is affected by gravel size and interstitial flow. Increased flow may improve hydrologic and biological connectivity within the streambed that improve egg survival and alevin emergence. Appendix O presents an analysis of this stressor.

Predation risk stressors are not anticipated to change. The metabolism of these predators is driven by water temperatures like other ectothermic animals, and thus predation rates or predator activity are likely positively correlated with temperature. Predator abundance and distribution is not anticipated to change due to operations. Temperature stressors are expected to decrease during this life stage (see water temperature stressor, Appendix D). Specifically, releases of Shasta Reservoir storage may result in 10°F cooler water temperature relative to Environmental baseline.

3.2.1.4.3 Young-of-Year Juveniles

Young-of-year juveniles are rearing and migrating in the middle Sacramento River. The amount of time spent rearing in the upper Sacramento River varies before juveniles migrate into the middle Sacramento River. This habitat is primarily used for rearing and as a through-way to the Bay-Delta. Time spent within and size distribution both entering and exiting the middle Sacramento River vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and juvenile condition (some affecting several parameters) during the migration.

Toxicity and contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Water quality monitoring has not shown contaminants at levels likely to affect juvenile growth, condition, or survival and toxicity and contaminants effects have not been observed in fish monitoring. Although operations are not anticipated to increase toxicity and contaminants, weather-driven flooding may result in increased contaminant concentrations in fish tissue. For example, methylmercury tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may increase. The increase may reduce connectivity, causing stress and mortality of spring-run Chinook salmon, as observed in historical fish monitoring. Juveniles can become stranded in habitats that are disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Although average flows are higher than under Environmental baseline condition and release of Shasta Reservoir Storage maintains flows in the fall, historical fish monitoring observed stranded juvenile spring-run Chinook salmon that may be due to variation in monthly flow. Appendix L presents an analysis of this stressor.

Outmigration cues stressors are not anticipated to change. Winter-run Chinook salmon outmigration cues into the Lower Sacramento River increases to more than 5% at the Knights Landing fish monitoring site with daily Wilkins Slough flows of 14,126 cfs (400cms, Del Rosario et al. 2013). Although flows are increasing during this period, average flows are not expected to exceed the 14,126 cfs threshold causing outmigration cues. Appendix J presents an analysis of this stressor.

Water temperature stressors are not anticipated to change. Seasonal operations result in warmer temperatures than 56°F at Red Bluff Diversion Dam but are cooler than Environmental baseline (Appendix B, Figure 13). Environmental baseline The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001). Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors are not anticipated to change. Juvenile Chinook salmon swimming performance declines at DO less than 7 mg O_2/l at a temperature of 67.1°F but decreases steadily with DO less than saturation (~10 mg O_2/l) at cooler temperatures (Davis et al. 1963). Historic water quality monitoring has not shown fall dissolved oxygen levels at below 7.0 mg/l. Releases of Shasta Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogens and disease stressors are not anticipated to change. On average, fall flows are higher than environmental baseline, which may reduce horizontal transmission due to reduced crowding. Moreover, water temperatures are almost always less than 59.9°F during the fall, which is below the temperature threshold when diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges (e.g., GCID, RD 108) are screened (see Appendix A).

Refuge habitat stressors may decrease. This decrease is likely discountable and/or insignificant. On average, flows are higher than environmental baseline in September and October, and similar to environmental baseline in November. An increase in flows may increase access to high quality refuge habitat. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run in the summer in the Upper Sacramento River is plotted in Section 3.3 of Appendix B. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may decrease. This decrease is likely discountable and/or insignificant. On average, flows are higher than environmental baseline in September and October, and similar to environmental baseline in November. An increase in flows results in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of juveniles. 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, 2020; Goertler et al. 2018, Steel et al. 2017; Bellido-Veiva et al. 2021). Appendix O presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of winter-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in juvenile spring-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots." 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.1.4.4 Yearlings Juveniles

Yearlings are rearing and migrating in the middle Sacramento River. The amount of time spent rearing in the upper Sacramento River varies before yearlings migrate into the middle Sacramento River. This habitat is primarily used for rearing and as a through-way to the Bay-Delta. Time spent within and size distribution both entering and exiting the middle Sacramento River vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and yearling condition (some affecting several parameters) during the migration.

Toxicity and contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Water quality monitoring has not shown contaminants at levels likely to affect yearling growth, condition, or survival and toxicity and contaminants effects have not been observed in fish monitoring. Although operations are not anticipated to increase toxicity and contaminants, weather-driven flooding may result in increased contaminant concentrations in fish tissue. For example, methylmercury tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may increase. The increase may reduce connectivity, causing stress and mortality of spring-run Chinook salmon, as observed in historical fish monitoring. Yearlings can become stranded in habitats that are disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Appendix L presents an analysis of this stressor.

Outmigration cues stressors are not anticipated to change. Winter-run Chinook salmon outmigration cues into the Lower Sacramento River increases to more than 5% at the Knights Landing fish monitoring site with daily Wilkins Slough flows of 14,126 cfs (400cms, Del Rosario et al. 2013). Although flows are increasing during this period, average flows are not expected to exceed the 14,126 cfs threshold causing outmigration cues. Appendix J presents an analysis of this stressor.

Water temperature stressors may decrease. The decrease is likely discountable and/or insignificant. Seasonal operations result in warmer temperatures than 56°F at Red Bluff Diversion Dam but are cooler than Environmental baseline (Appendix B, Figure 13). The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001). Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Juvenile Chinook salmon swimming performance declines at DO less than 7 mg O_2/l at a temperature of 67.1°F but decreases steadily with DO less than saturation (~10 mg O_2/l) at cooler temperatures (Davis et al. 1963). Historic water quality monitoring has not shown fall dissolved oxygen levels at below 7.0 mg/l. Releases of Shasta Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogens and disease stressors may decrease. The decrease is likely discountable and/or insignificant. On average, flows are higher than environmental baseline, which may reduce horizontal transmission due to reduced crowding. Moreover, water temperatures are almost always less than 59.9°F during the fall, which is below the temperature threshold when diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges (e.g., GCID, RD 108) are screened (see Appendix A).

Refuge habitat stressors may decrease. This decrease is likely beneficial. An increase in flows may increase access to high quality refuge habitat. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run in the summer in the Upper Sacramento River is plotted in Section 3.3 of Appendix B. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may decrease. This decrease is likely beneficial. An increase in flows results in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of yearlings. 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 yearlings (Jeffres et al. 2008, 2020; Goertler et al. 2018, Steel et al. 2017; Bellido-Veiva et al. 2021). Appendix O presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in spring-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.2 Clear Creek

3.2.2.1 Winter

In the winter, Reclamation and DWR's proposed storage of water will decrease flows on average in Clear Creek below Whiskeytown. Decreased flows in Clear Creek may change stressors on spring-run.

3.2.2.1.1 Adults

Adults are not present in Clear Creek in the winter.

3.2.2.1.2 Eggs

Eggs are not present in Clear Creek in the winter.

3.2.2.1.3 Young-of-year Juveniles

Juveniles are rearing and migrating in Clear Creek. The amount of time spent rearing in Clear Creek varies before yearlings migrate into the upper and middle reaches of the Sacramento River. This habitat is primarily used for rearing and as a through-way to the Sacramento River and Bay-Delta. Time spent within and size distribution both entering and exiting Clear Creek vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and condition (some affecting several parameters) during the migration.

Toxicity and contaminants stressors may increase. This increase is likely discountable and/or insignificant. During the juvenile rearing and outmigration period, storage of flows in Whiskeytown Reservoir in the winter will decrease flows. Maintenance of storage may reduce flows concentrating constituents from urban and agricultural land use that affect concentration in juveniles' prey. Contaminants can cause 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). Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may increase or may decrease. The increase may reduce connectivity, causing stress and mortality of spring-run Chinook salmon. When flows decrease, juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Alternately, stranding risk stressors may decrease from the dampening of flow fluctuations during precipitation events and would benefit from reduced predation.

Outmigration cues stressors may increase. The increase may mask the cue to migrate and increase travel time through Clear Creek. Storing water reduces flow magnitude, that juvenile salmon use as cues to continue migration. Spring-run Chinook salmon use flows for cues to begin and continue migration, and outmigration cues may be changed due to a decrease in flows. Appendix J presents an analysis of this stressor and Appendix H present analysis on the "Minimum Flows" conservation measure.

Water temperature stressors may decrease. This decrease is likely discountable and/or insignificant. During the juvenile rearing and outmigration period storage of water in the Whiskeytown Reservoir in the winter will decrease flows. Maintenance of Whiskeytown Reservoir storage may result in cooler water temperatures in the winter under environmental baseline; however, modeled winter water temperatures are colder than juvenile rearing and migration temperature needs (Appendix B, Section 4.2, *Water Temperatures and Dissolved Oxygen*). The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001).

Dissolved oxygen stressors may increase. This increase is likely discountable and/or insignificant. During the juvenile rearing and outmigration period storage of water in the Whiskeytown Reservoir in the winter will decrease flows. Observed swimming performance of Chinook salmon juveniles declined at DO less than 7 mg O_2/l at a temperature of 67.1°F but decreased steadily with DO less than saturation (~10 mg O_2/l) at cooler temperatures (Davis et al. 1963), as are expected in the winter. Upper Clear Creek is very steep and monitoring shows white water which indicates high levels of gas exchange.

Pathogens and disease stressors are not anticipated to change. During the juvenile rearing and outmigration period storage of water in the Whiskeytown Reservoir in the winter will decrease flows. Maintenance of Whiskeytown Reservoir storage may decrease flows and may cause crowding into a smaller habitat area and warmer water temperatures. 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 is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Modeled winter water temperatures (Appendix B, Section 4.2) are colder than this threshold. Also, observed winter temperatures have remained below this threshold and pathogen and disease stressors have not been observed in the winter for juvenile spring-run Chinook salmon.

Entrainment risk stressors are not anticipated to change. There are no CVP diversion facilities on Clear Creek or facilities used to divert water for CVPIA refuges on Clear Creek that may entrain spring-run Chinook salmon (see Appendix A).

Refuge habitat stressors may increase. The increase may reduce suitable margin and off-channel habitats for juvenile spring-run Chinook salmon. Maintenance of Whiskeytown Reservoir storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for juveniles. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the winter in Clear Creek is plotted in Appendix B, Section 4.3, *Suitable Habitat*. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. During the juvenile rearing and outmigration period, the Proposed Action will both release and then store water first increasing then decreasing flows on Clear Creek in the fall and winter. The increase may result in a change of food web processes and a decrease in quality food available to juvenile spring-run Chinook salmon. Maintenance of Whiskeytown Reservoir storage results in less inundated habitats. 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, 2020; Goertler et al. 2018).

Predation and competition stressor may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in juvenile winter-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.2.1.4 Yearling juveniles

Yearlings are rearing and migrating in Clear Creek. The amount of time spent rearing in Clear Creek varies before yearlings migrate into the upper and middle reaches of the Sacramento River. This habitat is primarily used for rearing and as a through-way to the Bay-Delta. Time spent within and size distribution both entering and exiting Clear Creek vary among years, although yearling presence in low. Several stressors have been identified, each possibly affecting survival, residence time and migration, and condition (some affecting several parameters) during the migration. Yearling juveniles are not observed in measurable numbers in the winter in Clear Creek.

Toxicity and contaminants stressors may increase. This increase is likely discountable and/or insignificant. Maintenance of Whiskeytown Reservoir storage may reduce flows concentrating constituents from urban and agricultural land use that affect concentration in yearling juveniles' prey. Contaminants can cause sub-lethal effects and 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). Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may increase or may decrease. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam. The increase may reduce connectivity, causing stress and mortality of spring-run Chinook salmon. When flows decrease, juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Alternately, stranding risk stressors may decrease from the dampening of flow fluctuations during precipitation events and would benefit from reduced predation. Appendix L presents an analysis of this stressor. However, release levels are within the channel of the river and do not connect with off-channel stranding areas in Clear Creek. Yearling juvenile stranding has not been observed in fish monitoring in Clear Creek.

Outmigration cues stressors may increase. The increase may mask the cue to migrate and increase travel time through Clear Creek. Storing water reduces flow magnitude, that yearling juvenile salmon use as cues to continue migration. Spring-run Chinook salmon use flows for cues to begin and continue migration, and outmigration cues may be changed due to a decrease in flows. Appendix J presents an analysis of this stressor.

Water temperature stressors are not anticipated to change. Maintenance of Whiskeytown Reservoir storage may result in cooler water temperatures in the winter under environmental baseline; however, modeled winter water temperatures are colder than juvenile rearing and migration temperature needs (Appendix B, Section 4.2). The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001).

Dissolved oxygen stressors may decrease. The Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam. Observed swimming performance of Chinook salmon yearling juveniles declined at DO less than 9 mg O_2/l at a temperature of 52.7°F but decreased more severely with DO less than 5 mg O_2/l (Davis et al. 1963). Water quality monitoring has not shown dissolved oxygen at levels below 5 mg O_2/l in the winter. Cooler water temperatures may reduce overall harm to yearlings spending time in Clear Creek.

Pathogens and disease stressors are not anticipated to change. Maintenance of Whiskeytown Reservoir storage may decrease flows and may cause crowding into a smaller habitat area and warmer water temperatures. A decrease in flows may influence pathogen and disease exposure, including increased transfer from hatchery fish to natural-origin yearlings; however, transmission directionality is difficult to track and evidence of transfer is lacking (Naish et al. 2007; Kent 2011; Nekouei et al. 2019). Yearling survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Modeled winter water temperatures (Appendix B, Section 4.2) are colder than this threshold. Also, observed winter temperatures have remained below this threshold and pathogen and disease stressors have not been observed for juvenile spring-run Chinook salmon in the winter.

Entrainment risk stressors are not anticipated to change. There are no CVP diversion facilities on Clear Creek or facilities used to divert water for CVPIA refuges on Clear Creek that may entrain spring-run Chinook salmon (see Appendix A).

Refuge habitat stressors may increase. During the yearling outmigration period, the Proposed Action will store water in the winter decreasing flows on the Sacramento River and Delta outflow. The decrease flows may reduce suitable margin and off-channel habitats for juvenile spring-run Chinook salmon. Maintenance of Whiskeytown Reservoir storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for yearlings. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the winter in Clear Creek is plotted in Section 4.3 of Appendix B. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. The increase may reduce suitable margin and off-channel habitats for juvenile spring-run Chinook salmon. Maintenance of Whiskeytown Reservoir storage results in less inundated habitats. 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 yearlings (Jeffres et al. 2008, 2020; Goertler et al. 2018). Appendix O defines refuge habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam.

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

Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2017) that are influenced by operations. Predation and competition is not independent from other stressors, such as refuge habitat and food availability and quality. Predation effects associated with the Proposed Action are captured in the analysis of these stressors. Any residual effects of predation and competition associated with the Proposed Action are considered insignificant.

3.2.2.2 Spring

In the spring, Reclamation and DWR’s proposed release of water will decrease flows on average in Clear Creek below Whiskeytown. Decreased flows in Clear Creek may change stressors on spring-run.

3.2.2.2.1 Adults

Adults are migrating and holding in Clear Creek.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity and contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Whiskeytown Reservoir storage may reduce flows and concentrate contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmon and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within 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 bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. Levels safe for human consumption are assumed not likely to impact fish health and (Murphy et al. 2022) identifies Chinook salmon as safe to eat. Appendix J presents an analysis of this stressor.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented within various fishery technical teams in Clear Creek.

Water temperature stressors may decrease. The decrease is likely discountable and/or insignificant. Operations may result in cooler water temperatures than environmental baseline in the spring. Evidence suggests that optimal water temperatures between 37.9°F and 60.8°F for Pacific Northwest Chinook salmon migrating and between 42.8°F and 57.2°F for hatchery Chinook salmon holding (Reiser and Bjornn 1979, McCullough 1999). Studies on Pacific Northwest salmon showed migration halting and pre-spawn mortality occurring at temperatures greater than 68°F (Goneia et al. 2006, Bowerman et al. 2018). Modeled early spring water temperatures are colder than adult migration temperature needs, while environmental baseline temperatures may exceed these thresholds in late spring (Appendix B, Section 4.2).

Dissolved oxygen stressors may decrease. The decrease is discountable and/or insignificant. During the adult migration period, the Proposed Action will release water resulting in increased flows that may provide a higher dissolved oxygen saturation potential. Chinook salmon wait to migrate until dissolved oxygen is at least 5.0 mg/l (Carter 2005) but higher DO levels are preferable (Bjornn and Reiser 1991). Water quality monitoring has not shown dissolved oxygen at levels below 5.0 mg/l in the spring. DO levels fluctuate daily ranging typically between 10 and 15 mg/L at the Clear Creek gage.

Pathogen stressors may decrease. The decrease is likely discountable and/or insignificant. Operations may result in cooler water temperatures than environmental baseline in the spring (Appendix B, Section 4.2). At water temperatures above 59.9°F diseases affecting Chinook salmon become highly virulent (McCullough 1999). Modeled water temperatures with operations remain less than this threshold in the spring and when compared to environmental baseline modeled temperature, which exceed these temperatures.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since it does not remove or introduce spring-run Chinook salmon into the population. Additionally, there is no spring-run Chinook hatchery in the upper Sacramento River, so genetic introgression is not a stressor.

3.2.2.2.2 Eggs

Eggs are not present in Clear Creek in the spring.

3.2.2.2.3 Young-of-year Juveniles

Juveniles are rearing and migrating in Clear Creek. The amount of time spent rearing in Clear Creek varies before yearlings migrate into the upper and middle reaches of the Sacramento River. This habitat is primarily used for rearing and as a through-way to the Sacramento River and Bay-Delta. Time spent within and size distribution both entering and exiting Clear Creek vary among years, although presence in low. Several stressors have been identified, each possibly affecting survival, residence time and migration, and condition (some affecting several parameters) during the migration.

Toxicity and contaminants stressors may increase. This increase is likely discountable and/or insignificant. Maintenance of storage may reduce flows concentrating constituents from urban and agricultural land use that affect concentration in juvenile's prey. Contaminants can cause sub-lethal effects and 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). Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may increase. During the juvenile rearing and outmigration period, the Proposed Action will both release and then store water, first increasing, then decreasing, flows on Clear Creek. Appendix H presents analyses of "Minimum Instream Flows" and "Ramping Rates" conservation measures. These release levels are generally within the channel of the river and typically do not connect with off-channel stranding areas in Clear Creek. Juvenile stranding has not been observed in fish monitoring in Clear Creek.

Outmigration cues stressors may increase. Storage of water in Whiskeytown will reduce downstream flows on Clear Creek. The increase may mask the cue to migrate and increase travel time in Clear Creek into the Sacramento River. Storing water reduces flow magnitude, that juvenile salmon use as cues to continue migration. Spring-run Chinook salmon use flows for cues to begin and continue migration, and outmigration cues may be changed due to a decrease in flows. Appendix J presents an analysis of this stressor.

Water temperature stressors may decrease. The decrease is likely beneficial. The proposed release of water may result in cooler water temperatures than environmental baseline in the spring. The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001). Modeled spring water temperatures fall within temperature needs of juvenile Chinook, while environmental baseline temperatures may exceed these thresholds in late spring (Appendix B, Section 4.2). Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Observed swimming performance of Chinook salmon juveniles declined at DO less than 7 mg O_2/l at a temperature of 67.1°F but decreased steadily with DO less than saturation (~10 mg O_2/l) at cooler temperatures (Davis et al. 1963). Water quality monitoring has not shown dissolved oxygen at levels below 5.0 mg/l in the spring. DO levels fluctuate daily ranging typically between 10 and 15 mg/L at the Clear Creek gage.

Pathogens and disease stressors may increase. The increase is likely discountable and/or insignificant. During the juvenile rearing and outmigration period, releases of Whiskeytown Reservoir in the fall will increase flows while storage of Whiskeytown Reservoir in the winter will decrease flows. Maintenance of storage may decrease flows and may cause crowding into a smaller habitat area and warmer water temperatures. 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 is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River and its tributaries (reviewed in Lehman et al. 2020).

Entrainment risk stressors are not anticipated to change. There are no CVP diversion facilities on Clear Creek or facilities used to divert water for CVPIA refuges on Clear Creek that may entrain spring-run Chinook salmon (see Appendix A).

Refuge habitat stressors may increase. The increase may reduce suitable margin and off-channel habitats for juvenile spring-run Chinook salmon. Maintenance of Whiskeytown Reservoir storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for juveniles. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the spring in Clear Creek is plotted in Section 4.3 of Appendix B. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. The increase may result in a change of food web processes and a decrease in quality food available to juvenile spring-run Chinook salmon. Maintenance of Whiskeytown Reservoir storage results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix O defines refuge habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the “Outmigration Cues” and “Entrainment Risk” stressors in juvenile winter-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta “hotspots”. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.2.2.4 Yearling juveniles

Yearlings are rearing in Clear Creek. The amount of time spent rearing in Clear Creek varies before yearlings migrate into the upper and middle reaches of the Sacramento River. This habitat is primarily used for rearing and as a through-way to the Bay-Delta. Time spent within and size distribution both entering and exiting Clear Creek vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and condition (some affecting several parameters) during the migration. Yearling juveniles are not observed in measurable numbers in the spring in Clear Creek.

Toxicity and contaminants stressors may increase. This increase is likely discountable and/or insignificant. Maintenance of storage may reduce flows concentrating constituents from urban and agricultural land use that affect concentration in yearlings’ prey. Contaminants can cause sub-lethal effects and 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). Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may decrease. The decrease is likely beneficial. Stranding risk stressors may decrease from storage of water in the winter. This is due to stability from reservoir regulating the flow fluctuations during precipitation events throughout the winter. These release levels are within the channel of the river and do not connect with off-channel stranding areas in Clear Creek. Yearling stranding has not been observed in fish monitoring in Clear Creek.

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

Water temperature stressors may decrease. The decrease is likely beneficial. During the yearling rearing period, the Proposed Action will store water decreasing flows in the spring and release water increasing flows in the summer on Clear Creek below Whiskeytown Dam. Spring-run chinook salmon require cool water temperature for optimal growth. The proposed release of water may result in cooler water temperatures than environmental baseline in the spring. The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001). Modeled spring water temperatures fall within temperature needs of yearling juvenile Chinook, while environmental baseline temperatures may exceed these thresholds in late spring (Appendix B, Section 4.2). Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Observed swimming performance of Chinook salmon yearling juveniles declined at DO less than 9 mg O_2/l at a temperature of 52.7°F but decreased more severely with DO less than 5 mg O_2/l (Davis et al. 1963). Water quality monitoring has not shown dissolved oxygen at levels below 5.0 mg/l in the spring. DO levels fluctuate daily ranging typically between 10 and 15 mg/L at the Clear Creek gage.

Pathogens and disease stressors may decrease. The decrease is likely discountable and/or insignificant. 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 is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River and its tributaries (reviewed in Lehman et al. 2020). Operations may result in cooler water temperatures than environmental baseline in the spring (Appendix B, Section 4.2). At water temperatures above 59.9°F diseases affecting Chinook salmon become highly virulent (McCullough 1999). Modeled water temperatures remain less than this threshold in the spring. In contrast, the threshold is exceeded in April and May under the environmental baseline.

Entrainment risk stressors are not anticipated to change. There are no CVP diversion facilities on Clear Creek or facilities used to divert water for CVPIA refuges on Clear Creek that may entrain spring-run Chinook salmon (see Appendix A).

Refuge habitat stressors may increase. The increase may reduce suitable margin and off-channel habitats for juvenile spring-run Chinook salmon. Maintenance of Whiskeytown Reservoir storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for yearlings. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the spring in Clear Creek is plotted in Section 4.3 of Appendix B. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. The increase may result in a change of food web processes and a decrease in quality food available to juvenile spring-run Chinook salmon. Maintenance of Whiskeytown Reservoir storage results in less inundated habitats. 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 yearlings (Jeffres et al. 2008, 2020; Goertler et al. 2018). Appendix O defines refuge habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in spring-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.2.3 Summer

In the summer, Reclamation and DWR's release of water will increase flows on average in Clear Creek below Whiskeytown. Increased flows in Clear Creek may change stressors on spring-run.

3.2.2.3.1 Adults

Adults are migrating and holding in Clear Creek.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity and contaminants stressors may decrease. This decrease is discountable and/or insignificant. Releases of Whiskeytown Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmon and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within 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 bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. Appendix J presents an analysis of this stressor.

Stranding risk stressors are not anticipated to change. Adult spring-run Chinook salmon use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented within various fishery technical teams in Clear Creek.

Water temperature stressors may decrease. The decrease is likely beneficial. Proposed release of water may result in cooler water temperatures than environmental baseline in the summer. Evidence suggests that optimal water temperatures between 37.9°F and 60.8°F for Pacific Northwest Chinook salmon migrating and between 42.8°F and 57.2°F for hatchery Chinook salmon holding (Reiser and Bjornn 1979, McCullough 1999). Studies on Pacific Northwest salmon showed migration halting and pre-spawn mortality occurring at temperatures greater than 68°F (Goneia et al. 2006, Bowerman et al. 2018). Modeled summer water temperatures are optimal while environmental baseline temperatures exceed these thresholds in the summer (Appendix B, Section 4.2). Appendix L presents analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/l (Carter 2005); however, higher levels of dissolved oxygen are preferable (Bjornn and Reiser 1991). Operations may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogen stressors may decrease. The decrease is likely beneficial. Operations may result in cooler water temperatures than environmental baseline in the summer (Appendix B, Section 4.2); and modeled summer water temperatures than those that increase adult susceptivity to pathogen stressors. Water temperatures less than 59.9°F occur in the summer, above which temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999). Crowding may be reduced due to increased flows and more holding habitat. Lower densities of holding adults may decrease the potential for lateral transmission of disease.

Spawning habitat stressors may increase. The increase in the stressor may reduce the quantity and quality of spring-run Chinook salmon spawning habitat. Habitat suitability curves show higher flows reduce spawning habitat quality and quantity and there are indications of redd superimposition, where suitable temperatures limit spatial extent. Appendix O presents an analysis of this stressor.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since it does not remove or introduce spring-run Chinook salmon into the population.

3.2.2.3.2 Eggs

Eggs are not present in Clear Creek in the summer.

3.2.2.3.3 Young-of-year Juveniles

Juveniles are not present in Clear Creek in the summer.

3.2.2.3.4 Yearling Juveniles

Yearlings are rearing in Clear Creek. The amount of time spent rearing in Clear Creek varies before yearlings migrate into the upper and middle reaches of the Sacramento River. This habitat is primarily used for rearing and as a through-way to the Bay-Delta. Time spent within and size distribution both entering and exiting Clear Creek vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and condition (some affecting several parameters) during the migration. Yearling juveniles are not observed in measurable numbers in the summer in Clear Creek.

Toxicity and contaminants stressors may decrease. The decrease is likely discountable and/or insignificant since water quality monitoring has not shown contaminants at levels likely to affect yearling growth, condition, or survival and toxicity and contaminant effects have not been observed in fish monitoring. Additionally, methylmercury tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may decrease. The decrease is likely beneficial. Flows during the summer are consistent under both proposed operations and environmental baseline. Yearling juveniles are not observed in measurable numbers in the summer in Clear Creek and yearling stranding has not been observed in fish monitoring in Clear Creek.

Outmigration cues stressors are not anticipated to change. Yearlings rearing in Clear Creek will not experience the full suite of stressors identified in the SAIL model. This stressor is not applicable to rearing yearlings.

Water temperature stressors may decrease. The decrease is likely beneficial. Seasonal operations result in optimal, cooler water temperatures than environmental baseline in the summer (Appendix B, Section 4.2). The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001). Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Yearling Chinook salmon swimming performance declines at DO less than 9 mg O_2/l at a temperature of 52.7°F and decreases more severely with DO less than 5 mg O_2/l (Davis et al. 1963). Historical water quality monitoring has not shown summer dissolved oxygen levels at below 7 mg/l. Releases of Shasta Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogens and disease stressors may decrease. The decrease is likely beneficial. Releases of Whiskeytown Reservoir storage may result in cooler water temperatures in the summer, while environmental baseline temperatures exceed 59.9°F (Appendix B, Section 4.2). Yearling juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River and its tributaries (reviewed in Lehman et al. 2020). At water temperatures above 59.9°F diseases affecting Chinook salmon become highly virulent (McCullough 1999). Modeled water temperatures remain below this threshold in the summer.

Entrainment risk stressors are not anticipated to change. There are no CVP diversion facilities on Clear Creek or facilities used to divert water for CVPIA refuges on Clear Creek that may entrain spring-run Chinook salmon (see Appendix A).

Refuge habitat stressors may decrease. This decrease is likely beneficial. An increase in flows may increase access to high quality refuge habitat. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run in the summer in Clear Creek is plotted in Section 4.3 of Appendix B. Appendix O presents an analysis of this stressor.

Food availability and quality stressors may decrease. This decrease is likely beneficial. An increase in flows results in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of yearlings. 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 yearlings (Jeffres et al. 2008, 2020; Goertler et al. 2018, Steel et al. 2017; Bellido-Veiva et al. 2021). Appendix O presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the “Outmigration Cues” and “Entrainment Risk” stressors in spring-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta “hotspots”. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.2.4 Fall

In the fall, Reclamation and DWR’s proposed release of water will increase flows on average in Clear Creek below Whiskeytown. Release of water is an absolute action. Increased flows in Clear Creek may change stressors on spring-run.

3.2.2.4.1 Adults

Adults are holding and spawning in Clear Creek. Adults move into the upper watershed where they hold until ready for spawning. This life-history strategy may leave adults vulnerable to multiple factors that affect survival, timing, and distribution. Additionally, adult body condition upon return to spawning areas can influence effects of stressors on pre-spawn mortality or fecundity. Several stressors have been identified for habitat attributes that affect spawning and holding.

In-river fishery or poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Releases of Whiskeytown Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmon and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within 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 bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. Levels safe for human consumption are assumed not likely to impact fish health and Murphy et al. (2022) identifies Chinook salmon as safe to eat. Appendix J presents an analysis of this stressor.

Stranding risk stressors are not anticipated to change. Adult spring-run Chinook salmon use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented within various fishery technical teams in Clear Creek.

Water temperature stressors may decrease. The decrease is likely beneficial. Proposed release of water may result in cooler water temperatures than environmental baseline in the fall and modeled fall water temperatures are optimal while environmental baseline temperatures exceed thresholds for optimal Chinook salmon in the fall (Appendix B, Section 4.2). Evidence suggests that optimal water temperatures between 37.9°F and 60.8°F for Pacific Northwest Chinook salmon migrating and between 42.8°F and 57.2°F for hatchery Chinook salmon holding (Reiser and Bjornn 1979, McCullough 1999). Studies on Pacific Northwest salmon showed migration halting and pre-spawn mortality occurring at temperatures greater than 68°F (Goneia et al. 2006, Bowerman et al. 2018). Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. This decrease is likely discountable and/or insignificant. Releases of Shasta Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential. Dissolved oxygen generally increases with a decrease in water temperatures, and with increased flows.

Pathogen and disease stressors may decrease. The decrease is likely beneficial. Releases of Whiskeytown Reservoir storage may result in cooler water temperatures than environmental baseline in the fall (Appendix B, Section 4.2); and modeled fall water temperatures are colder than those that increase adult susceptibility to pathogen stressors. Water temperatures are below 59.9°F, which is the temperature when diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Spawning habitat stressors may increase. The increase in the stressor may reduce the quantity and quality of spring-run Chinook salmon spawning habitat. Habitat suitability curves show higher flows reduce spawning habitat quality and quantity and there are indications of redd superimposition, where suitable temperatures limit spatial extent. USFWS (2015) estimated spawning habitat versus flow relationships in Clear Creek and showed habitat increasing with flow over the range from 50 cfs to 900 cfs. Appendix O presents an analysis of this stressor.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since it does not remove or introduce spring-run Chinook salmon into the population.

3.2.2.4.2 Eggs

Eggs are present in Clear Creek. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact eggs survival during incubation, but CVP and SWP operations are not a proximate cause of in-river fishery or trampling stressors.

Toxicity and contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Releases of Whiskeytown Reservoir storage may increase flows and dilute contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect eggs and toxicity and contaminant 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 in prey during this life stage.

Stranding and dewater stressors may increase. The increase may result in dewatering spawning habitat and desiccating eggs, as observed in redd monitoring. Although average flows are higher than under environmental baseline condition and release of storage maintains flows in the fall, historical redd monitoring observed dewatered spring-run Chinook salmon redds that may be due to variation in monthly flow. Appendix L presents an analysis of this stressor.

Water temperature stressors may increase. The increase may be lethal to some individuals, suitable water temperatures are required for egg incubation and development. Egg mortality occurs at temperatures above 56°F (McCollough 1999). Seasonal operations result in cooler water temperatures than environmental baseline in Clear Creek in the fall (Appendix B, Section 4.2) and on average remain below the 56°F threshold. Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. This decrease is likely discountable and/or insignificant. Chinook salmon egg survival decreases when dissolved oxygen is less than 5.5 mg/l (Del Rio et al. 2019); however, historic water quality monitoring has not shown fall dissolved oxygen at levels below 5.5 mg/l. In addition, releases from Whiskeytown Reservoir may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogens and disease stressors may decrease. The decrease is likely discountable and/or insignificant. On average, fall flows are higher than environmental baseline, which may reduce horizontal transmission due to reduced overcrowding. Moreover, water temperatures are almost always less than 59.9°F during the fall, which is below the temperature threshold when diseases affecting Chinook salmon become highly virulent (McCullough 1999). Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992).

Sedimentation and gravel quantity stressors may decrease. The increase is likely discountable and/or insignificant. Flows in Clear Creek are less than channel-forming flows with little, if any, recruitment of gravel to encourage creation and maintenance of gravel spawning beds. Appendix O presents an analysis of this stressor. Increased surface flows may reduce sedimentation. Build-up of fine sediment can decrease permeability for embryos (Bjornn and Reiser 1991). Gravel quantity is addressed in the "Spawning Habitat" stressor of the "Adult holding and Spawning" section.

Redd quality stressors may decrease. The decrease is likely beneficial. Egg and alevin emergence is affected by gravel size and interstitial flow. In the fall, increased flow may improve hydrologic and biological connectivity within the streambed that improve egg survival and alevin emergence. Appendix O presents an analysis of this stressor.

Predation risk stressors are not anticipated to change. The metabolism of these predators is driven by water temperatures like other ectothermic animals, and thus predation rates or predator activity are likely positively correlated with temperature. Predator abundance and distribution is not anticipated to change due to operations. Temperature stressors are expected to decrease during this life stage (see water temperature stressor, Appendix D).

3.2.2.4.3 Young-of-year Juveniles

Juveniles are rearing and migrating in Clear Creek. The amount of time spent rearing in Clear Creek is limited before migrating into the upper and middle reaches of the Sacramento River, and juveniles' presence is very high in the fall. This habitat is primarily used for rearing and migrating and as a through-way to the Sacramento River and Bay-Delta. Time spent within and size distribution both entering and exiting Clear Creek vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and condition (some affecting several parameters) during the migration.

Toxicity and contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Water quality monitoring has not shown contaminants at levels likely to affect juvenile growth, condition, or survival and toxicity and contaminants effects have not been observed in fish monitoring. Although operations are not anticipated to increase toxicity and contaminants, weather-driven flooding may result in increased contaminant concentrations in fish tissue. For example, methylmercury tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may increase. The increase may reduce connectivity, causing stress and mortality of spring-run Chinook salmon, as observed in historical fish monitoring. Juveniles can become stranded in habitats that are disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Appendix L presents an analysis of this stressor.

Outmigration cues stressors may decrease. The decrease is likely beneficial. Releases of Whiskeytown Reservoir storage may increase flow magnitude that juvenile spring-run Chinook salmon use as cues for migration. Historic observations from fish monitoring show that a large percentage of juvenile spring-run Chinook salmon outmigrate from Clear Creek in the fall (Appendix C, Figure 10). Appendix J presents an analysis of this stressor.

Water temperature stressors may decrease. The decrease is likely discountable and/or insignificant. Seasonal operations may result in cooler water temperatures than environmental baseline in the fall M (Appendix B, Section 4.2). The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F - 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001Environmental baseline Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Juvenile Chinook salmon swimming performance declines at DO less than 7 mg O_2/l at a temperature of 67.1°F but decreases steadily with DO less than saturation (~10 mg O_2/l) at cooler temperatures (Davis et al. 1963). Releases of Whiskeytown Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogens and disease stressors may increase. The decrease is likely discountable and/or insignificant. Operations may result in cooler water temperatures than environmental baseline in the fall (Appendix B, Section 4.2). Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River and its tributaries (reviewed in Lehman et al. 2020). Moreover, water temperatures remain less than 59.9°F during the fall, which is below the temperature threshold when diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Entrainment risk stressors are not anticipated to change. There are no CVP diversion facilities on Clear Creek or facilities used to divert water for CVPIA refuges on Clear Creek that may entrain spring-run Chinook salmon (see Appendix A).

Refuge habitat stressors may decrease in September and October and increase in November. The increase can result in juveniles lacking cover to avoid predation or habitat to stop and hold during outmigration. An increase in flows may increase access to high quality refuge habitat. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run in the fall in Clear Creek is plotted in Section 4.3 of Appendix B. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may decrease in September and October and increase in November. The increase can impact growth rates of foraging juvenile spring-run Chinook salmon. An increase in flows results in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of juveniles. 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, 2020; Goertler et al. 2018, Steel et al. 2017; Bellido-Veiva et al. 2021). Appendix O defines refuge habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in juvenile winter-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.2.4.4 Yearling Juveniles

Yearlings are rearing and migrating in Clear Creek. The amount of time spent rearing in Clear Creek varies before yearlings migrate into the upper and middle reaches of the Sacramento River. This habitat is primarily used for rearing and as a through-way to the Sacramento River and Bay-Delta. Time spent within and size distribution both entering and exiting Clear Creek vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and condition (some affecting several parameters) during the migration. Yearling juveniles are not observed in measurable numbers in the fall in Clear Creek.

Toxicity and contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Water quality monitoring has not shown contaminants at levels likely to affect yearling growth, condition, or survival and toxicity and contaminants effects have not been observed in fish monitoring. Although operations are not anticipated to increase toxicity and contaminants, weather-driven flooding may result in increased contaminant concentrations in fish tissue. For example, methylmercury tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors may increase. The increase may reduce connectivity, causing stress and mortality of spring-run Chinook salmon, as observed in historical fish monitoring. Yearlings can become stranded in habitats that are disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Appendix L presents an analysis of this stressor.

Outmigration cues stressors may decrease. The decrease is likely beneficial. Releases of Whiskeytown Reservoir storage may increase flow magnitude that juvenile spring-run Chinook salmon use as cues for migration. Historic observations from fish monitoring show that a large percentage of juvenile spring-run Chinook salmon outmigrate from Clear Creek in the fall (Appendix C, Figure 10). Appendix J presents an analysis of this stressor.

Water temperature stressors may decrease. The decrease is likely beneficial. Seasonal operations may result in cooler water temperatures than environmental baseline in the fall (Appendix B, Section 4.2). The acceptable range of temperatures for growth of Chinook salmonids, from a synthesis of evidence, is 40.1°F – 66.4°F, with optimum growth occurring between 50°F – 60°F (EPA 2001). Appendix L presents an analysis of this stressor.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Juvenile Chinook salmon swimming performance declines at DO less than 9 mg O_2/l at a temperature of 52.7°F but decreases more severely with DO less than 5 mg O_2/l (Davis et al. 1963). Releases of Whiskeytown Reservoir storage may result in cooler water temperature relative to environmental baseline that may provide a higher dissolved oxygen saturation potential.

Pathogens and disease stressors may decrease. The decrease is likely beneficial. Operations may result in cooler water temperatures than environmental baseline in the fall (Appendix B, Section 4.2). Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River and its tributaries (reviewed in Lehman et al. 2020). Moreover, water temperatures remain less than 59.9°F during the fall, which is below the temperature threshold when diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Entrainment risk stressors are not anticipated to change. There are no CVP diversion facilities on Clear Creek or facilities used to divert water for CVPIA refuges on Clear Creek that may entrain spring-run Chinook salmon (see Appendix A).

Refuge habitat stressors may decrease. The decrease is likely beneficial. On average, flows are higher than environmental baseline and an increase in flows may increase access to high quality refuge habitat. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run in the fall in Clear Creek is plotted in Section 4.3 of Appendix B. Appendix O defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may decrease. The decrease is likely beneficial. On average, flows are higher than environmental baseline and an increase in flows results in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of yearlings. 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 yearlings (Jeffres et al. 2008, 2020; Goertler et al. 2018, Steel et al. 2017; Bellido-Veiva et al. 2021). Appendix O defines refuge habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in spring-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O, Appendix L, Appendix I, and Appendix J present analysis of these stressors.

3.2.3 Bay-Delta

3.2.3.1 Winter

In the winter, Reclamation and DWR's proposed water operations will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on spring-run.

3.2.3.1.1 Adults

Adults are migrating in the Delta. Adults are undergoing an energetically taxing salt-to-freshwater transition to spawn. Several stressors have been identified to possibly delay adult migration, decrease adult survival during migration, or increase energy necessary to undergo the transition.

In-river fishery and poaching stressors are not anticipated to change. Chinook salmon fishing is not allowed in the Delta in the winter. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity and contaminants stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow relative to environmental baseline that may concentrate contaminant constituents. During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. A 0.2 mg/kg threshold for methylmercury is protective of both juvenile and adult fish (Beckvar et al. 2005). Water quality monitoring has not shown contaminants at levels likely to affect adult salmon and toxicity effects have not been observed in fish monitoring. Levels safe for human consumption are assumed not likely to impact fish health and Murphy et al. (2022) identifies Chinook salmon as safe to eat.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented within various fishery technical teams in the Bay-Delta.

Water temperature stressors are not anticipated to change. Although Delta water temperature is positively correlated with Delta inflow in the winter (Bashevkin and Mahardja 2022) and CVP and SWP storage and diversion decreases Delta inflow and outflow, Bay-Delta water temperature is mainly driven by air temperature, solar radiation, and meteorology (Vroom et al. 2017, Daniels and Danner 2020). Moreover, it is unlikely that flow alterations from Keswick will influence water temperature in the lower Sacramento River and north Delta (Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures measured at Prisoners Point rarely exceed 56°F in the winter.

Dissolved oxygen stressors are not anticipated to change. Dissolved oxygen less than 5.0mg/L may affect migration (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below this in the winter.

Pathogens stressors are not anticipated to change. Water temperature above 59.9°F result in highly virulent diseases affecting Chinook salmon (McCullough 1999). Water quality monitoring has not shown water temperatures greater than this in the winter.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since it does not remove or introduce spring-run Chinook salmon into the population.

3.2.3.1.2 Eggs

Eggs are not present.

3.2.3.1.3 Young-of Year Juveniles

Young-of-year juveniles are rearing and migrating in the Delta. Juvenile use of the Bay-Delta varies both within and among years. During the winter months, some early migrants can leave the Delta, though migration can occur through May. A large storm pulse during the winter may cue juveniles rearing in the middle Sacramento River to migrate into the Bay-Delta, but in years without a storm pulse or pulses, juveniles historically migrate in a single pulse during late winter. Several stressors have been identified to possibly affect survival, residence time and migration, and condition. Habitat attributes may have compounding effects; it is important to not consider a single stressor alone.

Toxicity and contaminants stressors may increase. The increase is likely discountable and/or insignificant. Exposure to contaminants can lead to reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). CVP and SWP storage and diversion of water decreases Delta inflow and outflow concentrating constituents. Historical fisheries monitoring has not reported large-scale evidence of toxicity and contaminants in Bay-Delta fishes. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors are not anticipated to change from decreased Delta inflow and outflow. Juvenile stranding has not been observed in fish monitoring in the Bay-Delta.

Outmigration cues stressors may increase. This increase may mask the cue to migrate and increase travel time in the Delta, which may reduce outmigration survival. Appendix I presents analysis on this stressor.

Water temperature stressors may increase. This increase is likely discountable and/or insignificant. Although Delta water temperature is positively correlated with Delta inflow in the winter (Bashevkin and Mahardja 2022) and CVP and SWP storage and diversion decreases Delta inflow and outflow, Bay-Delta water temperature is mainly driven by air temperature, solar radiation, and meteorology (Vroom et al. 2017, Daniels and Danner 2020). Moreover, it is unlikely that flow alterations from Keswick will influence water temperature in the lower Sacramento River and north Delta (Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures measured at Prisoners Point do not exceed suitable temperatures in the winter (60°F; EPA 2001).

Dissolved Oxygen are not anticipated to change. Dissolved oxygen less than 5.0mg/L may affect migration (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below 5.0 mg/Lin the winter.

Pathogens and disease stressors are not anticipated to change. Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Water quality monitoring has not shown water temperatures greater than 59.9°F in the winter.

Entrainment risk stressors may increase. The increase may result in higher levels of entrainment and loss of juvenile spring-run Chinook salmon. CVP and SWP storage and diversions result in entrainment at the Skinner and Tracy fish facilities. Appendix I presents the analysis on this stressor.

Refuge habitat stressors may increase. The increase may reduce suitable margin and off-channel habitats for juvenile spring-run Chinook salmon. Maintenance of storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for juveniles. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the winter in the Bay Delta is plotted in Section 8.3 of Appendix B. Appendix P defines refuge habitat and presents analyzes on this stressor.

Food availability and quality stressors may increase. The increase may result in a change of food web processes and a decrease in quality food available to juvenile spring-run Chinook salmon. Maintenance of storage results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix P presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the “Outmigration Cues” and “Entrainment Risk” stressors in juvenile winter-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix I presents analysis of these stressors.

3.2.3.1.4 Yearling Juveniles

Yearlings are migrating in the Delta. Yearling use of the Bay-Delta varies both within and among years. During the winter months, some early migrants can leave the Delta, though migration can occur through May. A large storm pulse during the winter may cue yearlings rearing in the middle Sacramento River to migrate into the Bay-Delta, but in years without a storm pulse or pulses, yearlings historically migrate in a single pulse during late winter. Several stressors have been identified to possibly affect survival, residence time and migration, and condition. Habitat attributes may have compounding effects; it is important to not consider a single stressor alone.

Toxicity and contaminants stressors may increase. The increase is likely discountable and/or insignificant. Exposure to contaminants can result in sub-lethal effects such as reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). CVP and SWP storage and diversion of water decreases Delta inflow and outflow concentrating constituents. Historical fisheries monitoring has not reported large-scale evidence of toxicity and contaminants in Bay-Delta fishes. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors are not anticipated to change from decreased Delta inflow and outflow. Yearling stranding has not been observed in fish monitoring in the Bay-Delta.

Outmigration cues stressors may increase. This increase may mask the cue to migrate and increase travel time in the Delta, which may reduce outmigration survival. Appendix I - Old and Middle River Management presents analysis on this stressor.

Water temperature stressors are not anticipated to change. Although Delta water temperature is positively correlated with Delta inflow in the winter (Bashevkin and Mahardja 2022) and CVP and SWP storage and diversion decreases Delta inflow and outflow, Bay-Delta water temperature is mainly driven by air temperature, solar radiation, and meteorology (Vroom et al. 2017, Daniels and Danner 2020). Moreover, it is unlikely that flow alterations from Keswick will influence water temperature in the lower Sacramento River and north Delta (Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures measured at Prisoners Point do not exceed suitable temperatures in the winter (60°F; EPA 2001).

Dissolved oxygen stressors are not anticipated to change. Chinook salmon yearling juveniles' swimming performance declined at DO less than 9 mg O_2/l at a temperature of 52.7°F but decreased more severely with DO less than 5 mg O_2/l (Davis et al. 1963). Water quality monitoring has not shown dissolved oxygen at levels below 5.0 mg/l in the winter.

Pathogens and disease stressors are not anticipated to change. Yearling survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Water quality monitoring has not shown water temperatures greater than 59.9°F in the winter.

Entrainment risk stressors may increase. The increase may result in higher levels of entrainment and loss of juvenile spring-run Chinook salmon. CVP and SWP storage and diversions result in entrainment at the Skinner and Tracy fish facilities. Appendix I presents the analysis on this stressor.

Refuge habitat stressors may increase. The increase may reduce suitable margin and off-channel habitats for juvenile spring-run Chinook salmon. Maintenance of storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for yearlings. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the winter in the Bay Delta is plotted in Section 8.3 of Appendix B. Appendix P defines refuge habitat and presents analyzes on this stressor.

Food availability and quality stressors may increase. The increase may result in a change of food web processes and a decrease in quality food available to yearling spring-run Chinook salmon. Maintenance of storage results in less inundated habitats. 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 yearlings (Jeffres et al. 2008, 2020; Goertler et al. 2018). Appendix P presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in spring-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix I presents analysis of these stressors.

3.2.3.2 Spring

In the spring, Reclamation and DWR's proposed water operations will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on spring-run.

3.2.3.2.1 Adults

Adults are migrating in the Delta. Adults move through the Bay-Delta into reaches of the Middle and upper Sacramento River, where they hold until ready for spawning. This life-history strategy may leave adults vulnerable to multiple factors that affect survival, timing, and distribution. Additionally, adult body condition upon return to spawning areas can influence effects of stressors on pre-spawn mortality or fecundity. Several stressors have been identified for habitat attributes that affect spawning and holding.

In-river fishery and poaching stressors are not anticipated to change. There is no Chinook salmon fishing permitted in the Delta in the spring. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity and contaminants stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow relative to environmental baseline that may concentrate contaminant constituents. During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage. A 0.2 mg/kg threshold for methylmercury is protective of both juvenile and adult fish (Beckvar et al. 2005). Water quality monitoring has not shown contaminants at levels likely to affect adult salmon and toxicity effects have not been observed in fish monitoring. Levels safe for human consumption are assumed not likely to impact fish health and (Murphy et al. 2022) identifies Chinook salmon as safe to eat.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult fish kills due to stranding have not been reported or documented within various fishery technical teams in the Bay-Delta.

Water temperature stressors is not anticipated to change. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022). Reservoir operations may influence water temperature to a minimal extent in the lower reaches of the Sacramento River (Daniels and Danner 2020). The historical record of temperatures in the Delta at Prisoner's Point shows water temperatures greater than 68°F within the Delta in May. There is uncertainty about whether the decreased inflow from reservoir operations is a cause for increased Delta water temperatures. The range of potential reservoir operations is unlikely to have a measurable effect on Delta water temperatures. 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).

Dissolved oxygen stressors are not anticipated to change. Dissolved oxygen less than 5.0mg/L may affect migration (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below this in the spring.

Pathogen stressors may increase. This increase is likely discountable and/or insignificant. Water temperatures greater than 59.9°F do occur in the spring, and this is the threshold when diseases affecting Chinook salmon become highly virulent (McCullough 1999). On average, Prisoner Point water temperature has been lower than 59.9°F in early spring, but higher in late spring (Appendix B, Section 8.2). There is uncertainty about whether the decreased spring outflow is a cause for changes in Delta water temperatures. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin et al. 2022); however, this relationship is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature and meteorology (Vroom et al. 2017).

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since it does not remove or introduce spring-run Chinook salmon into the population.

3.2.3.2.2 Eggs

Eggs are not present in the Delta.

3.2.3.2.3 Young-of-Year Juveniles

Young-of-year juveniles are rearing and migrating in the Delta. Juvenile use of the Bay-Delta varies both within and among years. During the spring months, some early migrants can leave the Delta, though migration can occur through May. A large storm pulse during the winter may cue juveniles rearing in the middle Sacramento River to migrate into the Bay-Delta, with a second pulse between February and March. The majority of the population is present within the Bay-Delta during the spring. Several stressors have been identified to possibly affect survival, residence time and migration, and condition. Habitat attributes may have compounding effects; it is important to not consider a single stressor alone.

Toxicity and contaminants stressors may increase. The increase is likely discountable and/or insignificant. Exposure to contaminants can result in sub-lethal effects such as reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). CVP and SWP storage and diversion of water decreases Delta inflow and outflow concentrating constituents. Historical fisheries monitoring has not reported large-scale evidence of toxicity and contaminants in Bay-Delta fishes. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010).

Stranding risk stressors are not anticipated to change from decreased Delta inflow and outflow. Juvenile stranding has not been observed in fish monitoring in the Bay-Delta.

Outmigration cues stressors may increase. This increase may mask the cue to migrate and increase travel time in the Delta, which may reduce outmigration survival. Appendix I presents analysis on this stressor.

Water temperature stressors may increase. The increase is likely discountable and/or insignificant. Although Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022) and CVP and SWP storage and diversion decreases Delta inflow and outflow, Bay-Delta water temperature is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature, solar radiation, and meteorology (Vroom et al. 2017, Daniels and Danner 2020). Moreover, it is unlikely that flow alterations from Keswick will influence water temperature in the lower Sacramento River and north Delta (Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures measured at Prisoners Point rarely exceed suitable temperatures in the spring (60°F; EPA 2001).

Dissolved Oxygen stressors are not anticipated to change. Dissolved oxygen less than 5.0mg/L may affect migration (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below 5.0 mg/l in the spring.

Pathogens and disease stressors may increase. This increase is likely discountable and/or insignificant. Water temperatures greater than 59.9°F occur in the spring, are when diseases affecting Chinook salmon become highly virulent (McCullough 1999). On average, Prisoner Point water temperatures have been lower than 59.9°F in March, but higher in April and May (Appendix B, Section 8.2). There is uncertainty about whether the decreased spring outflow is a cause for changes in Delta water temperatures. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin et al. 2022); however, this relationship is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature and meteorology (Vroom et al. 2017).

Entrainment risk stressors may increase. The increase may result in higher levels of entrainment and loss of juvenile spring-run Chinook salmon. CVP and SWP storage and diversions result in entrainment at the Skinner and Tracy fish facilities. Appendix I presents the analysis on this stressor.

Refuge habitat stressors may increase. The increase may reduce suitable margin and off-channel habitats for juvenile spring-run Chinook salmon. Maintenance of storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for juveniles. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the spring in the Bay Delta is plotted in Section 8.3 of Appendix B. Appendix P defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. The increase may result in a change of food web processes and a decrease in quality food available to juvenile spring-run Chinook salmon. Maintenance of storage results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix P presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in juvenile winter-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix I presents analysis of these stressors.

3.2.3.2.4 Yearlings

Yearlings are not present in the Delta in the spring.

3.2.3.3 Summer

In the summer, Reclamation and DWR's proposed water operation will decrease Delta outflow on average.

3.2.3.3.1 Adults

Adults are not present in the Delta in the summer.

3.2.3.3.2 Eggs

Eggs are not present in the Delta in the summer.

3.2.3.3.3 Juveniles

Juveniles are not present in the Delta in the summer.

3.2.3.3.4 Yearlings

Yearlings are not present in the Delta in the summer.

3.2.3.4 Fall

In the fall, Reclamation and DWR's proposed water operations will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on spring-run.

3.2.3.4.1 Adults

Adults are not present in the fall.

3.2.3.4.2 Eggs

Eggs are not present in the fall.

3.2.3.4.3 Juveniles

Juveniles are not present in the fall.

3.2.3.4.4 Yearlings

Yearlings are migrating in the Delta. Yearling use of the Bay-Delta varies both within and among years. Several stressors have been identified to possibly affect survival, residence time and migration, and condition. Habitat attributes may have compounding effects; it is important to not consider a single stressor alone.

Toxicity and contaminants stressors may increase. The increase is likely discountable and/or insignificant. Exposure to contaminants can result in sub-lethal effects such as reduced growth or suppression of juvenile immune systems possibly leading to infection and disease (Arkoosh et al. 2001; Kroglund and Finstad 2003; Lundin et al. 2021). CVP and SWP storage and diversion of water decreases Delta inflow and outflow concentrating constituents. Historical fisheries monitoring has not reported large-scale evidence of toxicity and contaminants in Bay-Delta fishes. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants; however, CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent.

Stranding risk stressors are not anticipated to change from decreased Delta inflow and outflow. Yearling stranding has not been observed in fish monitoring in the Bay-Delta.

Outmigration cues stressors may increase. This increase may mask the cue to migrate and increase travel time in the Delta, which may reduce outmigration survival. Appendix I presents analysis on this stressor.

Water temperature stressors may increase or may decrease. The increase or decrease is likely discountable and/or insignificant. CVP and SWP storage and diversion decreases Delta outflow in the fall. There is uncertainty about whether the decreased outflow is a cause for changes in Delta water temperatures. Delta water temperature is negatively correlated with Delta inflow in the fall (Bashevkin et al. 2022); however, this relationship is mainly driven by air temperature and meteorology (Vroom et al. 2017).

Dissolved oxygen stressors are not anticipated to change. Observed swimming performance of Chinook salmon yearling juveniles declined at DO less than 9 mg O_2/l at a temperature of 52.7°F but decreased more severely with DO less than 5 mg O_2/l (Davis et al. 1963). Water quality monitoring has not shown dissolved oxygen at levels below 5 mg/l in the fall.

Pathogens and disease stressors may increase. This increase is likely discountable and/or insignificant. Water temperatures greater than 59.9°F occur in the fall (Appendix B, Section 8.2). Above this threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999). There is uncertainty about whether the decreased outflow is a cause for changes in Delta water temperatures. Delta water temperature is negatively correlated with Delta inflow in the fall (Bashevkin et al. 2022); however, this relationship is mainly driven by air temperature and meteorology (Vroom et al. 2017).

Entrainment risk stressors may increase. The increase may result in higher levels of entrainment and loss of yearling spring-run Chinook salmon. CVP and SWP storage and diversions result in entrainment at the Skinner and Tracy fish facilities. Appendix I presents the analysis on this stressor.

Refuge habitat stressors may increase. The increase may reduce suitable margin and off-channel habitats for yearling spring-run Chinook salmon. Maintenance of storage decreases flows that reduce suitable margin and off-channel habitats being available as refuge habitat for yearlings. Access to off-channel habitats has been linked to higher growth rates and survival (Limm and Marchetti 2009; Zeug et al. 2020). Suitable habitat for spring-run Chinook salmon in the fall in the Bay Delta is plotted in Section 8.3 of Appendix B. Appendix P defines refuge habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. The increase may result in a change of food web processes and a decrease in quality food available to yearling spring-run Chinook salmon. Maintenance of storage results in less inundated habitats. 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 yearlings (Jeffres et al. 2008, 2020; Goertler et al. 2018). Appendix P presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store water will reduce flow and warm temperatures relative to the environmental baseline. Predation of spring-run Chinook salmon by aquatic and terrestrial species affects migration, growth, and survival of spring-run Chinook salmon, discussed in the "Outmigration Cues" and "Entrainment Risk" stressors in spring-run Chinook salmon sections of this document. Predation, for the purposes of this document, is identified at the Delta fish collection facilities and Bay-Delta "hotspots". 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix I presents analysis of these stressors.

3.3 Species Effects Determination

The seasonal operation of the CVP and SWP may affect, and is likely to adversely affect, CV spring-run Chinook salmon. The seasonal operation of the CVP is also likely to have beneficial effects. Deconstruction of the seasonal operations systematically evaluated each stressor identified by conceptual models. Stressors not linked to the operation of the CVP and SWP were identified as "are not anticipated to change." Stressors that were insignificant or discountable were documented. Stressors with a material effect on the fitness of species were identified, and seasonal operations will consider minimization and/or compensation through conservation measures.

Stressors on adults influenced by the seasonal operations include:

- Water temperatures: Increased flows are anticipated to increase water temperature stressors in the Sacramento River and Clear Creek. A conservation measure for Sacramento River and Clear Creek water temperature that considers flows may benefit water temperatures for some adults and adversely affect others. Managing water temperatures for egg incubation provides colder waters than needed for adults, but that management action may start later in the year, depending on seasonal operations.
- Spawning habitat: Decreased flows may provide less habitat availability and may increase crowding. A conservation measure for maintenance and construction of spawning habitat may minimize or benefit potential spawning habitat.
- Redd Dewatering: The transition between seasonal summer and fall releases below Keswick Dam may increase spring-run Chinook redd dewatering in the Sacramento River. A conservation measure for fall instream flows may minimize potential dewatering.

Stressors on yearlings influenced by the seasonal operations include:

- Stranding risk: Reduced releases below Keswick Dam and Whiskeytown Dam during the yearling rearing period (November through April) pose a stranding risk to yearlings. A conservation measure for ramping rates may avoid or minimize the potential for yearling stranding.
- Outmigration cues: The change in timing of flows in the Sacramento River, Clear Creek and Bay-Delta during the yearling outmigration period may disrupt outmigration cures and reduce survival. Conservation measures for minimum instream flows and pulse flows may avoid or minimize outmigration cue stressors.
- Entrainment risk: All CVP and SWP facilities have fish screens. However, juveniles may be entrained at the Delta Cross Channel and routed into areas of the Delta with poor survival by the export facilities or entrained at the salvage facilities for the CVP and SWP. Several actions may avoid, minimize, or benefit the potential for Bay-Delta juvenile entrainment including a conservation measure for the Delta Cross Channel, a conservation measure for routing at Georgiana Slough, a conservation measure for Old and Middle River flow management, and a conservation measure for salvage before the export facilities.
- Refuge habitat: Decreased flows may provide decreased habitat availability. A conservation measure for the construction of additional rearing habitat on the Sacramento River and Clear Creek may minimize or benefit potential refuge habitat.
- Food availability and quality: Decreased flows may provide less food availability through a reduction in suitable feeding areas. A conservation measure for the construction of additional tributary and tidal rearing habitat may minimize or benefit food availability and quality.

Stressors on juveniles influenced by the seasonal operations include:

- Stranding risk: Reduced releases below Keswick Dam and Whiskeytown Dam during the juvenile rearing period (November through April) pose a stranding risk to yearlings. A conservation measure for instream minimum flows and ramping rates may avoid or minimize the potential for yearling stranding.
- Outmigration cues: The change in timing of flows in the Sacramento River, Clear Creek and Bay-Delta during the yearling outmigration period may disrupt outmigration cures and reduce survival. Conservation measures for minimum instream flows and spring pulse flows may avoid or minimize outmigration cue stressors.
- Entrainment risk: All CVP and SWP facilities have fish screens. However, juveniles may be entrained at the Delta Cross Channel and routed into areas of the Delta with poor survival by the export facilities or entrained at the salvage facilities for the CVP and SWP. Several actions may avoid, minimize, or benefit the potential for Bay-Delta juvenile entrainment including a conservation measure for the Delta Cross Channel, a conservation measure for routing at Georgiana Slough, a conservation measure for Old and Middle River flow management, and a conservation measure for salvage before the export facilities.
- Refuge habitat: Decreased flows may provide decreased habitat availability. A conservation measure for the construction of additional rearing habitat on the Sacramento River and Clear Creek may minimize or benefit potential refuge habitat.
- Food availability and quality: Decreased flows may provide less food availability through a reduction in suitable feeding areas. A conservation measure for the construction of additional tributary and tidal rearing habitat may minimize or benefit food availability and quality.

Stressors on eggs and alevins influenced by the seasonal operations include:

- Stranding: The transition between seasonal summer and fall releases below Keswick Dam may increase spring-run Chinook stranding in the Sacramento River. A conservation measure for fall instream flows may minimize potential dewatering.
- Water temperatures and dissolved oxygen: The management of cold water in Whiskeytown Reservoir and Shasta Reservoir is necessary to maintain suitable water temperature for egg incubation. Management actions for Sacramento River and Clear Creek water temperature management that considers seasonal operations may benefit some eggs and alevin and adversely affect others.

3.4 Critical Habitat Physical and Biological Features

Critical habitat has been designated for spring-run (70 FR 52488, September 2, 2005) and includes all river reaches accessible to listed spring-run in the Sacramento River and its tributaries in California. Also included were river reaches and estuarine areas of the Delta, all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait, all waters of San Pablo Bay westward of the Carquinez

Bridge, and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge.

The critical habitat for spring-run lists the essential physical and biological features, which include:

3.4.1 Spawning Sites

Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development is essential for the conservation of spring-run. These features are essential to conservation because without them the species cannot successfully spawn and produce offspring.

The species effects determination found related potential stressors of:

- Spawning habitat
- Water temperatures
- Dewatering

There are no additional operation effects on spawning sites when species are not present.

3.4.2 Rearing Sites

Freshwater rearing sites with the following criteria are essential for the conservation of spring-run: 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. These features are essential to conservation because without them juveniles cannot access and utilize areas needed to forage, grow, and develop behaviors (e.g., predator avoidance, competition) for survival.

The species effects determination found related potential stressors of:

- Water temperature
- Juvenile stranding
- Refuge habitat
- Food availability and quality

There are no additional operation effects on rearing sites when species are not present.

3.4.3 Migration Corridors

Freshwater migration corridors with the following criteria are essential for the conservation of spring-run: habitat free of obstruction 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.

These features are essential to conservation because without them juveniles cannot use the variety of habitats that allow them to avoid high flows, avoid predators, successfully compete, begin the behavioral and physiological changes needed for life in the ocean, and reach the ocean in a timely manner. Similarly, these features are essential for adults because they allow fish in a non-feeding condition to successfully swim upstream, avoid predators, and reach spawning areas on limited energy stores.

The species effects determination found related potential stressors of:

- Outmigration cues
- Refuge habitat
- Food availability and quality
- Entrainment Risk

There are no additional operation effects on migration corridors when species are not present

3.4.4 Estuarine Areas

Estuarine areas with the following criteria are essential for the conservation of spring-run: habitat free of obstruction 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. These features are essential to conservation because without them juveniles cannot reach the ocean in a timely manner and use the variety of habitats that allow them to avoid predators, compete successfully, and complete the behavioral and physiological changes needed for life in the ocean. Similarly, these features are essential to the conservation of adults because they provide a final source of abundant forage that will provide the energy stores needed to make the physiological transition to fresh water, migrate upstream, avoid predators, and develop to maturity upon reaching spawning areas.

The species effects determination found related potential stressors of:

- Outmigration cues
- Refuge habitat
- Food availability and quality

There are no operation effects on estuarine areas when species are not present.

3.5 Critical Habitat Effect Determination

The seasonal operation is likely to adversely affect critical habitat for CV spring-run Chinook salmon.

- Degraded spawning substrate is reintroduced in the action area through gravel augmentation projects
- Impacts to juvenile rearing habitat and migration corridors are compensated through the construction of additional habitat and implementing recommendations based on new research
- Impacts to juvenile passage from the Sacramento River to the Pacific Ocean are actively managed through spring pulse flows, minimum instream flows, fall and winter instream flows, Old and Middle River flow management

4 Steelhead

The federally listed ESU of California CV steelhead distinct population segment (*Oncorhynchus mykiss*) (steelhead) and designated critical habitat occurs in the action area and may be affected by the seasonal operations of the 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.

4.1 Conceptual Lifecycle Models

An action may affect fish when the change in conditions overlap with the location and timing of fish and/or their habitats. The SAIL winter-run Chinook salmon conceptual model (Windell et al. 2017) has been adapted for steelhead 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).

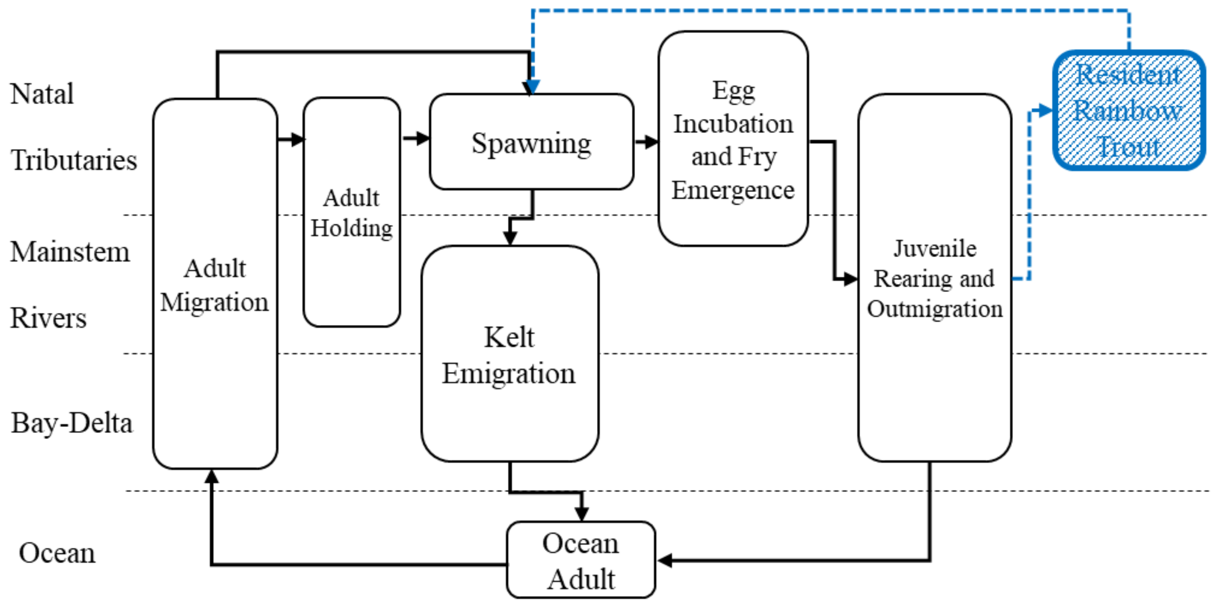

Figure 5. Simplified Geographic Life Stage Domains for Steelhead (adapted from Windell et al. 2017, Figure 2)

In addition to the winter-run Chinook salmon life stages and stressors, the proposed conceptual lifecycle framework for steelhead considers an additional life stage: kelts.

The stressors are deconstructed as follows:

- Adult Kelt Emigration
    - Freshwater entry and post-spawning (kelt) emigration
    - Residual Lipid Content of White Muscle Post-Spawning (not included in stressors list)
    - Pathogens
    - Predation risk

Each deconstruction of the action considers the 38 stressors for the winter-run life stages and the additional steelhead life stage. Additional and/or alternative conceptual models (e.g., CVPIA Science Integration Team, South Delta Salmonid Research Collaborative) may be incorporated as applicable.

Environmental conditions such as food availability, water temperature, and stream flow can influence the expression of anadromy in *O. mykiss* (Beakes and Phillis 2021). For example, low and variable summer stream flows produce warmer temperatures and greater competition for food as suitable habitat contracts. When conditions limit growth due to density-dependent competition or increasing metabolic demands of the individual anadromy becomes more common (Pearsons et al. 2008; Courter et al. 2009; Berejikian et al. 2013). In contrast, cooler temperatures and lower individual metabolic rates produce higher rates of freshwater maturation for equivalent somatic growth, particularly in females (McMillan et al. 2012; Sloat and Reeves 2014). The propensity of individuals to adopt the anadromous life history (i.e., steelhead) is the product of interactions between genetic and environmental factors. Recent research has shown some gene complexes associated with anadromy (e.g., Omy5) indirectly impact life-history expression through mediation of early somatic growth rates (Kelson et al. 2020). Further, past research has shown the expression of anadromy is related to an individual's state during their juvenile rearing phase and a genetically controlled size threshold required to initiate smolt transformation and anadromy (Tomkins and Hazel 2007; Hutchings 2011; Pulido 2011; Dodson et al. 2013). Growth rate and body-size thresholds above which anadromy is adopted have been described theoretically (Thorpe et al. 1998; Rikardsen et al. 2004; Mangel and Satterthwaite 2008) and documented empirically for steelhead (Thrower et al. 2004; Satterthwaite et al. 2010; Beakes et al. 2010; Phillis et al. 2016). The outcome of these genetic-environment interactions will vary within populations (e.g., males vs. females) and between populations according to the costs and benefits of alternative life history pathways.

For kelts, much of the available information on repeat spawning for steelhead comes from the Pacific Northwest (e.g., Mayer et al. 2008; Narum et al. 2008) because iteroparity in California steelhead populations is considered relatively rare (Moyle 2002). In Pacific Northwest populations, the rate of downstream migration post-spawning reach 54% (Mayer et al. 2008), but the rate of survival for kelts is often low (Narum et al. 2008). Factors that affect kelt survival include, but are not limited to, freshwater entry and post-spawning (kelt) emigration, residual lipid content of white muscle post-spawning, pathogens, and predation.

Monitoring data from snorkeling, carcass surveys, redd surveys, rotary screw traps, trawls, and beach seines describe the timing of steelhead presence (Figure 6) (Appendix C).

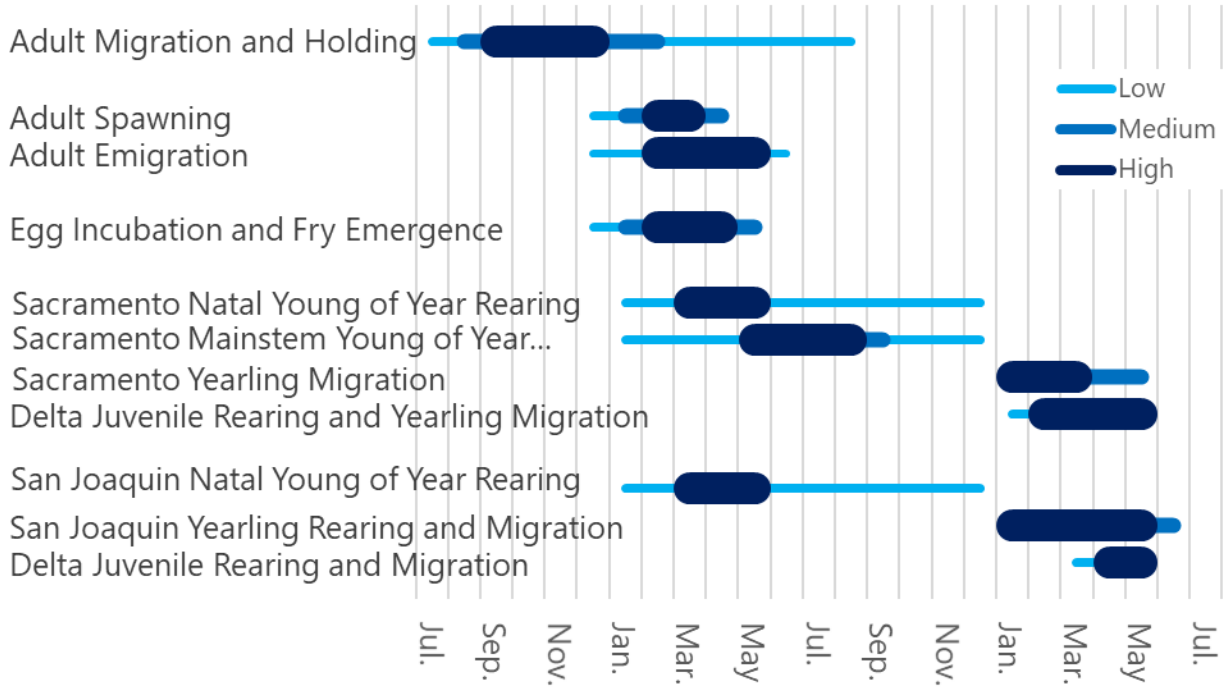

Figure 6. Temporal Life Stage Domains for Steelhead from Appendix C

The six spatial domains defined for steelhead are the Sacramento River, Clear Creek, the American River, the Stanislaus River, the Bay-Delta, and the San Joaquin River. Unique timing is provided for San Joaquin origin steelhead based on Mossdale trawl. The presence of a life-stage in the Central Valley and Bay-Delta (adult migration and holding) occurs over multiple calendar years. The ocean life stage is outside the action area determined by NMFS and therefore is not shown.

4.2 Species Effects Deconstruction

Steelhead are anticipated in Clear Creek, the Sacramento, American, Stanislaus, and San Joaquin Rivers; and in the Bay-Delta and may experience effects from the seasonal operations as described below. The Sacramento River, Clear Creek, American River, Stanislaus River, and San Joaquin River include adult migration and holding, adult spawning and emigration, egg incubation and fry emergence, and juvenile rearing and outmigration. The Bay-Delta includes adult migration and holding, and juvenile rearing. Modeling of water temperatures was not finalized for the Effects Analysis and therefore the order of magnitude that Proposed Action will significantly influence water temperatures was unknown. Determinations for these related stressors were based on the historic record.

4.2.1 Sacramento River

4.2.1.1 Winter

In the winter, Reclamation and DWR's proposed storage of water will decrease flows on average in the Sacramento River below Keswick Dam. Decreased flow in the upper Sacramento River may change stressors on steelhead.

4.2.1.1.1 Adults

Adults are migrating, holding, spawning, and rearing in the Sacramento River in the winter, undergoing an energetically taxing salt-to-freshwater transition to spawn. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase or decrease. The increase is likely insignificant. Maintenance of Shasta Reservoir storage may reduce flows and concentrate contaminants. The timing of snowmelt may play a role in the mobilization of contaminants although studies on contaminants present in snowmelt and rainfall runoff have reported differing results (Parajulee et al. 2017, Chen et al. 2018).Water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed during fish monitoring. Water quality in the Sacramento River and its tributaries within 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 bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Reduced flows may concentrate contaminants when present, while increased flows may dilute contaminants. During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding of steelhead in the winter has not been observed in the Upper Sacramento River due to seasonal operations.

Water temperature stressors may increase. The increase is likely insignificant. Maintenance of Shasta Reservoir storage may result in warmer water temperatures in the winter; however, historic winter water temperatures are within the range of adult migration, holding, and spawning temperature needs. Evidence from watersheds outside of the Central Valley suggests that temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994, Keefer et al. 2018). Optimal 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.

Dissolved oxygen stressors may increase or decrease. The increase is likely discountable Studies on salmonids have demonstrated that adults wait to migrate until dissolved oxygen is at least 5.0 mg/l (Carter 2005), and recommended oxygen levels for spawning anadromous salmonids should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). Maintenance of Shasta Reservoir storage may result in warmer water temperature and lower dissolved oxygen; however, water quality monitoring has not shown dissolved oxygen at levels below this in the winter. 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.

Food Availability and Quality stressors may increase or decrease. 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.

Pathogens and disease stressors may increase. The increase is likely discountable. Maintenance of Shasta Reservoir storage may result in warmer water temperatures in the winter; however historic water temperatures are colder than those that increase adult susceptibility to pathogen stressors. Water temperature less than 59.9°F occur in the winter, above which temperature threshold diseases affecting salmonids become highly virulent (McCullough 1999).

Spawning habitat stressors may decrease. The decrease is likely discountable. Habitat suitability curves show lower flows increase steelhead spawning habitat quantity and quality (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.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.1.1.2 Eggs

Eggs are incubating and fry are emerging in the Sacramento River. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity from contaminants stressors may increase or decrease. The increase is likely insignificant. Maintenance of Shasta Reservoir storage may decrease flows and concentrate contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect eggs and no fish effects have been observed in fish monitoring. During incubation, eggs do not eat, and subsequently are not exposed to contaminants in prey during this life stage.

Stranding and dewatering stressors may increase. Winter and spring flow reductions have the potential to expose redds in the Sacramento River.

Water temperature stressors may increase. 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, with negative thermal effects developing at or near 53.6°F (Kwain 1975; Humpesch 1985) and sharp increases in mortality at 57.2°F or 59°F (Velsen 1987; Rombough 1988). Historical water temperatures are below this threshold in the winter.

Dissolved oxygen stressors may increase and decrease. The increase is likely discountable and/or insignificant. Steelhead 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. Maintenance of Shasta Reservoir storage may result in warmer temperatures and decreased flows, which may decrease dissolved oxygen concentrations; however, water quality monitoring has rarely shown dissolved oxygen at levels below 8 mg/L in the winter.

Pathogens and disease stressors may increase. 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. 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). Water temperatures greater than 59.9°F is the threshold above which diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Sedimentation and gravel quantity stressors may increase. The increase is likely insignificant. Deposition of fine sediment has been shown to degrade eggs and alevin essential functions and development (Bennett et al. 2003, Jensen et al. 2009and build-up of fine sediment can decrease permeability for embryos (Bjornn and Reiser 1991). Fine sediment deposition typically occurs under baseflow conditions and areas of slow water velocity (Wood and Armitage 1997.). Although there will be 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.

Redd quality stressors may increase and/or decrease. The increase is likely discountable. Although there will be decreased flows during the egg incubation period, flow rates are still generally higher than other times of the year in the Sacramento River. 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).). Appendix L presents an analysis regarding the effects on egg incubation from temperature and flow.

Predation stressors are not anticipated to change. Predator abundance and distribution is not anticipated to change due to operations.

4.2.1.1.3 Juveniles

Juveniles are rearing and outmigrating in the Sacramento River. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates dependent on an individual's physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Shasta Reservoir storage may reduce flows and concentrate constituents from urban and agricultural land use that affect concentration in juvenile's prey. Contaminants can cause 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). Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). 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).

Stranding risk stressors may increase and/or decrease. The increase and/or decrease is likely discountable and/or insignificant. Average winter flows are expected to increase from December to January and from January to February following a similar pattern to the run-of-river. When flows decrease juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in Shasta Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may increase. The increase is likely discountable and/or insignificant. 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). 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). Maintenance of Shasta Reservoir storage may result in increased water temperatures in the winter that are closer to optimal temperatures; however, historical winter water temperatures are below or within the range of rearing temperature needs. See

Outmigration Cues stressor for water temperatures that affect outmigrating juveniles. There is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may increase. The increase is likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring consistently has not exhibited dissolved oxygen levels below 9 mg/L in the winter. However, there is uncertainty on how these changes in 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).

Pathogen and disease stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Shasta Reservoir storage may decrease flows and may cause crowding into a smaller habitat area and increase water temperatures. 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 Chinook survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic winter water temperatures are colder than this threshold. However, there is uncertainty on how these changes in pathogen and disease stressors may affect occurrence of anadromy among juvenile steelhead, 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).

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108).

Refuge habitat stressors may increase. The increase may harm juvenile steelhead. Maintenance of Shasta Reservoir storage decreases flows that reduce suitable margin and off-channel habitats available as refuge habitat for juveniles. Suitable habitat for steelhead in the winter in the Upper Sacramento River is plotted in Appendix B (Section 3.3). Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Maintenance of Shasta Reservoir storage results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Reduced releases from Shasta Reservoir may decrease flows below Shasta Dam. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the Delta and Sacramento River is ubiquitous. Introduced non-native piscivorous species such as striped and largemouth bass have become well-established predators in the Central Valley system. Juvenile steelhead are preyed upon by aquatic and terrestrial species and this can directly or indirectly influence juveniles' migration, growth, and survival. 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.

4.2.1.2 Spring

In the spring, Reclamation and DWR's proposed storage of water will decrease flows on average in the Sacramento River below Keswick Dam. Decreased flow in the upper Sacramento River may change stressors on steelhead.

4.2.1.2.1 Adults

Adults are spawning, undertaking kelt emigration, and rearing in the Sacramento River in the spring, undergoing an energetically taxing freshwater-to-salt transition to forage. Several stressors have been identified that may delay spawning or affect kelt emigration.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Shasta Reservoir storage may reduce flows and concentrate contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within 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 bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not typically eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the spring has not been observed in the Upper Sacramento River due to seasonal operations.

Water temperature stressors may increase. The increase may harm by reducing spawning success. The increase is likely insignificant during kelt emigration and adult migration. Evidence from watersheds outside of the Central Valley suggests that temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, and Nielson et al. 1994, Keefer et al. 2018). Optimal 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. Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F (Bell 1991, Richter and Kolmes 2005, FERC 1993). Historic water temperatures may go above the thermal threshold for successful spawning towards the end of the spawning season March through May. Historic water temperatures are below the migration impairment threshold for March through May.

Dissolved oxygen stressors may increase or decrease. The increase and decrease are likely discountable and/or insignificant. Studies on salmonids have demonstrated that adults wait to migrate when dissolved oxygen is at least 5.0 mg/l (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). Changing flows with seasonal operations may result in warmer water temperature and potentially lower dissolved oxygen in March and April but colder temperatures in May compared to the environmental baseline. However, in these months, water quality monitoring has shown dissolved oxygen levels are typically well above 5.0 mg/L in the spring.

Pathogens and disease stressors may increase. The increase may harm during spawning and kelt emigration. Maintenance of Shasta Reservoir storage may result in warmer water temperatures in the spring. Historic water temperatures are above the virulence threshold of 59.9°F (McCullough 1999) for kelts between April through June and for spawning adults between March through May.

Spawning habitat stressors decrease. The decrease is likely discountable and/or insignificant. Habitat suitability curves show lower flows increase steelhead spawning habitat quantity and quality (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.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.1.2.2 Eggs

Eggs are incubating and fry are emerging in the Sacramento River in the spring. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity from contaminants stressors may increase or decrease. The increase is likely insignificant. Maintenance of Shasta Reservoir storage may decrease flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect eggs and no fish effects have been observed in fish monitoring. During incubation, eggs do not eat, and subsequently are not exposed to contaminants in prey during this life stage.

Stranding and dewatering stressors may increase. Winter and spring flow reductions have the potential to expose redds in the Sacramento River. Appendix L presents an analysis of this stressor.

Water temperature stressors may increase. Lab-based studies of predominantly rainbow trout, all conducted on populations outside of the Central Valley, reported maximum hatching success between 44.6°F and 50°F, with negative thermal effects developing at or near 53.6°F (Kwain 1975; Humpesch 1985) and sharp increases in mortality at 57.2°F or 59°F (Velsen 1987; Rombough 1988). Historical water temperatures in the Sacramento River below Keswick Dam have exceeded 53.6°F at least one day during egg incubation March through July, in 100% of water years 1995-2023.

Dissolved oxygen stressors may increase or decrease. Increases and decreases are likely discountable and/or insignificant. 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. Maintenance of Shasta Reservoir storage may result in warmer temperatures and decreased flows, which may decrease dissolved oxygen concentrations; however, water quality monitoring has rarely shown dissolved oxygen at levels below 8 mg/L in the winter.

Pathogens and disease stressors may increase. Seasonal operations result in decreased flows and either increased or decreased water temperature, which may increase pathogen concentration and horizontal transmission, while increasing temperature may increase pathogen virulence. 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). Water temperatures greater than 59.9°F is the threshold above which diseases affecting Chinook salmon become highly virulent (McCullough 1999). Historic water temperatures in the Sacramento River have exceeded the virulence threshold of 59.9°F (McCullough 1999) during egg incubation between April and July, in 100% of water years 1995-2023.

Sedimentation and gravel quantity stressors may increase. The increase is likely insignificant. 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). Fine sediment deposition typically occurs under baseflow conditions and areas of slow water velocity (Wood and Armitage 1997). Although there will be 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.

Redd quality stressors may increase or decrease. The increase and/or decrease is likely discountable. Although there will be decreased flows during the egg incubation period, flow rates are still generally higher than other times of the year and well above baseflow conditions in the Sacramento River. 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). Appendix L presents an analysis regarding the effects on egg incubation from temperature and flow.

Predation stressors are not anticipated to change. Predator abundance and distribution is not anticipated to change due to operations.

4.2.1.2.3 Juveniles

Juveniles are rearing and outmigrating in the Sacramento River in the spring. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates dependent on an individual's physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Shasta Reservoir storage may reduce flows and concentrate constituents from urban and agricultural land use that affect concentration in juvenile's prey. Contaminants can cause 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). Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery juveniles were reported for 199 samples, and approximately 1% of sampled fish (n = 2; 0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). 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).

Stranding risk stressors may increase or decrease. The increase may harass, harm, and kill juvenile steelhead. Flows are decreased in March and April when juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators to have a higher success rate on stranded fish. The decrease may be beneficial. Flows increase in May for seasonal operations when juveniles' risk of being stranded in disconnected habitat is decreased. Stranding risk stressors may decrease from the dampening of flow fluctuations during precipitation events and would benefit from reduced predation. Appendix J presents an analysis of this stressor.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in Shasta Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may increase or decrease. The increase or decrease is likely discountable and/or insignificant. 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). 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). Changing flows from seasonal operations may result in warmer water temperatures in March and April and cooler temperatures in May; however, modeled water temperatures are below or within the range of rearing and outmigrating temperature needs. Historical water temperatures from 1995-2022 at Red Bluff are below the 66.2°F threshold for optimal water temperatures for juveniles rearing. Appendix L presents an analysis of this stressor. See Outmigration Cues stressor for water temperatures that affect outmigrating juveniles. There is uncertainty on how changes in temperature 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).

Dissolved oxygen stressors may increase or decrease. The increase and decrease are likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring consistently has not exhibited dissolved oxygen levels below 9 mg/L in the spring. However, there is uncertainty on how these changes in 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).

Pathogen and disease stressors may increase or decrease. The increase may cause harm to juvenile steelhead and the decrease is likely discountable and/or insignificant. Maintenance of Shasta Reservoir storage may decrease flows, may cause crowding into a smaller habitat area, and may increase or decrease water temperatures. 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 is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic water temperatures in April and May are above the virulence threshold, when juveniles are outmigrating and rearing. Diseased *O. mykiss* have not been observed in the Sacramento River in the spring. The effect of changing flow and temperature may be offsetting. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108).

Refuge habitat stressors may decrease or increase. The decrease is likely beneficial, and the increase may harm juvenile steelhead. Decreasing flows relative to the environmental baseline in March and April can decrease access to high quality refuge habitat while an increase in flows in May could increase access to high quality refuge habitat. This habitat provides lower velocities and greater cover, which decreases predation risk and improves survival. Suitable habitat for steelhead in the spring in the Upper Sacramento River is plotted in Appendix B (Section 3.3). Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase. The increase may harm juvenile Steelhead. Maintenance of Shasta Reservoir storage results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Reduced releases from Shasta Reservoir may decrease flows below Shasta Dam. Indirect effects of predation are described further in the “Outmigration Cues”, “Entrainment Risk”, and “Refuge Habitat” sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the Delta and Sacramento River is ubiquitous. Introduced non-native piscivorous species such as striped and largemouth bass have become well-established predators in the Central Valley system. Juvenile steelhead are preyed upon by aquatic and terrestrial species and this can directly or indirectly influence juveniles’ migration, growth, and survival. 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.

4.2.1.3 Summer

In the summer, Reclamation and DWR’s proposed release of water will increase flows on average in the Sacramento River below Keswick Dam. Increased flow in the upper Sacramento River may change stressors on steelhead.

4.2.1.3.1 Adults

Adult are migrating, holding, and rearing in the Sacramento River. Several stressors have been identified that may affect migration and rearing influencing maturation and migration.

In-river fishery or poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants may decrease. The decrease is likely discountable and/or insignificant. Releases of Shasta Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within 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 bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding of steelhead in the summer has not been observed in the Upper Sacramento River due to seasonal operations.

Water temperature stressors may increase. The increase is likely insignificant. Evidence from watersheds outside of the Central Valley suggests that temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994; Keefer et al. 2018). Optimal 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. Historic water temperatures are below the migration impairment threshold for kelts in June and adults on their spawning migration July and August.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/l (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). There were no steelhead specific studies found. Changing flows with seasonal operations may result in colder water temperatures and water quality monitoring has shown dissolved oxygen levels are typically above 5.0 mg/L in the summer.

Pathogens and disease stressors may increase. The increase may harm during adult migration and kelt emigration. Maintenance of Shasta Reservoir storage may result in warmer water temperatures in the summer. Historic water temperatures are above the virulence threshold of 59.9°F (McCullough 1999) for kelts in June and adults on their spawning migration July and August.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.1.3.2 Eggs

Eggs may be present in the upper Sacramento River in the summer. Based on spawning timing it is possible that eggs and fry are emerging as late as July. 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 2021). For the Sacramento River, spawning timing was taken from historic data by Hallock (1989) which indicates spawning starts in December, peaks in February, and can last until May. Adding 50 days for incubation timing, gives an incubation and fry emergence window of December through July (states June in steelhead chapter with the 50 days).

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity from contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Increases in 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. During incubation, eggs do not eat, and subsequently are not exposed to contaminants in prey during this life stage.

Stranding and dewatering stressors may decrease. The decrease may be beneficial. Increasing flows from May through August for seasonal operations, relative to decreasing flows may reduce dewatering of spawning habitat. Appendix L presents an analysis of this stressor.

Water temperature stressors may increase or decrease. The increase may cause harm by reducing egg survival and the decrease is likely discountable and/or insignificant. The impact may vary monthly. Lab-based studies of predominantly rainbow trout, all conducted on populations outside of the Central Valley, reported maximum hatching success between 44.6°F and 50°F, with negative thermal effects developing at or near 53.6°F (Kwain 1975; Humpesch 1985) and sharp increases in mortality at 57.2°F or 59°F (Velsen 1987; Rombough 1988). Historic water temperatures in the Sacramento River below Keswick Dam have exceeded 53.6°F at least one day during egg incubation June through July, in 100% of water years 1995-2023.

Dissolved oxygen stressors may increase or decrease. Increases and decreases are likely discountable and/or insignificant. 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. Water quality monitoring has not consistently shown dissolved oxygen at levels below 8 mg/L during egg incubation. Dissolved oxygen levels below Keswick Dam occasionally drop below 8 mg/L for short periods towards the end of the incubation period. **Pathogens stressors** may increase. 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 result in increased flows and either increased or decreased water temperature, which may increase pathogen concentration and horizontal transmission, while increasing temperature may increase pathogen virulence. The effect of changing flow and temperature may be offsetting. Historic water temperatures in the Sacramento River have exceeded the virulence threshold of 59.9°F

(McCullough 1999) during egg incubation between June and July, in 100% of water years 1995-2023.

Sedimentation and gravel quantity stressors may decrease. The decrease is likely discountable and/or insignificant. Although there will be increased flows during the summer portion of the egg incubation and fry emergence period, the changes will likely be insignificant and/or discountable to the sedimentation and gravel quantity.

Redd quality stressors may decrease. The decrease is likely discountable and/or insignificant. The increased flows (May through July) may decrease aquatic vegetation and improve hydrological and biological connectivity within the streambed that affect egg survival and alevin emergence. 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). Appendix L presents an analysis regarding the effects on egg incubation from temperature and flow.

Predation stressors are not anticipated to change. Predator abundance and distribution is not anticipated to change due to operations.

4.2.1.3.3 Juveniles

Juveniles are rearing in the middle Sacramento River. The amount of time spent rearing in the upper Sacramento River varies before juveniles migrate into the middle Sacramento River. This habitat is primarily used for rearing and as a migration corridor to the Bay-Delta. Time spent within and size distribution both entering and exiting the middle Sacramento River vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and juvenile condition (some affecting several parameters) during the migration.

Toxicity from contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Releases of Shasta Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminate studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook Salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). However, no sublethal effects were observed in these juveniles. There is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile steelhead, 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).

Stranding risk stressors may decrease. The decrease is likely beneficial due to the decreased risk associated with stranding. Increased flows prevent juveniles from becoming stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Seasonal operations on the

Sacramento River from Keswick Dam may increase flows May through July resulting in less stranding.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. There is 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). In the summer period, juveniles are rearing and have finished outmigration by May. However, increased flows and increased food availability in the summer may lead to higher rates of residency.

Water temperature stressors may decrease. The decrease is likely beneficial. 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). 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). Historical water temperatures in the summer rarely exceed 66.2°F (2 out of 28 years or 7%). See Outmigration Cues stressor for water temperatures that affect outmigrating juveniles. There is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring consistently has not exhibited dissolved oxygen levels below 9 mg/L in the summer. However, there is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. The increase cause harm to rearing juveniles and the decrease is likely discountable and/or insignificant. Releases of Shasta Reservoir storage may result in cooler water temperatures in the summer; however historic water temperatures in the summer exceed the virulence threshold. Water temperatures greater than 59.9°F are above the virulence threshold for diseases that affect salmonids (McCullough 1999). Increased flows may reduce crowding in smaller habitat areas and reduce infectibility. Diseased juvenile *O. mykiss* have not been observed in the Sacramento River in summer. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108).

Refuge habitat stressors may decrease. This decrease is likely beneficial. An increase in flows may increase access to high quality refuge habitat. This habitat provides lower velocities and greater cover, which decreases predation risk and improves survival. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may decrease. The decrease may be beneficial. Maintenance of Shasta Reservoir storage results in increased flows and more inundated habitats. This alters food web processes and riparian vegetation, increasing food availability and quality, and impacting the successful growth and survival of juveniles. An increase in flows results in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of juveniles. Higher water temperatures in the summer may provide an increase to the food supply, as seen by increased growth rates of juvenile *O.mykiss* in the American River relative to juveniles from colder coastal streams (Sogard et al. 2011). Flows may also increase in the Sacramento River in the summer, but the Proposed Action may also lower the water temperature. The interaction of these two effects on the food supply may be offsetting. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the Delta and Sacramento River is ubiquitous. Introduced non-native piscivorous species such as striped and largemouth bass have become well-established predators in the Central Valley system. Juvenile steelhead are preyed upon by aquatic and terrestrial species and this can directly or indirectly influence juveniles' migration, growth, and survival. 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.

4.2.1.4 Fall

In the fall, Reclamation and DWR's proposed release of water will increase flows on average in the Sacramento River below Keswick Dam. Increased flow in the upper Sacramento River may change stressors on steelhead.

4.2.1.4.1 Adults

Adults are migrating, holding, and rearing in the Sacramento River. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration.

In-river fishery or poaching stressors are not anticipated to change. There is no in-river fishery for steelhead in the upper Sacramento River during the fall. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may decrease. This decrease is discountable and/or insignificant. Releases of Shasta Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within 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 bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the fall has not been observed in the Upper Sacramento River due to seasonal operations.

Water temperature stressors may increase. The increase is likely insignificant during adult migration and holding. Evidence from watersheds outside of the Central Valley suggests that temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994; Keefer et al. 2018). Optimal 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. Historical water temperatures are below the migration impairment threshold for adults on their spawning migration September through November.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/l (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). There were no steelhead specific studies found. Changing flows with seasonal operations result in colder modeled water temperature, which should correlate to higher dissolved oxygen; however, water quality monitoring has shown dissolved oxygen levels are typically well above 5.0 mg/L in the fall.

Pathogens and disease stressors may increase. The increase may harm during adult migration and kelt emigration. Maintenance of Shasta Reservoir storage may result in warmer water temperatures in the summer. Historic water temperatures are above the virulence threshold of 59.9°F (McCullough 1999) for kelts in June and adults on their spawning migration July and August.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.1.4.2 Eggs

Eggs are not present in Sacramento River in the fall.

4.2.1.4.3 Juveniles

Juveniles are rearing and outmigrating in the middle Sacramento River. The amount of time spent rearing in the upper Sacramento River varies before juveniles migrate into the middle Sacramento River. This habitat is primarily used for rearing and as a migration corridor to the Bay-Delta. Time spent within and size distribution both entering and exiting the middle Sacramento River vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and juvenile condition (some affecting several parameters) during the migration.

Toxicity from contaminants stressors may decrease. This decrease is likely discountable and/or insignificant. Releases of Shasta Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminate studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). There is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors may increase. The increase may harass, harm, and kill juvenile steelhead. Flows decrease in September and October and are not anticipated to change in November. When flows decrease juveniles can become stranded in habitats that are disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Appendix L presents an analysis of this stressor.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may decrease. The decrease is likely beneficial. 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). 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). Historical water temperatures in the fall rarely exceed 66.2°F (zero out of the last 28 years). See Outmigration Cues stressor for water temperatures that affect outmigrating juveniles. There is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring consistently has not exhibited dissolved oxygen levels below 9 mg/L in the fall. However, there is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. The increase cause harm to rearing juveniles and the decrease is likely discountable and/or insignificant. Releases of Shasta Reservoir storage may result in cooler water temperatures in the fall; however historic water temperatures in the fall exceed the virulence threshold. Water temperatures greater than 59.9°F are above the virulence threshold for diseases that affect salmonids (McCullough 1999). Increased flows may also reduce crowding in smaller habitat areas and reduce infectibility. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108).

Refuge habitat stressors may decrease. The decrease is likely insignificant and/or discountable. An increase in flows may increase access to high quality refuge habitat. This habitat provides lower velocities and greater cover, which decreases predation risk and improves survival. Suitable habitat for steelhead in the spring in the Upper Sacramento River is plotted in Appendix B (Section 3.3). Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may decrease. The decrease is likely beneficial. Maintenance of Shasta Reservoir storage results in increased flows and more inundated habitats. This alters food web processes and riparian vegetation, increasing food availability and quality, and impacting the successful growth and survival of juveniles. An increase in flows results in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of juveniles. Higher water temperatures in the summer may provide an increase to the food supply, as seen by increased growth rates of juvenile *O. mykiss* in the American River relative to juveniles from colder coastal streams (Sogard et al. 2011). Flows may also increase in the Sacramento River in the early fall but the Proposed Action may also lower the water temperature. The interaction of these two effects on the food supply may be offsetting. Appendix O defines habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the Delta and Sacramento River is ubiquitous. Introduced non-native piscivorous species such as striped and largemouth bass have become well-established predators in the Central Valley system. Juvenile steelhead are preyed upon by aquatic and terrestrial species and this can directly or indirectly influence juveniles' migration, growth, and survival. 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.

4.2.2 Clear Creek

4.2.2.1 Winter

In the winter, Reclamation and DWR's proposed storage of water will decrease flows on average.

4.2.2.1.1 Adults

Adults are migrating, holding, and spawning in Clear Creek.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Whiskeytown Reservoir may reduce flows and concentrate contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmon and no fish effects have been observed during fish monitoring. Water quality in the Sacramento River and its tributaries within 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 bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not typically eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding of steelhead in the winter has not been observed in Clear Creek due to seasonal operations.

Water temperature stressors may decrease. The decrease is likely insignificant. Historical water temperatures are within the need for adult migration and spawning during this period. Evidence from watersheds outside of the Central Valley suggests that only temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994, Keefer et al. 2018). Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F, which encompasses expected temperatures in the winter across alternatives (Bell 1991, Richter and Kolmes 2005, FERC 1993). Optimal 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).

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). There were no steelhead specific studies found. Historical DO measurements for Clear Creek are limited. Changing flows from seasonal operations may result in colder water temperature and higher dissolved oxygen, and water quality monitoring in the Sacramento River above Clear Creek suggests dissolved oxygen levels are well above 5.0 mg/L in winter. Upper Clear Creek is steep and there is often white water. During the winter, dissolved oxygen is likely at saturation due to the facilitation of gas exchange in white water conditions.

Pathogens and disease stressors may decrease. This decrease is likely discountable and/or insignificant. Historic water temperatures are under the virulence threshold for adult migration and spawning during this period. Water temperatures less than 59.9°F occur in the winter, above which temperature threshold diseases affecting salmonids become highly virulent (McCullough 1999). Historic water temperatures are below the virulence threshold throughout the winter period.

Spawning habitat stressors may decrease. This decrease is likely beneficial. Flows may decrease during winter seasonal operations in Clear Creek compared to the environmental baseline and increase the total spawning habitat available for steelhead. Steelhead spawning habitat availability in Clear Creek is expected to peak around 300 cfs and decline as flow increases (U.S. Fish and Wildlife Service 2015). A decrease in flows relative to the environmental baseline in winter may increase spawning habitat and pre-spawning holding habitat.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.2.1.2 Eggs

Eggs are incubating and fry are emerging in Clear Creek. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity from contaminants stressors may increase and decrease. The increase is likely discountable and/or insignificant. Decreases in flows may concentrate constituents. 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.

Stranding and dewatering stressors may decrease. The decrease may be beneficial. The rate of flow reduction is low which may reduce the potential for redd dewatering. **Water temperature stressors** may increase. Lab-based studies of predominantly rainbow trout, all conducted on populations outside of the Central Valley, reported maximum hatching success between 44.6°F and 50°F, with negative thermal effects developing at or near 53.6°F (Kwain 1975; Humpesch 1985) and sharp increases in mortality at 57.2°F or 59°F (Velsen 1987; Rombough 1988). 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.

Dissolved oxygen stressors may increase and decrease. The decrease is likely discountable and/or insignificant. 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. Historical DO measurements for Clear Creek are limited. Changing flows with seasonal operations may result in colder temperatures and water quality monitoring in the Sacramento River above Clear Creek has not consistently shown dissolved oxygen at levels below 8 mg/L in the winter. Upper Clear Creek is steep and there is often white water. During the winter, dissolved oxygen is likely at saturation due to the facilitation of gas exchange in white water conditions.

Pathogens and disease stressors may increase or decrease. The decrease or increase is likely insignificant. 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). Historical water temperatures in Clear Creek do not exceed the threshold during egg incubation and fry emergence.

Sedimentation and gravel quantity stressors may increase. The increase is likely discountable and/or insignificant. Decreased flows may deposit fine sediment, which 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). Flow rates in Clear Creek are still generally higher than other times of the year and well above baseflow conditions in the four steelhead spawning watersheds. Fine sediment deposition typically occurs under baseflow conditions and areas of slow water velocity (Wood and Armitage 1997). As such, any potential increase in fine-sediment deposition will likely be discountable and/or insignificant. Appendix O defines habitat and presents an analysis of this stressor.

Redd quality stressors may increase and/or decrease. The increase is likely discountable and/or insignificant. Although there will be 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). In addition, fine sediment deposition typically occurs in areas of slow water velocity (Wood and Armitage 1997).

Predation stressors are not anticipated to change. Predator abundance and distribution is not anticipated to change due to operations.

4.2.2.1.3 Juveniles

Juveniles are rearing and may start to outmigrate in Clear Creek. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates dependent on an individual's physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), however, no sublethal effects were observed in these juveniles. There is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile steelhead, 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).

Stranding risk stressors are not anticipated to change. Average winter flows are expected to increase from December to January and from January to February following a similar pattern to environmental baseline. When flows decrease juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. The increase may harm juvenile steelhead. Storing water in Whiskeytown Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may decrease. The decrease is likely discountable and/or insignificant. 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). 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). Changing flows associated with seasonal operations may result in colder water temperatures in the winter. However, there is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Historical DO measurements for Clear Creek are limited. Water quality monitoring in the Sacramento River consistently has not exhibited dissolved oxygen levels below 9 mg/L in the winter. Upper Clear Creek is steep and there is often white water. During the winter, dissolved oxygen is likely at saturation due to the facilitation of gas exchange in white water conditions. However, there is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. The increase and decrease are likely discountable and/or insignificant. Decrease flows may cause crowding into smaller habitat areas and may increase pathogen concentration and horizontal transmission, and decreased temperature may decrease pathogen virulence. 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). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic winter water temperatures are colder than this threshold. Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). This stressor has not been observed in *O. mykiss* in the winter in Clear Creek. The effect of changing flow and temperature may be offsetting. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change. There are no CVP facilities on Clear Creek or facilities used to divert water for CVPIA refuges on Clear Creek to entrain steelhead (see Appendix A).

Refuge habitat stressors may increase. The increase may harm juvenile steelhead. Changing operations decreases flows relative to environmental baseline that reduce suitable margin and off-channel habitats being available as refuge habitat for juveniles. The decrease in flows is also likely to reduce the availability of rearing habitat (U.S. Fish and Wildlife Service 2015). Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Maintenance of Whiskeytown storage results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Reduced releases from Shasta Reservoir may decrease flows below Shasta Dam. Indirect effects of predation are described further in the “Outmigration Cues”, “Entrainment Risk”, and “Refuge Habitat” sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.2.2 Spring

In the spring, Reclamation and DWR’s proposed release of water will decrease flows on average.

4.2.2.2.1 Adults

Adults are spawning, rearing, and undertaking kelt emigration back to the Sacramento River in the spring, undergoing an energetically taxing freshwater-to-salt transition to forage. Several stressors have been identified that may delay spawning, affect kelt emigration, or refuge habitat.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Whiskeytown Reservoir may reduce flows and concentrate contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmon and no fish effects have been observed during fish monitoring. Water quality in the Sacramento River and its tributaries within the Central Valley is regulated by the US Environmental Protection Agency. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adults do not typically eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the spring has not been observed in Clear Creek due to seasonal operations.

Water temperature stressors may decrease. The decrease is likely beneficial. Historical water temperatures are within the need for adult migration and holding during this period but do occasionally exceed optimal spawning temperatures. Changing flows result in colder modeled water temperatures and provide water temperatures closer to those required for adult spawning. This may increase spawning success. Evidence from watersheds outside of the Central Valley suggests that only temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994, Keefer et al. 2018). Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F (Bell 1991, Richter and Kolmes 2005; FERC 1993). Optimal 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).

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). Changing flows from seasonal operations may result in colder water temperature and higher dissolved oxygen and water quality monitoring in the Sacramento River above Clear Creek suggests dissolved oxygen levels are well above 5.0 mg/L in spring. Historical DO measurements for Clear Creek are limited. Upper Clear Creek is very steep and monitoring shows white water which indicates high levels of gas exchange.

Pathogens and disease stressors may decrease. The decrease may be beneficial to spawning adults. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Seasonal operations result in decreased water temperature, which may decrease horizontal transmission and pathogen virulence. At water temperatures above 59.9°F, diseases affecting Chinook salmon become highly virulent (McCullough 1999). Historic water temperatures are below the virulence threshold throughout the spring period.

Spawning habitat stressors may decrease. This decrease is likely beneficial. Flows may decrease during spring seasonal operations in Clear Creek compared to Environmental baseline and increase the total spawning habitat available for steelhead. Steelhead spawning habitat availability in Clear Creek is expected to peak around 300 cfs and decline as flow increases (U.S. Fish and Wildlife Service 2015). A decrease in flows relative to Environmental baseline in spring may increase spawning habitat and pre-spawning holding habitat.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.2.2.2 Eggs

Eggs are incubating and fry are emerging in the Clear Creek in the spring. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity and contaminants stressors may increase and decrease. The increase is likely discountable and/or insignificant. Decreases in flows may concentrate constituents. 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.

Stranding and dewatering stressors may decrease. The decrease may be beneficial. The release of water from Whiskeytown Reservoir results in higher flows in Clear Creek during the redd construction season. The rate of flow reduction is low throughout the spring period, which may reduce the potential for redd dewatering.

Water temperature stressors may increase. Lab-based studies of predominantly rainbow trout, all conducted on populations outside of the Central Valley, reported maximum hatching success between 44.6°F and 50°F, with negative thermal effects developing at or near 53.6°F (Kwain 1975; Humpesch 1985) and sharp increases in mortality at 57.2°F or 59°F (Velsen 1987; Rombough 1988). Changing flows with seasonal operations may result in colder water temperatures below 53.6°F, and historical water temperatures in May are often above the 53.6°F criteria.

Dissolved oxygen stressors may decrease or increase. The decrease or increase is likely discountable and/or insignificant. 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. Changing flows with seasonal operations result in colder temperatures but decreased flows (with potentially contradictory effects on oxygen); however, water quality monitoring in the Sacramento River above Clear Creek has not consistently shown dissolved oxygen at levels below 8 mg/L in the spring. Historical DO measurements for Clear Creek are limited. Upper Clear Creek is very steep and monitoring shows white water which indicates high levels of gas exchange.

Pathogens and disease stressors may increase. The increase is likely insignificant. 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). 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 WTemp_CC_IGO).

Sedimentation and gravel quantity stressors may increase. The increase is likely discountable and/or insignificant. Decreased flows may deposit fine sediment, which 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). Flow rates in Clear Creek are still generally higher than other times of the year and well above baseflow conditions in the four steelhead spawning watersheds. Fine sediment deposition typically occurs under baseflow conditions and areas of slow water velocity (Wood and Armitage 1997). As such, any potential increase in fine-sediment deposition will likely be discountable and/or insignificant. Appendix O defines habitat and presents an analysis of this stressor.

Redd quality stressors may increase and/or decrease. The increase is likely discountable and/or insignificant. Although there will be decreased flows during the egg incubation period, flow rates are still generally higher than other times of the year and well above baseflow conditions in Clear Creek. 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). In addition, fine sediment deposition typically occurs in areas of slow water velocity (Wood and Armitage 1997).

Predation stressors are not anticipated to change. Predator abundance and distribution is not anticipated to change due to alternatives.

4.2.2.2.3 Juveniles

Juveniles are rearing and outmigrating in Clear Creek in the spring. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates dependent on an individual’s physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity and contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminants studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), However, no sublethal effects were observed in these juveniles. There is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors may decrease. The decrease is likely insignificant and/or discountable Stable spring flows for seasonal operations, relative to decreasing flows for Environmental baseline, may reduce risk of dewatering. Historically, USFWS monitoring in Clear Creek for steelhead has not produced any numbers on stranding in their annual reports, and there are currently no stranding reports.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. The increase may harm juvenile steelhead. Storing water in Whiskeytown Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may decrease. The decrease is likely beneficial. 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). 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). Historic water temperatures are below the 66.2°F threshold throughout the year. However, there is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring in the Sacramento River above Clear Creek typically has not exhibited dissolved oxygen levels below 9 mg/L in the spring. Historical DO measurements for Clear Creek are limited. Upper Clear Creek is very steep and monitoring shows white water which indicates high levels of gas exchange. However, there is uncertainty on how these changes in 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).

Pathogen and disease stressors may increase or decrease. The increase may cause harm and the decrease is likely discountable and/or insignificant. Decreased flows may cause crowding into smaller habitat areas and increase pathogen concentration and horizontal transmission, while decreased temperature may decrease pathogen virulence. 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). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic water temperatures reach the virulence threshold in May. Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). This stressor has not been observed in *O. mykiss* in the spring in Clear Creek. The effect of changing flow and temperature may be offsetting. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change. There are no CVP facilities on Clear Creek or facilities used to divert water for CVPIA refuges on Clear Creek to entrain steelhead (see Appendix A).

Refuge habitat stressors may increase. The increase may harm juvenile steelhead. Changing operations decreases flows relative to Environmental baseline and reduces suitable margin and off-channel habitats being available as refuge habitat for juveniles. The decrease in flows is also likely to reduce the availability of rearing habitat (U.S. Fish and Wildlife Service 2015). Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Maintenance of Whiskeytown storage results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Reduced releases from Shasta Reservoir may decrease flows below Shasta Dam. Indirect effects of predation are described further in the “Outmigration Cues”, “Entrainment Risk”, and “Refuge Habitat” sections. There is uncertainty about the effects of the Proposed

Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. 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. 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.

Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.2.3 Summer

In the summer, Reclamation's proposed release of water will increase flows on average in Clear Creek below Whiskeytown. Increased flow in Clear Creek may change stressors on steelhead.

4.2.2.3.1 Adults

Adults are migrating and holding in Clear Creek. Several stressors have been identified that may affect migration and rearing influencing maturation and migration.

In-river fishery or poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Releases of Whiskeytown storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within the Central Valley is regulated by the US Environmental Protection Agency. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the summer has not been observed in Clear Creek due to seasonal operations.

Water temperature stressors may increase or decrease. The decrease is likely insignificant and/or discountable while the increase may harm migrating adults. Evidence from watersheds outside of the Central Valley suggests that temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994, Keefer et al. 2018). Optimal 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).Historic water temperatures are above the thermal threshold for migration impairment in August.

Dissolved oxygen stressors may increase or decrease. The increase or decrease is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). There were no steelhead specific studies found. Changing flows from seasonal operations may result in colder water temperature and higher dissolved oxygen; and water quality monitoring in the Sacramento River above Clear Creek suggests dissolved oxygen levels are well above 5.0 mg/L in summer. Historical DO measurements for Clear Creek are limited.

Pathogens and disease stressors may increase or decrease. The decrease is likely insignificant and/or discountable while the increase may harm migrating adults. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). At water temperatures above 59.9°F, diseases affecting Chinook salmon become highly virulent (McCullough 1999). Historic water temperatures are above the virulence threshold in August.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.2.3.2 Eggs

Presence of eggs in Clear Creek in the summer is highly unlikely. The spawning window ends in April and fry emergence likely finishes by late May.

4.2.2.3.3 Juveniles

Juveniles are rearing to outmigration in Clear Creek. The amount of time spent rearing in Clear Creek varies before juveniles migrate into the middle Sacramento River. This habitat is primarily used for rearing and as a migration corridor to the Sacramento River and Bay-Delta. Time spent within and size distribution both entering and exiting Clear Creek vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and juvenile condition (some affecting several parameters) during the migration.

Toxicity and contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Releases of storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook Salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). However, no sublethal effects were observed in these juveniles. There is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors are not anticipated to change. Average summer flows are expected to decrease from June to July but remain stable from July to August following a similar pattern to the Environmental baseline. Higher and more stable flows for seasonal operations prevent juveniles from becoming stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate when preying on stranded fish.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in Whiskeytown Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may decrease. The decrease is likely beneficial. 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). 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). Historic water temperatures are generally below the 66.2°F threshold throughout the year. However, there is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring in the Sacramento River above Clear Creek typically has not exhibited dissolved oxygen levels below 9 mg/L in the summer. Historical DO measurements for Clear Creek are limited. However, there is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. The increase may cause harm and the decrease is likely discountable and/or insignificant. Increased flows may reduce crowding in smaller habitat areas and reduce infectibility. Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic summer water temperatures are warmer than this threshold. Diseased juvenile *O. mykiss* have not been observed in Clear Creek in summer. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change. There are no CVP facilities on Clear Creek or facilities used to divert water for CVPIA refuges on Clear Creek to entrain steelhead (see Appendix A).

Refuge habitat stressors may increase or decrease. The increase or decrease is likely insignificant and/or discountable. Changing operations may either increase or decrease flows relative to Environmental baseline and increase/decrease suitable margin and off-channel habitats being available as refuge habitat for juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may decrease. The decrease is likely beneficial. An increase in flows results in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of yearlings. Higher water temperatures in the summer may provide an increase to the food supply, as seen by increased growth rates of juvenile *O.mykiss* in the American River relative to juveniles from colder coastal streams (Sogard et al. 2011). Flows may also increase in Clear Creek in the summer, but the Proposed Action may also lower the water temperature. The interaction of these effects on the food supply may be offsetting. Appendix O defines habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Reduced releases from Shasta Reservoir may decrease flows below Shasta Dam. Indirect effects of predation are described further in the “Outmigration Cues”, “Entrainment Risk”, and “Refuge Habitat” sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. 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. 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.

Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.2.4 Fall

In the fall, Reclamation and DWR’s proposed release of water on average will increase flows.

4.2.2.4.1 Adults

Adults are present in low numbers throughout the fall period, migrating to their spawning habitat. Video monitoring from Clear Creek has shown adults (*O. mykiss* individuals greater than 16 inches) as early as August (Killam 2022).

In-river fishery or poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Releases of Whiskeytown storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the summer has not been observed in Clear Creek due to seasonal operations.

Water temperature stressors may increase or decrease. The decrease is likely insignificant and/or discountable while the increase may harm migrating adults. Evidence from watersheds outside of the Central Valley suggests that temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994, Keefer et al. 2018). Optimal 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). Historical water temperatures are above the thermal threshold for migration impairment in September.

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). There were no steelhead specific studies found. Changing flows from seasonal operations may result in colder water temperature and higher dissolved oxygen; and water quality monitoring in the Sacramento River suggests dissolved oxygen levels are well above 5.0 mg/L in summer. Historical DO measurements for Clear Creek are limited.

Pathogens and disease stressors may increase or decrease. The decrease is likely insignificant and/or discountable while the increase may harm migrating adults. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). At water temperatures above 59.9°F, diseases affecting Chinook salmon become highly virulent (McCullough 1999). Historic water temperatures are above the virulence threshold in September.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.2.4.2 Eggs

Eggs are not present in the fall in Clear Creek.

4.2.2.4.3 Juveniles

Juveniles are rearing in the fall in Clear Creek. Monitoring data indicates passage in lower Clear Creek may start as early as November.

Toxicity from contaminants stressors may decrease. The decrease is likely discountable and/or insignificant. Releases of Shasta Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). However, no sublethal effects were observed in these juveniles. There is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors are not anticipated to change in September and October and may increase in November. The increase is due to relative stable flow for seasonal operations relative to increases in flow for Environmental baseline and may harass, harm and kill juveniles. Flow decreases result in juveniles that can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate when preying on stranded fish. Higher flows can prevent juveniles that can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Appendix L presents an analysis of this stressor.

Water temperature stressors may decrease. The decrease is likely beneficial. 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). 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). Historic water temperatures are generally below the 66.2°F threshold throughout the year. However, there is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring in the Sacramento River typically has not exhibited dissolved oxygen levels below 9 mg/L in the fall. Historical DO measurements for Clear Creek are limited. However, there is uncertainty on how these changes in 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).

Pathogens and disease stressors may decrease. The decrease may be beneficial. Increased flows may reduce crowding in smaller habitat areas and reduce infectibility. Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic water temperatures in September are warmer than this threshold. Diseased juvenile *O. mykiss* have not been observed in Clear Creek in fall. However, there is uncertainty on how these 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).

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in Whiskeytown Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Entrainment risk stressors are not anticipated to change. There are no CVP facilities on Clear Creek or facilities used to divert water for CVPIA refuges on Clear Creek to entrain steelhead (see Appendix A).

Refuge habitat stressors may increase or decrease. The increase or decrease is likely insignificant and/or discountable. Changing operations may either increase or decrease flows and increase/decrease suitable margin and off-channel habitats being available as refuge habitat for juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase or decrease. The increase may cause harm to juvenile steelhead while the decrease may be beneficial. An increase in flows in the early fall may result in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of juveniles. Reduced flows relative to the environmental baseline in the late fall may result in 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, 2020; Goertler et al. 2018). Higher water temperatures in the fall may provide an increase to the food supply, as seen by increased growth rates of juvenile *O. mykiss* in the American River relative to juveniles from colder coastal streams (Sogard et al. 2011). The Proposed Action may lower the water temperature. The interaction of these effects on the food supply may be offsetting. Appendix O defines habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Reduced releases from Shasta Reservoir may decrease flows below Shasta Dam. Indirect effects of predation are described further in the “Outmigration Cues”, “Entrainment Risk”, and “Refuge Habitat” sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.3 American River

4.2.3.1 Winter

In the winter, Reclamation and DWR’s proposed storage of water will decrease flows on average in the American River below Nimbus Dam. Decreased flow in the American River may change stressors on steelhead.

4.2.3.1.1 Adults

Adults are holding, spawning, and emigrating in the American River in the winter, undergoing an energetically taxing salt-to-freshwater transition to spawn. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration.

In-river fishery or poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Folsom storage may reduce flows and concentrate constituents however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within the Central Valley is regulated by the US Environmental Protection Agency. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the winter has not been observed in the American River due to seasonal operations.

Water temperature stressors may increase or decrease. The increase or decrease is likely discountable and/or insignificant. Changing flows may result in warmer water temperatures in the winter; however, historic water temperatures are within the range of adult migration, holding, and spawning temperature needs during this period. Evidence from watersheds outside of the Central Valley suggests that only temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994, Keefer et al. 2018). Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F, which encompass expected temperatures in the winter across alternatives (Bell 1991, Richter and Kolmes 2005, FERC 1993). Optimal 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).

Dissolved oxygen stressors may increase. The increase is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). There were no steelhead specific studies found. Changing flows from seasonal operations may result in warmer water temperature and lower dissolved oxygen; however, water quality monitoring in the Sacramento River suggests dissolved oxygen levels are well above 5.0 mg/L in winter. Historical DO measurements for the American River are limited.

Pathogens and disease stressors may increase or decrease. The increase or decrease is likely discountable and/or insignificant. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Seasonal operations result in decreased flows and increased water temperature, which may increase pathogen concentration and horizontal transmission, while increasing temperature may reduce pathogen virulence. Historic water temperatures less than 59.9°F occur in the winter, above which temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Spawning habitat stressors may decrease. The decrease is likely discountable and/or insignificant in the winter. Seasonal operations show a decrease in winter flows compared to Environmental baseline. Flow-habitat relationships show spawning habitat availability through Weight Usable Area in the American River peaks between 1,500 cfs - 2,500 cfs before gradually declining (U.S. Fish and Wildlife Service 2003), thus flows outside of this range may result in a decrease in suitable habitat.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.3.1.2 Eggs

Eggs are incubating to fry emergence in the American River. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Releases of Folsom storage may decrease flows and concentrate contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect eggs and no fish effects have been observed in fish monitoring. During incubation, eggs do not eat, and subsequently are not exposed to contaminants in prey during this life stage.

Stranding and dewatering stressors may increase. Winter flow reductions have the potential to expose redds in the American River. Appendix M, *Folsom Reservoir Flow and Temperature Management*, presents an analysis of this stressor.

Water temperature stressors may increase or decrease. Although seasonal operations may result in warmer water temperatures, historic temperatures are still less than 53.6°F during in the winter. Lab-based studies of predominantly rainbow trout, all conducted on populations outside of the Central Valley, reported maximum hatching success between 44.6°F and 50°F, with negative thermal effects developing at or near 53.6°F (Kwain 1975; Humpesch 1985) and sharp increases in mortality at 57.2°F or 59°F (Velsen 1987; Rombough 1988). In addition, there is a very small proportion of the population that spawn on the mainstem Sacramento River.

Dissolved oxygen stressors may increase. The increase is likely discountable and/or insignificant. 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. Changing flows with seasonal operations may result in warmer temperatures and decreased flows (and thus lower oxygen levels). However, water quality monitoring in the Sacramento River has not consistently shown dissolved oxygen at levels below 8 mg/L in the winter. Historical DO measurements for the American River are limited.

Pathogens and disease stressors may increase. 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 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 salmonids become highly virulent (McCullough 1999).

Sedimentation and gravel quantity stressors may increase. The increase is likely discountable and/or insignificant. Decreased flows may deposit fine sediment, which 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). Flow rates in the Sacramento River are still generally higher than other times of the year. Fine sediment deposition typically occurs under baseflow conditions and areas of slow water velocity (Wood and Armitage 1997).The relatively high seasonal flows during the steelhead egg incubation season are likely sufficient to potentially reduce fine sedimentation deposition rates.

Appendix O defines habitat and presents an analysis of this stressor.

Redd quality stressors may increase and/or decrease. The increase is likely discountable and/or insignificant. Although there will be decreased flows during the egg incubation period, flow rates are still generally higher than other times of the year in the American River. 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). In addition, fine sediment deposition typically occurs under baseflow conditions and areas of slow water velocity (Wood and Armitage 1997).

Predation risk stressors are not anticipated to change. Predator abundance and distribution is not anticipated to change due to operations.

4.2.3.1.3 Juveniles

Juveniles are rearing and outmigrating in the American River. After emergence, steelhead fry in the American River tend to remain and rear near the area they were spawned and oversummer in the river. The next fall or winter juveniles can exhibit a range of migration rates dependent on an individual’s physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Folsom storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminants studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors are not anticipated to change. Average winter flows are expected to increase from December to January and from January to February following a similar pattern to the environmental baseline. Flows are expected to decrease from February to March which are covered in the spring section. When flows decrease juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Recent fish monitoring has not shown stranded fish in January or February (Sellheim et al. 2020, Sweeney et al. 2021, Sweeney et al. 2022). There is uncertainty regarding how changes in flow 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). Appendix M presents an analysis of this stressor.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in Folsom Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may increase or decrease. The increase or decrease is likely discountable and/or insignificant. 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). 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). Changing flows associated with seasonal operations may result in warmer water temperatures in the winter closer to optimum temperatures; however, historic winter water temperatures are below or within the range of rearing and outmigrating temperature needs. However, there is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may increase. The increase is likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring in the Sacramento River consistently has not exhibited dissolved oxygen levels below 9 mg/L in the winter. Historical DO measurements for the American River are limited. Water quality monitoring reports from the main channel are above 5.0 mg/L in the winter (LSA Associates 2003; Day and Starr 2021). However, there is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. The increase is likely discountable and/or insignificant. Decreased flows may cause crowding into smaller habitat areas and increase pathogen concentration and horizontal transmission, while increased temperature may increase pathogen virulence. 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). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic winter water temperatures are colder than this threshold. This stressor has not been observed in *O. mykiss* in the winter in the American River. The effect of changing flow and temperature may be offsetting. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change in the American River. CVP facilities on the American River and facilities used to divert water for CVPIA refuges are screened.

Refuge habitat stressors may increase. The increase may harm juvenile steelhead. Changing operations decreases flows relative to environmental baseline and reduces suitable margin and off-channel habitats being available as refuge habitat for juveniles. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles. Appendix O defines habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Changing operations results in decreased flows and less inundated habitats relative to environmental baseline. This alters food web processes and riparian vegetation, decreasing food availability and quality, and impacting the successful growth and survival of juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the “Outmigration Cues”, “Entrainment Risk”, and “Refuge Habitat” sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the American River 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.3.2 Spring

In the spring, Reclamation and DWR's proposed storage of water will decrease flows on average in the American River below Nimbus Dam. Decreased flow in the American River may change stressors on steelhead.

4.2.3.2.1 Adults

Adults are spawning, migrating, and holding in the American River in the spring, undergoing an energetically taxing freshwater-to-salt transition to forage. Several stressors have been identified that may delay spawning or affect kelt emigration.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Folsom storage may reduce flows and concentrate contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Water quality in the Sacramento River and its tributaries within the Central Valley is regulated by the US Environmental Protection Agency. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the spring has not been observed in the American River due to seasonal operations.

Water temperature stressors may increase or decrease. The increase may reduce spawning success. The decrease may be beneficial by increasing spawning success. Evidence from watersheds outside of the Central Valley suggests that only temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994, Keefer et al. 2018). Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F (Bell 1991, Richter and Kolmes 2005, FERC 1993). Optimal 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. Changing flows may result in colder water temperatures some months in the spring, but historic water temperatures are above the migration impairment threshold in April through June and the spawning threshold in March and April.

Dissolved oxygen stressors may increase or decrease. The increases and decreases are likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). Changing flows from seasonal operations may result in warmer water temperature (and lower dissolved oxygen); however, water quality monitoring in the Sacramento River suggests dissolved oxygen levels are well above 5.0 mg/L in spring. Historical DO measurements for the American River are limited. Water quality monitoring reports from the main stem are above 5.0 mg/L in the spring (LSA Associates 2003; Day and Starr 2021).

Pathogens and disease stressors may increase or decrease. The increase may reduce spawning success. The decrease may be beneficial by increasing spawning success. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Seasonal operations result in decreased flows and increased water temperature, which may increase pathogen concentration and horizontal transmission, while decreasing temperature may reduce pathogen virulence. Water temperatures less than 59.9°F occur in the spring, above which temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999). Changing flows may result in warmer temperatures some months and colder water temperatures during other months in the spring, but historic water temperatures are above virulence threshold in April during spawning and migration and in May and June during kelt emigration.

Spawning habitat stressors may decrease. The decrease is likely beneficial. Seasonal operations show a decrease in spring flows compared to Environmental baseline. 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), thus flows outside of this range may result in a decrease in suitable habitat.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.3.2.2 Eggs

Eggs are incubating and fry emerging in the American River in the spring. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fisher and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Releases of Folsom storage may decrease flows and dilute contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect eggs and no fish effects have been observed in fish monitoring. During incubation, eggs do not eat, and subsequently are not exposed to contaminants in prey during this life stage.

Stranding and dewatering stressors may increase or decrease. The increase may harass, harm, and kill eggs. The decrease may be beneficial. Flows may be decreased from February to March, and then increased from April to May when redds can become dewatered. Smaller reductions in flow for seasonal operations may reduce dewatering of spawning habitat. Appendix M presents an analysis of this stressor.

Water temperature stressors may increase or decrease. The increase may cause harm by reducing egg survival and the decrease is likely discountable and/or insignificant. Lab-based studies of predominantly rainbow trout, all conducted on populations outside of the Central Valley, reported maximum hatching success between 44.6°F and 50°F, with negative thermal effects developing at or near 53.6°F (Kwain 1975; Humpesch 1985) and sharp increases in mortality at 57.2°F or 59°F (Velsen 1987; Rombough 1988). Changing flows with seasonal operations may result in colder water temperatures during some months in the spring, and other months may exceed the incubation threshold. Historic water temperatures are above the threshold infrequently in March and frequently in April and May.

Dissolved oxygen stressors may increase or decrease. Increases and decreases are likely discountable and/or insignificant. 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. Changing flows with seasonal operations may result in warmer temperatures and decreased flows (and thus lower oxygen levels). Historical DO measurements for the American River are limited. Water quality monitoring reports from the mainstem American River are above 5 mg/L in the spring (LSA Associates 2003; Day and Starr 2021).

Pathogens stressors may increase or decrease. The increase may cause harm by reducing egg survival and the decrease is likely discountable and/or insignificant. 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 result in decreased flows and increased or decreased water temperature, which may increase pathogen concentration and horizontal transmission, while increasing temperature may increase pathogen virulence. The effect of changing flow and temperature may be offsetting. Historic water temperatures occasionally exceed the virulence threshold April through July, the temperature threshold above which diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Sedimentation and gravel quantity stressors may increase. The increase is likely discountable and/or insignificant. Decreased flows may deposit fine sediment, which 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). Flow rates in the American River are still generally higher than other times of the year. Fine sediment deposition typically occurs in areas of slow water velocity (Wood and Armitage 1997). Appendix O defines habitat and presents an analysis of this stressor.

Redd quality stressors may increase. The increase is likely discountable and/or insignificant. Although there will be decreased flows during the egg incubation period, flow rates are still generally higher than other times of the year in the American River. Fine sediment deposition typically occurs in areas of slow water velocity (Wood and Armitage 1997).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).

Predation stressors are not anticipated to change. Predator abundance and distribution is not anticipated to change due to operations.

4.2.3.2.3 Juveniles

Juveniles are rearing and outmigrating in the American River in the spring. Juveniles can exhibit a range of migration rates dependent on an individual's physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Folsom storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile steelhead, 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).

Stranding risk stressors may increase. The increase may cause harm to juvenile steelhead during rearing and outmigration. Average spring flows are expected to decrease from February to March at a rate that is higher than the environmental baseline. When flows decrease juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Recent fish monitoring has shown stranded fish in both March and April (Sellheim et al. 2020, Sweeney et al. 2021, Sweeney et al. 2022). Smaller reductions in flow from seasonal operations, relative to reductions for Environmental baseline, may decrease dewatering. There is uncertainty on factors that cue migration and how changes in flow 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). Appendix M presents an analysis of this stressor.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in Folsom Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

While the flow management in the spring is being designed to benefit salmon, we aren't certain how it this form of management will benefit steelhead.

Water temperature stressors may increase or decrease. The increase or decrease is likely discountable and/or insignificant. 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). 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). Changing flows from seasonal operations may result in colder water temperatures during some months in the spring but may also exceed the optimum temperatures threshold during this period. There is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may increase or decrease. The increases and decreases are likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Historical DO measurements for the American River are limited. Water quality monitoring in the Sacramento River consistently has not exhibited dissolved oxygen levels below 9 mg/L in the spring. Water quality monitoring reports from the main stem are above 5.0 mg/L in the spring (LSA Associates 2003; Day and Starr 2021). 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 2017 and 2022 after flow reductions, some isolated pools had dissolved oxygen below 8.0 mg/L, which may be considered stressful for juvenile salmonids (Sweeney et al. 2017, 2022). See Stranding risk for more details on stranding in the American River. There is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. The increase may cause harm to juveniles rearing and outmigrating and the decrease may be beneficial. Decreased flows may cause crowding into smaller habitat areas and increase pathogen concentration and horizontal transmission, while increased or decreased temperatures relative may change pathogen virulence. 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). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic water temperatures are warmer than this threshold in May. This stressor has not been observed in *O. mykiss* in the spring in the American River. The effect of changing flow and temperature may be offsetting. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change in the American River. CVP facilities on the American River and facilities used to divert water for CVPIA refuges are screened.

Refuge habitat stressors may increase. The increase may harm juvenile steelhead. Water operations decreases flows relative to the environmental baseline and reduces suitable margin and off-channel habitats being available as refuge habitat for juveniles. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles. Suitable habitat for steelhead in the spring in the American River is plotted in Appendix B. Appendix O defines habitat and presents an analysis of this stressor.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Changing operations results in decreased flows and less inundated habitats relative to the environmental baseline. This alters food web processes and riparian vegetation, decreasing food availability and quality, and impacting the successful growth and survival of juveniles. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles. Appendix O defines habitat and presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the American River 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.3.3 Summer

In the summer, Reclamation and DWR's proposed release of water will increase flows on average in the American River below Nimbus Dam. Increased flow in the American River may change stressors on steelhead.

4.2.3.3.1 Adults

Adults are generally not present in the American River in the summer. There is the potential for kelt emigration until June, but the potential stressors and their effects are discussed in the Spring section.

4.2.3.3.2 Eggs

Eggs are not present in the American River in the summer.

4.2.3.3.3 Juveniles

Juveniles are outmigrating in the American River. The amount of time spent rearing in the American River varies before juveniles migrate and most juveniles spend six to 12 months rearing in the American River before emigrating. Time spent within and size distribution vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and juvenile condition (some affecting several parameters) during the migration.

Toxicity from contaminants stressors may decrease. This decrease is likely discountable and/or insignificant. Releases of Folsom storage may increase flows and dilute constituents however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors may decrease. The decrease is likely beneficial due to decreased risk associated with stranding. Increased flows prevent juveniles that are rearing from becoming stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate when preying on stranded fish. There is uncertainty on factors that cue migration and how changes in flow 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). Appendix M presents an analysis of this stressor.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in Folsom Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may increase or decrease. The increase may cause harm to juveniles rearing and the decrease may be beneficial. 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). 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). Historic water temperatures in the summer exceed 66.2°F and changing flows from seasonal operations may result in colder water temperatures. However, there is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Historical DO measurements for the American River are limited. Water quality monitoring in the Sacramento River consistently has not exhibited dissolved oxygen levels below 9 mg/L in the summer. A water quality monitoring report from LSA Associates (2003) reported that the main stem below Nimbus Dam was above 5.0 mg/L in the summer. Side channel habitat may become desiccated in the summer, however, the Proposed Action is expected to have increased flows at a higher rate than the environmental baseline. However, there is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. The increase may cause harm to juveniles rearing and the decrease may be beneficial. Increased flows may reduce crowding in smaller habitat areas and reduce infectibility. Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic summer water temperatures are warmer than this threshold. Diseased juvenile *O. mykiss* have been observed in the American River in summer (Water Forum 2005). The effect of changing flow and temperature may be offsetting. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change in the American River. CVP facilities on the American River and facilities used to divert water for CVPIA refuges are screened.

Refuge habitat stressors may decrease. The decrease may be beneficial. Water operations increases flows relative to the environmental baseline and increases suitable margin and off-channel habitats being available as refuge habitat for juveniles. Tributary Habitat Restoration (Appendix O) defines refuge habitat and analyzes this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may decrease. The decrease is likely beneficial. Changing operations results in increased flows and more inundated habitats relative to the environmental baseline. This alters food web processes and riparian vegetation, increasing food availability and quality, and impacting the successful growth and survival of juveniles. An increase in flows results in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of juveniles. Higher water temperatures in the summer may provide an increase to the food supply, as seen by increased growth rates of juvenile *O. mykiss* in the American River relative to juveniles from colder coastal streams (Sogard et al. 2011). Flows may also increase in the American River in the summer, but the Proposed Action may also lower the water temperature. The interaction of these two effects on the food supply may be offsetting. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the “Outmigration Cues”, “Entrainment Risk”, and “Refuge Habitat” sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the American River 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.3.4 Fall

In the fall, Reclamation and DWR’s proposed release of water will increase flows on average in the American River below Nimbus Dam. Increased flow in the American River may change stressors on steelhead.

4.2.3.4.1 Adults

Adults are typically not present in the American River in the fall. Data from the Nimbus Fish Hatchery indicates some presence in November, but overall presence is low. Potential effects in November are discussed in the Winter section.

4.2.3.4.2 Eggs

Eggs are not present in the American River in the fall.

4.2.3.4.3 Juveniles

Juveniles are rearing in the American River in the fall. The amount of time spent rearing in the American River varies before juveniles migrate. Time spent within and size distribution vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and juvenile condition (some affecting several parameters) during the migration.

Toxicity from contaminants stressors may decrease. This decrease is likely discountable and/or insignificant. Releases of Folsom storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors may increase or decrease. The increase or decrease is likely insignificant and/or discountable. When flows decrease in October, juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Increased flows in November may prevent juveniles from becoming stranded in habitat disconnected from the main channel. The magnitude of flow changes varies among alternatives. The increases and decreases during this period may not be significant enough to affect stranding. There is uncertainty on factors that cue migration and how changes in flow 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). Appendix M presents an analysis of this stressor.

Water temperature stressors may decrease or increase. The decrease is likely beneficial, and the increase may harm juvenile steelhead rearing. 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). 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). Historic water temperatures in the fall exceed 66.2°F and changing flows from seasonal operations may result in colder water temperatures. However, there is uncertainty on how these changes in temperature 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).

Dissolved Oxygen stressors may decrease. The decrease is likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971).

Historical DO measurements for the American River are limited. Water quality monitoring in the Sacramento River consistently has not exhibited dissolved oxygen levels below 9 mg/L in the fall. A water quality monitoring report from LSA Associates (2003) reported that the main stem below Nimbus Dam was above 5.0 mg/L in the fall. Side channel habitat may become desiccated in the fall, however, the Proposed Action is expected to have increased flows at a similar rate as the environmental baseline. There is uncertainty on how these changes in 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).

Pathogens and disease stressors may decrease or increase. The decrease is likely beneficial, and the increase may harm juvenile steelhead rearing. Increased flows may reduce crowding in smaller habitat areas and reduce infectibility. Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic water temperatures in the fall exceed the virulence threshold but changing flows from seasonal operations may result in colder water temperatures. Diseased juvenile *O. mykiss* have been observed in the American River in fall. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change in the American River. CVP facilities on the American River and facilities used to divert water for CVPIA refuges are screened.

Refuge habitat stressors may decrease. The decrease may be beneficial. Water operations increases flows relative to Environmental baseline and increases suitable margin and off-channel habitats being available as refuge habitat for juveniles. Suitable habitat for steelhead in the fall in the American River is plotted in Appendix B. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality may decrease. The decrease is beneficial. Changing operations results in increased flows and more inundated habitats relative to the environmental baseline. This alters food web processes and riparian vegetation, increasing food availability and quality, and impacting the successful growth and survival of juveniles. An increase in flows results in more inundated habitat, which increases food availability and quality. Greater food availability may improve the growth and survival of juveniles. Higher water temperatures in the summer may provide an increase to the food supply, as seen by increased growth rates of juvenile *O. mykiss* in the American River relative to juveniles from colder coastal streams (Sogard et al. 2011). Flows may also increase in the Sacramento River in the summer, but the Proposed Action may also lower the water temperature. The interaction of these two effects on the food supply may be offsetting. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the “Outmigration Cues”, “Entrainment Risk”, and “Refuge Habitat” sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the American River 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.4 Stanislaus River

4.2.4.1 Winter

In the winter, Reclamation and DWR’s proposed storage of water will decrease flows in the Stanislaus River below Goodwin Dam. Decreased flow in the Stanislaus River may change stressors on steelhead.

4.2.4.1.1 Adults

Adults are spawning and emigrating in the Stanislaus River in the winter, undergoing an energetically taxing salt-to-freshwater transition to spawn. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration.

In-river fishery or poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of New Melones storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the winter has not been observed in the Stanislaus River due to seasonal operations.

Water temperature stressors may increase or decrease. Both increases and decreases are likely discountable and/or insignificant. Evidence from watersheds outside of the Central Valley suggests that only temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994, Keefer et al. 2018). Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F, which encompasses expected temperatures in the winter across alternatives (Bell 1991, Richter and Kolmes 2005, FERC 1993). Optimal 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).Changing flows may result in cooler water temperatures in some months during the winter period. However, historic water temperatures are within the range of adult migration, holding, and spawning temperature needs.

Dissolved oxygen stressors may increase or decrease. Increases and decreases are likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). There were no steelhead specific studies found. Changing flows from seasonal operations may result in cooler water temperature and higher dissolved oxygen than Environmental baseline in December and January but warmer temperatures in February; however, water quality monitoring in the Stanislaus River suggests dissolved oxygen levels are well above 5.0 mg/L in winter.

Pathogens and disease stressors may increase or decrease. The increase and decrease are likely discountable and/or insignificant. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Seasonal operations result in increased and decreased water temperature, that may affect pathogen virulence. However, historic winter water temperatures are expected to remain below 59.9°F, which is below the temperature threshold diseases affecting some salmonids become highly virulent (McCullough 1999).

Spawning habitat stressors may decrease. The decrease is likely beneficial. Decreased flows may increase the quantity and quality of spawning habitats. Competition by spawners for limited habitat may lead to redd superimposition. Aceituno 1993 determined flows of 200 cfs provided maximum weighted usable area for steelhead spawning.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.4.1.2 Eggs

Eggs are incubating and fry emerging in the Stanislaus River. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity from contaminants stressors may increase and decrease. The increase is likely discountable and/or insignificant. Decreases in flows may concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect eggs and no fish effects have been observed in fish monitoring.

Stranding and dewatering stressors may increase and decrease. The increase is likely discountable and/or insignificant. Stanislaus River may have some months with a higher rate of flow reduction 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. Modeled flows are expected to increase from month to month across all alternatives in the winter; thus, winter flows are expected to remain at or above spawning flows. Appendix N, *New Melones Stepped Release Plan*, and Appendix O present an analysis of this stressor.

Water temperature stressors may increase or decrease. The increases or decreases are likely discountable and/or insignificant. Lab-based studies of predominantly rainbow trout, all conducted on populations outside of the Central Valley, reported maximum hatching success between 44.6°F and 50°F, with negative thermal effects developing at or near 53.6°F (Kwain 1975; Humpesch 1985) and sharp increases in mortality at 57.2°F or 59°F (Velsen 1987; Rombough 1988). Seasonal operations may result in colder water temperatures during some months of the winter. Historic water temperatures in the winter are generally below thresholds of the environmental baseline for migration and spawning during this period.

Dissolved oxygen stressors may increase or decrease. Both increases and decreases are likely discountable and/or insignificant. 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. Changing flows with seasonal operations may result in colder temperatures and decreased flows (with offsetting effects on oxygen). Aside from rare periods of hypoxia, water quality monitoring in the Stanislaus River has not consistently shown dissolved oxygen at levels below 8 mg/L in the winter.

Pathogens and disease stressors may increase or decrease. The increase and decrease are likely discountable and/or insignificant. 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 result in decreased flows and increased/decreased water temperature, which may increase pathogen concentration and horizontal transmission, while increasing temperature may increase pathogen virulence. The effect of changing flow and temperature may be offsetting. Historic water temperatures greater than 59.9°F do not occur in the winter, the temperature threshold above which diseases affecting some salmonids become highly virulent (McCullough 1999).

Sedimentation and gravel quantity stressors may increase. The increase is likely discountable and/or insignificant. Decreased flows may deposit fine sediment, which 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). Flow rates in the Stanislaus River are still generally higher than other times of the year. Fine sediment deposition typically occurs in areas of slow water velocity (Wood and Armitage 1997). Appendix O defines habitat and presents an analysis of this stressor.

Redd quality stressors may increase and/or decrease. The increase is likely discountable and/or insignificant. Although there will be decreased flows during the egg incubation period, flow rates are still generally higher than other times of the year and well above baseflow conditions in the Stanislaus River. 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). In addition, fine sediment deposition typically occurs in areas of slow water velocity (Wood and Armitage 1997). Appendix O defines habitat and presents an analysis of this stressor.

Predation risk stressors are not anticipated to change. Predator abundance and distribution is not anticipated to change due to operations.

4.2.4.1.3 Juveniles

Juveniles are rearing and outmigrating in the Stanislaus River in the winter. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates dependent on an individual's physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of New Melones storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows 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 two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors may increase or decrease. The increase may harass, harm, and kill juvenile steelhead. When flows decrease juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. The decrease may be beneficial. Stranding risk stressors may decrease from the dampening of flow fluctuations during precipitation events and would benefit from reduced predation. There is uncertainty on factors that cue migration and how changes in flow 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). Appendix N presents an analysis of this stressor.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in New Melones reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature may increase or decrease. The increases and decreases are likely discountable and/or insignificant. Changing flows associated with seasonal operations may result warmer temperatures; however, historic winter water temperatures are below or within the range of rearing and outmigrating temperature needs. 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). 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). However, there is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may increase or decrease. An increase in oxygen stressors may harm by causing physiological stress while a decrease may be beneficial and reduce physiological stress. Changing flows associated with seasonal operations may result in colder water temperatures in December and January and warmer temperatures in February. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring shows dissolved oxygen levels can vary near or below 9 mg/L in the winter. There is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. The increase and decrease are likely discountable and/or insignificant. Decreased flows may cause crowding into smaller habitat areas and increase pathogen concentration and horizontal transmission, while either increased or decreased temperature may change pathogen virulence. 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). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic winter water temperatures are colder than this threshold. This stressor has not been observed in *O. mykiss* in the winter in the Stanislaus River. The effect of changing flow and temperature may be offsetting. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change. CVP operations are not a proximate cause of entrainment on the Stanislaus River.

Refuge habitat stressors may increase. The increase may harm juvenile steelhead. Changing operations decreases flows relative to Environmental baseline and reduces suitable margin and off-channel habitats being available as refuge habitat for juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Changing operations results in decreased flows and less inundated habitats relative to Environmental baseline. This alters food web processes and riparian vegetation, decreasing food availability and quality, and impacting the successful growth and survival of juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.4.2 Spring

In the spring, Reclamation and DWR's proposed diversion of water will decrease flows in the Stanislaus River below Goodwin Dam. Decreased flow in the Stanislaus River may change stressors on steelhead.

4.2.4.2.1 Adults

Adults are spawning and emigrating in the Stanislaus River in the spring, undergoing an energetically taxing freshwater-to-salt transition to forage. Several stressors have been identified that may delay spawning or affect emigration.

In-river fishery or poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of New Melones storage may reduce flows and concentrate contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the spring has not been observed in the Stanislaus River due to seasonal operations.

Water temperature stressors may increase or decrease. The increase may harm by reducing spawning success or impairing kelt emigration. The decrease may be beneficial by increasing spawning success. Evidence from watersheds outside of the Central Valley suggests that only temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, and Nielson et al. 1994, Keefer et al. 2018). Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F (Bell 1991, FERC 1993). Optimal 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. Changing flows may result in colder temperatures in some months during the spring, but may also exceed thermal thresholds during this period. Historic water temperatures are within the range of adult migration and holding needs but exceed spawning temperature needs in March and April.

Dissolved Oxygen stressors may increase or decrease. Increases and decreases are likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). Changing flows from seasonal operations may result in warmer water temperature and lower dissolved oxygen than Environmental baseline in March but cooler temperatures in April and May; however, water quality monitoring in the Stanislaus River suggests dissolved oxygen levels are well above 5.0 mg/L in spring.

Pathogens and disease stressors may increase or decrease. The increase may harm by reducing spawning success and the decrease may be beneficial. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Seasonal operations result in decreased flows and decreased water temperature, which may increase pathogen concentration and horizontal transmission, while decreasing temperature may reduce pathogen virulence. This stressor has not been observed in *O. mykiss* in the spring in the Stanislaus River. The effect of changing flow and temperature may be offsetting. Water temperatures in the spring occasionally exceed 59.9°F during adult migration and spawning in April, the virulence threshold that causes diseases in some salmonids (McCullough 1999).

Spawning habitat stressors may decrease. The decrease is likely beneficial. Decreased flows may increase the quantity and quality of spawning habitats. Competition by spawners for limited habitat may lead to redd superimposition. Aceituno 1993 determined flows of 200 cfs provided maximum weighted usable area for steelhead spawning. Appendix O defines habitat and presents an analysis of this stressor.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.4.2.2 Eggs

Eggs are present in the Stanislaus River in the spring. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

In-river fishery and trampling stressors are not anticipated to change. Trampling stressors may impact egg survival during incubation, but CVP and SWP operations are not a proximate cause of trampling.

Toxicity and contaminants stressors may increase and decrease. The increase is likely discountable and/or insignificant. Decreases in flows may concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect eggs and no fish effects have been observed in fish monitoring.

Stranding and dewatering stressors may increase or decrease. The increase may harass, harm, and kill eggs. Monthly flows fluctuate in March through June when redds can become dewatered. The decrease may be beneficial. Different patterns of spring flows increase and decrease with seasonal operations, relative to decreasing flows for Environmental baseline, which may reduce dewatering of spawning habitat. Appendix N and Appendix O present an analysis of this stressor.

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.

Water temperature stressors may increase or decrease. The increase may cause harm to steelhead eggs and the decrease is likely discountable and/or insignificant. Lab-based studies of predominantly rainbow trout, all conducted on populations outside of the Central Valley, reported maximum hatching success between 44.6°F and 50°F, with negative thermal effects developing at or near 53.6°F (Kwain 1975; Humpesch 1985) and sharp increases in mortality at 57.2°F or 59°F (Velsen 1987; Rombough 1988). Changing flows with seasonal operations may result in colder temperatures during some months in the spring, but the historic temperatures often exceed the lethal threshold of 57.2°F in April through June.

Dissolved oxygen stressors may increase or decrease. Both increases and decreases are likely discountable and/or insignificant. 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. Changing flows with seasonal operations may result in warmer temperatures and decreased flows (and thus lower dissolved oxygen). Water quality monitoring in the Stanislaus River has not consistently shown dissolved oxygen at levels below 8 mg/L in the spring.

Pathogens stressors may increase or decrease. The increase may cause harm to steelhead eggs and decrease may be beneficial. 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 result in decreased flows and increased or decreased water temperature, which may increase pathogen concentration and horizontal transmission, while increasing temperature may increase pathogen virulence. The effect of changing flow and temperature may be offsetting. Historic water temperatures greater than 59.9°F occasionally occur in May and frequently in June, the temperature threshold above which diseases affecting some salmonids become highly virulent (McCullough 1999).

Sedimentation and gravel quantity stressors may increase. The increase is likely discountable and/or insignificant. Decreased flows may deposit fine sediment, which 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). Flow rates in the Sacramento River are still generally higher than other times of the year and well above baseflow conditions in the four steelhead spawning watersheds. Fine sediment deposition typically occurs under baseflow conditions and areas of slow water velocity (Wood and Armitage 1997). As such, any potential increase in fine-sediment deposition will likely be discountable and/or insignificant. Appendix O defines habitat and presents an analysis of this stressor.

Redd quality stressors may increase. The increase is likely discountable and/or insignificant. Decreased flows may deposit fine sediment, which 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). Flow rates in Clear Creek are still generally higher than other times of the year and well above baseflow conditions in the four steelhead spawning watersheds. Fine sediment deposition typically occurs under baseflow conditions and areas of slow water velocity (Wood and Armitage 1997). As such, any potential increase in fine-sediment deposition will likely be discountable and/or insignificant. Appendix O defines habitat and presents an analysis of this stressor.

Predation stressors are not anticipated to change. Predator abundance and distribution is not anticipated to change due to operations.

4.2.4.2.3 Juveniles

Juveniles are rearing and migrating in the Stanislaus River in the spring. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates that depend on individual's physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of New Melones storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows 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 two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors may increase or decrease. The increase may harass, harm, and kill juvenile steelhead. When flows decrease juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. Fish monitoring observed stranded juvenile steelhead in April 2016 (CDFW 2023). The decrease may be beneficial. Increased flows in some months and alternatives prevent juveniles from becoming stranded in habitats disconnected from the main channel. The magnitude of flow changes varies among alternatives. There is uncertainty on factors that cue migration and how changes in flow 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). Appendix N presents an analysis of this stressor.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in New Melones reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may decrease. The decrease is likely beneficial. 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). 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). Changing flows from seasonal operations may result in warmer water temperatures in some months during the spring, however, historic water temperatures in the spring are generally below upper temperature limits. There is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may increase or decrease. An increase in oxygen stressors may harm by causing physiological stress while a decrease may be beneficial and reduce physiological stress. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring shows dissolved oxygen levels can vary near or below 9 mg/L in the spring. There is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. This increase may cause harm to juvenile steelhead and the decrease is likely discountable and/or insignificant. Decreased flows may cause crowding in smaller habitat areas. A decrease in flows may influence pathogen and disease exposure including increased transfer from hatchery fish to natural-origin juveniles. Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic water temperatures in the spring are generally colder than this threshold in the early spring but often exceed the threshold in May. Diseased *O. mykiss* have not been observed in the Stanislaus River in the spring. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change. CVP operations are not a proximate cause of entrainment on the Stanislaus River.

Refuge habitat stressors may increase. The increase can harm juvenile steelhead. Changing operations decreases flows relative to Environmental baseline and reduces suitable margin and off-channel habitats being available as refuge habitat for juveniles. Suitable habitat for steelhead in the spring in the Stanislaus River is plotted in Appendix B. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Changing operations results in decreased flows and less inundated habitats relative to Environmental baseline. This alters food web processes and riparian vegetation, decreasing food availability and quality, and impacting the successful growth and survival of juveniles. Appendix

O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.4.3 Summer

In the summer, Reclamation and DWR proposed water operations will increase flows in the Stanislaus River below Goodwin Dam. Increased flow in the Stanislaus River may change stressors on steelhead.

4.2.4.3.1 Adults

Adults are generally not present in the Stanislaus River in the summer. There is the potential for kelt emigration until June, but this would be a small proportion of the population and these effects are discussed in the spring section above.

4.2.4.3.2 Eggs

Eggs are generally not present in the Stanislaus River in the summer. They may be present in early June in a small proportion. These effects are discussed in the spring section above.

4.2.4.3.3 Juveniles

Juveniles are rearing in the Stanislaus River in the summer. The amount of time spent rearing in the Stanislaus River varies before juveniles migrate. Time spent within and size distribution vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and juvenile condition (some affecting several parameters) during the migration.

Toxicity from contaminants stressors may decrease. This decrease is likely discountable and/or insignificant. Releases of New Malones storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery

Chinook salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors may increase or decrease. The increase or decrease is likely insignificant and/or discountable. When flows decrease, juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. When flows increase, there is a decreased likelihood of stranding of juveniles in habitat disconnected from the main channel. The magnitude of flow changes varies among alternatives. The rate of flow reductions between June and July is expected to be lower under the Proposed Action, but the overall river stage in the Stanislaus River is expected to be low, particularly in drought years. There is uncertainty on factors that cue migration and how changes in flow 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). Appendix N presents an analysis of this stressor.

Water temperature stressors may increase or decrease. The increase may cause harm to juvenile steelhead rearing while the decrease may be beneficial. 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). 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). Historic water temperatures in the summer rarely exceed 66.2°F and changing flows from seasonal operations may result in colder water temperatures. There is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may increase or decrease. The increase may cause harm to juvenile steelhead rearing while decrease may be beneficial. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring shows dissolved oxygen levels can vary near or below 9 mg/L in the summer. There is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. The increase may cause harm to juvenile steelhead rearing while the decrease may be beneficial. Increased flows may reduce crowding in smaller habitat areas and reduce infectibility. Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic summer water temperatures are warmer than this threshold. The effect of changing flow and temperature may be offsetting. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change. CVP operations are not a proximate cause of entrainment on the Stanislaus River.

Refuge habitat stressors may increase or decrease. The increase may harm juvenile steelhead and the decrease is beneficial. Decreasing flows relative to Environmental baseline in June can decrease access to high quality refuge habitat while an increase in flows in July and August may increase access to high quality refuge habitat. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability stressors may increase or decrease. The increase may harm juvenile steelhead and the decrease is likely beneficial. Changing operations results in decreased flows and less inundated habitats relative to the environmental baseline in June and increased flows in July and August. This alters food web processes and riparian vegetation, changing food availability and quality, and impacting the successful growth and survival of juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.4.4 Fall

In the fall, Reclamation and DWR's proposed storage release of water will decrease flows in the Stanislaus River below Goodwin Dam. Decreased flow in the Stanislaus River may change stressors on steelhead.

4.2.4.4.1 Adults

Adults are seen through video monitoring in the Stanislaus River in the fall. Data on adult migration in the Stanislaus River is limited, but video monitoring through FISHBIO has indicated that adult presence of *O. mykiss* starts as early as September.

In-river fishery or poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of New Melones storage may reduce flows and concentrate contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the spring has not been observed in the Stanislaus River due to seasonal operations.

Water temperature stressors may increase or decrease. The increase may harm by reducing spawning success or impairing migration. The decrease may be beneficial. Evidence from watersheds outside of the Central Valley suggests that only temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, and Nielson et al. 1994, Keefer et al. 2018). Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F (Bell 1991, FERC 1993). Optimal 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). Changing flows may result in colder temperatures in some months during the fall but may also exceed thermal thresholds during this period. Historic water temperatures exceed the thermal threshold during adult migration and holding needs in September and October and exceed spawning temperature needs in October and November.

Dissolved Oxygen stressors may increase or decrease. Increases and decreases are likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). There were no steelhead specific studies found. Water quality monitoring in the Stanislaus River suggests dissolved oxygen levels are well above 5.0 mg/L in the fall.

Pathogens and disease stressors may increase or decrease. The increase may harm by reducing spawning success or impairing migration. The decrease may be beneficial. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Seasonal operations result in decreased flows and decreased water temperature, which may increase pathogen concentration and horizontal transmission, while decreasing temperature may reduce pathogen virulence. The effect of changing flow and temperature may be offsetting. Historic water temperatures in September and October exceed the 59.9°F virulence threshold that causes diseases in some salmonids (McCullough 1999).

Spawning habitat stressors may increase. The increase is likely discountable and/or insignificant. Decreased flows may reduce the quantity and quality of spawning habitats. Competition by spawners for limited habitat may lead to redd superimposition. A decrease in flows may cause a deficit in spawning habitat or reduce its quality. There is uncertainty on how these changes in spawning stressor 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). Appendix O defines habitat and presents an analysis of this stressor.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.4.4.2 Eggs

Eggs are generally not present in the Stanislaus River in the fall. They may be present in early November in a small proportion.

4.2.4.4.3 Juveniles

Juveniles are rearing and outmigrating in the Stanislaus River in the fall. The amount of time spent rearing in the Stanislaus River varies before juveniles migrate. Time spent within and size distribution vary among years. Several stressors have been identified, each possibly affecting survival, residence time and migration, and juvenile condition (some affecting several parameters) during the migration.

Toxicity from contaminants stressors may decrease. This decrease is likely discountable and/or insignificant. Releases of New Malones storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010). However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding stressors may increase or may decrease. The increase may harass, harm, and kill juvenile steelhead. The decrease may be beneficial. When flows decrease juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. When flows increase juveniles are less likely to become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or where they may be exposed to higher levels of predation. The magnitude of flow changes varies among alternatives. There is uncertainty on factors that cue migration and how changes in flow 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). Appendix N presents an analysis of this stressor.

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in Shasta Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may increase or decrease. The increase may harm juvenile steelhead, and the decrease is beneficial. 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). 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). Historic water temperatures in September occasionally exceed 66.2°F and changing flows from seasonal operations may result in colder water temperatures below temperature limits. However, there is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may decrease. The decrease may be beneficial. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring shows dissolved oxygen levels can vary near or below 9 mg/L in the fall. However, there is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. The increase may harm juvenile steelhead, and the decrease may be beneficial. Increased flows may decrease crowding in smaller habitat areas and decrease infectibility. Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic fall water temperatures are warmer than this threshold in September and October. there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change. CVP operations are not a proximate cause of entrainment on the Stanislaus River.

Refuge habitat stressors may increase or decrease. The increase may harm juvenile steelhead and the decrease is beneficial. Decreasing flows relative to the environmental baseline in November can decrease access to high quality refuge habitat while an increase in flows in September and October may increase access to high quality refuge habitat. Suitable habitat for steelhead in the fall in the Stanislaus River is plotted in Appendix B. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase or decrease depending on month. The increase may harm juvenile steelhead and the decrease is likely beneficial. Changing operations results in increased flows and more inundated habitats relative to the environmental baseline in September and October but decreased flows in November. This alters food web processes and riparian vegetation, changing food availability and quality, and impacting the successful growth and survival of juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix O presents an analysis of these stressors.

4.2.5 Bay-Delta

4.2.5.1 Winter

In the winter, Reclamation and DWR's proposed water operations will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on steelhead.

4.2.5.1.1 Adults

Adults are migrating in the Delta. Adults are undergoing an energetically taxing salt-to-freshwater transition to spawn. Several stressors have been identified to possibly delay adult migration, decrease adult survival during migration, or increase energy necessary to undergo the transition.

In-river fishery and poaching stressors are not anticipated to change. No steelhead fishing is allowed in the Delta in the winter. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow relative to environmental baseline that may concentrate contaminant constituents. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the winter has not been observed in the Delta due to seasonal operations.

Water temperature stressors are not anticipated to change. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is positively correlated with Delta inflow in the winter (Bashevkin and Mahardja 2022); however, water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017). There is uncertainty about whether the decreased inflow is a cause for decreased Delta water temperatures. CVP and SWP operations do not appear to be a proximate cause of Delta water temperatures in the winter.

Dissolved oxygen stressors are not anticipated to change. Dissolved oxygen less than 5.0mg/L may affect migration of Chinook salmon (Carter 2005). There were no steelhead species-specific studies found. Water quality monitoring at Delta monitoring stations has not shown dissolved oxygen at levels below this in the winter.

Pathogens stressors are not anticipated to change. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Water temperatures less than 59.9°F occur in the winter, above which temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999). Water quality monitoring has not shown water temperatures greater than this in the winter.

[PLACEHOLDER] Competition, Introgression, and Broodstock Removal

4.2.5.1.2 Eggs

Eggs are not present in the Delta.

4.2.5.1.3 Juveniles

Juveniles are rearing and migrating in the Delta. Juvenile use of the Bay-Delta varies both within and among years. Several stressors have been identified to possibly affect survival, residence time and migration, and condition. Habitat attributes may have compounding effects; it is important to not consider a single stressor alone.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants; however, CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. A review of contaminant studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook Salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), However, no sublethal effects were observed in these juveniles. There were no steelhead specific studies found. There is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors are not anticipated to change. Juvenile stranding has not been observed in fish monitoring in the Bay-Delta. There is uncertainty on factors that cue migration and how changes in flow 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).

Water temperature stressors are not anticipated to change. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is positively correlated with Delta inflow in the winter (Bashevkin and Mahardja 2022); however, water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017). There is uncertainty about whether the decreased inflow is a cause for decreased Delta water temperatures. CVP and SWP operations do not appear to be a proximate cause of Delta water temperatures in the winter.

Dissolved oxygen stressors are not anticipated to change. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring generally has not shown dissolved oxygen at levels below these thresholds in the winter. There is uncertainty on how these changes in 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).

Pathogens and disease stressors are not anticipated to change. Juvenile survival is influenced by specific diseases (e.g., *Ceratomyxa shasta*, furunculosis) present in the Sacramento River (reviewed in Lehman et al. 2020). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Water quality monitoring has not shown water temperatures greater than this in the winter. However, there is uncertainty on how these 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).

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. This increase may mask the cue to migrate and increase travel time in the Delta, which may reduce outmigration survival. Appendix I presents analysis on this stressor.

Entrainment risk stressors may increase. The increase may result in higher levels of entrainment and loss of juvenile steelhead. CVP and SWP storage and diversions result in entrainment at the Skinner and Tracy fish facilities. Entrainment is defined in two ways: (1) fish routed through specific migratory pathways in the Delta (Delta route-specific travel time and survival); and (2) fish encountering CVP facilities where they may be pulled into diversions or the export facilities. In both, outmigrating juveniles may be exposed to predation in different locations within the Delta. Appendix I presents an analysis of this stressor.

Refuge habitat stressors may increase. The increase may harm juvenile steelhead. A decrease in Delta outflow may reduce both opportunities to avoid predators and foraging opportunities in a productive environment. Habitat capacity may also influence juveniles' choice to switch from rearing and foraging to migrating behavior. Delta habitat restoration (Appendix P) defines refuge habitat and analyzes this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase. This increase is likely discountable and/or insignificant. Maintenance of storage results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix P presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence, growth, and anadromy among juvenile steelhead.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the Delta and Sacramento River is ubiquitous. Introduced non-native piscivorous species such as striped and largemouth bass have become well-established predators in the Central Valley system. Juvenile steelhead are preyed upon by aquatic and terrestrial species and this can directly or indirectly influence juveniles' migration, growth, and survival. 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.

Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and

Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix L, Appendix I, and Appendix J present analysis of these stressors.

4.2.5.2 Spring

In the spring, Reclamation and DWR's proposed water operations will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on steelhead.

4.2.5.2.1 Adults

Adults are migrating in the Delta. Adults move through the Bay-Delta into reaches of the middle and upper Sacramento River, where they hold until ready for spawning. This life-history strategy may leave adults vulnerable to multiple factors that affect survival, timing, and distribution. Additionally, adult body condition upon return to spawning areas can influence effects of stressors on pre-spawn mortality or fecundity. Several stressors have been identified for habitat attributes that affect spawning and holding.

In-river fishery and poaching stressors are not anticipated to change. There is steelhead fishing permitted in the Delta in the spring. In-river fishery and poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow relative to environmental baseline that may concentrate contaminant constituents. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the spring has not been observed in the Delta due to seasonal operations.

Water temperature stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and 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 Bay-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). There is uncertainty about whether the decreased inflow is a cause for increased Delta water temperatures.

Dissolved oxygen stressors are not anticipated to change. Dissolved oxygen less than 5.0mg/L may affect migration of Chinook salmon (Carter 2005). There were no steelhead specific studies found. Water quality monitoring at Delta monitoring stations has not shown dissolved oxygen at levels below this in the spring.

Pathogens and disease stressors may increase. The increase is likely discountable and/or insignificant. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Water temperatures greater than 59.9°F occur in the spring, are when diseases affecting Chinook salmon become highly virulent (McCullough 1999). On average, Prisoner Point water temperatures have been lower than 59.9°F in March, but higher in April and May (Appendix B, Section 8.2). There is uncertainty about whether the decreased spring outflow is a cause for changes in Delta water temperatures. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin et al. 2022); however, this relationship is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature and meteorology (Vroom et al. 2017).

[PLACEHOLDER] Competition, Introgression, and Broodstock Removal

4.2.5.2.2 Eggs

Eggs are not present in the Delta.

4.2.5.2.3 Juveniles

Juveniles are rearing and migrating in the Delta. Juvenile use of the Bay-Delta varies both within and among years. Several stressors have been identified to possibly affect survival, residence time and migration, and condition. Habitat attributes may have compounding effects; it is important to not consider a single stressor alone.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants; however, CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. A review of contaminant studies shows a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fishes (Beckvar et al. 2005). Tissue concentrations of Feather River Hatchery Chinook Salmon juveniles were reported for 199 samples, and two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), However, no sublethal effects were observed in these juveniles. There were no steelhead species-specific studies found. There is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors are not anticipated to change. Juvenile stranding has not been observed in fish monitoring in the Bay-Delta. There is uncertainty on factors that cue migration and how changes in flow 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).

Water temperature stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and 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 Bay-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). There is uncertainty about whether the decreased inflow is a cause for increased Delta water temperatures.

Dissolved oxygen stressors may increase. The increase is likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring generally has not shown dissolved oxygen at levels below these thresholds in the spring. However, there is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase. This increase is likely discountable and/or insignificant. Water temperatures greater than 59.9°F occur in the spring, are when diseases affecting Chinook salmon become highly virulent (McCullough 1999). On average, Prisoner Point water temperatures have been lower than 59.9°F in March, but higher in April and May (Appendix B, Section 8.2). There is uncertainty about whether the decreased spring outflow is a cause for changes in Delta water temperatures. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin et al. 2022); however, this relationship is mainly driven by timing of snowmelt (Knowles and Cayan 2002), air temperature and meteorology (Vroom et al. 2017). This stressor has not been observed in *O. mykiss* in the spring in the Bay-Delta. However, there is uncertainty on how these 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).

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. This increase may mask the cue to migrate and increase travel time in the Delta, which may reduce outmigration survival. Appendix I presents analysis on this stressor.

Entrainment risk stressors may increase. The increase may result in higher levels of entrainment and loss of juvenile steelhead. CVP and SWP storage and diversions result in entrainment at the Skinner and Tracy fish facilities. Entrainment is defined in two ways: (1) fish routed through specific migratory pathways in the Delta (Delta route-specific travel time and survival); and (2) fish encountering CVP facilities where they may be pulled into diversions or the export facilities. In both, outmigrating juveniles may be exposed to predation in different locations within the Delta. Appendix I presents an analysis of this stressor.

Refuge habitat stressors may increase. The increase may harm juvenile steelhead. A decrease in Delta outflow may reduce both opportunities to avoid predators and foraging opportunities in a productive environment. Habitat capacity may also influence juveniles' choice to switch from rearing and foraging to migrating behavior. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles. Appendix P presents an analysis of this stressor.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Maintenance of storage results in less inundated habitats. 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, 2020; Goertler et al. 2018). Appendix P presents an analysis of this stressor.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the Delta and Sacramento River is ubiquitous. Introduced non-native piscivorous species such as striped and largemouth bass have become well-established predators in the Central Valley system. Juvenile steelhead are preyed upon by aquatic and terrestrial species and this can directly or indirectly influence juveniles' migration, growth, and survival. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix L, Appendix I, and Appendix J present analysis of these stressors.

4.2.5.3 Summer

In the summer, Reclamation and DWR's proposed water operations will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on steelhead.

4.2.5.3.1 Adults

Adults are migrating in the Delta. Adults move through the Bay-Delta into reaches of the middle and upper Sacramento River, and tributaries of the Sacramento River and San Joaquin River, where they hold until ready for spawning. This life-history strategy may leave adults vulnerable to multiple factors that affect survival, timing, and distribution. Additionally, adult body condition upon return to spawning areas can influence effects of stressors on pre-spawn mortality or fecundity. Several stressors have been identified for habitat attributes that affect spawning and holding.

In-river fishery and poaching stressors are not anticipated to change. No steelhead fishing is allowed in the Delta in the summer. Poaching may impact adult survival during migration and can cause migration delays, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow relative to environmental baseline that may concentrate contaminant constituents. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the summer has not been observed in the Delta due to seasonal operations.

Water temperature stressors may decrease. The decrease is likely discountable and/or insignificant. Summer seasonal operations increase Delta inflow. Delta water temperature is negatively correlated with Delta inflow (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). Inflow is largely controlled by operations during the summer and fall due to lower contributions from precipitation and snowmelt. However, in the Bay-Delta water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the increased summer inflow is a cause for decreased Delta water temperatures.

Dissolved oxygen stressors are not anticipated to change. Dissolved oxygen less than 5.0mg/L may affect migration of salmonids (Carter 2005). Water quality monitoring at Delta monitoring stations has not shown dissolved oxygen at levels below this in the summer.

Pathogens and disease stressors may increase. This increase is likely discountable and/or insignificant. Water temperatures greater than 59.9°F occur in the summer, are when diseases affecting Chinook salmon, and possibly steelhead, become highly virulent (McCullough 1999). On average, Prisoner Point water temperatures have been greater than 59.9°F occurring between June and August (Appendix B, Section 8.2). There is uncertainty about whether the decreased spring outflow is a cause for changes in Delta water temperatures.

[PLACEHOLDER] Competition, Introgression, and Broodstock Removal

4.2.5.3.2 Eggs

Eggs are not present in the Delta.

4.2.5.3.3 Juveniles

Juveniles are typically not present in the Delta. There may be some presence in June, as noted by observed counts of juvenile *O. mykiss* in the Mossdale trawl and Knights Landing rotary screw trap. These effects are wrapped into the spring section.

4.2.5.4 Fall

In the fall, Reclamation and DWR's proposed water operations will decrease Delta outflow on average. No life stages of steelhead are present in the Delta in the fall.

4.2.5.4.1 Adults

Adults are not present in the Delta.

4.2.5.4.2 Eggs

Eggs are not present in the Delta.

4.2.5.4.3 Juveniles

Juveniles are not present in the Delta.

4.2.6 San Joaquin River

4.2.6.1 Winter

In the winter, Reclamation and DWR's operations on average decrease flows on the San Joaquin River. Decreased flow on the San Joaquin River may change stressors on steelhead.

4.2.6.1.1 Adults

Adults are migrating and holding in the San Joaquin River in the winter, undergoing an energetically taxing salt-to-freshwater transition to spawn. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Millerton Lake storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the winter has not been observed in the San Joaquin River due to seasonal operations.

Water temperature stressors may increase or decrease. Both increases and decreases are likely discountable and/or insignificant. Evidence from watersheds outside of the Central Valley suggests that only temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, and Nielson et al. 1994, Keefer et al. 2018). Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F, which encompasses expected temperatures in the winter across alternatives (Bell 1991, Richter and Kolmes 2005, FERC 1993). Optimal temperatures for steelhead vary across watersheds but generally fall in the range 41-66°F with migration impairment at daily maximum temperatures above 66.2°F in the Pacific Northwest (Keefer et al. 2009). Changing flows may result in warmer temperatures, however, historic water temperatures in the winter are within the range of adult migration, holding, and spawning temperature needs.

Dissolved oxygen stressors may increase or decrease. The increases and decreases are likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). There were no steelhead specific studies found. Changing flows from seasonal operations may result in warmer water temperature and lower dissolved oxygen; however, water quality monitoring in the San Joaquin River suggests dissolved oxygen levels are well above 5.0 mg/L in winter.

Pathogens and disease stressors may increase or decrease. The increase and decrease are likely discountable and/or insignificant. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). Seasonal operations result in decreased flows and either increased or decreased water temperature, which may increase pathogen concentration and horizontal transmission, while decreasing temperature may reduce pathogen virulence. The effect of changing flow and temperature may be offsetting. Historic water temperatures less than 59.9°F occur in the winter, above which temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.6.1.2 Eggs

Eggs are not present in the San Joaquin River in winter.

4.2.6.1.3 Juveniles

Juveniles are rearing and outmigrating in the San Joaquin River in the winter. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates dependent on an individual's physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of New Melones storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows 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 two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile steelhead, 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).

Stranding risk stressors may increase or decrease. The increase may harass, harm, and kill juvenile steelhead. Flows are expected to increase under the Proposed Action throughout the winter but there may be alternatives with reduced releases in order to build storage. When flows decrease juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. The decrease may be beneficial. Stranding risk stressors may decrease from the dampening of flow fluctuations during precipitation events and would benefit from reduced predation. There is uncertainty on factors that cue migration and how changes in flow 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).

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in Shasta Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may increase or decrease. The increases and decreases are likely discountable and/or insignificant. 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). 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). Changing flows associated with seasonal operations may alter water temperatures however, historic water temperatures in the winter are below or within the range of rearing and outmigrating temperature needs. There is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may increase or decrease. The increases and decreases are likely discountable and/or insignificant. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring generally shows dissolved oxygen levels stay above 9 mg/L in the winter. There is uncertainty on how these changes in 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).

Pathogens and disease stressors may increase or decrease. The increase and decrease are likely discountable and/or insignificant. Decrease flows may cause crowding into smaller habitat areas increase pathogen concentration and horizontal transmission, while changing temperature may change pathogen virulence. Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic water temperatures are colder than this threshold in the winter. This stressor has not been observed in *O. mykiss* in the winter in the San Joaquin River. The effect of changing flow and temperature may be offsetting. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change in the San Joaquin River. CVP facilities on the San Joaquin River and facilities used to divert water for CVPIA refuges are screened.

Refuge habitat stressors may increase. The increase may harm juvenile steelhead. Changing operations decreases flows relative to Environmental baseline and reduces suitable margin and off-channel habitats being available as refuge habitat for juveniles. Tributary Habitat Restoration (Appendix O) defines refuge habitat and analyzes this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Changing operations results in decreased flows and less inundated habitats relative to the environmental baseline. This alters food web processes and riparian vegetation, decreasing food availability and quality, and impacting the successful growth and survival of juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the Delta and San Joaquin River 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix I and Appendix J present analysis of these stressors.

4.2.6.2 Spring

In the spring, Reclamation and DWR's operations on average will decrease flows on the San Joaquin River. Decreased flow on the San Joaquin River may change stressors on steelhead.

4.2.6.2.1 Adults

Adults and kelts are emigrating in the San Joaquin River.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Millerton Lake storage may reduce flows and concentrate contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the spring has not been observed in the San Joaquin River.

Water temperature stressors may increase or may not change. The increase may harm by during adult migration and kelt emigration. Evidence from watersheds outside of the Central Valley suggests that only temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994, Keefer et al. 2018). Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F (Bell 1991, Richter and Kolmes 2005, FERC 1993). Optimal temperatures for steelhead vary across watersheds but generally fall in the range 41-66°F with migration impairment at daily maximum temperatures above 66.2°F in the Pacific Northwest (Keefer et al. 2009).Changing flows may result in warmer water temperatures in the spring. Adult steelhead may be present in March when temperatures can exceed the migration impairment threshold of 66.2°F. From March through May, the lethal threshold of 69.8°F is occasionally reached in May. Spawning does not occur in the San Joaquin River.

Dissolved oxygen stressors may increase or may not change. The increase is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). There were no steelhead specific studies found. Changing flows from seasonal operations may result in warmer water temperature and lower dissolved oxygen; however, water quality monitoring in the San Joaquin River suggests dissolved oxygen levels are well above 5.0 mg/L in spring.

Pathogens and disease stressors may increase or may not change. The increase may harm by increasing physiological stress. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). 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. The effect of changing flow and temperature may be offsetting. Water temperatures greater than 59.9°F occur in the spring, above which temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Food availability and quality stressors may increase. The increase is likely insignificant and/or discountable. Decreased flows may result in less inundated habitats in some areas. Reaches of the lower San Joaquin River are highly channelized with low complexity, which may decrease the amount of macroinvertebrates as a food supply. Like most salmonids, steelhead typically do not eat during their migrations and spawning in freshwater, so any changes to the food supply is likely insignificant.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.6.2.2 Eggs

Eggs are not present in the San Joaquin River in spring.

4.2.6.2.3 Juveniles

Juveniles are rearing and outmigrating in the San Joaquin River in the spring. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates dependent on an individual’s physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Millerton Lake storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows 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 two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors may increase. The increase may harass, harm, and kill juvenile steelhead. Flows decreases for seasonal operations in from April to May but does not for the Environmental baseline. When flows decrease juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. There is uncertainty on factors that cue migration and how changes in flow 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).

Outmigration cues stressors may increase. The increase may harm juvenile steelhead. Storing water in Shasta Reservoir reduces flow magnitude that juvenile salmonids use as cues to continue migration. Research over the last decade has identified that rivers and streams with more stable flows tend to favor residency (Kendall et al. 2014). Delaying outmigration may lead to protracted freshwater residency and predation or early maturation. 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).

Water temperature stressors may increase or may not change. The increase may cause harm to juvenile steelhead rearing and outmigrating. 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). 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). Changing flows from seasonal operations may result in warmer water temperatures in the spring and or may not change. Historic water temperatures are above the threshold of 66.2F in April and May. However, there is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may increase or may not change. The increase may harm by causing physiological stress. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring shows dissolved oxygen levels can vary near or below 9 mg/L in the spring. There is uncertainty on how these changes in 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).

Pathogen and disease stressors may increase or may not change. The increase may cause physiological stress. Decreased flows may cause crowding into smaller habitat areas and increase pathogen concentration and horizontal transmission, while increasing temperature may increase pathogen virulence. Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic water temperatures in the spring are warmer than this threshold. This stressor has not been observed in *O. mykiss* in the spring in the San Joaquin River. The effect of changing flow and temperature may be offsetting. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change in the San Joaquin River. CVP facilities on the San Joaquin River and facilities used to divert water for CVPIA refuges are screened.

Refuge habitat stressors may increase. The increase can harm juvenile steelhead. Changing operations decreases flows relative to Environmental baseline and reduces suitable margin and off-channel habitats being available as refuge habitat for juveniles. Suitable habitat for steelhead in the spring in the San Joaquin is plotted in Appendix B. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Changing operations results in decreased flows and less inundated habitats relative to the environmental baseline. This alters food web processes and riparian vegetation, decreasing food availability and quality, and impacting the successful growth and survival of juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the Delta and San Joaquin River 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix I and Appendix J present analysis of these stressors.

4.2.6.3 Summer

In the summer, Reclamation and DWR operations will decrease flows on average on the San Joaquin River.

4.2.6.3.1 Adults

Adults and kelts are emigrating in the San Joaquin River.

In-river fishery and poaching stressors are not anticipated to change. Poaching may impact adult survival during migration, but CVP and SWP operations are not a proximate cause of in-river fishery or poaching.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Millerton Lake storage may reduce flows and concentrate contaminants; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. Contaminants are commonly found on floodplains (e.g., methylmercury, selenium); however, releases as part of seasonal operations would be below bankfull flow that would mobilize these contaminants. Studies have shown a 0.2 mg/kg threshold for methylmercury as protective of both juvenile and adult fish (Beckvar et al. 2005). During migration, adult steelhead typically do not eat, which reduces their exposure to contaminants in prey during this life stage.

Stranding risk stressors are not anticipated to change. Adults use deep migration and holding habitats. Adult stranding in the summer has not been observed in the San Joaquin River.

Water temperature stressors may increase or may not change. The increase may harm during adult migration and kelt emigration. Evidence from watersheds outside of the Central Valley suggests that only temperatures above 69.8°F to 71.6°F either blocked adult steelhead migration or were lethal to adult migrating steelhead (Coutant 1970, Snyder and Blahm 1971, Nielson et al. 1994, Keefer et al. 2018). Successful steelhead spawning tends to occur at temperatures between 45°F and 55°F (Bell 1991, Richter and Kolmes 2005, FERC 1993). Optimal temperatures for steelhead vary across watersheds but generally fall in the range 41-66°F with migration impairment at daily maximum temperatures above 66.2°F in the Pacific Northwest (Keefer et al. 2009). Changing flows may result in warmer water temperatures in the summer. Adult steelhead are potentially migrating as early as July when historic water temperatures exceed the lethal threshold of 69.8°F and kelts may be emigrating in June in lethal water temperatures. Spawning does not occur in the San Joaquin River.

Dissolved oxygen stressors may increase or may not change. The increase is likely discountable and/or insignificant. Chinook salmon wait to migrate when dissolved oxygen is at least 5.0 mg/L (Carter 2005), and recommended oxygen levels for spawning anadromous fish should be no lower than 5.0 mg/L (Reiser and Bjornn 1979). There were no steelhead specific studies found. Changing flows from seasonal operations may result in warmer water temperature and lower dissolved oxygen than Environmental baseline in March but equivalent temperatures in April and May; however, water quality monitoring in the San Joaquin River suggests dissolved oxygen levels are well above 5.0 mg/L in spring.

Pathogens and disease stressors may increase or may not change. The increase may harm by increasing physiological stress. Salmonid pathogens can be transmitted both vertically (i.e., parent to offspring) or horizontally (i.e., between individuals, Baxa-Antonio et al. 1992). 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. The effect of changing flow and temperature may be offsetting. Water temperatures greater than 59.9°F occur in the summer, above which temperature threshold diseases affecting Chinook salmon become highly virulent (McCullough 1999).

Food availability and quality stressors may increase. The increase is likely insignificant and/or discountable. Decreased flows may result in less inundated habitats in some areas. Reaches of the lower San Joaquin River are highly channelized with low complexity, which may decrease the volume of macroinvertebrates as a food supply. Like most salmonids, steelhead typically do not eat during their migrations and spawning in freshwater, so any changes to the food supply is likely insignificant.

Competition, introgression, and broodstock removal stressors are not anticipated to change. CVP and SWP operations are not a proximate cause of these stressors since they do not remove or introduce adult steelhead into the population.

4.2.6.3.2 Eggs

Eggs are not present in the San Joaquin River in the summer.

4.2.6.3.3 Juveniles

Juveniles are rearing in the San Joaquin River in the summer. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates dependent on an individual's physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Millerton Lake storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows 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 two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors may increase. The increase may harass, harm, and kill juvenile steelhead. When flows decrease juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. The magnitude of flow decreases varies among alternatives. There is uncertainty on factors that cue migration and how changes in flow 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).

Water temperature stressors may increase or may not change. The increase may cause harm to juvenile steelhead rearing. 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). 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). Historic water temperatures in the summer exceed 66.2°F and are likely to reach the upper temperature limits of 73°F. Changing flows from seasonal operations results in may result in slightly colder water temperatures but historic data indicate the changes aren't significant enough to impact juvenile steelhead. However, there is uncertainty on how these changes in temperature 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).

Dissolved oxygen stressors may decrease. The decrease may be beneficial. Rearing salmonids appear to exhibit no negative effects at average dissolved oxygen levels of 9 mg/L (Davis 1975, Carter 2005), and a study on rainbow trout observed decreased swimming speed at dissolved oxygen levels of 5.1 mg/L at 57.2°F (Jones et al. 1971). Water quality monitoring shows dissolved oxygen levels can vary near or below 9 mg/L in the summer. There is uncertainty on how these changes in 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).

Pathogen and disease stressors may increase or may not change. The increase may cause harm to juvenile steelhead rearing. 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). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic summer water temperatures are warmer than this threshold. There is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change in the San Joaquin River. CVP facilities on the San Joaquin River and facilities used to divert water for CVPIA refuges are screened.

Refuge habitat stressors may increase. The increase may harm juvenile steelhead. Changing operations decreases flows relative to Environmental baseline and reduces suitable margin and off-channel habitats being available as refuge habitat for juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Changing operations results in decreased flows and less inundated habitats relative to the environmental baseline. This alters food web processes and riparian vegetation, decreasing food availability and quality, and impacting the successful growth and survival of juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the Delta and San Joaquin River 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. 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. Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix I and Appendix J present analysis of these stressors.

4.2.6.4 Fall

In the fall, Reclamation and DWR's proposed storage and release of water will decrease on average.

4.2.6.4.1 Adults

Adults are not present in the San Joaquin River in the fall.

4.2.6.4.2 Eggs

Eggs are not present in the San Joaquin River in the fall.

4.2.6.4.3 Juveniles

Juveniles are rearing in the San Joaquin River in the fall. After emergence, fry either swim or are passively advected downstream. Juveniles can exhibit a range of migration rates dependent on an individual's physiological stage and condition and flow conditions. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during the migration.

Toxicity from contaminants stressors may increase. The increase is likely discountable and/or insignificant. Maintenance of Millerton Lake storage may reduce flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect adult salmonids and no fish effects have been observed in fish monitoring. A review of contaminant studies shows 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 two sampled fish (0.234 mg/kg in a floodplain fish and 0.269 mg/kg in a Sacramento River fish) in winter floods between 2001 and 2005 were above this threshold (Henery et al. 2010), However, no sublethal effects were observed in these juveniles. However, there is uncertainty on how these changes in toxicity from contaminants may affect occurrence of anadromy among juvenile Steelhead, 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).

Stranding risk stressors may decrease. The decrease is likely insignificant and/or discountable. Flows for seasonal operations are relatively stable between months in the fall Environmental baseline. When flows decrease, juveniles can become stranded in habitat disconnected from the main channel where habitats are desiccated and fish cannot survive, or they may be exposed to higher levels of predation. Stranding pools may have clearer visibility, which may allow visual predators a higher success rate on stranded fish. There is uncertainty on factors that cue migration and how changes in flow 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).

Water temperature stressors may increase or may not change. The increase may cause harm to juvenile steelhead rearing. 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). 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). Historic water temperatures indicate temperatures in the fall exceed 66.2°F and are likely to reach the upper temperature limits of 73°F. Changing flows from seasonal operations results in may result in slightly colder water temperatures but historic data indicate the changes aren't significant enough to impact juvenile steelhead. There is uncertainty on how these changes in temperature 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).

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Pathogen and disease stressors may increase or may not change. The increase may cause harm to juvenile steelhead rearing. 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). Diseases affecting Chinook salmon become highly virulent at temperatures above 59.9°F (McCullough 1999). Historic water temperatures are warmer than this threshold. However, there is uncertainty on how these 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).

Entrainment risk stressors are not anticipated to change in the San Joaquin River. CVP facilities on the San Joaquin River and facilities used to divert water for CVPIA refuges are screened.

Refuge habitat stressors may increase. The increase may harm juvenile steelhead. Changing operations decreases flows relative to Environmental baseline and reduces suitable margin and off-channel habitats being available as refuge habitat for juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in habitat stressors may affect occurrence of anadromy among juveniles.

Food availability and quality stressors may increase. The increase may harm juvenile steelhead. Changing operations results in decreased flows and less inundated habitats relative to the environmental baseline. This alters food web processes and riparian vegetation, decreasing food availability and quality, and impacting the successful growth and survival of juveniles. Appendix O defines habitat and presents an analysis of this stressor. There is uncertainty on how these changes in food stressors may affect occurrence of anadromy among juveniles.

Predation and competition stressors may increase. The increase is likely insignificant and/or discountable. Indirect effects of predation are described further in the "Outmigration Cues", "Entrainment Risk", and "Refuge Habitat" sections. There is uncertainty about the effects of the Proposed Action on predator abundance and predation rates not included in the effects described in the stressors mentioned above. Predator presence in the Delta and San Joaquin River 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. 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.

Competition an individual experiences also is a function of inseparable variables such as refuge habitat, prey availability, and environmental conditions that are influenced by operations. The effects of predation and competition related to refuge habitat, water temperature (McInturf and Fangue 2022), and outmigration cues stressors have been included in those stressor sections of this appendix (Appendix D). Appendix I and Appendix J present analysis of these stressors.

4.3 Species Effects Determination

The seasonal operation of the CVP and SWP may affect and is likely to adversely affect California CV steelhead. The seasonal operation of the CVP is also likely to have beneficial effects. Deconstruction of the seasonal operations systematically evaluated each stressor identified by conceptual models. Stressors not linked to the operation of the CVP and SWP were identified as "are not anticipated to change." Stressors that were insignificant or discountable were documented. Stressors with a material effect on the fitness of species were identified, and seasonal operations will consider minimization and/or compensation through conservation measures.

Stressors on adults and resident *O. mykiss* influenced by seasonal operations include:

- Water Temperatures: Increased flows may affect water temperature stressors in the Sacramento River and Clear Creek. A conservation measure for Sacramento River and Clear Creek water temperature that considers flows may benefit water temperatures for some adults and adversely affect others. Managing water temperatures for egg incubation provides colder waters than needed for adults, but that management action may start later in the year, depending on seasonal operations.
- Stranding Risk: Seasonal flows may affect stranding risks for adult steelhead in CVP streams. Conservation measures for ramping rates and minimum instream flows may avoid or minimize the potential for adult stranding.
- Spawning Habitat: Decreased flows may provide less habitat availability and may increase crowding. A conservation measure for maintenance and construction of spawning habitat may minimize or benefit potential spawning habitat.

Stressors on eggs and alevins influenced by seasonal operations include:

- Dewatering: The transition between seasonal winter and spring flows on the American River may increase steelhead redd dewatering. A conservation measure for ramping rates and instream flows may minimize potential dewatering.
- Sedimentation and gravel quantity: Fine sediment deposition and quantity of spawning gravel available decreases with reduced flows. The construction of spawning habitat is anticipated to improve redd quality.

Stressors on juveniles influenced by seasonal operations include:

- Stranding: Reduced releases below CVP reservoirs during the juvenile rearing period pose a stranding risk to juveniles. A conservation measure for ramping rates may avoid or minimize the potential for yearling stranding.
- Outmigration: The change in timing of flows for seasonal operations below CVP reservoirs and in the Bay-Delta may disrupt outmigration cures and reduce survival. Conservation measures for minimum instream flows and pulse flows may avoid or minimize outmigration cue stressors.
- Refuge Habitat: Decreased flows may provide decreased habitat availability. A conservation measure for the construction of additional rearing habitat on the Sacramento River, American River, Stanislaus River, and Clear Creek may minimize or benefit potential refuge habitat.
- Food Availability and Quality: Decreased flows may provide less food availability through a reduction in suitable feeding areas in the Bay-Delta and below CVP reservoirs. A conservation measure for the construction of additional tributary and tidal rearing habitat may minimize or benefit food availability and quality.

- Entrainment: Reduced flows affect routing and entrainment of steelhead in the Bay-Delta. Several actions may avoid, minimize, or benefit the potential for Bay-Delta juvenile entrainment including a conservation measure for the Delta Cross Channel, a conservation measure for routing at Georgiana Slough, a conservation measure for Old and Middle River flow management, and a conservation measure for salvage before the export facilities.

4.4 Critical Habitat Physical and Biological Features

Critical habitat has been designated for steelhead (70 FR 52488, September 2, 2005), and includes all river reaches accessible to listed steelhead in the Sacramento River and its tributaries in California.

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 (Figure 24). With the exception of Clifton Court Forebay, the entirety of the proposed action area in the Central Valley is designated critical habitat for steelhead.

The critical habitat for steelhead lists the essential physical and biological features, which include:

4.4.1 Adult Passage

Freshwater spawning habitat for steelhead is in the reaches of the Sacramento River from Keswick Dam to Red Bluff Diversion Dam. Unobstructed access from the Pacific Ocean to the upper Sacramento River is essential for the conservation of steelhead. The availability of freshwater riparian habitat can support successful juvenile development and survival.

The species effect determination found related potential stressors of:

- Stranding

There are no additional operations effects on adult passage when species are not present.

4.4.2 Spawning and Rearing Substrate

The availability of good water quality and floodplain for spawning and rearing substrate are essential for the conservation of steelhead. Water flow fluctuations, water temperature, loss of floodplain habitat, loss of natural river morphology and alternation of physical habitat are stressors that can reduce the freshwater spawning habitat for steelhead. Without them the species cannot successfully spawn and produce offspring.

The species effect determination found related potential stressors of:

- Sedimentation and gravel quantity
- Refuge habitat

There are no additional operations effects on spawning substrate when species are not present.

4.4.3 Juvenile Riparian Habitat and Passage

Riparian habitat that provides for successful juvenile development and survival are essential for the conservation of steelhead. In the late summer and fall, due to the reduction in natural flow and habitat on coastal California streams, the survival conditions become stressful for steelhead. At low flows, critical riffles may become natural barriers to upstream and downstream passage for steelhead, which may prevent adult steelhead from moving to spawning areas or prevent smolts from migrating downstream to staging areas before entering the ocean. The low flows may prevent or delay rearing juvenile steelhead from moving between adequate summer freshwater rearing habitats, seeking productive feeding areas, and avoiding predation. Without adequate flows for juvenile to access passage downstream, the juveniles may not easily migrate from the spawning grounds to the Pacific Ocean.

The species effect determination found related potential stressors of:

- Outmigration cues
- Entrainment risk

There are no additional operations effects on juvenile riparian habitat and passage when species are not present.

4.4.4 Uncontaminated Habitat Areas and Prey

A functioning migration corridor for the emigration of juvenile steelhead from the upper Sacramento River to the Delta and its tributaries is dependent on the condition of flows, temperature, suitable habitat, and a lack of fish predators. Habitat areas that are not contaminated are essential for the conservation of steelhead.

The species effect determination found related potential stressors of:

- Food availability and quality

There are no additional operations effects on uncontaminated habitat areas and prey when species are not present.

4.4.5 Suitable Flows

Suitable river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles are essential for the conservation of steelhead. A suitable flow regime should include stable and sufficient water flow rates in spawning and rearing reaches to maintain water temperatures within the optimal range for egg, larval, and juvenile survival and development. Successful migration of adult steelhead to and from spawning grounds is also dependent on sufficient water flow. Spawning success is associated with water flow and water temperature.

The species effect determination found related potential stressors of:

- Outmigration cues

- Refuge habitat
- Food availability and quality
- Stranding
- Entrainment risk

There are no additional operations effects on suitable flows when species are not present.

4.4.6 Water Temperature

Spawning success is associated with water flow and water temperature. Water temperatures between 40°F and 55°F (4.4°C and 12.8°C) are suitable for successful spawning, egg incubation, and fry development for steelhead (WDOE 2002).

The species effect determination found related potential stressors of:

- Egg incubation

There are no additional operation effects on water temperatures when species are not present.

4.5 Critical Habitat Effect Determination

The seasonal operation is likely to adversely affect critical habitat for steelhead.

- Degraded spawning and rearing substrate is reintroduced in the proposed action area through gravel augmentation projects
- Degraded water temperatures for egg incubation and adult holding are actively managed through Cold Water Pool Management
- Impacts to juvenile rearing and refuge habitat are compensated through the construction of additional habitat and implementing recommendations based on new research
- Flow management is actively managed to reduce or avoid impacts to stressors on steelhead for all life stages

5 Green Sturgeon

The southern distinct population segment of North American green sturgeon (Acipenser medirostris) (green sturgeon) and designated critical habitat occurs in the action area and may be affected by the seasonal operations. Green sturgeon are an anadromous fish species that can live 60 to 70 years and grow to a size of 9 feet. Green sturgeon spawn in the Sacramento River and spend most of their life in the nearshore marine environment and coastal bays and estuaries along the west coast of North America.

5.1 Conceptual Lifecycle Models

An action may affect fish when the change in conditions overlaps with the location and timing of fish and/or their habitats. The SAIL conceptual model (Heublein et al. 2017) describes life stages and geographic locations for green sturgeon (Figure).

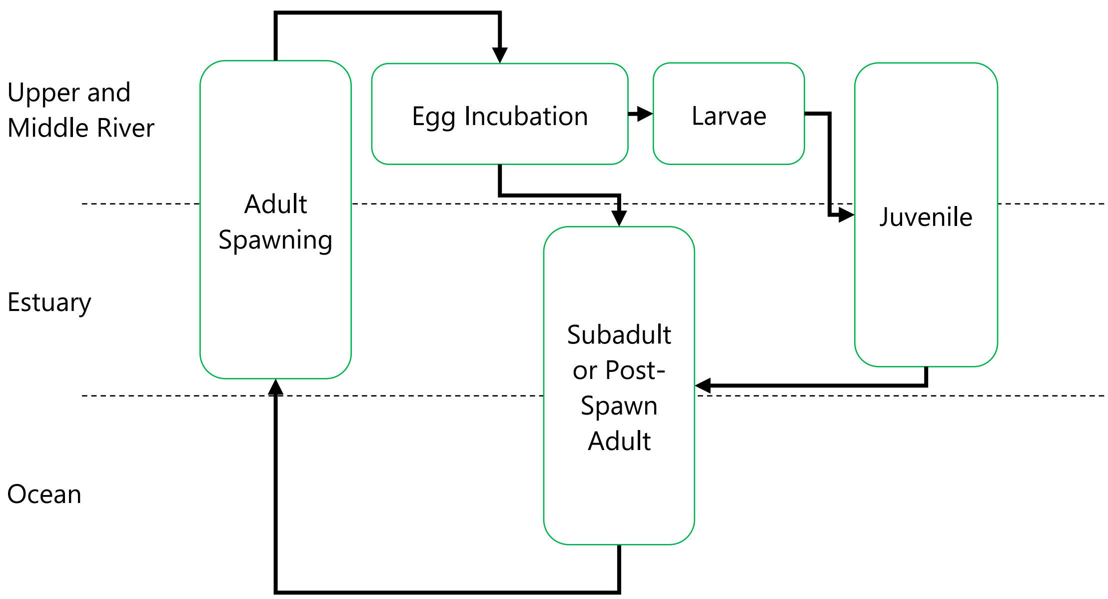

Figure 7. Geographic Life Stage Domains for Green Sturgeon (developed from Heublein et al. 2017)

SAIL models describe linkages between landscape attributes and environmental drivers to habitat attributes that may affect fish (stressors) based on life stage. The green sturgeon SAIL model provides life stages and stressors of:

- Adult to Spawning Adult
    - H25: Harvest
    - H29: Food
    - H26, H27: Water Temperature & Salinity
    - H30: Toxicity & DO
    - H28: Migration & Foraging Habitat
    - H31: Predation Risk
- Egg to Larvae
    - H3: Flow

    - H2: Water Temperature
    - H5: Toxicity & DO
    - H4: Incubation Habitat
    - H6: Predation Risk
- Larvae to Juvenile
    - H8: Flow
    - H9: Water Temperature
    - H13: Toxicity & DO
    - H12: Entrainment Risk
    - H10: Rearing Habitat
    - H14: Food
    - H11: Predation Risk
- Juvenile to Subadult/Adult
    - H16: Flow
    - H17, H20: Water Temperature & Salinity
    - H21: Toxicity & DO
    - H22: Entrainment Risk
    - H18: Rearing Habitat
    - H19: Food
    - H23: Predation Risk
- Spawning Adult to Egg & Post-Spawn Adult
    - H37: Harvest
    - H34, H39: Flow
    - H35, H38, H40: Water Temperature
    - H41: Toxicity & DO
    - H33: Barriers
    - H36: Spawning Habitat

Each deconstruction of the action considers the 31 stressors for the five life stages listed above. Additional and/or alternative conceptual models (e.g., CVPIA Science Integration Team) may be incorporated as applicable.

The temporal occurrence of green sturgeon (Figure 8) (Appendix C) was informed from Heublein et al. 2017 and updated with information from Red Bluff monitoring (Poytress pers. comm.) and information on telemetered green sturgeon (Colborne pers. comm.).

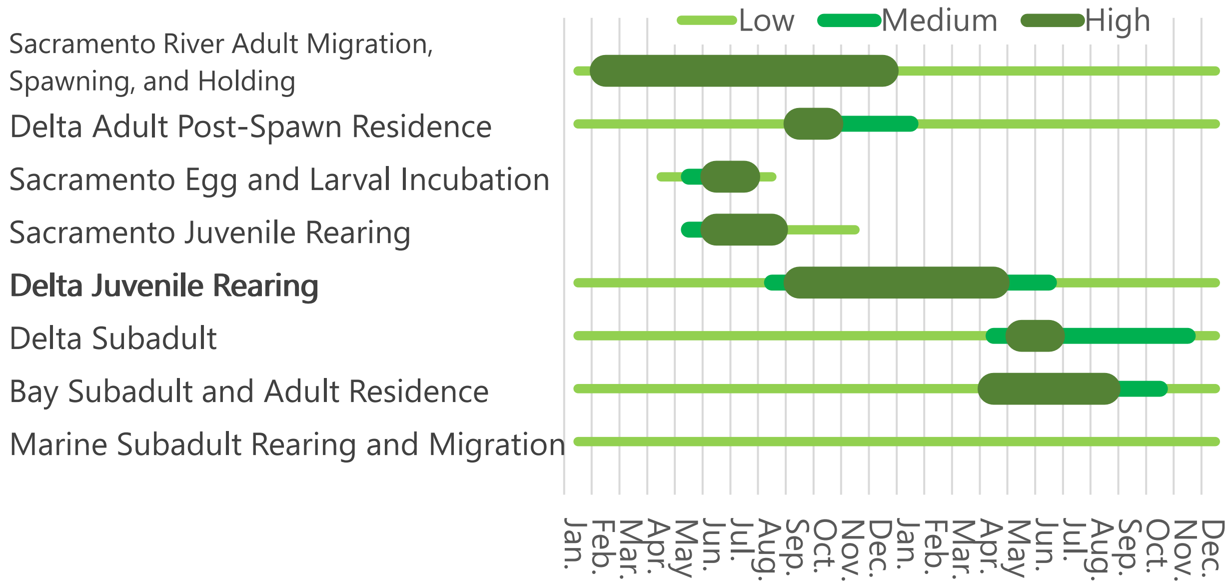

Figure 8. Temporal Life Stage Domains for Green Sturgeon from Appendix C

The two spatial domains defined for green sturgeon are the Sacramento River and Bay-Delta. The presence for Sacramento spawning and Bay-Delta subadult stages span more than one year. Green sturgeon remain subadults for multiple years and likely rear at least a portion of that multi-year time in bays and estuaries adjacent to the Sacramento River (*i.e.*, the Sacramento-San Joaquin Delta and the Suisun, San Pablo, and San Francisco Bays). The ocean life stage is a critical habitat action area determined by NMFS and is shown but not evaluated in the species effects deconstruction.

5.2 Species Effects Deconstruction

Green sturgeon are anticipated in the Sacramento River and Bay-Delta and may experience effects from components of the seasonal operations as described below. The Sacramento River includes adult migration and holding, adult spawning and emigration, egg incubation and larvae presence, and juvenile rearing and outmigration. The Bay-Delta includes migrating adults and post-spawn adults and migrating juveniles. It is not expected that operations in the Proposed Action will affect the estuarine subadult and adult residence and outmigration lifestage due to these individuals generally not being located within the proposed action area (Miller et al. 2020).

5.2.1 Sacramento River

5.2.1.1 Winter

In the winter, Reclamation and DWR's proposed storage of water will decrease flows on average in the Sacramento River below Keswick Dam. Decreased flow in the upper Sacramento River may change stressors on green sturgeon.

5.2.1.1.1 Adults

Adults are outmigrating in the upper Sacramento River in the winter. Adults present and outmigrating in the winter represent the tail end of the life stage exhibiting that behavior. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration.

Harvest stressors are not anticipated to change. Although there have been improvements to fishing regulations to eliminate harvest and reduce bycatch mortality (National Oceanic and Atmospheric Administration 2022), illegal harvest of green sturgeon as a consequence of poaching or misidentification as white sturgeon may occur. CVP and SWP operations are not a proximate cause of bycatch mortality or illegal harvest of green sturgeon.

Flow stressors may increase. The increase is likely insignificant. The majority of adult green sturgeon have been found to "late" outmigrate the winter following spawning, as opposed to outmigrating "early" shortly after spawning (Colborne et al. 2022). River discharge is hypothesized to cue "late" outmigrating adult green sturgeon in the winter (Colborne et al. 2022). The impact of delayed outmigration on adult sturgeon is not known.

Water temperature stressors are not anticipated to change. Very little is known about the thermal requirements of adult green sturgeon (Rodgers et al. 2019). While there is uncertainty regarding whether water temperature serves as a migration cue, Colborne et al. (2022) observed migration between 52-59°F (11-15°C) in the Sacramento River, and migration occurred mainly in the spring and fall. Modeled winter water temperatures are colder than these observed migration temperatures (Appendix B, Section 3.2). Appendix L presents an analysis of this stressor.

Salinity stressors are not anticipated to change. Green Sturgeon present in the Sacramento River upstream of the Bay-Delta would not be anticipated to experience high salinity concentrations. See Appendix B.

Toxicity and DO stressors. Toxicity stressors may increase. The increase is likely insignificant. As benthic feeders, green sturgeon are hypothesized to be more susceptible to toxicity; however, the foraging behaviors are not well documented in the Sacramento River. CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent; however, CVP and SWP storage and diversion of water decreases river flows limiting the potential for dilution of contaminants. DO stressors are not anticipated to change. Very little is known about dissolved oxygen stressors in adults. Dissolved oxygen less than 5.0mg/L may affect migration of other large bodied anadromous fish (Carter 2005). Reclamation's water quality monitoring at Bend Bridge, Balls Ferry, and Red Bluff Diversion Dam have not shown dissolved oxygen at levels below this in the winter.

Barriers stressors are not anticipated to change. Migrating adult green sturgeon are unlikely to encounter barriers in the Sacramento River that would impede outmigration. CVP and SWP operations is not a proximate cause of potential stranding in flooded bypasses.

Spawning habitat stressors are not anticipated to change. Spawning does not occur during the winter months between December and February in the Sacramento River.

5.2.1.1.2 Eggs

Eggs are not present in the upper Sacramento River in the winter.

5.2.1.1.3 Larvae

Larvae are not present in the upper Sacramento River in the winter.

5.2.1.1.4 Juveniles

Juveniles are present in the upper Sacramento River. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during migration.

Flow stressors are not anticipated to change. There is uncertainty about the effects of flow on juveniles. Body condition in larval green sturgeon was negatively correlated with discharge (Zarri et al. 2019). If this relationship applies to juveniles, it suggests decreased releases may not adversely impact juvenile body condition.

Water Temperature are not anticipated to change. There is a strong temperature-dependence for growth between 51.8 and 68°F (Hamda et al. 2019), and lab studies indicate bioenergetic performance to be optimal between 59-66.2°F (15-19°C) (Mayfield and Cech 2004). Modeled winter water temperatures under seasonal operations are below the observed growth and optimal temperature ranges in winter. Similarly, water temperatures under Environmental baseline are below the observed growth and optimal temperature ranges in winter (Appendix B, Section 3.2). Appendix L presents an analysis of this stressor.

Salinity stressors are not anticipated to change. Green Sturgeon present in the Sacramento River upstream of the Bay-Delta would not be anticipated to experience high salinity concentrations. See Appendix B.

Toxicity and DO stressors may increase. The increase is likely insignificant for both toxicity and dissolved oxygen. Shasta Reservoir storage may decrease flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect juveniles and no fish effects have been observed in fish monitoring. Releases of Shasta Reservoir storage may result in decreased flows which may decrease dissolved oxygen concentrations; however, water quality monitoring has not shown dissolved oxygen at low levels in the winter. Very little is known about dissolved oxygen stressors in juveniles.

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108). It is uncertain if current screen criteria (developed for salmonids) prevent Southern distinct population segment (DPS) green sturgeon from impingement and entrainment. Currently, no screen criteria have been developed for green sturgeon (National Oceanic and Atmospheric Administration 2022).

Rearing habitat stressors are not anticipated to change. There is limited information on rearing habitat requirements and availability for green sturgeon juveniles. In the Delta and Bay, juvenile green sturgeon used a broad range of habitats, which is partly due to variation in hydrologic connectivity and water-year type (Thomas et al. 2022). This broad range of habitat use is hypothesized to also occur in rivers. CVP and SWP operations are not a proximate cause for variation in water year. Appendix O defines habitat and presents an analysis of this stressor.

Food stressors may decrease. The decrease is likely insignificant. Releases of Shasta Reservoir storage may decrease flows during the winter. Increased flows on the Sacramento River have been observed to change benthic macroinvertebrate community composition (Nelson and Lieberman 2002).

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk a juvenile experiences is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22 cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.2.1.2 Spring

In the spring, Reclamation and DWR’s proposed storage of water will decrease flows on average in the Sacramento River below Keswick Dam. Decreased flow in the upper Sacramento River may change stressors on green sturgeon.

5.2.1.2.1 Adults

Adults are migrating, spawning, and holding in the upper Sacramento River in the spring. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration. Green sturgeon spawning and holding in the Sacramento River are undergoing an energetically taxing transition to spawn.

Harvest stressors are not anticipated to change. Although there have been improvements to fishing regulations to eliminate harvest and reduce bycatch mortality (National Oceanic and Atmospheric Administration 2022), illegal harvest of green sturgeon as a consequence of poaching or misidentification as white sturgeon may occur. CVP and SWP operations is not a proximate cause of bycatch mortality or illegal harvest of green sturgeon.

Flow stressors are not anticipated to change. Mora et al. (2009) concluded that flow regulation reduces discharge closer to values associated with spawning sturgeon sighting data. Between 2008-2012, Poytress et al. (2015) observed an average discharge at Bend Bridge of 314 cubic meters per second (range: 269-396 cubic meters per second) during spawning events. Modeled flows in the spring range from 250-550 cubic meters per second (10,000-19,000 cubic feet per second) at Bend Bridge compared to the Environmental baseline range of 400-700 cubic meters per second (15,000-24,000 cubic feet per second) (Appendix B, Section 3.1). Therefore, modeled ranges are within the spawning range for green sturgeon.

Water temperature stressors may decrease. The decrease is likely insignificant. Maintenance of Shasta Reservoir storage may result in warmer water temperatures in March and April and cooler water in May. Very little is known about the thermal requirements of adult green sturgeon (Rodgers et al. 2019). While there is uncertainty regarding whether water temperature serves as a migration cue, Colborne et al. (2022) observed migration between 52-59°F (11-15°C) in the Sacramento River. Spawning of southern DPS in the Sacramento River has occurred between 49-64°C (9.6-17°C) (Poytress et al. 2015). Modeled spring water temperatures are within these observed migration and spawning temperature ranges in March and April, and operations decrease May temperatures below 60°F to be more suitable for migration and spawning (Appendix B, Section 3.2). Appendix L presents an analysis of this stressor.

Salinity stressors are not anticipated to change. Green Sturgeon present in the Sacramento River upstream of the Bay-Delta would not be anticipated to experience high salinity concentrations. See Appendix B.

Toxicity and DO stressors. Toxicity stressors may increase. The increase is likely insignificant. CVP and SWP storage and diversion of water decreases river flows limiting the potential for dilution of contaminants; however, CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. DO stressors are not anticipated to change. Very little is known about dissolved oxygen stressors in adults. Dissolved oxygen less than 5.0mg/L may affect migration of other large bodied anadromous fish (Carter 2005). Water quality monitoring at upper Sacramento River sites has not shown dissolved oxygen at levels below this in the spring.

Barriers stressors are not anticipated to change. The effect of bypass channels on adult green sturgeon migration at low flow is unknown (Heublein et al. 2017a). Migrating adult green sturgeon are unlikely to encounter other barriers in the Sacramento River that would impede migration to spawning habitat. CVP and SWP operations is not a proximate cause of potential stranding in flooded bypasses.

Spawning habitat stressors are not anticipated to change. Green sturgeon spawning occurs in the spring and discharge influences the availability of spawning habitat. Green sturgeon prefer habitat with velocities of 1.0-1.1 meters per second and 8-9 meter deep (Wyman et al. 2018), both of which are influenced by discharge. Wyman et al. (2018) showed that spawning habitat wetted usable area (WUA) becomes inversely related to discharge starting at around 350-400 cubic meters per second. At lower velocities, adult green sturgeon may select for microhabitats with optimal velocity conditions (Wyman et al. 2018). Modeled flows in the spring range from 150-550 cubic meters per second (6,000-19,000 cubic feet per second) between Keswick Dam and Bend Bridge, respectively, compared to the Environmental baseline range of 350-700 cubic meters per second (12,000-24,000 cubic feet per second) (Appendix B, Section 3.1). Modeled flows are below discharges at which WUA starts to decline.

5.2.1.2.2 Eggs

Eggs are present in the upper Sacramento River in the spring. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

Flow stressors are not anticipated to change. Gravel appropriate for green sturgeon egg incubation is maintained by flows. Brown (2007) observed eggs when daily river flows at Bend Bridge reached at least 400 cubic meters per second in 2001; Between 2008-2012, Poytress et al. (2015) observed an average discharge at Bend Bridge of 314 cubic meters per second (range: 269-396 cubic meters per second) during spawning events and concluded that mean water velocities appeared sufficient to maintain clean gravel and reduce the likelihood of sand suffocation Modeled flows in the spring range from 250-550 cubic meters per second (10,000-19,000 cubic feet per second) at Bend Bridge compared to the Environmental baseline range of 400-700 cubic meters per second (15,000-24,000 cubic feet per second).

Water temperature stressors may decrease. The decrease is likely beneficial. Maintenance of Shasta Reservoir storage may result in warmer water temperatures. In laboratory studies, the optimal thermal range to maximize hatching success and avoid deleterious effects was 57.2-60.8°F (14-16°C) (Rodgers et al. 2019). Decreased hatching success and length was observed at 51.8°F (11°C) and deformed embryos were observed at temperatures ≥ 63.5°F (17.5°C) (Van Eenennaam et al. 2005). In field studies, embryos have been collected on the Sacramento River between 52.3-60.3°F (11.3-15.8°C) (Brown 2007, Poytress et al. 2015). Modeled spring water temperatures indicate operations to increase (March) or decrease (May) temperatures to be closer to the optimal thermal range when compared with Environmental baseline (Appendix B, Section 3.2). Appendix L presents an analysis of this stressor.

Toxicity and DO stressors may increase. The increase is likely insignificant for both toxicity and dissolved oxygen. Releases of Shasta Reservoir storage may decrease flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect eggs and no fish effects have been observed in fish monitoring. During incubation, eggs do not eat, which reduces their exposure to contaminants in prey during this life stage. Releases of Shasta Reservoir storage may result in decreased flows which may decrease dissolved oxygen concentrations; however, water quality monitoring has not shown dissolved oxygen at low levels in the spring. Very little is known about dissolved oxygen stressors in eggs.

Incubation habitat stressors may increase. The increase is likely insignificant. Flows influence habitat attributes important for green sturgeon eggs incubation such as sedimentation, substrate, and turbidity in spawning grounds. Mean daily discharge throughout green sturgeon incubation habitat can range between 269-396 cubic meters per second, which is sufficient to maintain clean gravel and reduce the risk of suffocation by sand deposition (Poytress et al. 2015). Modeled flows from the spring range 150-550 cubic meters per second (6,000-19,000 cubic feet per second) between Keswick Dam and Bend Bridge, respectively, compared to the Environmental baseline range of 350-700 cubic meters per second (12,000-24,000 cubic feet per second) (Appendix B, Section 3.1). Modeled flow should be sufficient but may be occasional low near Keswick Dam to maintain habitat quality, although green sturgeon have only been documented to spawn as far north as the confluence with Cow Creek, near Redding.

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk green sturgeon eggs experience is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.2.1.2.3 Larvae

Larvae are present in the upper Sacramento River. Several stressors have been identified for habitat attributes that affect larvae development, relative abundance, and distribution.

Flow stressors may decrease. This decrease is likely insignificant. Releases of Shasta Reservoir storage may decrease flows. Body condition in larval green sturgeon was negatively correlated with discharge (Zarri et al. 2019). Condition was positive when discharges at Keswick were less than 250 cms (~8800 cfs) (Zarri et al. 2019). Environmental baseline releases range approximately 7,500-15,000 cfs, whereas modeled releases range approximately 6,000-10,000 cfs (Appendix B). However, flow at the Red Bluff Diversion Dam has been positively correlated with larval abundance (Heublein et al. 2017a). Information on flow and requirements for rearing green sturgeon larvae is limited.

Water Temperature stressors may decrease. The decrease is likely beneficial. Maintenance of Shasta Reservoir storage may result in warmer water temperatures in the spring. In laboratory studies, temperatures greater than 64.4°F (18°C) have been found to be detrimental to newly hatched larvae, with notochord deformities occurring between 68-78.8°F (20-26°C) (Linares-Casenave et al. 2013). Post yolk-sac larvae exhibited accelerated growth at higher temperatures 75.2°F (24°C) when food was maintained in the lab (Linares-Casenave et al. 2013). In the field, yolk-sac larvae have been collected between 55.2-55.8°F (12.9 and 13.2°C) (Brown 2007, Poytress et al. 2015), but temperatures are held at <56 °F) in these areas. Zarri et al. (2019) noted that warmer temperatures were associated with fuller stomachs and improved body condition but did not indicate an optimal temperature. Modeled spring water temperatures indicate operations increase temperatures in March to be more suitable for larvae when compared with Environmental baseline and decrease temperatures in May to fall below temperatures at which deformities have been observed (Appendix B, Section 3.2). Appendix L presents an analysis of this stressor.

Toxicity and DO stressors may increase. The increase is likely insignificant for both toxicity and dissolved oxygen. Releases of Shasta Reservoir storage may decrease flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect larvae and no fish effects have been observed in fish monitoring. Releases of Shasta Reservoir storage may result in decreased flows which may decrease dissolved oxygen concentrations; however, water quality monitoring has not shown dissolved oxygen at low levels in the spring. Very little is known about dissolved oxygen stressors in larvae.

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108). It is uncertain if current screen criteria (developed for salmonids) prevent Southern DPS green sturgeon from impingement and entrainment. Currently, no screen criteria have been developed for green sturgeon (National Oceanic and Atmospheric Administration 2022).

Rearing Habitat stressors are not anticipated to change. There is uncertainty about rearing habitat characteristics and availability for larval green sturgeon, although they occur in proximity of spawning habitats. The lowest and highest mortality rates in laboratory tests were observed in slate-rock (7%) and cobble-bottomed (40%) treatments, respectively (Nguyen and Crocker 2006), and riverbed substrate is not anticipated to change due to operations aside from restoration actions. Appendix O Restoration defines habitat and presents an analysis of this stressor.

Food stressors may decrease. The decrease is likely insignificant. Decreased flows on the Sacramento River have been observed to increase prey taxon richness and abundance, especially the presence of cyclopoid copepods (Zarri and Palkovacs 2018). Green sturgeon larvae smaller than 30mm (i.e., larvae and small juvenile) rely on zooplankton prey with a strong reliance on cyclopoid copepods (Zarri and Palkovacs 2018).

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk a larvae experiences is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.2.1.2.4 Juveniles

Juveniles are present in the upper Sacramento River. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during migration.

Flow stressors may decrease. This decrease is likely insignificant. There is uncertainty about the effects of flow on juveniles. For the younger larval life stage, releases of Shasta Reservoir storage may decrease flows. Body condition in larval green sturgeon was negatively correlated with discharge (Zarri et al 2019). If this relationship applies to juveniles, it suggests reduced releases may also improve juvenile body condition. Decreased releases of Shasta Reservoir storage may increase temperatures in the spring and there is a strong temperature-dependence for growth between 51.8 and 68°F. (Hamda et al 2019) and growth may potentially increase at lower flows. The combination of lower discharge and higher temperatures appear to benefit larval sturgeon body condition (Zarri et al. 2019) and may similarly benefit juveniles.

Water Temperature stressors may increase or decrease. The increase and decrease are likely insignificant. Shaping of Shasta Reservoir storage may result in warmer water temperatures in March and April and cooler water in May. Lab studies indicate bioenergetic performance to be optimal between 59-66.2°F (15-19°C) (Mayfield and Cech 2004). Modeled spring water temperatures indicate operations increase temperatures in March to be closer to juvenile optimum temperatures when compared with Environmental baseline, and decrease temperatures in May to fall below optimal juvenile optimum temperatures when compared with Environmental baseline (Appendix B, Section 3.2). However, young juveniles have been found to maintain swimming performance across a wider range of temperatures (Rodgers et al. 2019). Appendix L presents an analysis of this stressor.

Salinity stressors are not anticipated to change. Green Sturgeon present in the Sacramento River upstream of the Bay-Delta would not be anticipated to experience high salinity concentrations. See Appendix B.

Toxicity and DO stressors may increase. The increase is likely insignificant for both toxicity and dissolved oxygen. Shasta Reservoir storage may decrease flows and concentrate constituents; however, water quality monitoring has not shown contaminants at levels likely to affect juveniles and no fish effects have been observed in fish monitoring. Releases of Shasta Reservoir storage may result in decreased flows which may decrease dissolved oxygen concentrations; however, water quality monitoring in the upper Sacramento River has not shown dissolved oxygen at low levels in the spring. Very little is known about dissolved oxygen stressors in juveniles.

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108). It is uncertain if current screen criteria (developed for salmonids) prevent Southern DPS green sturgeon from impingement and entrainment. Currently, no screen criteria have been developed for green sturgeon (National Oceanic and Atmospheric Administration 2022).

Rearing habitat stressors are not anticipated to change. There is limited information on rearing habitat requirements and availability for green sturgeon juveniles. In the Delta and Bay, juvenile green sturgeon used a broad range of habitats, which is partly due to variation in hydrologic connectivity and water-year type (Thomas et al. 2022). This broad range of habitat use is hypothesized to also occur in rivers. CVP and SWP operations are not a proximate cause for variation in water year. Appendix O Restoration defines habitat and presents an analysis of this stressor.

Food stressors may decrease. The decrease is likely insignificant. Decreased flows on the Sacramento may change benthic macroinvertebrate community composition (Nelson and Lieberman 2002). The effect of these changes on the availability of prey for juvenile green sturgeon is unknown.

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk a juvenile experiences is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.2.1.3 Summer

In the summer, Reclamation and DWR's proposed release of water will increase flows on average in the Sacramento River below Kewsick Dam. Increased flow in the upper Sacramento River may change stressors on green sturgeon.

5.2.1.3.1 Adults

Adults are migrating, spawning, and holding in the upper Sacramento River. Several stressors have been identified that may impact adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration. Green sturgeon spawning and holding in the Sacramento River are undergoing an energetically taxing transition to spawn.

Harvest stressors are not anticipated to change. Although there have been improvements to fishing regulations to eliminate harvest and reduce bycatch mortality (National Oceanic and Atmospheric Administration 2022), illegal harvest of green sturgeon as a consequence of poaching or misidentifications white sturgeon may occur. CVP and SWP operations is not a proximate cause of bycatch mortality or illegal harvest of green sturgeon.

Flow stressors may decrease. The decrease is likely insignificant. Approximately 30% of adult green sturgeon have been found to "early" outmigrate the summer following spawning, as opposed to outmigrating "late" the following winter (Colborne et al. 2022). "Early" outmigration is correlated with higher minimum daily flows (Colborne et al. 2022). An increase in flow may cue adults after spawning to outmigrate towards the Bay-Delta (Colborne et al. 2022). The impact of "early" versus "late" outmigration on adult sturgeon is not known.

Water temperature stressors may decrease. The decrease is likely insignificant. Very little is known about the thermal requirements of adult green sturgeon (Rodgers et al. 2019). While there is uncertainty regarding whether water temperature serves as a migration cue, Colborne et al. (2022) observed migration between 52-59°F (11-15°C) in the Sacramento River, and migration occurred mainly in the spring and fall. Spawning of southern DPS in the Sacramento River has occurred between 49-64°C (9.6-17°C) (Poytress et al. 2015). Modeled summer water temperatures under seasonal operations are within these observed migration and spawning temperature ranges, while temperatures under Environmental baseline are above these temperature ranges (Appendix B, Section 3.2). Appendix L presents an analysis of this stressor.

Salinity stressors are not anticipated to change. Green Sturgeon present in the Sacramento River upstream of the Bay-Delta would not be anticipated to experience high salinity concentrations. See Appendix B.

Toxicity and DO stressors may decrease. The decrease is likely insignificant. CVP and SWP storage and diversion of water increase river flows increasing the potential for dilution of contaminants; however, CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. DO stressors on adults are not anticipated to change. Very little is known about dissolved oxygen stressors in adults. Dissolved oxygen less than 5.0 mg/L may affect migration of other large bodied anadromous fish (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below this in the summer.

Barriers stressors are not anticipated to change. The effect of bypass channels on adult green sturgeon migration at low flow is unknown (Heublein et al. 2017a). Migrating adult green sturgeon are unlikely to encounter other barriers in the Sacramento River that would impede migration to spawning habitat. CVP and SWP operations is not a proximate cause of potential stranding in flooded bypasses.

Spawning habitat stressors are not anticipated to change. Green sturgeon spawning occurs in the spring and early summer and discharge influences the availability of spawning habitat. Green sturgeon prefer habitat with velocities of 1.0-1.1 meters per second and 8-9 meter deep (Wyman et al. 2018), both of which are influenced by discharge. Wyman et al. (2018) showed that spawning habitat WUA becomes inversely related to discharge starting at around 350-400 cubic meters per second. At higher velocities, adult green sturgeon may select for microhabitats with optimal velocity conditions (Wyman et al. 2018). Modeled flows in the summer range from 283-396 cubic meters per second between Keswick Dam and Bend Bridge compared to a range of 113-255 cubic meters per second (Appendix B, Section 3.1).

5.2.1.3.2 Eggs

Eggs are present in the upper Sacramento River in the summer. Egg to fry survival is highly dependent on a few parameters. Several stressors have been identified for habitat attributes that affect egg survival, timing, and condition.

Flow stressors are not anticipated to change. Gravel appropriate for green sturgeon egg incubation is maintained by flows. Brown (2007) observed eggs when daily river flows at Bend Bridge reached at least 400 cubic meters per second in 2001; Between 2008-2012, Poytress et al. (2015) observed an average discharge at Bend Bridge of 314 cubic meters per second (range: 269-396 cubic meters per second) during spawning events and concluded that mean water velocities appeared sufficient to maintain clean gravel and reduce the likelihood of sand suffocation. Modeled flows in the spring range from 250-550 cubic meters per second (10,000-19,000 cubic feet per second) at Bend Bridge compared to the Environmental baseline range of 400-700 cubic meters per second (15,000-24,000 cubic feet per second).

Water temperature stressors may decrease. The decrease is likely beneficial. In laboratory studies, the optimal thermal range to maximize hatching success and avoid deleterious effects was 57.2-60.8°F (14-16°C) (Rodgers et al. 2019). Decreased hatching success and length was observed at 51.8°F (11°C) and deformed embryos were observed at temperatures ≥ 63.5°F (17.5°C) (Van Eenennaam et al. 2005). In field studies, embryos have been collected on the Sacramento River between 52.3-60.3°F (11.3-15.8°C) (Brown 2007, Poytress et al. 2015). Modeled summer water temperatures under seasonal operations are within these observed optimal thermal ranges, while temperatures under Environmental baseline are above these temperature ranges (Appendix B, Section 3.2). Appendix L presents an analysis of this stressor.

Toxicity and DO stressors may decrease. The decrease is likely insignificant for both toxicity and dissolved oxygen. Releases of Shasta Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect eggs and no fish effects have been observed in fish monitoring. During incubation, eggs do not eat, which reduces their exposure to contaminants in prey during this life stage. Very little is known about dissolved oxygen stressors in eggs. Releases of Shasta Reservoir storage may result in increased flows which may increase dissolved oxygen concentrations, and water quality monitoring in the upper Sacramento River has not shown dissolved oxygen at low levels in the summer.

Incubation habitat stressors may decrease. The decrease is likely to be beneficial. Flows influence habitat attributes important for green sturgeon eggs incubation such as sedimentation, substrate, and turbidity in spawning grounds. Mean daily discharge throughout green sturgeon incubation habitat can range between 270 – 400 cubic meters per second, which is sufficient to maintain clean gravel and reduce the risk of suffocation by sand deposition (Poytress et al. 2015). Modeled flows from the summer range 250 – 400 cubic meters per second (10,000-14,000 cubic feet per second) between below Keswick Dam and Bend Bridge, compared to 100 – 250 cubic meters per second (4,000-9,000 cubic feet per second) (Appendix B, Section 3.1).

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk green sturgeon eggs experience is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22 cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.2.1.3.3 Larvae

Larvae are present in the upper Sacramento River. Several stressors have been identified for habitat attributes that affect larvae development, relative abundance, and distribution.

Flow stressors may increase. This increase is likely insignificant. Releases of Shasta Reservoir storage may increase flows and body condition in larval green sturgeon was negatively correlated with discharge (Zarri et al 2019). Condition was positive when discharges at Keswick were less than 250 cms (~8800 cfs) (Zarri et al. 2019). Environmental baseline releases range approximately 4,000-7,000 cfs, whereas modeled releases range approximately 9,000-14,000 cfs (Appendix B). However, flows at the Red Bluff Diversion Dam have been positively correlated with larval abundance (Heublein et al. 2017a). There is limited information on rearing habitat requirements for green sturgeon larvae.

Water Temperature stressors may decrease. The decrease is likely beneficial. Release of Shasta Reservoir storage may result in colder water temperatures in the summer. In laboratory studies, temperatures greater than 64.4°F (18°C) have been found to be detrimental to newly hatched larvae, with notochord deformities occurring between 68-78.8°F (20-26°C) (Linares-Casenave et al. 2013). Post yolk-sac larvae exhibited accelerated growth at higher temperatures 75.2°F (24°C) when food was maintained in the lab. In the field, yolk-sac larvae have been collected between 55.2-55.8°F (12.9 and 13.2°C) (Brown 2007, Poytress et al. 2015), but temperatures are held at approximately 56 °F) in these areas. Zarri et al. (2019) noted that warmer temperatures were associated with fuller stomachs and improved body condition but did not indicate an optimal temperature. Modeled summer water temperatures indicate operations decrease temperatures to be more suitable for larvae when compared with Environmental baseline, maintaining temperatures to less than 64.4°F (Appendix B, Section 3.2). Appendix L presents an analysis of this stressor.

Toxicity and DO stressors may decrease. The decrease is likely insignificant for both toxicity and dissolved oxygen. Releases of Shasta Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect larvae and no fish effects have been observed in fish monitoring. Very little is known about dissolved oxygen stressors in larvae. Releases of Shasta Reservoir storage may result in increased flows which may increase dissolved oxygen concentrations; however, water quality monitoring has not shown dissolved oxygen at low levels in the summer.

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108). It is uncertain if current screen criteria (developed for salmonids) prevent Southern DPS green sturgeon from impingement and entrainment. Currently, no screen criteria have been developed for green sturgeon (National Oceanic and Atmospheric Administration 2022).

Rearing habitat stressors are not anticipated to change. There is uncertainty about rearing habitat characteristics and availability for larval green sturgeon, although they occur in proximity of spawning habitats. The lowest and highest mortality rates in laboratory tests were observed in slate-rock (7%) and cobble-bottomed (40%) treatments, respectively (Nguyen and Crocker 2006), and riverbed substrate is not anticipated to change due to operations aside from restoration actions. Appendix O defines habitat and presents an analysis of this stressor.

Food stressors may increase. The increase is likely insignificant. Releases of Shasta Reservoir storage may increase flows, which on the Sacramento River has been observed to decrease prey taxon richness and abundance, especially the presence of cyclopoid copepods (Zarri and Palkovacs 2018). Green sturgeon larvae smaller than 30mm (i.e., larvae and small juvenile) rely on zooplankton prey with a strong reliance on cyclopoid copepods (Zarri and Palkovacs 2018).

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk a larvae experiences is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22 cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.2.1.3.4 Juveniles

Juveniles are present in the upper Sacramento River. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during migration.

Flow stressors may increase. This increase is likely insignificant. There is uncertainty about the effects of flow on juveniles. Body condition in larval green sturgeon was negatively correlated with discharge (Zarri et al. 2019). If this relationship applies to juveniles, it suggests increased releases may also reduce juvenile body condition. Increased releases of Shasta Reservoir storage may reduce temperatures in the summer and there is a strong temperature-dependence for growth between 51.8 and 68°F. (Hamda et al. 2019) and growth may potentially decrease at higher flows. The combination of higher discharge and lower temperatures appears to reduce larval sturgeon body condition (Zarri et al. 2019) and may similarly impact juveniles.

Water Temperature may decrease. The decrease is likely beneficial. Lab studies indicate bioenergetic performance to be optimal between 59-66.2°F (15-19°C) (Mayfield and Cech 2004). Modeled summer water temperatures under seasonal operations are within these observed optimal temperature ranges, while temperatures under Environmental baseline are above these temperature ranges (Appendix B, Section 3.2). Appendix L presents an analysis of this stressor.

Salinity stressors are not anticipated to change. Green Sturgeon present in the Sacramento River upstream of the Bay-Delta would not be anticipated to experience high salinity concentrations. See Appendix B.

Toxicity and DO stressors may decrease. The decrease is likely insignificant for both toxicity and dissolved oxygen. Releases of Shasta Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect juveniles and no fish effects have been observed in fish monitoring. Releases of Shasta Reservoir storage may result in increased flows which may increase dissolved oxygen concentrations; however, water quality monitoring has not shown dissolved oxygen at low levels in the summer. Very little is known about dissolved oxygen stressors in juveniles.

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108). It is uncertain if current screen criteria (developed for salmonids) prevent Southern DPS green sturgeon from impingement and entrainment. Currently, no screen criteria have been developed for green sturgeon (National Oceanic and Atmospheric Administration 2022).

Rearing habitat stressors are not anticipated to change. There is limited information on rearing habitat requirements and availability for green sturgeon juveniles. In the Delta and Bay, juvenile green sturgeon used a broad range of habitats, which is partly due to variation in hydrologic connectivity and water-year type (Thomas et al. 2022). This broad range of habitat use is hypothesized to also occur in rivers. CVP and SWP operations are not a proximate cause for variation in water year. Appendix O defines habitat and presents an analysis of this stressor.

Food stressors may increase. The increase is likely insignificant. Releases of Shasta Reservoir storage may increase flows, which on the Sacramento River has been observed to change benthic macroinvertebrate community composition (Nelson and Lieberman 2002).

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk a juvenile experiences is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22 cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.2.1.4 Fall

In the fall, Reclamation and DWR's proposed release of water will increase flows on average in the Sacramento River below Keswick Dam. Increased flow in the upper Sacramento River may change stressors on green sturgeon.

5.2.1.4.1 Adults

Adults are migrating and holding in the upper Sacramento River. Several stressors have been identified that may impact adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration.

Harvest stressors are not anticipated to change. Although there have been improvements to fishing regulations to eliminate harvest and reduce bycatch mortality (National Oceanic and Atmospheric Administration 2022), illegal harvest of green sturgeon as a consequence of poaching or misidentification as white sturgeon may occur. CVP and SWP operations are not a proximate cause of bycatch mortality or illegal harvest of green sturgeon.

Flow stressors may decrease. The decrease is likely insignificant. The majority of adult green sturgeon have been found to "late" outmigrate staring in late fall following spawning, as opposed to outmigrating "early" shortly after spawning (Colborne et al. 2022). River discharge is hypothesized to cue "late" outmigrating adult green sturgeon in the winter (Colborne et al. 2022). Thus, this would allow for the appropriate cue for "late" outmigration to occur.

Water temperature stressors may decrease. The decrease is likely insignificant. Very little is known about the thermal requirements of adult green sturgeon (Rodgers et al. 2019). While there is uncertainty regarding whether water temperature serves as a migration cue, Colborne et al. (2022) observed migration between 52-59°F (11-15°C) in the Sacramento River. Spawning of southern DPS in the Sacramento River has occurred between 49-64°C (9.6-17°C) (Poytress et al. 2015). Modeled fall water temperatures under seasonal operations are within these observed migration and spawning temperature ranges, while temperatures under Environmental baseline are above these temperature ranges in September and October (Appendix B, Section 3.2). Appendix L presents an analysis of this stressor.

Salinity stressors are not anticipated to change. Green Sturgeon present in the Sacramento River upstream of the Bay-Delta would not be anticipated to experience high salinity concentrations. See Appendix B.

Toxicity and DO stressors. Toxicity stressors may decrease. The decrease is likely insignificant. CVP and SWP storage and diversion of water increase river flows limiting the potential for dilution of contaminants; however, CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. DO stressors on adults are not anticipated to change. Very little is known about dissolved oxygen stressors in adults. Dissolved oxygen less than 5.0mg/L may affect migration of other large bodied anadromous fish (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below this in the fall.

Barriers stressors are not anticipated to change. The effect of bypass channels on adult green sturgeon migration at low flow is unknown (Heublein et al. 2017a). Migrating adult green sturgeon are unlikely to encounter other barriers in the Sacramento River that would impede migration to spawning habitat. CVP and SWP operations are not a proximate cause of potential stranding in flooded bypasses.

Spawning habitat stressors are not anticipated to change. Spawning does not occur during the fall months between September and November in the Sacramento River.

5.2.1.4.2 Eggs

Eggs are not present in the upper Sacramento River in the fall.

5.2.1.4.3 Larvae

Larvae are not present in the upper Sacramento River in the fall.

5.2.1.4.4 Juveniles

Juveniles are present in the upper Sacramento River. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during migration.

Flow stressors may increase. This increase is likely insignificant. There is uncertainty about the effects of flow on juveniles. Body condition in larval green sturgeon was negatively correlated with discharge (Zarri et al. 2019). If this relationship applies to juveniles, it suggests increased releases may also reduce juvenile body condition. Increased releases of Shasta Reservoir storage may reduce temperatures in the fall and there is a strong temperature-dependence for growth between 51.8 and 68°F. (Hamda et al. 2019) and growth may potentially decrease at higher flows. The combination of higher discharge and lower temperatures appears to reduce larval sturgeon body condition (Zarri et al. 2019) and may similarly impact juveniles.

Water Temperature are not anticipated to change. Lab studies indicate bioenergetic performance to be optimal between 59-66.2°F (15-19°C) (Mayfield and Cech 2004). Modeled fall water temperatures under seasonal operations are within the observed growth and optimal temperature ranges in September, but below the observed optimal temperature range in October and November. In contrast, water temperatures under Environmental baseline are above the temperature ranges for growth in September, but within the observed growth and optimal temperature ranges in October and November (Appendix B, Section 3.2). Appendix L presents an analysis of this stressor.

Salinity stressors are not anticipated to change. Green Sturgeon present in the Sacramento River upstream of the Bay-Delta would not be anticipated to experience high salinity concentrations. See Appendix B.

Toxicity and DO stressors may decrease. The decrease is likely insignificant for both toxicity and dissolved oxygen. Releases of Shasta Reservoir storage may increase flows and dilute constituents; however, water quality monitoring has not shown contaminants at levels likely to affect juveniles and no fish effects have been observed in fish monitoring. Releases of Shasta Reservoir storage may result in increased flows which may increase dissolved oxygen concentrations; however, water quality monitoring has not shown dissolved oxygen at low levels in the fall. Very little is known about dissolved oxygen stressors in juveniles.

Entrainment risk stressors are not anticipated to change. CVP facilities on the Sacramento River (Red Bluff Pumping Plant) and facilities used to divert water for CVPIA refuges are screened (e.g., GCID, RD 108). It is uncertain if current screen criteria (developed for salmonids) prevent Southern DPS green sturgeon from impingement and entrainment. Currently, no screen criteria have been developed for green sturgeon (National Oceanic and Atmospheric Administration 2022).

Rearing habitat stressors are not anticipated to change. There is limited information on rearing habitat requirements and availability for green sturgeon juveniles. In the Delta and Bay, juvenile green sturgeon used a broad range of habitats, which is partly due to variation in hydrologic connectivity and water-year type (Thomas et al. 2022). This broad range of habitat use is hypothesized to also occur in rivers. CVP and SWP operations are not a proximate cause for variation in water year. Appendix O defines habitat and presents an analysis of this stressor.

Food stressors may increase. The increase is likely insignificant. Releases of Shasta Reservoir storage may increase flows, which on the Sacramento River has been observed to change benthic macroinvertebrate community composition (Nelson and Lieberman 2002).

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk a juvenile experiences is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22 cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.2.2 Bay-Delta

5.2.2.1 Winter

In the winter, Reclamation and DWR’s proposed storage and diversion of water will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on green sturgeon.

5.2.2.1.1 Adults

Adults are migrating and holding in the Delta in the winter. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration.

Harvest stressors are not anticipated to change. Although there have been improvements to fishing regulations to eliminate harvest and reduce bycatch mortality (National Oceanic and Atmospheric Administration 2022), illegal harvest of green sturgeon as a consequence poaching or misidentification as white sturgeon may occur. CVP and SWP operations are not a proximate cause of bycatch mortality or illegal harvest of green sturgeon.

Food stressors are not anticipated to change. Radtke (1966) identified *Corophium* sp. (amphipods) and *Neomysis* sp. (Opossum shrimp) in green sturgeon stomachs from the Delta. Stomachs of green sturgeon in San Pablo Bay contained the greatest variety of food items including *Corophium* sp., *Photis californica* (amphipod), *Cragon franciscorum* (Bay shrimp), *Macoma* sp. (clam), *Synidotea laticauda* (isopod), and unidentified crab and fish (Ganssle 1966). The stomachs of green sturgeon in Suisun Bay included *Corophium* sp., *C. franciscorum*, *Neomysis* sp., and annelid worms (Ganssle 1966). Available benthic food items have changed during the recent past, and invasive Corbula has replaced native mollusks and shrimps. CVP and SWP operations are not the proximate cause for changes in food stressors in the Bay-Delta.

Water temperature stressors are not anticipated to change. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is positively correlated with Delta inflow in the winter (Bashevkin and Mahardja 2022); however, water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017). There is uncertainty about whether the decreased inflow is a cause for decreased Delta water temperatures. CVP and SWP operations do not appear to be a proximate cause of Delta water temperatures in the winter.

Salinity stressors may increase. The increase is likely insignificant. Decreased inflows compared with Environmental baseline may increase the amount of brackish habitat in the Bay-Delta. Little is known about the water quality parameters that influence adult Green Sturgeon movement in the Delta and they are hypothesized to use a broad range of habitats and water quality conditions. A telemetry study in the Bay-Delta detected green sturgeon at salinities between 8.8-32.1 ppt, with no specific salinity preferences (Kelly et al. 2007).

Toxicity and DO stressors. Toxicity stressors may increase. The increase is likely insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow, limiting the potential for dilution of contaminants; however, CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. Adult green sturgeon do not spend a substantial portion of their life foraging in the Bay-Delta (Heublein et al. 2017a). DO stressors are not anticipated to change. Very little is known about dissolved oxygen stressors in adults. Dissolved oxygen less than 5.0mg/L may affect migration of other large bodied anadromous fish (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below this in the winter.

Migration and foraging habitat stressors are not anticipated to change. Green sturgeon have been observed to migrate upriver through the estuary quickly as a group, starting in early February and peaking in late March (Miller et al. 2020; Colborne et al. 2022). CVP and SWP operations are not a proximate cause of changes to foraging habitat attributes including availability of quality food supply and localized subtidal and tidal foraging areas are not influenced by seasonal operations.

Predation risk stressors are not anticipated to change. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22cm and sturgeon are not the preferred prey of these predators

(Baird et al. 2020). At the adult life stage, pinnipeds (California sea lions) are likely the primary predator for Green Sturgeon, as has been observed in White Sturgeon (Heublein et al. 2017a). CVP and SWP operations is not a proximate cause of changes to the predation risk stressors.

5.2.2.1.2 Eggs

Eggs are not present in the Delta.

5.2.2.1.3 Larvae

Larvae are not present in the Delta in the winter.

5.2.2.1.4 Juveniles

Juveniles are rearing in the Delta in the winter. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during migration.

Flow stressors may increase. The increase is likely insignificant. Although decreased outflow and increased winter diversions may change the duration of juvenile residency, juvenile green sturgeon may occupy brackish and freshwater habitats in the Delta for up to one and a half years until they can tolerate seawater (Allen 2005, Poletto et al. 2013). Juveniles may remain in the Bay-Delta for up to three years based on capture of fish of this age in fish monitoring surveys and salvage. The long delta residency of green sturgeon juveniles is unlikely to be influenced by seasonal changes in delta flows.

Water temperature stressors are not anticipated to change. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is positively correlated with Delta inflow in the winter (Bashevkin and Mahardja 2022); however, water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017). There is uncertainty about whether the decreased inflow is a cause for decreased Delta water temperatures. CVP and SWP operations do not appear to be a proximate cause of Delta water temperatures in the winter.

Salinity stressors are not anticipated to change. Juveniles at 196dph were found to display a preference for seawater (Poletto et al. 2013). Exposure of young juveniles (<170 dph) to brackish water can impact growth and survival. Negative impacts on growth and development occur at salinities > 10 ppt, and decreased survival occurs at 20-30 ppt (Allen et al. 2011, Allen and Cech, 2007). Low food availability may also interact with high salinities to decrease body condition factor (Vaz et al. 2015). CVP and SWP operations are not the proximate cause for changes in habitat area <10ppt salinity.

Toxicity and DO stressors. Toxicity stressors may increase. The increase is likely insignificant. CVP and SWP storage and diversion of water decreases inflow and outflow, limiting the potential for dilution of contaminants; however, CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. Increasing uptake of L-selenomethionine (SeMet) in juvenile green sturgeon results in an increase in mortality in fish fed 200mg SeMet/kg after only two weeks; smaller quantities of SeMet decreases feeding efficiency and reduced growth rates after four weeks (De Riu et al. 2014). DO stressors are not anticipated to change. Very little is known about dissolved oxygen stressors in juveniles. Water quality monitoring has not shown dissolved oxygen at low levels in the winter.

Entrainment risk stressors may increase. The increase may result in higher levels of entrainment juvenile green sturgeon. CVP and SWP storage and diversions result in entrainment at the Skinner and Tracy fish facilities. Entrainment is defined in two ways: (1) fish routed through specific migratory pathways in the Delta (Delta route-specific travel time and survival); and (2) fish encountering CVP facilities where they may be pulled into diversions or the export facilities. In both, outmigrating juveniles may be exposed to predation in different locations within the Delta. Historic salvage of green sturgeon at the Delta export facilities is low in quantity and highly variable. Appendix I presents an analysis of this stressor.

Rearing habitat stressors are not anticipated to change. There is limited information on rearing habitat requirements and availability for green sturgeon juveniles. In the Delta and Bay, juvenile green sturgeon used a broad range of habitats, which is partly due to variation in hydrologic connectivity and water-year type (Thomas et al. 2022), and this broad range of habitat use is hypothesized to also occur in rivers. CVP and SWP operations are not a proximate cause for variation in water year. Appendix O presents an analysis of this stressor.

Food stressors are not anticipated to change. Mysid shrimp and amphipods (*Corophium*) were observed to be the primary food items in juvenile (<57cm) green sturgeon stomachs (Radtke 1966). Available benthic food items have changed during the recent past, and invasive Corbula has replaced native mollusks and shrimps. Green sturgeon foraging is thought to occur in tidal and subtidal habitats, as has been observed in the Columbia River estuary (Dumbauld et al. 2008). CVP and SWP operations are not the proximate cause for changes in shrimp and amphipod counts in the Bay-Delta and do not impact subtidal and tidal habitat availability.

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk a juvenile experiences is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.2.2.2 Spring

In the spring, Reclamation and DWR's proposed water operations will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on green sturgeon.

5.2.2.2.1 Adults

Adults are residing in the Delta in the spring. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration. Green sturgeon holding in the Sacramento River are preparing to undergo an energetically taxing transition to spawn.

Harvest stressors are not anticipated to change. Although there have been improvements to fishing regulations to eliminate harvest and reduce bycatch mortality (National Oceanic and Atmospheric Administration 2022), illegal harvest of green sturgeon as a consequence poaching or misidentification as white sturgeon may occur. CVP and SWP operations are not a proximate cause of bycatch mortality or illegal harvest of green sturgeon.

Food stressors are not anticipated to change. Radtke (1966) identified *Corophium* sp. (amphipods) and *Neomysis* sp. (Opossum shrimp) in green sturgeon stomachs from the Delta. Stomachs of green sturgeon in San Pablo Bay contained the greatest variety of food items including *Corophium* sp., *Photis californica* (amphipod), *Cragon franciscorum* (Bay shrimp), *Macoma* sp. (clam), *Synidotea laticauda* (isopod), and unidentified crab and fish (Ganssle 1966). The stomachs of green sturgeon in Suisun Bay included *Corophium* sp., *C. franciscorum*, *Neomysis* sp., and annelid worms (Ganssle 1966). Available benthic food items have changed during the recent past, and invasive Corbula has replaced native mollusks and shrimps. CVP and SWP operations are not the proximate cause for changes in food stressors in the Bay-Delta.

Water temperature stressors may increase. The increase is likely insignificant. CVP and SWP storage and 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 Bay-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). There is uncertainty about whether the decreased inflow is a cause for increased Delta water temperatures.

Salinity stressors may increase. The increase is likely insignificant. Decreased inflows compared with Environmental baseline may increase the amount of brackish habitat in the Bay-Delta. Little is known about the physical parameters that influence adult Green Sturgeon movement and they are hypothesized to use a broad range of habitats and water quality conditions. A telemetry study in the Bay-Delta detected green sturgeon at salinities between 8.8-32.1 ppt, with no specific salinity preferences (Kelly et al. 2007).

Toxicity and DO stressors. Toxicity stressors may increase. The increase is likely insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants; however, CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. Adult green sturgeon do not spend a substantial portion of their life foraging in the Bay-Delta (Heublein et al. 2017a). DO stressors are not anticipated to change. Very little is known about dissolved oxygen stressors in adults. Dissolved oxygen less than 5.0mg/L may affect migration of other large bodied anadromous fish (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below this in the spring.

Migration and foraging habitat stressors are not anticipated to change. Green sturgeon have been observed to migrate upriver through the estuary quickly as a group, starting in early February and peaking in late March (Miller et al. 2020; Colborne et al. 2022). The extent to which adult sturgeon feed during spawning migration is poorly known and may be minimal (Heublein et al. 2017a). CVP and SWP operations are not a proximate cause to changes in foraging habitat attributes including availability of quality food supply and localized subtidal and tidal foraging areas are not influenced by seasonal operations.

Predation risk stressors are not anticipated to change. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020). At the adult life stage, pinnipeds (California sea lions) are likely the primary predator for Green Sturgeon, as has been observed in White Sturgeon (Heublein et al. 2017a). CVP and SWP operations is not a proximate cause of changes in predation risk stressors.

5.2.2.2.2 Eggs

Eggs are not present in the Delta.

5.2.2.2.3 Larvae

Larvae are not present in the Delta.

5.2.2.2.4 Juveniles

Juveniles are rearing in the Delta in the spring. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during migration.

Flow stressors may increase. The increase is likely insignificant. Although decreased outflow and increased spring diversions may change the duration of juvenile residency, juvenile green sturgeon may occupy brackish and freshwater habitats in the Delta for up to one and a half years until they can tolerate seawater (Allen 2005, Poletto et al. 2013). Juveniles may remain in the Bay-Delta for up to three years based on capture of fish of this age in fish monitoring surveys and salvage. The long delta residency of green sturgeon juveniles is unlikely to be influenced by seasonal changes in delta flows.

Water temperature stressors may increase. The increase is likely insignificant. CVP and SWP storage and 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 Bay-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). There is uncertainty about whether the decreased inflow is a cause for increased Delta water temperatures.

Salinity stressors are not anticipated to change. Decreased inflows compared with Environmental baseline may increase the amount of brackish habitat in the Bay-Delta. It is hypothesized that changes in salinity may influence the distribution of juvenile Green Sturgeon (Heublein et al. 2017a). Juveniles at 196dph were found to display a preference for seawater (Poletto et al. 2013). While exposure of young juveniles (<170 dph) to brackish water can impact growth and survival, growth effects occur at salinities > 10 ppt, and survival effects occur at 20-30 ppt (Allen and Cech 2007, Allen et al. 2011). Low food availability may also interact with high salinities to decrease body condition factor (Vaz et al. 2015). However, CVP and SWP operations are not the proximate cause for changes in distribution and movement of Green Sturgeon.

Toxicity and DO stressors. Toxicity stressors may increase. The increase is likely insignificant. CVP and SWP storage and diversion of water decreases inflow and outflow, limiting the potential for dilution of contaminants; however, CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. Increasing uptake of SeMet in juvenile green sturgeon results in an increase in mortality in fish fed 200mg SeMet/kg after only two weeks; smaller quantities of SeMet decreases feeding efficiency and reduced growth rates after four weeks (De Riu et al. 2014). DO stressors are not anticipated to change. Very little is known about dissolved oxygen stressors in juveniles. Water quality monitoring has not shown dissolved oxygen at low levels in the spring.

Entrainment risk stressors may increase. The increase may result in higher levels of entrainment juvenile green sturgeon. CVP and SWP storage and diversions result in entrainment at the Skinner and Tracy fish facilities. Entrainment is defined in two ways: (1) fish routed through specific migratory pathways in the Delta (Delta route-specific travel time and survival); and (2) fish encountering CVP facilities where they may be pulled into diversions or the export facilities. In both, outmigrating juveniles may be exposed to predation in different locations within the Delta. Historic salvage of green sturgeon at the Delta export facilities is low in quantity and highly variable. Appendix I presents an analysis of this stressor.

Rearing Habitat stressors are not anticipated to change. There is limited information on rearing habitat requirements and availability for green sturgeon juveniles. In the Delta and Bay, juvenile green sturgeon used a broad range of habitats, which is partly due to variation in hydrologic connectivity and water-year type (Thomas et al. 2022). CVP and SWP operations are not a proximate cause for variation in water year. Appendix O defines habitat and presents an analysis of this stressor.

Food stressors are not anticipated to change. Mysid shrimp and amphipods (*Corophium*) were observed to be the primary food items in juvenile (<57cm) green sturgeon stomachs (Radtke 1966). Available benthic food items have changed during the recent past, and invasive Corbula has replaced native mollusks and shrimps. Green sturgeon foraging is thought to occur in tidal and subtidal habitats, as has been observed in the Columbia River estuary (Dumbauld et al. 2008). CVP and SWP operations are not the proximate cause for changes in shrimp and amphipod counts in the Bay-Delta and do not impact subtidal and tidal habitat availability.

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk a juvenile experiences is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.2.2.3 Summer

In the summer, Reclamation and DWR’s proposed water operations will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on green sturgeon.

5.2.2.3.1 Adults

Adults are residing in the Delta in the summer. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration. Green sturgeon holding in the Sacramento River are preparing to undergo an energetically taxing transition to spawn.

Harvest stressors are not anticipated to change. Although there have been improvements to fishing regulations to eliminate harvest and reduce bycatch mortality (National Oceanic and Atmospheric Administration 2022), illegal harvest of green sturgeon as a consequence poaching or misidentification as white sturgeon may occur. CVP and SWP operations is not a proximate cause of bycatch mortality or illegal harvest of green sturgeon.

Food stressors are not anticipated to change. Radtke (1966) identified *Corophium* sp. (amphipods) and *Neomysis* sp. (Opossum shrimp) in green sturgeon stomachs from the Delta. Stomachs of green sturgeon in San Pablo Bay contained the greatest variety of food items including *Corophium* sp., *Photis californica* (amphipod), *Cragon franciscorum* (Bay shrimp), *Macoma* sp. (clam), *Synidotea laticauda* (isopod), and unidentified crab and fish (Ganssle 1966). The stomachs of green sturgeon in Suisun Bay included *Corophium* sp., *C. franciscorum*, *Neomysis* sp., and annelid worms (Ganssle 1966). Available benthic food items have changed during the recent past, and invasive Corbula has replaced native mollusks and shrimps. CVP and SWP operations are not the proximate cause for changes in food stressors in the Bay-Delta.

Water temperature stressors may decrease. The decrease is likely discountable and/or insignificant. Summer seasonal operations increase Delta inflow. Delta water temperature is negatively correlated with Delta inflow (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). Inflow is largely controlled by operations during the summer and fall due to lower contributions from precipitation and snowmelt. However, in the Bay-Delta water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the increased summer inflow is a cause for decreased Delta water temperatures.

Salinity stressors may decrease. The decrease is likely discountable and/or insignificant. Increased inflows compared with Environmental baseline may decrease the amount of brackish habitat in the Bay-Delta. Little is known about the physical parameters that influence Green Sturgeon. A telemetry study in the Bay-Delta detected green sturgeon at salinities between 8.8-32.1 ppt, with no specific salinity preferences (Kelly et al. 2007).

Toxicity and DO stressors. Toxicity stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants; however, CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. Adult green sturgeon do not spend a substantial portion of their life foraging in the Bay-Delta (Heublein et al. 2017a). DO stressors are not anticipated to change. Very little is known about dissolved oxygen stressors in adults. Dissolved oxygen less than 5.0mg/L may affect migration of other large bodied anadromous fish (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below this in the summer.

Migration and foraging habitat stressors are not anticipated to change. Most spawning adults have migrated upriver (Miller et al., 2020; Colborne et al. 2022); post-spawn adults may be holding in the Delta for varied amounts of time before returning to the ocean (Colborne et al. 2022). CVP and SWP seasonal operations is not a proximate cause for variability in Delta holding times or changes in foraging habitat attributes including availability of quality food supply and localized subtidal and tidal foraging areas are not influenced by seasonal operations.

Predation risk stressors are not anticipated to change. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020). At the adult life stage, pinnipeds (California sea lions) are likely the primary predator for Green Sturgeon, as has been observed in White Sturgeon (Heublein et al. 2017a). CVP and SWP operations is not a proximate cause of changes in predation risk stressors.

5.2.2.3.2 Eggs

Eggs are not present in the Delta.

5.2.2.3.3 Larvae

Larvae are not present in the Delta.

5.2.2.3.4 Juveniles

Juveniles are rearing in the Delta in the summer. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during migration.

Flow stressors may increase. The increase is likely discountable and/or insignificant. Although decreased outflow and increased diversions may change the duration of juvenile residency, juvenile green sturgeon may occupy brackish and freshwater habitats in the Delta for up to one and a half years until they can tolerate seawater (Allen 2005, Poletto et al. 2013). Juveniles may remain in the Bay-Delta for up to three years based on capture of fish of this age in fish monitoring surveys and salvage. The long delta residency of green sturgeon juveniles is unlikely to be influenced by seasonal changes in delta flows.

Water temperature stressors may decrease. The decrease is likely discountable and/or insignificant. Summer seasonal operations increase Delta inflow. Delta water temperature is negatively correlated with Delta inflow (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). Inflow is largely controlled by operations during the summer and fall due to lower contributions from precipitation and snowmelt. However, in the Bay-Delta water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the increased summer inflow is a cause for decreased Delta water temperatures.

Salinity stressors are not anticipated to change. Decreased inflows compared with Environmental baseline may increase the amount of brackish habitat in the Bay-Delta. It is hypothesized that changes in salinity may influence the distribution of juvenile Green Sturgeon (Heublein et al. 2017a). Juveniles at 196dph were found to display a preference for seawater (Poletto et al. 2013). While exposure of young juveniles (<170 dph) to brackish water can impact growth and survival, growth effects occur at salinities > 10 ppt, and survival effects occur at 20-30 ppt (Allen and Cech 2007, Allen et al. 2011). Low food availability may also interact with high salinities to decrease body condition factor (Vaz et al. 2015). However, CVP and SWP operations are not the proximate cause for changes in distribution and movement of Green Sturgeon.

Toxicity and DO stressors. Toxicity stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases inflow and outflow, limiting the potential for dilution of contaminants; however, CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. Increasing uptake of SeMet in juvenile green sturgeon results in an increase in mortality in fish fed 200mg SeMet/kg after only two weeks; smaller quantities of SeMet decreases feeding efficiency and reduced growth rates after four weeks (De Riu et al. 2014). DO stressors are not anticipated to change. Very little is known about dissolved oxygen stressors in juveniles. Water quality monitoring has not shown dissolved oxygen at low levels in the summer.

Entrainment risk stressors may increase. The increase may result in higher levels of entrainment juvenile green sturgeon. CVP and SWP storage and diversions result in entrainment at the Skinner and Tracy fish facilities. Entrainment is defined in two ways: (1) fish routed through specific migratory pathways in the Delta (Delta route-specific travel time and survival); and (2) fish encountering CVP facilities where they may be pulled into diversions or the export facilities. In both, outmigrating juveniles may be exposed to predation in different locations within the Delta. Historic salvage of green sturgeon at the Delta export facilities is low in quantity and highly variable. Appendix I presents an analysis of this stressor.

Rearing habitat stressors are not anticipated to change. There is limited information on rearing habitat requirements and availability for green sturgeon juveniles. In the Delta and Bay, juvenile green sturgeon used a broad range of habitats, which is partly due to variation in hydrologic connectivity and water-year type (Thomas et al. 2022). CVP and SWP operations are not a proximate cause for variation in water year. Appendix O defines habitat and presents an analysis of this stressor.

Food stressors are not anticipated to change. Mysid shrimp and amphipods (*Corophium*) were observed to be the primary food items in juvenile (<57cm) green sturgeon stomachs (Radtke 1966). Available benthic food items have changed during the recent past, and invasive Corbula has replaced native mollusks and shrimps. Green sturgeon foraging is thought to occur in tidal and subtidal habitats, as has been observed in the Columbia River estuary (Dumbauld et al. 2008). CVP and SWP operations are not the proximate cause for changes in shrimp and amphipod counts in the Bay-Delta and do not impact subtidal and tidal habitat availability.

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk a juvenile experiences is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.2.2.4 Fall

In the fall, Reclamation and DWR's proposed water operations will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on green sturgeon.

5.2.2.4.1 Adults

Adults are residing in the Delta in the fall. Several stressors have been identified that may delay adult migration, increase energy necessary to undergo the transition, or decrease adult survival during migration. Green sturgeon holding in the Sacramento River are preparing to undergo an energetically taxing transition to spawn.

Harvest stressors are not anticipated to change. Although there have been improvements to fishing regulations to eliminate harvest and reduce bycatch mortality (National Oceanic and Atmospheric Administration 2022), illegal harvest of green sturgeon as a consequence poaching or misidentification as white sturgeon may occur. CVP and SWP operations is not a proximate cause of bycatch mortality or illegal harvest of green sturgeon.

Food stressors are not anticipated to change. Radtke (1966) identified *Corophium* sp. (amphipods) and *Neomysis* sp. (Opossum shrimp) in green sturgeon stomachs from the Delta. Stomachs of green sturgeon in San Pablo Bay contained the greatest variety of food items including *Corophium* sp., *Photis californica* (amphipod), *Cragon franciscorum* (Bay shrimp), *Macoma* sp. (clam), *Synidotea laticauda* (isopod), and unidentified crab and fish (Ganssle 1966). The stomachs of green sturgeon in Suisun Bay included *Corophium* sp., *C. franciscorum*, *Neomysis* sp., and annelid worms (Ganssle 1966). Available benthic food items have changed during the recent past, and invasive Corbula has replaced native mollusks and shrimps. CVP and SWP operations are not the proximate cause for changes in shrimp and amphipod counts in the Bay-Delta.

Water temperature stressors may increase or may decrease. The increase or decrease is likely discountable and/or insignificant. CVP and SWP storage and diversion of water increase Delta inflow in September and October and decrease inflow in November compared to Environmental baseline. Delta water temperature is negatively correlated with Delta inflow (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). Inflow is largely controlled by operations during the summer and fall due to lower contributions from precipitation and snowmelt. However, in the Bay-Delta water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the increased fall inflow is a cause for increased or decreased Delta water temperatures.

Salinity stressors may increase or decrease. The increase and decrease are likely discountable and/or insignificant. Increased inflows in September and October and decreased inflows in November compared with Environmental baseline may alter the amount of brackish habitat in the Delta. Little is known about the physical parameters that influence Green Sturgeon. A telemetry study in the Bay-Delta detected green sturgeon at salinities between 8.8-32.1 ppt, with no specific salinity preferences (Kelly et al. 2007).

Toxicity and DO stressors. Toxicity stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants; however, CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. Adult green sturgeon do not spend a substantial portion of their life foraging in the Bay-Delta (Heublein et al. 2017a). DO stressors are not anticipated to change. Very little is known about dissolved oxygen stressors in adults. Dissolved oxygen less than 5.0mg/L may affect migration of other large bodied anadromous fish (Carter 2005). Water quality monitoring has not shown dissolved oxygen at levels below this in the fall.

Migration and foraging habitat stressors are not anticipated to change. Post-spawn adults may be holding in the Delta for varied amounts of time before returning to the ocean (Colborne et al. 2022). CVP and SWP seasonal operations is not a proximate cause for variability in Delta holding times or changes to foraging habitat attributes including availability of quality food supply and localized subtidal and tidal foraging areas to are not influenced by seasonal operations.

Predation risk stressors are not anticipated to change. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020). At the adult life stage, pinnipeds (California sea lions) are likely the primary predator for Green Sturgeon, as has been observed in White Sturgeon (Heublein et al. 2017a). CVP and SWP operations is not a proximate cause of changes in predation risk stressors.

5.2.2.4.2 Eggs

Eggs are not present in the Delta.

5.2.2.4.3 Larvae

Larvae are not present in the Delta.

5.2.2.4.4 Juveniles

Juveniles are rearing in the Delta in the fall. Several stressors have been identified to possibly affect survival, residence time and migration, and juvenile growth during migration.

Flow stressors may increase. The increase is likely discountable and/or insignificant. Juvenile green sturgeon may occupy brackish and freshwater habitats in the Delta for up to one and a half years until they can tolerate seawater (Allen 2005, Poletto et al 2013). Juveniles may remain in the Bay-Delta for up to three years based on capture of fish of this age in fish monitoring surveys and salvage. The long delta residency of green sturgeon juveniles is unlikely to be influenced by seasonal changes in delta flows.

Water temperature stressors may increase or may decrease. The increase or decrease is likely discountable and/or insignificant. CVP and SWP storage and diversion of water increase Delta inflow in September and October and decrease inflow in November compared to Environmental baseline. Delta water temperature is negatively correlated with Delta inflow (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). Inflow is largely controlled by operations during the summer and fall due to lower contributions from precipitation and snowmelt. However, in the Bay-Delta water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the increased fall inflow is a cause for increased or decreased Delta water temperatures.

Salinity stressors may increase or decrease. The increase and decrease are likely discountable and/or insignificant. Increased inflows in September and October and decreased inflows in November compared with Environmental baseline may alter the amount of brackish habitat in the Bay-Delta. It is hypothesized that changes in salinity may influence the distribution of juvenile Green Sturgeon (Heublein et al. 2017a). Juveniles at 196dph were found to display a preference for seawater (Poletto et al. 2013). While exposure of young juveniles (<170 dph) to brackish water can impact growth and survival, growth effects occur at salinities > 10 ppt, and survival effects occur at 20-30 ppt (Allen et al. 2011, Allen and Cech, 2007). Low food availability may also interact with high salinities to decrease body condition factor (Vaz et al. 2015). CVP and SWP operations are not the proximate cause for changes in habitat area <10ppt salinity.

Toxicity and DO stressors. Toxicity stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases inflow and outflow, limiting the potential for dilution of contaminants; however, CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent. Increasing uptake of SeMet in juvenile green sturgeon results in an increase in mortality in fish fed 200mg SeMet/kg after only two weeks; smaller quantities of SeMet decreases feeding efficiency and reduced growth rates after four weeks (De Riu et al. 2014). DO stressors are not anticipated to change. Very little is known about dissolved oxygen stressors in juveniles. Water quality monitoring has not shown dissolved oxygen at low levels in the fall.

Entrainment risk stressors may increase. The increase may result in higher levels of entrainment juvenile green sturgeon. CVP and SWP storage and diversions result in entrainment at the Skinner and Tracy fish facilities. Entrainment is defined in two ways: (1) fish routed through specific migratory pathways in the Delta (Delta route-specific travel time and survival); and (2) fish encountering CVP facilities where they may be pulled into diversions or the export facilities. In both, outmigrating juveniles may be exposed to predation in different locations within the Delta. Historic salvage of green sturgeon at the Delta export facilities is low in quantity and highly variable. Appendix I presents an analysis of this stressor.

Rearing habitat stressors are not anticipated to change. There is limited information on rearing habitat requirements and availability for green sturgeon juveniles. In the Delta and Bay, juvenile green sturgeon used a broad range of habitats, which is partly due to variation in hydrologic connectivity and water-year type (Thomas et al. 2022). CVP and SWP operations are not a proximate cause for variation in water year. Appendix O defines habitat and presents an analysis of this stressor.

Food stressors are not anticipated to change. Mysid shrimp and amphipods (*Corophium*) were observed to be the primary food items in juvenile (<57cm) green sturgeon stomachs (Radtke 1966). Available benthic food items have changed during the recent past, and invasive Corbula has replaced native mollusks and shrimps. Green sturgeon foraging is thought to occur in tidal and subtidal habitats, as has been observed in the Columbia River estuary (Dumbauld et al. 2008). CVP and SWP operations are not the proximate cause for changes in shrimp and amphipod counts in the Bay-Delta and do not impact subtidal and tidal habitat availability.

Predation risk stressors are not anticipated to change. Predation of green sturgeon by aquatic and terrestrial species affects migration, growth, and survival of green sturgeon and is inherently linked with numerous other stressors (Grossman et al. 2013; Grossman 2016) this Appendix evaluates. The predation risk a juvenile experiences is a function of inseparable variables including predator presence, prey vulnerability, and environmental conditions. In laboratory studies with Striped Bass and Largemouth Bass, predation risk was reduced with increased size, and diminished to zero once Green Sturgeon reached 20-22cm and sturgeon are not the preferred prey of these predators (Baird et al. 2020).

5.3 Species Effects Determination

The seasonal operation of the CVP and SWP may affect and is likely to adversely affect the southern DPS of Norther American Green Sturgeon. The seasonal operation of the CVP is also likely to have beneficial effects. Deconstruction of the seasonal operations systematically evaluated each stressor identified by conceptual models. Stressors not linked to the operation of the CVP and SWP were identified as “not anticipated to change.” Stressors that were insignificant or discountable were documented. Stressors with a material effect on the fitness of species were identified, and the seasonal operation incorporates minimization and/or compensation through conservation measures.

Stressors on adults influenced by the seasonal operations include:

- Spawning habitat: Reduced released below Keswick may increase spawning habitat stressors in the Sacramento River in the spring. Adverse effects are minimized through seasonal flow management.
- Barriers: Decreased flows during the spring in the Sacramento River may increase barriers stressors. Adverse effects are minimized through operation and maintenance at structures that are known barriers (e.g., Fremont Weir).

Stressors on eggs influenced by the seasonal operations include:

- Water Temperatures: Decreased flows in the spring and lower temperatures from coldwater pool management in the summer may impact egg incubation conditions and survival. Adverse effects are minimized through allowing uninterrupted migratory corridor so adults may select habitats that provide temperatures that are suitable for spawning, egg incubation, and juvenile growth.

- Incubation habitat: Decreased flows in the spring may provide less habitat quality. Adverse effects are minimized through seasonal flow operations.

Stressors on larvae influenced by the seasonal operations include:

- Flow: Lower spring flows could reduce larval abundance. Adverse effects are minimized by seasonal flow operations.
- Water Temperatures: Actions to preserve cold water for use later in the year modify summer river temperatures (e.g., operation of the TCD, warm-water power bypass). Colder water temperature may have an adverse effect, which are minimized by allowing adults to select habitats that provide temperatures that are suitable for spawning, egg incubation, and juvenile growth.
- Rearing habitat: Decreased flows in the spring may provide less habitat quality. Adverse effects are minimized through seasonal operations.

Stressors on juveniles influenced by the seasonal operations include:

- Flow: Reduced releases below Keswick may increase flow stressors. Adverse effects are minimized by seasonal flow operations.
- Water temperature: Actions to preserve cold water for use later in the year may warm river temperatures (e.g., operation of the TCD, warm-water power bypass). Adverse effects are minimized by allowing adults to select habitats that provide temperatures that are suitable for spawning, egg incubation, and juvenile growth.
- Rearing habitat: Decreased flows may provide less habitat quality. Adverse effects are minimized through seasonal operations.
- Entrainment: Reduced outflow in the Delta during multiple seasons may increase entrainment stressors. Adverse effects are minimized by Old and Middle River (OMR) management.

5.4 Critical Habitat Physical and Biological Features

Critical habitat for green sturgeon was designated on October 9, 2009 (70 FR 52299).

The geographical extent of designated critical habitat includes: coastal U.S. marine waters within 60 fathoms (fm) depth from Monterey Bay, California (including Monterey Bay), north to Cape Flattery, Washington, including the Strait of Juan de Fuca, Washington, to its United States boundary; the Sacramento River, lower Feather River, and lower Yuba River in California; the Sacramento-San Joaquin Delta and Suisun, San Pablo, and San Francisco Bays in California; the lower Columbia River estuary; and certain coastal bays and estuaries in California (Humboldt Bay), Oregon (Coos Bay, Winchester Bay, Yaquina Bay, and Nehalem Bay), and Washington (Willapa Bay and Grays Harbor). This rule designates approximately 515 kilometer (km) (320 miles (mi)) of freshwater river habitat, 2,323 km^2 (897 mi^2) of estuarine habitat, 29,581 km^2(11,421 mi^2) of marine habitat, 784 km^2 (487 mi^2) of habitat in the Sacramento-San Joaquin

Delta, and 350 km^2 (135 mi^2) of habitat within the Yolo and Sutter bypasses (Sacramento River, CA).

The critical habitat for green sturgeon lists the essential physical and biological features, which include:

5.4.1 Food Resources

Green sturgeon need abundant prey items for larval, juvenile, subadult, and adult life stages. Although specific data on food resources for green sturgeon within freshwater riverine systems is very limited, juvenile green sturgeon most likely feed on fly larvae, amphipods, and bivalves, based on nutritional studies on the closely-related white sturgeon (Schreiber 1962; Radtke 1966). Food resources are important for juvenile foraging, growth, and development during their downstream migration to the Delta and bays. In addition, subadult and adult green sturgeon may forage during their downstream post-spawning migration, while holding within deep pools (Erickson et al. 2002), or on non-spawning migrations within freshwater rivers. Subadult and adult green sturgeon in freshwater rivers most likely feed on benthic prey species similar to those fed on in bays and estuaries, including shrimp, clams, and benthic fishes (Moyle et al. 1995; Erickson et al. 2002; Moser and Lindley 2007; Dumbauld et al. 2008).

The species effect determination found related potential stressors of:

- Food

5.4.2 Spawning Substrate

Green sturgeon need substrates suitable for egg deposition and development (e.g., bedrock sills and shelves, cobble and gravel, or hard clean sand, with interstices or irregular surfaces to “collect” eggs and provide protection from predators, and free of excessive silt and debris that could smother eggs during incubation), larval development (e.g., substrates with interstices or voids providing refuge from predators and from high flow conditions), and subadults and adults (e.g., substrates for holding and spawning). For example, spawning is believed to occur over substrates ranging from clean sand to bedrock (Emmett et al. 1991; Moyle et al. 1995), with preferences for gravel, cobble, and boulder (Poytress et al. 2009; Erickson pers. Comm.). Eggs likely adhere to substrates or settle into crevices between substrates (Deng 2000; Van Eenennaam et al. 2001; Deng et al. 2002). Both embryos and larvae exhibited a strong affinity for benthic structure during laboratory studies (Van Eenennaam et al. 2001; Deng et al. 2002; Kynard et al. 2005) and may seek refuge within crevices but use flat-surfaced substrates for foraging (Nguyen and Crocker 2006).

The species effect determination found related potential stressors of:

- Incubation habitat

5.4.3 Flow for Behavior, Growth, and Survival

A flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of fresh water discharge over time) is necessary for normal behavior, growth, and survival of all life stages. Such a flow regime should include stable and sufficient water flow rates in spawning and rearing reaches to maintain water temperatures within the optimal range for egg, larval, and juvenile survival and development (11°C -19°C) (COSEWIC 2004; Mayfield and Cech 2004; Van Eenennaam et al. 2005; Allen et al. 2006). Sufficient flow is needed to reduce the incidence of fungal infestations of the eggs (Deng et al. 2002; Parsley et al. 2002). In addition, sufficient flow is needed to flush silt and debris from cobble, gravel, and other substrate surfaces to prevent crevices from being filled in (and potentially suffocating the eggs; Deng et al. 2002) and to maintain surfaces for feeding (Nguyen and Crocker 2006). Successful migration of adult green sturgeon to and from spawning grounds is also dependent on sufficient water flow. Spawning success is associated with water flow and water temperature. Spawning in the Sacramento River is believed to be triggered by increases in water flow to about 400 m^3/s (average daily water flow during spawning months: 198-306 m^3/s) (Brown 2007). Post-spawning downstream migrations are triggered by increased flows, ranging from 174-417 m^3/s in the late summer (Vogel 2005) and greater than 100 m^3/s in the winter (Erickson et al. 2002; Benson et al. 2007; Corwin pers. comm.).

The species effect determination found related potential stressors of:

- Flow

5.4.4 Water Quality

Water quality, including temperature, salinity, oxygen content, and other chemical characteristics, is necessary for normal behavior, growth, and viability of all life stages. Suitable water temperatures would include relatively stable water temperatures within spawning reaches (wide fluctuations could increase egg mortality or deformities in developing embryos); temperatures within 11°C -17°C (optimal range = 14°C -16°C) in spawning reaches for egg incubation (March–August) (Van Eenennaam et al. 2005); temperatures below 20°C for larval development (Werner et al. 2007); and temperatures below 24°C for juveniles (Mayfield and Cech 2004; Allen et al. 2006). Suitable salinity levels range from fresh water (<3 parts per thousand [ppt]) for larvae and early juveniles (about 100 dph) to brackish water (10 ppt) for juveniles prior to their transition to salt water. Exposure to higher salinities may affect the temperature tolerances of juvenile green sturgeon (Sardella et al. 2008), and prolonged exposure to higher salinities may result in decreased growth and activity levels and even mortality (Allen and Cech 2007). Adequate levels of dissolved oxygen are needed to support oxygen consumption by fish in their early life stages (ranging from 61.78 mg to 76.06 mg O_2 hr^{-1} kg^{-1} for juveniles) (Allen and Cech 2007). Suitable water quality would also include water containing acceptably low levels of contaminants (e.g., pesticides, polyaromatic hydrocarbons [PAHs], elevated levels of heavy metals) that may disrupt normal development of embryonic, larval, and juvenile stages of green sturgeon. Water with acceptably low levels of such contaminants would protect green sturgeon from adverse impacts on growth, reproductive development, and reproductive success (e.g., reduced egg size and abnormal gonadal development) likely to result from exposure to contaminants (Fairey et al. 1997; Foster et al. 2001a; Foster et al. 2001b; Kruse and Scarnecchia 2002; Feist et al. 2005; Greenfield et al. 2005).

The species effect determination found related potential stressors of:

- Toxicity and Dissolved Oxygen
- Salinity

5.4.5 Migratory Corridor

A migratory is pathway necessary for the safe and timely passage of southern DPS fish within riverine habitats and between riverine and estuarine habitats (e.g., an unobstructed river or dammed river that still allows for safe and timely passage). We define safe and timely passage to mean that human-induced impediments (either physical, chemical, or biological) do not alter the migratory behavior of the fish such that its survival or the overall viability of the species is compromised (e.g., an impediment that compromises the ability of fish to reach their spawning habitat in time to encounter con-specifics and reproduce). Unimpeded migratory corridors are necessary for adult green sturgeon to migrate to and from spawning habitats, and for larval and juvenile green sturgeon to migrate downstream from spawning/rearing habitats within freshwater rivers to rearing habitats within the estuaries.

The species effect determination found related potential stressors of:

- Barriers

5.4.6 Water Depth

Deep (≥5 m) holding pools for both upstream and downstream holding of adult or subadult fish, with adequate water quality and flow are needed to maintain the physiological needs of the holding adult or subadult fish. Deep pools of ≥5 m depth with high associated turbulence and upwelling are critical for adult green sturgeon spawning and for summer holding within the Sacramento River (Poytress et al. 2009). Adult green sturgeon in the Klamath and Rogue rivers also occupy deep holding pools for extended periods of time, presumably for feeding, energy conservation, and/or refuge from high water temperatures (Erickson et al. 2002; Benson et al. 2007).

The species effect determination found related potential stressors of:

- Spawning habitat

5.4.7 Sediment Quality

Sediment quality (i.e., chemical characteristics) is necessary for normal behavior, growth, and viability of all life stages. This includes sediments free of elevated levels of contaminants (e.g., selenium, PAHs, and pesticides) that may adversely affect green sturgeon. Based on studies of white sturgeon, bioaccumulation of contaminants from feeding on benthic species may adversely affect the growth, reproductive development, and reproductive success of green sturgeon.

The species effect determination found related potential stressors of:

- Incubation habitat

5.5 Critical Habitat Effect Determination

The seasonal operation is not likely to adversely affect critical habitat for the southern DPS of North American green sturgeon.

6 Delta Smelt

Delta smelt was one of the most common and abundant pelagic fish caught by California Department of Fish and Game trawl surveys in the Delta during the early 1970s (Stevens and Miller 1983; Moyle et al. 1989; Stevens et al. 1990). A euryhaline, “semi-anadromous” species, as initially coined by Moyle et al. (1992), its distribution ranged from western Suisun Bay upstream to Sacramento on the Sacramento River and to Mossdale on the San Joaquin River (Radtke 1966; Moyle 1976; Moyle et al. 1992). Delta smelt is adapted for life in the mixing zone (brackish water/freshwater interface) of the Sacramento-San Joaquin estuary with 90% of fish caught at salinities <6 psu and a majority of both adults and juveniles caught at salinities <2 psu (Bennet 2005). The current juvenile and adult distribution, however, is mostly restricted to the “North Delta Arc” from the Cache Slough and Lindsay Slough Complex in the north Delta to the Sacramento River and Suisun Marsh (Merz et al. 2011). Larvae and juveniles are present in the central and south Delta, and increased incidental entrainment risk is possible under certain hydraulic conditions (reverse Old and Middle river flow) (Kimmerer 2008; Grimaldo et al. 2009). Currently, Delta smelt are a rare sight in monitoring surveys that provide data on fish abundance, leading to its status being listed as threatened (1993) under the Federal ESA.

6.1 Conceptual Lifecycle Models

An action may affect fish when the change in conditions overlap with the location and timing of fish and/or their habitats. Conceptual models from the Delta Smelt Management Analysis, and Synthesis Team (IEP MAST 2015) describes life stages and geographic locations for Delta smelt (Figure); however, the subadult life stage was omitted due to similar geographic locations, operational conditions, and stressors.

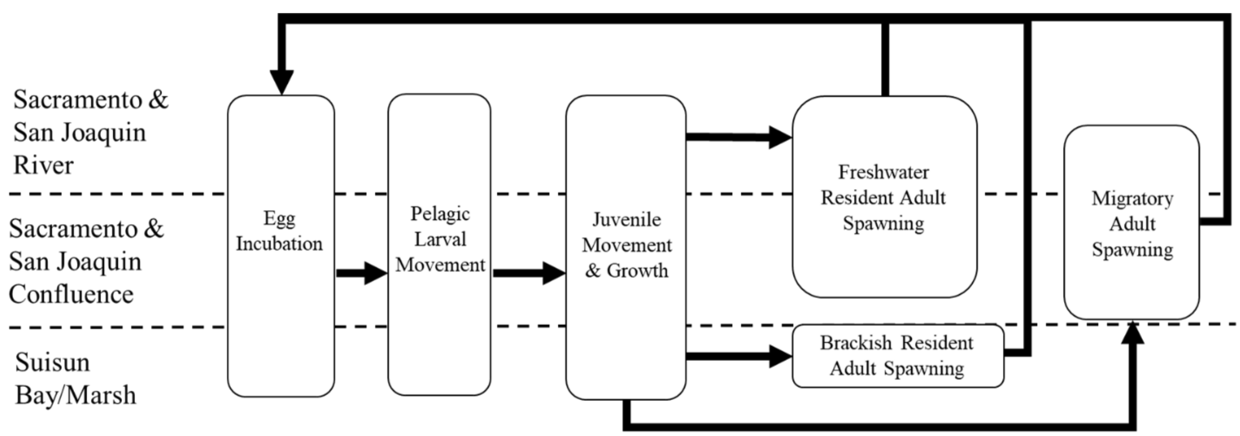

Figure 9. Simplified Geographic Life Stage Domains for Delta smelt

The Delta smelt Management, Analysis, and Synthesis Team (MAST) describes linkages between landscape attributes and environmental drivers to habitat attributes that may affect fish (stressors) based on life stage. The MAST model provides life stages and stressors of:

- Adults
    - H_{na}: Toxicity
    - H_{na}: Water Temperature
    - H4: Food Availability/Visibility
    - H3, H2: Predation Risk
    - H1: Entrainment Risk
- Eggs & Larvae
    - H1: Water Temperature
    - H2: Food Availability/Visibility
    - H3: Predation Risk
    - H4: Entrainment Risk & Transport Direction
- Juveniles
    - H4a: Toxicity from Harmful Algal Blooms
    - H1: Water Temperature
    - H3, H4b: Food Availability & Quality
    - H2: Predation Risk
    - H4: Entrainment Risk & Transport Direction
    - H3a: Harmful Algal Blooms
    - H4: Size and Location of low-salinity zone

Each deconstruction of the action considers the 13 stressors for the four life stages listed above. Additional and/or alternative conceptual models (e.g., Rose, Delta Smelt Structured Decision Making) may be incorporated as applicable.

Monitoring from trawls describes the timing of Delta smelt presence (Figure 10) (Appendix C).

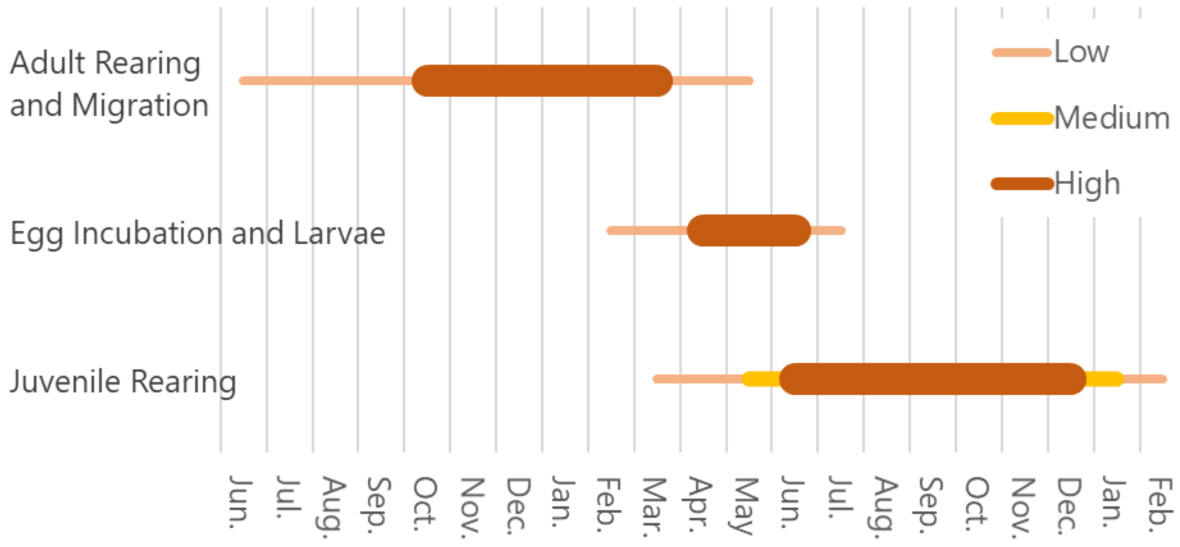

Figure 10. Temporal Life Stage Domains for Delta Smelt (developed from IEP MAST 2015) from Appendix C.

6.2 Species Effects Deconstruction

Delta smelt complete their entire lifecycle within the Bay-Delta and Suisun Marsh. While most individuals follow a semi-anadromous life history, migrating to freshwater in winter to spawn, hatching mostly in the spring and dispersing back to the low-salinity zone in the summer and fall to rear, small resident portions of the population entirely complete their life cycle in either fresh or brackish areas (Hobbs et al. 2019). As such, the different Delta smelt life stages may experience different effects from components of the seasonal operations.

6.2.1 Winter

In the winter, Reclamation and DWR's proposed storage and diversion of water will decrease Bay-Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on Delta smelt.

6.2.1.1 Adults

Adults are migrating from rearing habitats in Suisun Bay and Marsh to spawning grounds in the lower Sacramento River, North Delta including the Cache Slough Complex, Sacramento Deep Water Ship Channel, and the lower San Joaquin River.

Toxicity stressors may decrease. The decrease is likely insignificant. During the adult life stage, CVP and SWP storage and diversion decreases Delta inflow. Increased runoff can increase mobilization of contaminants from agricultural and urban areas.

Increased flows have been noted to increase loading of contaminants and mobilization of sediment bound contaminants in the Cache Slough as part of seasonal flow actions (Stillway et al. 2021). (NDFS Report). Contaminant concentrations depend on the sampling location and contaminant (Stillway et al. 2021). Contaminants also vary in their half-life and thus longevity in the system depends on the contaminant (Gan et al. 2005). In any case, effects are likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).

Water temperature stressors may increase. The increase is likely insignificant. Although Delta water temperature is positively correlated with Delta inflow in the winter (Bashevkin and Mahardja 2022) and CVP and SWP storage and diversion decreases Delta inflow and outflow, Bay-Delta water temperature is mainly driven by air temperature, solar radiation, and meteorology (Vroom et al. 2017, Daniels and Danner 2020). Moreover, it is unlikely that flow alterations from Keswick will influence water temperature in the lower Sacramento River and north Delta (Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures do not exceed 68°F (adult delta smelt non-lethal effects) in the winter. 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.

Food availability stressors may increase. Storage of water may reduce flows which could affect the quantity of food resources via lower subsidies from freshwater areas. Abundances of historically important Delta smelt zooplankton prey taxa, including *Eurytemora affinis* in the LSZ generally exhibit a positive correlation with Delta outflow (Kimmerer 2002).

Food availability is hypothesized to be important for adult spawning and survival (Miller et al. 2012), larval recruitment (Polanksy et al. 2020), and population growth rate (Rose et al. 2013b) but information on adult feeding in the wild during the winter-spring spawning period is insufficient (IEP MAST 2015) to differentiate effects of summer and fall food limitation from potential winter food limitation. Hung et al. (2014) found cultured female Delta Smelt with early-stage eggs had higher stomach content than males and spawning females, suggesting that feeding may be important for egg development.

Food visibility stressors may decrease. This decrease is likely insignificant. Delta smelt (~120 days post-hatch) ability to forage is optimal when turbidity levels are below 12 NTU (Hasenbein et al. 2013). CVP and SWP storage and diversions, including nondiscretionary flood control operations, decreases Delta inflow and outflow relative to environmental baseline which may reduce turbidity.

The contribution of diversions, via reduced outflow, to reducing the total suspended sediment budget in the estuary is small (Schoellhammer 2012). Wright and Schoelhamer (2005) estimated only about 2% of the sediment discharged at Freeport were diverted by CVP and SWP projects based on sediment deposition in Clifton Court Forebay. Additionally, the effect of larger scale decreases in turbidity can be explained largely by the proliferation of aquatic plants like *Egeria densa* (Hestir et al. 2015), and smaller scale changes in turbidity are largely tide- and wind-driven.

Predation stressors may increase. The increase is likely discountable and/or insignificant. During the adult migration and spawning period, the Proposed Action reduces Delta inflow and outflow, which may alter hydrodynamic conditions in the Delta. 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 during operations of those that are CVP/SWP facilities, Delta smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Any residual effects of predation associated with the Proposed Action is considered insignificant.

Entrainment risk stressors may increase. During the adult migration and spawning period, the Proposed Action will export water from the Delta and lead to the storage and diversion of water which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009) and [2] fish routed through specific migratory pathways in the Delta where tidal surfing behaviors (Sommer et al. 2011) route Delta smelt into areas with increased entrainment risk. Entrainment of adult Delta smelt into the South Delta and the facilities is most likely during the movement of fish from brackish waters to freshwater regions (Smith et al. 2021, Grimaldo et al. 2023, Grimaldo et al. 2009, Kimmerer 2008). Entrainment into the facilities tends to be highest when OMR flows are negative (i.e., reversed) and when turbidity is high (Smith et al. 2021). Multiple topic-specific appendices address aspects of adult migration through the Delta.

- Appendix G, *Specific Facility and Water Operations Deconstruction,* including sections for “Tracy Fish Collection Facility” and “Skinner Fish Delta Fish Protective Facility”
- Appendix I presents analysis of “Old and Middle River Management” and “Delta Cross Channel Closure” conservation measures

6.2.1.2 Juveniles

Juveniles are not present in the winter.

6.2.1.3 Eggs and Larvae

Eggs and Larvae are not present in the winter.

6.2.2 Spring

In the spring, Reclamation and DWR's proposed storage and diversion of water will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on Delta smelt.

6.2.2.1 Adults

Adults are present. Adult delta smelt are present in spawning grounds in Suisun Marsh, the lower Sacramento River, North Delta including the Cache Slough Complex, Sacramento Deep Water Ship Channel, and the lower San Joaquin River (Merz et al. 2011).

Toxicity stressors may decrease. The decrease is likely insignificant. During the adult life stage, CVP and SWP storage and diversion decreases Delta inflow. Increased runoff can increase mobilization of contaminants from agricultural and urban areas.

Increased flows have been noted to increase loading of contaminants and mobilization of sediment bound contaminants in the Cache Slough as part of seasonal flow actions (Stillway et al. 2021). (NDFS Report). Contaminant concentrations depend on the sampling location and contaminant (Stillway et al. 2021). Contaminants also vary in their half-life and thus longevity in the system depends on the contaminant (Gan et al. 2005). In any case, effects are likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).

Water temperature stressors may increase. The increase is likely insignificant. CVP and SWP storage and 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 Bay-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). There is uncertainty about whether the decreased inflow is a cause for increased Delta water temperatures. While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures at Prisoner's Point rarely exceed 68°F (adult delta smelt non-lethal effects) in early spring. 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.

Food availability stressors may increase. This increase may reduce prey availability, leading to decreased prey consumption, and growth and subsequent recruitment as wetter conditions have been found to be associated with higher gut fullness (Schultz 2019), as well as higher clutch size and gonadosomatic index (Kurobe et al. 2022). CVP and SWP storage and diversion decreases Delta inflow and outflow relative to the environmental baseline, which could affect the quantity of food resources via lower subsidies from freshwater areas. Abundances of historically important Delta smelt zooplankton prey taxa, including *Eurytemora affinis* in the LSZ generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). Appendix J (Appendix J) presents the analyses for this stressor. Appendix P analyzes zooplankton abundance near different types of habitats.

Food visibility stressors may decrease. This decrease is likely insignificant. Delta smelt (~120 days post-hatch) ability to forage is optimal when turbidity levels are below 12 NTU (Hasenbein et al. 2013). CVP and SWP storage and diversions, including nondiscretionary flood control operations, decreases Delta inflow and outflow relative to environmental baseline which may reduce turbidity. The contribution of diversions, via reduced outflow, to reducing the total suspended sediment budget in the estuary is small (Schoellhammer 2012). Wright and Schoelhamer (2005) estimated only about 2% of the sediment discharged at Freeport were diverted by CVP and SWP projects based on sediment deposition in Clifton Court Forebay. Additionally, the effect of larger scale decreases in turbidity can be explained largely by the proliferation of aquatic plants like *Egeria densa* (Hestir et al. 2015), and smaller scale changes in turbidity are largely tide- and wind-driven.

Predation stressors may increase. The increase is likely discountable and/or insignificant. During the adult migration and spawning period, the Proposed Action reduces Delta inflow and outflow, which may alter hydrodynamic conditions in the Delta. 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 during operations of those that are CVP/SWP facilities, Delta smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Any residual effects of predation associated with the Proposed Action is considered insignificant

Entrainment risk stressors may increase. CVP and SWP diversions may result in higher levels of entrainment loss of Delta smelt. Hydrodynamic alteration of flows in the Delta due to CVP and SWP diversions may route Delta smelt into areas where they may experience decreased survival. Entrainment at the export facilities may result in direct mortality. Appendix G including sections for “Tracy Fish Collection Facility” and “Skinner Fish Delta Fish Protective Facility”. Appendix I presents analysis.

6.2.2.2 Eggs and Larvae

Eggs and Larvae are present. Eggs are attached to substrate, while larvae are involuntarily transported (advected) by Sacramento River and tidal flows. Several stressors have been identified for these more sensitive life stages.

Water temperature stressors may increase. This increase is likely insignificant. CVP and SWP storage and 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).

The range of potential reservoir operations is unlikely to have a measurable effect on Delta water temperatures as in the Bay-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). Historical water temperatures at Prisoner's Point do not exceed 84°F (late-larval Delta smelt critical thermal maximum) in early spring (Komoroske et al. 2014). There is uncertainty about whether the decreased inflow is a cause for increased Delta water temperatures. The uncertainty is due to hypotheses that American River operations is a cause for changes in Delta water temperatures. 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.

Food availability stressors may increase. During the planktonic larvae stage, the storage and diversion of water will reduce Delta inflows and outflows. Delta smelt larvae (5-8 mm) consume copepod nauplii and copepodites before switching to adult copepods at larger sizes (> 13 mm) (Nobriga 2002, Slater and Baxter 2014). During the early spring, larvae feed mainly on cyclopoids in the early spring before switching to *Eurytemora affinis* in mid-spring (April-May) and then to *Pseudodiaptomus forbesi* and cladocerans in late-spring, early summer (May-June) (Norbriga 2002, Slater and Baxter 2014). Nobriga (2002) also found a positive relationship between feeding incidence and prey density and suggests long term declines in copepod abundance impacts Delta smelt larvae feeding success. Abundances of historically important Delta smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis*, generally exhibit a positive correlation with Delta outflow in the spring (Kimmerer 2002b). Hamilton et al. (2020) found pulse spring flows in dry water years can increase copepod biomass near Suisun Bay. Decreased Delta outflows may also limit critical allochthonous subsidies of alternate larval Delta smelt food resources (e.g., *Pseudodiaptomus forbesi*) through advection from more productive upstream areas to Delta smelt rearing habitats where local zooplankton productivity is severely impacted by competition with clams (Kimmerer et al. 2019).

Multiple analyses have shown prey abundance and density are important factors in explaining Delta smelt abundance (Miller et al. 2012, Mac Nally et al. 2010, Thomson et al. 2010, Maunder and Deriso 2011). Hamilton and Murphy (2018) observed effects of food limitation in the spring when modeling Delta smelt abundance over a 40-year period. Food limitation stressors vary on spatial, seasonal, and yearly time scales (Hammock et al. 2015). Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix P analyzes zooplankton abundance near different types of habitat.

Food visibility stressors may increase. This increase is likely insignificant. CVP and SWP storage and diversions, including nondiscretionary flood control operations, decreases Delta inflow and outflow relative to environmental baseline which may reduce turbidity. Delta smelt larvae ability to forage is optimal in turbidity levels greater than 25 NTU (Hassenbein et al. 2016). During periods of high inflow and outflow (e.g., storm events in the winter and spring), increased storage may result in reduced suspended sediment in regions of the Delta when compared with environmental baseline. However, the contribution of diversions to the total suspended sediment budget in the estuary is small (Schoellhammer 2012). Additionally, the effect of larger scale decreases in turbidity can be explained largely by the proliferation of aquatic plants like *Egeria densa* (Hestir et al. 2015), and smaller scale changes in turbidity are largely tide- and wind-driven.

Predation stressors may increase. The increase is likely discountable and/or insignificant. During the larvae development and transport period, the Proposed Action will store and divert water and reduce Delta inflows and outflow, which may alter hydrodynamic conditions in the Delta. Some Delta smelt predators have been found to have a relationship to flows. Higher summer inflows and spring water exports are followed by lower abundances of Mississippi silversides, however the mechanism behind this relationship remains unknown (Mahardja et al. 2016). Historically, on average, catch of silversides declines during the winter and spring months and is less than 2 CPUE (Mahardja et al. 2016). DNA studies of the gut content of Mississippi silversides have found Delta smelt DNA, likely from larval or early juvenile fish (Schreier et al. 2016, Baerwald et al. 2012). In addition, 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. During operations of the CVP/SWP export facilities, larval Delta smelt will be exposed to predation at the Delta fish collection facilities. 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). Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Other indirect effects of predation are described further in Appendix J – Spring Outflow Action, Appendix K, *Summer and Fall Delta Smelt Outflow and Habitat*, and Appendix I. Any residual effects of predation associated with the Proposed Action is considered insignificant.

Entrainment risk and transport direction stressors may increase for larvae and is not anticipated to change for eggs During the planktonic larvae stage, the Proposed Action will export water from the Delta and lead to the storage and diversion of water will reduce Delta inflows and outflows. Entrainment, for the purposes of this document, is defined and discussed in two ways: Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009) and [2] fish routed/advected through water ways in the Delta where they may experience decreased survival. Entrainment is largely explained by exports, OMR flows and water clarity (Smith et al. 2021, Grimaldo et al. 2023, Grimaldo et al. 2009, Kimmerer 2008). Entrainment at the export facilities may result in direct mortality (Kimmerer 2008). When adult Delta Smelt spawn in the south Delta, new hatched larvae have an increased chance of being entrained compared to larvae that hatched elsewhere in the Bay-Delta. When Delta smelt are entrained into the south Delta, they are exposed to greater predation risk since the invasive aquatic macrophyte, *Egeria densa*, dominates the littoral zone in the south Delta (Durand et al. 2016), which can reduce turbidity (Hestir et al. 2016) and potentially cause more predation on eggs and larvae (Bennett 2005, Schreier et al. 2016). Appendix I presents analysis.

6.2.2.3 Juveniles

Juveniles are present. Juveniles are rearing in the estuary, and their growth and survival is hypothesized to largely depend on quality, quantity, and availability of resources. Several stressors have been identified for the juvenile life stage as fish transition into subadults.

Toxicity from Harmful Algal Blooms stressors may increase. The increase is insignificant. Spring seasonal operations decrease Delta inflow. Toxicity from harmful algal blooms is a function of factors contributing to increased occurrence or persistence of cyanobacterial blooms, greater levels of toxin production within those blooms, and the incorporation of toxins into the food web. While common cyanobacteria, such as *Microcystis*, increase in frequency around 66°F (19°C) (Lehman et al. 2013) and thus be less common in the spring (Appendix B, Figure 56), some cyanobacteria in the Delta, such as *Planktothrix*, may thrive in cooler temperatures more common in the spring (Rohrlack 2018). In general, HABs presence is negatively correlated with flow and is a function of climatic hydrological conditions. Thus, the effect of operations-scale alterations in flow is relatively minor and difficult to isolate from the greater effect of large-scale inter-annual hydrologic variation on HABs (Hartman et al. 2022, Reclamation and DWR 2023). The drivers of toxin production by HABs such as Microcystis are not fully understood but include the prevalence of certain genetic variants and possibly environmental conditions, such as nutrient concentrations and ratios (Yancey et al. 2022). CVP and SWP operations do not influence the prevalence of toxin-producing genetic variants. The potential for CVP and SWP operations to influence the uptake and transfer of toxins through the food web is unknown and would be difficult to distinguish from other drivers.

Water temperature stressors may increase. The increase is likely insignificant. CVP and SWP storage and 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 Bay-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). There is uncertainty about whether the decreased inflow is a cause for increased Delta water temperatures. While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures at Prisoner's Point rarely exceed 81°F (juvenile Delta smelt 50% chronic morbidity) in early spring (Komoroske et al. 2014).

Food availability and quality stressors may increase. CVP and SWP operations in the spring may reduce Delta outflow. Abundances of historically important Delta smelt zooplankton prey taxa including *Eurytemora affinis* in the LSZ generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). Thus, CVP and SWP operations may reduce prey availability, Appendix K analyzes the effect of summer and fall food actions on zooplankton abundance in the Delta. Appendix P analyzes zooplankton abundance near different types of habitat.

Predation stressors may increase. The increase is likely discountable and/or insignificant. During the juvenile rearing period, the Proposed Action will store and divert water and reduce Delta inflows and outflow, which may alter hydrodynamic conditions in the Delta. 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. During operations of those that are CVP/SWP facilities, juvenile Delta smelt 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). Predation is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Any residual effects of predation associated with the Proposed Action is considered insignificant. **Entrainment risk and transport direction stressors** may increase. CVP and SWP diversions may result in higher levels of entrainment loss of Delta smelt. Hydrodynamic alteration of flows in the Delta due to CVP and SWP diversions may route Delta smelt into areas where they may experience decreased survival. Entrainment at the export facilities may result in direct mortality. Appendix I presents analysis of these stressors.

Size and location of LSZ stressors may increase. CVP and SWP operations during the spring shifts the position X2 eastward and reduces the size of the low salinity zone where juveniles are rearing. In general, the abiotic elements of delta smelt habitat quality and surface area are greater when the LSZ is in Suisun Bay than when it is located in the Delta (Feyrer et al. 2011, Bever et al. 2016). Appendix K presents analysis.

6.2.3 Summer

In the summer, Reclamation and DWR's proposed water operations will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on Delta smelt.

6.2.3.1 Adults

Adults are not present.

6.2.3.2 Eggs and Larvae

Eggs and larvae are not present.

6.2.3.3 Juveniles

Juveniles are present. Juveniles are rearing in the estuary, and their growth and survival is hypothesized to largely depend on quality, quantity, and availability of resources. Several stressors have been identified for the juvenile life stage as fish transition into subadults.

Toxicity from harmful algal blooms stressors may increase or decrease. The increase or decrease is likely insignificant. Summer seasonal operations increase Delta inflow. Toxicity from harmful algal blooms is a function of factors contributing to increased occurrence or persistence of cyanobacterial blooms, greater levels of toxin production within those blooms, and the incorporation of toxins into the food web. Freshwater HABs, such as Microcystis, occur in the summer and increase in frequency around 66°F (19°C) and with longer day lengths (Lehman et al. 2013). While Delta inflow is negatively correlated with water temperature (Bashevkin and Mahardja 2022), temperatures in the summer are likely above 66°F for the duration of summer under both alternatives and are mainly driven by air temperature and meteorology (Vroom et al. 2017). In general, HABs presence is negatively correlated with flow and is a function of climatic hydrological conditions. Thus, the effect of operations-scale alterations in flow is relatively minor and difficult to isolate from the greater effect of large-scale inter-annual hydrologic variation on HABs (Hartman et al. 2022, Reclamation and DWR 2023). The drivers of toxin production by HABs such as Microcystis are not fully understood but include the prevalence of certain genetic variants and possibly environmental conditions, such as nutrient concentrations and ratios (Yancey et al. 2022). CVP and SWP operations do not influence the prevalence of toxin-producing genetic variants. The potential for CVP and SWP operations to influence the uptake and transfer of toxins through the food web is unknown and would be difficult to distinguish from other drivers.

Water temperature stressors may increase or decrease. The decrease is likely insignificant. Summer seasonal operations increase Delta inflow. Delta water temperature is negatively correlated with Delta inflow and positively correlated with Delta inflow from July – September in Western regions (Bashevkin and Mahardja 2022) (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). Inflow is largely controlled by operations during the summer and fall due to lower contributions from precipitation and snowmelt. However, in the Bay-Delta, water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the increased summer inflow is a cause for decreased Delta water temperatures. While there is uncertainty about whether the increased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures at Prisoner’s Point do not exceed 81°F (juvenile Delta smelt 50% chronic morbidity) in summer (Komoroske et al. 2014).

Food availability and Quality stressors may increase and/or decrease. Changes to reservoir releases and diversion change the rate of Delta outflow. Delta outflow in the summer is sometimes greater and sometimes less than outflow under environmental baseline conditions. Abundances of historically important Delta smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). Decreased Delta outflows may also limit critical allochthonous subsidies of alternate Delta smelt food resources (e.g., *Pseudodiaptomus forbesi*) through advection from more productive upstream areas to Delta smelt rearing habitats where local zooplankton productivity is severely impacted by competition with clams (Kimmerer et al. 2019). Appendix K presents the analysis for this stressor.

Predation stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to release water will increase flow relative to the environmental baseline. 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. During operations of those that are CVP/SWP facilities, juvenile Delta smelt 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). Predation is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Any residual effects of predation associated with the Proposed Action is considered insignificant. **Entrainment risk and transport direction stressors** may increase. During the juvenile migration and rearing life stage, the Proposed Action will export water from the Delta and lead to the storage and diversion of water, which will reduce Delta inflows and outflows. Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009) and [2] fish routed/advected through water ways in the Delta where they may experience decreased survival. Entrainment is largely explained by exports, OMR flows and water clarity (Smith et al. 2021, Grimaldo et al. 2023, Grimaldo et al. 2009, Kimmerer 2008). Entrainment at the export facilities may result in direct mortality (Kimmerer 2008). When Delta smelt are entrained into the south Delta, they are exposed to greater predation risk since the invasive aquatic macrophyte, *Egeria densa,* dominates the littoral zone in the south Delta (Durand et al. 2016) and provides habitat for the invasive largemouth bass (Brown and Michniuk 2007) which prey on Delta smelt. Appendix I presents analysis

Size and location of LSZ stressors may increase and/or decrease. CVP and SWP operations during the summer may reduce the size of the low salinity zone at times and shift X2 eastward reducing juvenile rearing habitat. In general, the abiotic elements of delta smelt habitat quality and surface area are greater when the LSZ is in Suisun Bay than when it is located in the Delta (Feyrer et al. 2011, Bever et al. 2016). Appendix K presents the analysis for this stressor.

6.2.4 Fall

In the fall, Reclamation and DWR’s proposed diversions will decrease Delta outflow on average. Decreased outflow in the Bay-Delta may change stressors on Delta smelt.

6.2.4.1 Adults

Adults are present, rearing in the estuary. Their growth and survival is hypothesized to largely depend on quality, quantity, and availability of resources. Abundant, high-quality resources is expected to result in larger healthier adults that can produce multiple clutches of numerous higher quality eggs. Several stressors have been identified for the adult life stage as fish grow ahead in preparation for winter migration and spawning.

Toxicity stressors may decrease. The decrease is likely insignificant. CVP and SWP storage and diversion of water increase Delta inflow relative to environmental baseline in early fall. Increased runoff can increase mobilization of contaminants from agricultural and urban areas.

Increased flows have been noted to increase loading of contaminants and mobilization of sediment bound contaminants in the Cache Slough as part of seasonal flow actions (Stillway et al. 2021). (NDFS Report). Contaminant concentrations depend on the sampling location and contaminant (Stillway et al. 2021). Contaminants also vary in their half-life and thus longevity in the system depends on the contaminant (Gan et al. 2005). In any case, effects are likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).

Water temperature stressors may increase. The increase is likely insignificant. CVP and SWP storage and diversion of water increase Delta inflow in early fall and decrease outflow during late fall compared to environmental baseline. Delta water temperature is negatively correlated with Delta inflow in the spring (Bashevkin and Mahardja 2022).

The range of potential reservoir operations 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 and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the decreased inflow is a cause for increased Delta water temperatures. While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures at Prisoner's Point rarely exceed 68°F (adult delta smelt non-lethal effects) in early spring. 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.

Food availability stressors may increase. Storage of water may reduce flows which could affect the quantity of food resources via lower subsidies from freshwater areas. Abundances of historically important Delta smelt zooplankton prey taxa, including *Eurytemora affinis* in the LSZ generally exhibit a positive correlation with Delta outflow (Kimmerer 2002).

Food availability is hypothesized to be important for adult spawning and survival (Miller et al. 2012), larval recruitment (Polanksy et al. 2020), and population growth rate (Rose et al. 2013b) but information on adult feeding in the wild during the winter-spring spawning period is insufficient (IEP MAST 2015) to differentiate effects of summer and fall food limitation from potential winter food limitation. Hung et al. (2014) found cultured female Delta Smelt with early-stage eggs had higher stomach content than males and spawning females, suggesting that feeding may be important for egg development.

Food Visibility stressors may decrease. The decrease is likely insignificant. Delta smelt (~120 days post-hatch) ability to forage is optimal when turbidity levels are below 12 NTU (Hassenbein et al. 2013). CVP and SWP operations may increase Delta inflows on average in early Fall and decrease inflows on average in late Fall compared to the environmental baseline, which may increase or reduce turbidity. The contribution of diversions to the total suspended sediment budget in the estuary is small (Schoellhammer 2012), and the effect of larger scale decreases in turbidity can be explained largely by the proliferation of aquatic plants like *Egeria densa* (Hestir et al. 2015), and smaller scale changes in turbidity are largely tide- and wind-driven.

Predation stressors may increase. The increase is likely insignificant. During the adult migration and spawning period, the Proposed Action reduces Delta inflow and outflow, which may alter hydrodynamic conditions in the Delta. 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 during operations of those that are CVP/SWP facilities, Delta smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Any residual effects of predation associated with the Proposed Action is considered insignificant. Outflow presents the analysis of this stressor.

Entrainment risk stressors may increase. CVP and SWP diversions may result in higher levels of entrainment loss of Delta smelt. Hydrodynamic alteration of flows in the Delta due to CVP and SWP diversions may route Delta smelt into areas where they may experience decreased survival. Entrainment at the export facilities may result in direct mortality. Previous salvage data indicated fewer Delta Smelt are entrained between July – November (Grimaldo et al. 2009). Appendix I presents the analysis of this stressor. Appendix G including sections for “Tracy Fish Collection Facility” and “Skinner Fish Delta Fish Protective Facility”.

6.2.4.2 Eggs and Larvae

Eggs and Larvae are not present in the fall.

6.2.4.3 Juveniles

Juveniles are present. Juveniles are rearing in the estuary, and their growth and survival is hypothesized to largely depend on quality, quantity, and availability of resources. Several stressors have been identified for the juvenile life stage as fish transition into subadults then adults.

Toxicity from harmful algal blooms stressors may increase or decrease. The decrease and increase are likely insignificant. Inflow increases in early fall and decreases in late fall, relative to environmental baseline. Toxicity from harmful algal blooms is a function of factors contributing to increased occurrence or persistence of cyanobacterial blooms, greater levels of toxin production within those blooms, and the incorporation of toxins into the food web. Freshwater HABs, such as *Microcystis*, occur in the fall and increase in frequency around 66°F (19°C) and with longer day lengths (Lehman et al. 2013). While Delta inflow is negatively correlated with water temperature (Bashevkin and Mahardja 2022), temperatures are mainly driven by air temperature and meteorology (Vroom et al. 2017). In general, HABs presence is negatively correlated with flow and is a function of climatic hydrological conditions. Thus, the effect of operations-scale alterations in flow is relatively minor and difficult to isolate from the greater effect of large-scale inter-annual hydrologic variation on HABs (Hartman et al. 2022, Reclamation and DWR 2023). The drivers of toxin production by HABs such as Microcystis are not fully understood but include the prevalence of certain genetic variants and possibly environmental conditions, such as nutrient concentrations and ratios (Yancey et al. 2022). CVP and SWP operations do not influence the prevalence of toxin-producing genetic variants. The potential for CVP and SWP operations to influence the uptake and transfer of toxins through the food web is unknown and would be difficult to distinguish from other drivers.

Water temperature stressors may increase or may decrease. The increase or decrease is likely insignificant. CVP and SWP storage and diversion of water increase Delta inflow in early fall and decrease inflow in late fall compared to environmental baseline. Delta water temperature is positively correlated with Delta inflow from July – September in Western regions (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). Inflow is largely controlled by operations during the summer and fall due to lower contributions from precipitation and snowmelt. However, in the Bay-Delta water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the increased fall inflow is a cause for increased or decreased Delta water temperatures. While there is uncertainty about whether the alterations to inflow due to operations is a cause for changes in Delta water temperatures, historical water temperatures at Prisoner’s Point rarely exceed 81°F (juvenile Delta smelt 50% chronic morbidity) in the fall (Komoroske et al. 2014).

Food availability and quality stressors may increase During the juvenile rearing period, the Proposed Action will store and divert water on average, which will affect food availability and quality. Juvenile Delta smelt primarily feed on calanoid copepods, such as *Eurytemora affinis* and *Pseudodiaptomus forbesi*, throughout the spring, summer and fall seasons (Slater and Baxter 2014). Abundances of historically important Delta smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002b). Hamilton et al. (2020) found pulse spring flows in dry water years can increase copepod biomass near Suisun Bay. Decreased Delta outflows may also limit critical allochthonous subsidies of alternate Delta smelt food resources (e.g., *Pseudodiaptomus forbesi*) through advection from more productive upstream areas to Delta smelt rearing habitats where local zooplankton productivity is severely impacted by competition with clams (Kimmerer et al. 2019). Hassrick et al. (2023) found proportional subsidies to the low salinity zone in the fall increased with further seaward positions of X2. Multiple analyses have shown prey abundance and density are important factors in explaining Delta smelt abundance (Miller et al. 2012, Mac Nally et al. 2010, Thomson et al. 2010, Maunder and Deriso 2011, Hamilton and Murphy 2018). Food availability is considered an important component of Delta smelt growth. Food limitation stressors vary on spatial, seasonal and yearly time scales Hammock et al. (2015). Appendix K analyzes the effect of summer and fall food actions on zooplankton abundance in the Delta. Appendix P analyzes zooplankton abundance near different types of habitat.

Predation stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP operations to store and export water will reduce flow relative to the environmental baseline. 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. During operations of those that are CVP/SWP facilities, juvenile Delta smelt 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). Predation is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Any residual effects of predation associated with the Proposed Action is considered insignificant.

Entrainment risk stressors may increase. During the juvenile migration and rearing life stage, the Proposed Action will export water from the Delta and lead to the storage and diversion of water, which will reduce Delta inflows and outflows. Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009) and [2] fish routed/advected through water ways in the Delta where they may experience decreased survival. Entrainment is largely explained by exports, OMR flows and water clarity (Smith et al. 2021, Grimaldo et al. 2023, Grimaldo et al. 2009, Kimmerer 2008). Entrainment at the export facilities may result in direct mortality (Kimmerer 2008). When Delta smelt are entrained into the south Delta, they are exposed to greater predation risk since the invasive aquatic macrophyte, *Egeria densa*, dominates the littoral zone in the south Delta (Durand et al. 2016) and provides habitat for the invasive largemouth bass (Brown and Michniuk 2007) which prey on Delta smelt. Appendix I presents analysis.

Size and location of LSZ stressors may increase. CVP and SWP operations during the fall may reduce the size of the low salinity zone at times and shift X2 eastward reducing access to suitable habitat. In general, the abiotic elements of delta smelt habitat quality and surface area are greater when the LSZ is in Suisun Bay than when it is located in the Delta (Feyrer et al. 2011, Bever et al. 2016). Appendix K presents the analysis for this stressor.

6.3 Species Effects Determination

The seasonal operations of the CVP and SWP may affect and is likely to adversely affect Delta smelt. The seasonal operations of the CVP is also likely to have beneficial effects. Deconstruction of the seasonal operations systematically evaluated each stressor identified by conceptual models. Stressors not linked to the operation of the CVP and SWP were identified as "are not anticipated to change." Stressors that were insignificant or discountable were documented above. Stressors with a material effect on the fitness of species were identified, and the seasonal operations incorporates minimization and/or compensation through conservation measures.

Stressors on adults influenced by the seasonal operations include:

- Food availability and visibility: May be reduced from decreased net Delta outflows on average resulting from seasonal operations. Adverse effects are minimized by increasing food availability through tidal habitat restoration and Summer Fall Habitat Action.
- Entrainment: Risk may increase from export operations because of migratory patterns. Adverse effects are minimized by implementing real time OMR management.
- Size of LSZ may be reduced from decreased net Delta outflows on average, and location of LSZ would be shifted eastward. Adverse effects are minimized by implementing the tidal restoration Summer Fall Habitat Action.

Stressors on eggs and larvae influenced by the seasonal operations include:

- Food availability and visibility may be reduced from decreased net Delta outflows on average. Adverse effects on larvae are minimized by increasing food availability through tidal habitat restoration, Summer Fall Habitat Action, and seasonal operations.
- Entrainment risk and transport direction risk may increase from decreased inflows to the Delta on average. Adverse effects are minimized by implementing real time OMR management.

Stressors on juveniles influenced by the seasonal operations include:

- Food availability and visibility may be reduced from decreased net Delta outflows on average. Adverse effects are minimized by increasing food availability through tidal habitat restoration and Summer Fall Habitat Action.
- Entrainment risk and transport direction: May increase from export operations. Adverse effects are minimized by implementing real time OMR management.
- Size and location of LSZ may be decreased due to decreased outflow. Adverse effects are minimized by seasonal operations and Summer Fall Habitat Action.

6.4 Critical Habitat Physical and Biological Features

USFWS designated critical habitat for the Delta smelt on December 19, 1994 (U.S. Fish and Wildlife Service 1994). The geographic area encompassed by the designation includes all water and all submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma Sloughs; and the existing contiguous waters contained within the legal Delta (as defined in Section 12220 of the California Water Code) (U.S. Fish and Wildlife Service 1994). The entire designated critical habitat for Delta smelt is encompassed by the action area.

The 1994 critical habitat designation stated that "the primary constituent elements essential to the conservation of the Delta smelt are physical habitat, water, river flow, and salinity concentrations required to maintain Delta smelt habitat for spawning, larval and juvenile transport, rearing, and adult migration." The 1994 critical habitat designation then organized the primary constituent elements by habitat conditions required for each life stage, noting the specific geographic areas and seasons identified for each habitat condition represent the maximum possible range of each of these conditions. Depending on the water-year type (i.e., wet, above normal, normal, below normal, dry, critically dry), each of the habitat conditions specified below requires fluctuation (within-year and between-year) in the placement of the 2 ppt isohaline (a line drawn to connect all points of equal salinity) around three historical reference points.

USFWS's primary objective in designating critical habitat was to identify the key components of Delta smelt habitat that support successful completion of the life cycle, including spawning, larval and juvenile transport, rearing, and adult migration back to spawning sites (U.S. Fish and Wildlife Service 2019).

The primary constituent elements for the Delta smelt are:

6.4.1 Spawning Habitat ("Shallow Water Habitat")

Delta smelt adults seek shallow edge waters for spawning. Laboratory observations indicate that Delta smelt are broadcast spawners, discharging eggs and milt close to the bottom over substrates of sand or pebble (California Department of Water Resources and Reclamation 1994; Lindberg et al. 2003; Wang 2007). Rather than stick to immobile substrates, the adhesive eggs might adhere to sand particles, which keeps them negatively buoyant but not immobile (Hay 2007). Spawning occurs primarily during April through mid-May (Moyle 2002) in sloughs and shallow edge areas in the Bay-Delta. Spawning also has been recorded in Suisun Marsh and the Napa River (Hobbs et al. 2007). To ensure egg hatching and larval viability. spawning areas also must provide suitable water quality (i.e., low concentrations of pollutants).

Specific areas that have been identified as important Delta smelt spawning habitat include Barker, Lindsey, Cache, Prospect, Georgiana, Beaver, Hog, and Sycamore Sloughs and the Sacramento River in the Delta, and tributaries of northern Suisun Bay. However, most adult fish have since been observed to aggregate around Grizzly Island, Sherman Island, and in the Cache Slough complex, including the subsequently flooded Liberty Island (U.S. Fish and Wildlife Service 2019).

However, USFWS has noted that information on spawning habitat is incomplete, and because eggs are demersal and adhesive, they could attach to any number of substrates (U.S. Fish and Wildlife Service 2019).

There are no additional operations effects on spawning habitat when species are not present.

6.4.2 Larval and Juvenile Transport

To ensure that Delta smelt larvae are transported from the area where they are hatched to shallow, productive rearing or nursery habitat, the Sacramento and San Joaquin rivers and their tributary channels must be protected from physical disturbance (e.g., sand and gravel mining, diking, dredging, and levee or bank protection and maintenance) and flow disruption (e.g., water diversions that result in entrainment and in-channel barriers or tidal gates).

Adequate river flow is necessary to transport larvae from upstream spawning areas to rearing habitat in Suisun Bay. Additionally, river flow must be adequate to prevent interception of larval transport by the state and federal water projects and smaller agricultural diversions in the Bay-Delta. To ensure that suitable rearing habitat is available in Suisun Bay. The 2 ppt isohaline must be located westward of the Sacramento-San Joaquin River confluence during the period when larvae or juveniles are being transported, according to the historical salinity conditions that vary according to water-year type. Reverse flows that maintain larvae upstream in deep-channel regions of low productivity and expose them to entrainment interfere with those transport requirements. Suitable water quality must be provided so that maturation is not impaired by pollutant concentrations. The specific geographic area important for larval transport is confined to waters contained within the legal boundary of the Delta, Suisun Bay, and Montezuma Slough and its tributaries. The specific season when habitat conditions identified above are important for successful larval transport varies from year to year, depending on when peak spawning occurs and the water-year type.

USFWS identified situations in the Biological Opinion for the Delta smelt (1994) where additional flows might be required in the July through August period to protect Delta smelt that were present in the south and central Delta from being entrained in the state and federal project pumps, and to avoid jeopardy to the species.

The species effect determination found related potential stressors of:

- Entrainment risk
- Transport direction
- Size of LSZ

There are no additional operations effects on larval and juvenile transport when species are not present.

6.4.3 Rearing Habitat

Maintenance of the 2 ppt isohaline according to the historical salinity conditions described above and suitable water quality (low concentrations of pollutants) within the estuary is necessary to provide Delta smelt larvae and juveniles a shallow, protective, food-rich environment in which to mature to adulthood. This placement of the 2 ppt isohaline also serves to protect larval, juvenile, and adult Delta smelt from entrainment in the state and federal water projects. An area extending eastward from Carquinez Strait, including Suisun Bay, Grizzly Bay, Honker Bay, Montezuma Slough and its tributary sloughs, up the Sacramento River to its confluence with Three Mile Slough, and south along the San Joaquin River including Big Break, defines the specific geographic area critical to the maintenance of suitable rearing habitat. Three Mile Slough represents the approximate location of the most upstream extent of tidal excursion when the historical salinity conditions described above are implemented. Protection of rearing habitat conditions may be required from the beginning of February through the summer.

The species effect determination found related potential stressors of:

- Food availability and visibility
- Size and location of LSZ

There are no additional operations effects on rearing habitat when species are not present.

6.4.4 Adult Migration

Adult Delta smelt must be provided unrestricted access to suitable spawning habitat in a period that may extend from December to July. Adequate flow and suitable water quality may need to be maintained to attract migrating adults in the Sacramento River and San Joaquin River channels and their associated tributaries, including Cache and Montezuma Sloughs and their tributaries. These areas also should be protected from physical disturbance and flow disruption during migratory periods.

The species effect determination found related potential stressors of:

- Entrainment risk
- Food availability and visibility

There are no additional operations effects on adult migration when species are not present.

6.5 Critical Habitat Effect Determination

The seasonal operation is likely to adversely affect critical habitat for Delta smelt.

- Increased entrainment is minimized through seasonal operations in the action area
- Impacts to food availability and visibility are compensated through the construction of additional habitat and seasonal operations and habitat actions
- Size and location of LSZ are compensated through the construction of additional habitat and seasonal operations and habitat actions

7 Longfin Smelt

Longfin smelt, *Spirinchus thaleichthys*, is an euryhaline smelt (family Osmeridae) found in California's bay, estuary, and nearshore coastal environments along the Pacific Coast of North America. The San Francisco Estuary, Sacramento-San Joaquin Delta, and nearshore ocean outside the Golden Gate Bridge supports the largest longfin smelt population in California, listed as a DPS because of genetic isolation, with Humboldt Bay likely ranking second in longfin smelt abundance. Longfin smelt have a lifespan of approximately 2 to 3 years. Most reach maturity at two years of age and grow to a standard length between 124 mm to 140 mm. They are anadromous and semelparous, spend their adult life in bays, estuaries, and nearshore coastal areas, and migrate to the low-salinity zone (LSZ) and freshwater tributaries to spawn between November and May, with peak spawning occurring from January through March, after which most adults die. Newly hatched larvae are 5 mm to 8 mm long and are thought to be buoyant until their air bladder develops at approximately 12 mm, leading to seaward advection to salinities of up to 12 Practical Salinity Units (PSU) despite their distribution appearing to be centered in the LSZ (2 to 4 PSU). Older larvae then appear to undergo reverse diel and tidal vertical migrations to follow prey and maintain their position in the productive parts of the salinity gradient. Longfin smelt's diet is mainly composed of calanoid copepods (*Eurytemora affinis* or *Pseudodiaptomus forbesi*), with larger adults switching to mysid. Densities of both prey categories have been documented as positively correlated with Delta outflow.

7.1 Conceptual Lifecycle Models

An action may affect fish when the change in conditions overlap with the location and timing of fish and/or their habitats. There are no commonly used published peer reviewed conceptual models; therefore, Reclamation analyses are based on the life stages and geographic locations shown in Figure 11.

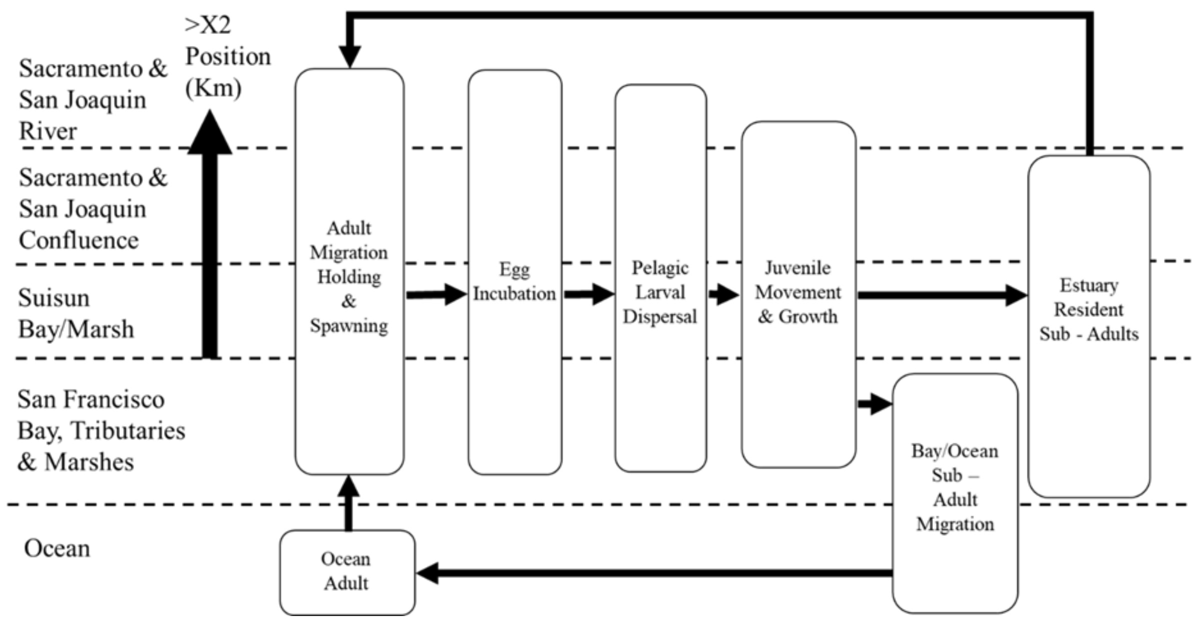

Figure 11. Simplified Geographic Life Stage Domains for longfin smelt

In the absence of a common model, Reclamation drew from recent longfin smelt Species Status Assessment (U.S. Fish and Wildlife Service 2022).

- Adults (little known about ocean life history)
    - Entrainment
    - Freshwater Flow
    - Water Temperature
    - Food Availability
    - Predation

- Toxins
- Eggs & Larvae
    - Entrainment (only Larvae)
    - Freshwater Flow
    - Water Temperature
    - Food Availability
    - Predation
    - Toxins
- Juveniles
    - Entrainment
    - Freshwater Flow
    - Water Temperature
    - Food Availability
    - Predation
    - Toxins

Each deconstruction of the action considers the 23 stressors for the four life stages listed above. Additional and/or alternative information may be incorporated as applicable.

Trawls provide the timing for longfin smelt presence (Figure 12) (Appendix C).

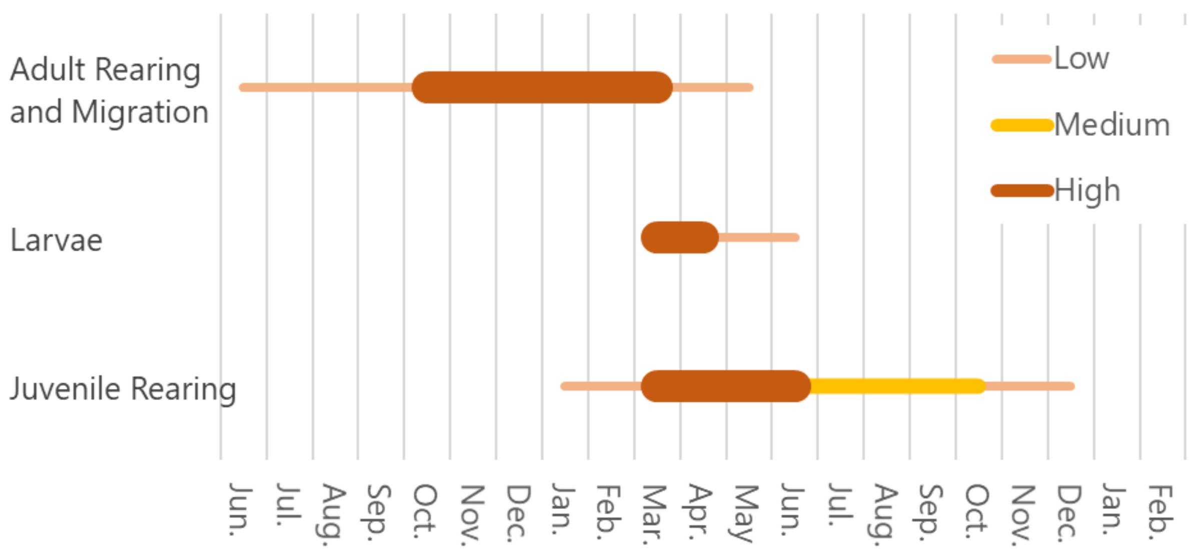

Figure 12. Temporal Life Stage Domains for Longfin Smelt from Appendix C.

Information on larval presence in winter is limited by a lack of survey data until recently. The CDFW smelt larval survey was expanded starting in 2022 to include sampling starting in December and detected larval Longfin smelt in the Delta as early as December 22.

7.2 Species Effects Deconstruction

Longfin smelt adults migrate into the Bay-Delta and Suisun Marsh to spawn, and larval and juvenile longfin migrate to the Bay-Delta to complete their lifecycle. The seasonal operations have little effect on conditions within the Bay-Delta.

7.2.1 Winter

In the winter, Reclamation and DWR's proposed storage, diversion, and export of water will decrease Delta outflow on average. Decreased flows in the Delta may change stressors on longfin smelt.

7.2.1.1 Adults

Adults are present.

Entrainment risk stressors may increase. During the adult migration and spawning period, the Proposed Action will export water from the Delta and lead to the storage and diversion of water, which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP facilities where they may be pulled into diversions or the export facilities when adults move into freshwater regions for spawning; and [2] fish routed through specific migratory pathways in the Delta where they may experience decreased survival. Entrainment of adult longfin Smelt was highest in winter (Grimaldo et al. 2009), when adults move to freshwater regions to spawn. It is predicted that the position of the LSZ within the estuary would relatively predict the extent of adult longfin smelt spawning and, therefore, risk of entrainment (U.S. Fish and Wildlife Service 2022). Entrainment is largely explained by OMR flows (Grimaldo et al. 2009). Entrainment at the export facilities may result in direct mortality (Kimmerer 2008). Entrainment can lead to consistently high rates of pre-screen losses of fish in Clifton Court Forebay due to predation (Castillo et al. 2012). MacWilliams and Gross (2013) demonstrated wind velocity and export rates affected residence time in the forebay and therefore exposure to predation. When fish are entrained into the south Delta, they are exposed to greater predation risk since the invasive aquatic macrophyte, *Egeria densa*, dominates the littoral zone in the south Delta (Durand et al. 2016) and provides habitat for the invasive largemouth bass (Brown and Michniuk 2007) which prey on other fish species. Multiple topic-specific appendices address aspects of adult migration through the Delta.

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

Freshwater flow stressors may increase. During the adult migration and spawning period, the Proposed Action will store and divert water from the Delta and change the size and position of the LSZ. Higher outflow increases connectivity to cooler, low salinity habitat which supports higher spawning effort and success further seaward of the Delta (Grimaldo et al. 2020) and Bay Area tributaries (Lewis et al. 2019). The Proposed Action may also move the LSZ further landward which would reduce the size of the LSZ and suitable spawning habitat for longfin smelt. This may also lead to entrainment of adult longfin smelt, which is discussed in the entrainment stressor. Modeling analyses indicated that freshwater flow had a positive association with the number of recruits per spawner for longfin smelt (Nobriga and Rosenfeld 2016). Appendix J and Appendix K presents analysis.

Water Temperature stressors may increase. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is positively correlated with Delta inflow in the winter (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).

The range of potential reservoir operations 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 and meteorology (Vroom et al. 2017, Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures do not exceed 57.2°F at Prisoner's Point (adult spawning temperature, Wang et al. 1986) in the winter and does exceed 57.2°F in some years in the spring. 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.

Food Availability stressors may increase. During the adult migration and spawning period, the proposed storage and diversion of water associated with the Proposed Action will reduce Delta inflows and outflows. Adult longfin smelt in the San Francisco Estuary feed primarily on mysids (U.S. Fish and Wildlife Service 2022) like other populations of longfin smelt in other regions (Sibley and Chigbu 1994), though they may rely more on copepod prey when mysids are less abundant (Feyrer et al. 2003). Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis* and *Neomysis mercedis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). *Neomysis mercedis* had a higher abundance as X2 was more seaward but since the invasion of the overbite clam, it now has higher abundances when X2 is more landward (Kimmerer 2002), but its abundance remains drastically reduced post-overbite clam invasion (Winder and Jassby 2011, Avila and Hartman 2020). Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix K analyzes the effect of summer and fall food actions on zooplankton abundance in the Delta. Appendix P analyzes zooplankton abundance near different types of habitats.

Predation stressors may increase. The increase or decrease is likely discountable and/or insignificant. During the adult migration and spawning period, the Proposed Action will store and divert water and reduce Delta inflows and outflow. 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 during operations of those that are CVP/SWP facilities, longfin smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Indirect effects of predation are described further in Appendix J – Spring Outflow Action, Appendix K, and Appendix I. Any residual effects of predation associated with the Proposed Action is considered insignificant.

Toxicity stressors may increase. The increase is likely discountable and/or insignificant. Toxins may be mobilized through flooding of agricultural and urban areas; however, the seasonal operation of the CVP does not increase the flooding frequency. CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants. Contaminants have a short half-life and effects likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent.

7.2.1.2 Eggs and Larvae

Eggs and Larvae are present.

Entrainment stressors is not anticipated to change for eggs and may increase for larvae. Eggs are not susceptible to entrainment risk stressors. The proposed diversion of water may increase the entrainment risk stressor during the larval rearing period, the Proposed Action will export water from the Delta and lead to the storage and diversion of water which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009) and [2] fish routed/advected through water ways in the Delta where they may experience decreased survival. Longfin smelt larvae occur in the southern Delta due to adult utilizing spawning habitat in the South Delta resulting in larvae hatching in the region, entrainment into the region via hydrodynamic processes (e.g., negative OMR flows), or a combination of both (California Department of Fish and Game 2009). Entrainment is largely explained by OMR flows (Grimaldo et al. 2009).

Multiple topic-specific appendices address aspects of adult migration through the Delta.

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Freshwater flow stressors may increase for both eggs and larvae. During the larval rearing and migration period, the Proposed Action will store and divert water from the Delta and decrease the size and position of the LSZ. Young of the year longfin smelt tend to aggregate in the LSZ (Dege and Brown 2004). Longfin smelt may benefit when the LSZ coincides with the increased shallow water and marsh habitats in Suisun Bay, by allowing early-stage longfin smelt to maintain horizontal position and access food resources in higher quality habitat (Hobbs et al. 2006, Grimaldo et al. 2017). Increased freshwater flow also increases turbidity which can benefit longfin smelt by making them less visible to predators (Ferrari et al. 2014) and improve foraging efficiency (Hasenbein et al. 2013). Longfin smelt abundance is positively correlated with freshwater flow and the average position of X2 (Jassby et al. 1995, Kimmerer 2002, Kimmerer et al. 2009, Thomson et al. 2010, U.S. Fish and Wildlife Service 2022). The mechanism behind X2/freshwater flow and longfin smelt abundance may not only be related to salinity but could also be related to more dynamic aspects such as retention by estuarine circulation or transport to rearing areas (Kimmerer et al. 2013). Appendix J and Appendix K presents analysis.

Water Temperature stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and 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).

The range of potential reservoir operations 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 and meteorology (Vroom et al. 2017, Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures do not exceed 59°F at Prisoner's Point (temperature at which detrimental effects on larvae and embryo rearing were observed, Yanagitsuru et al. 2021) in the winter. Water temperature does exceed 59°F in some years in the spring. However, 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.

Food Availability stressors is not anticipated to change for eggs and may increase for larvae. During the larval rearing the proposed storage and diversion of water associated with the Proposed Action will reduce Delta inflows and outflows. Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis* and *Neomysis mercedis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). Larval longfin smelt (< 18 mm) prey primarily on calanoid copepods such as *Eurytemora affinis* (Barros et al. 2022). Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix P analyzes zooplankton abundance near different types of habitats.

Predation stressors may increase. The increase is likely discountable and/or insignificant. During the larval rearing and migration period, the Proposed Action will store and divert water and reduce Delta inflows and outflow. 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 during operations of those that are CVP/SWP facilities, longfin smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Indirect effects of predation are described further in Appendix J – Spring Outflow Action, Appendix K, and Appendix I. Any residual effects of predation associated with the Proposed Action is considered insignificant.

Toxicity stressors may increase. The increase is likely discountable and/or insignificant. During the larval life stage, toxins may be mobilized through flooding of agricultural and urban areas; however, the seasonal operation of the CVP does not increase the flooding frequency. CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).

CVP and SWP storage and diversion of water decreases Delta inflow, limiting the potential for dilution of contaminants. In the Delta, the potential for dilution of contaminants depends on sampling location (Stillway et al. 2021). Contaminants are likely local and have little response to CVP and SWP flows (Werner et al. 2010).

7.2.1.3 Juveniles Rearing and Migration

Juveniles are present in the Bay-Delta. Juveniles are rearing in the estuary, and their growth and survival is hypothesized to largely depend on quality, quantity, and availability of resources.

Entrainment risk stressors may increase. The proposed diversion of water may increase the entrainment risk stressor. During the juvenile rearing and migration period, Proposed Action will export water from the Delta and lead to the storage and diversion of water which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009) and [2] fish routed/advected through water ways in the Delta where they may experience decreased survival. Grimaldo et al. (2009) found OMR flow was the only variable that explained interannual salvage abundance for age-0 longfin smelt. Salvage of age-0 fish peaked in April – May (Grimaldo et al. 2009).

Multiple topic-specific appendices address aspects of adult migration through the Delta.

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Freshwater flow stressors may increase. CVP and SWP operations during the winter may reduce the size of the Low Salinity Zone at times and shift X2 eastward reducing access to suitable habitat. This reduces overlap with larger shoal and marsh habitats, and lower water velocities may reduce connectivity with higher habitat (Hobbs et al. 2006 and Grimaldo et al. 2017). Longfin smelt abundance is positively correlated with freshwater flow and the average position of X2 (Jassby et al. 1995, Kimmerer 2002, Kimmerer et al. 2009, Thomson et al. 2010, U.S. Fish and Wildlife Service 2022). The mechanism behind X2/freshwater flow and longfin smelt abundance may not only be related to salinity but could also be related to more dynamic aspects such as retention by estuarine circulation or transport to rearing areas (Kimmerer et al. 2013). Appendix J and Appendix K discuss this stressor in greater detail.

Water Temperature stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and 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 Bay-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 historical water temperatures do not exceed 68°F at Prisoner's Point (juvenile cellular stress response, Jeffries et al. 2016) in the early spring. There is uncertainty about whether the decreased inflow from reservoir operations would lead to increased Delta water temperatures; however, the correlations include wet years with flood operations. 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.

Food Availability stressors may increase. During the juvenile rearing and migration period the storage and diversion of water will reduce Delta inflows and outflows. Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis* and *Neomysis mercedis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). Larval longfin smelt (< 18 mm) prey primarily on calanoid copepods such as *Eurytemora affinis* and transition to feeding on larger mysids as they grow (> 25 mm) (Barros et al. 2022). Lojkovic-Burris et al. (2022) found longfin smelt fed on calanoid copepod prey when mysids were not readily available. Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix P analyzes zooplankton abundance near different types of habitats.

Predation stressors may increase. During the juvenile rearing and migration period, the Proposed Action will store and divert water and reduce Delta inflows and outflow. 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 during operations of those that are CVP/SWP facilities, longfin smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Indirect effects of predation are described further in Appendix J – Spring Outflow Action, Appendix K, and Appendix I. Any residual effects of predation associated with the Proposed Action are considered insignificant.

Toxicity stressors may increase. The increase is likely discountable and/or insignificant. Toxins may be mobilized through flooding of agricultural and urban areas; however, the seasonal operation of the CVP does not increase the flooding frequency. CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants. Contaminants have a short half-life and effects likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent.

7.2.2 Spring

In the spring, Reclamation and DWR’s proposed storage, diversion, and exports of water will decrease Delta outflow on average. Decreased flows in the Bay-Delta may change stressors on longfin smelt.

7.2.2.1 Adults

Adults are present.

Entrainment stressors may increase. During the adult migration and spawning period, the Proposed Action will export water from the Delta and lead to the storage and diversion of water, which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP facilities where they may be pulled into diversions or the export facilities when adults move into freshwater regions for spawning; and [2] fish routed through specific migratory pathways in the Delta where they may experience decreased survival. Entrainment of adult longfin Smelt was highest in winter (Grimaldo et al. 2009), when adults move to freshwater regions to spawn. It is predicted that the position of the LSZ within the estuary would relatively predict the extent of adult longfin smelt spawning and, therefore, risk of entrainment (U.S. Fish and Wildlife Service 2022). Entrainment is largely explained by OMR flows (Grimaldo et al. 2009). Entrainment at the export facilities may result in direct mortality (Kimmerer 2008). Entrainment can lead to consistently high rates of pre-screen losses of fish in CCF due to predation (Castillo et al. 2012). MacWilliams and Gross (2013) demonstrated wind velocity and export rates affected residence time in the forebay and therefore exposure to predation. When fish are entrained into the south

Delta, they are exposed to greater predation risk since the invasive aquatic macrophyte, *Egeria densa*, dominates the littoral zone in the south Delta (Durand et al. 2016) and provides habitat for the invasive largemouth bass (Brown and Michniuk 2007) which prey on other fish species. Multiple topic-specific appendices address aspects of adult migration through the Delta.

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Freshwater flow stressors may increase. During the adult migration and spawning period, the Proposed Action will store and divert water from the Delta and change the size and position of the LSZ. Higher outflow increases connectivity to cooler, low salinity habitat which supports higher spawning effort and success further seaward of the Delta (Grimaldo et al. 2020) and Bay Area tributaries (Lewis et al. 2019). The Proposed Action may also move the LSZ further landward which would reduce the size of the LSZ and suitable spawning habitat for longfin smelt. This may also lead to entrainment of adult longfin smelt, which is discussed in the entrainment stressor. Modeling analyses indicated that freshwater flow had a positive association with the number of recruits per spawner for longfin smelt (Nobriga and Rosenfeld 2016). Appendix J and Appendix K presents analysis.

Water Temperature stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is positively correlated with Delta inflow in the winter and 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).

The range of potential reservoir operations 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 and meteorology (Vroom et al. 2017, Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures do not exceed 57.2°F at Prisoner’s Point (adult spawning temperature, Wang et al. 1986) in the winter and does exceed 57.2°F in some years in the spring. 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.

Food Availability stressors may increase. During the adult migration and spawning period, the proposed storage and diversion of water associated with the Proposed Action will reduce Delta inflows and outflows. Adult longfin smelt in the San Francisco Estuary feed primarily on mysids (U.S. Fish and Wildlife Service 2022) like other populations of longfin smelt in other regions (Sibley and Chigbu 1994), though they may rely more on copepod prey when mysids are less abundant (Feyrer et al. 2003). Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis* and *Neomysis mercedis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). *Neomysis mercedis* had a higher abundance as X2 was more seaward but since the invasion of the overbite clam, it now has higher abundances when X2 is more landward (Kimmerer 2002), but its abundance remains drastically reduced post-overbite clam invasion (Winder and Jassby 2011, Avila and Hartman 2020). Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix K analyzes the effect of summer and fall food actions on zooplankton abundance in the Delta. Appendix P analyzes zooplankton abundance near different types of habitats.

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Toxicity stressors may increase. The increase is likely discountable and/or insignificant. During the adult life stage, toxins may be mobilized through flooding of agricultural and urban areas; however, the seasonal operation of the CVP does not increase the flooding frequency. In the Delta, the potential for dilution of contaminants depends on sampling location (Stillway et al. 2021). Contaminants are likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).

7.2.2.2 Eggs and Larvae

Eggs and Larvae are present.

Entrainment stressors are not anticipated to change for eggs and may increase for larvae. Eggs are not susceptible to entrainment risk stressors. The proposed diversion of water may increase the entrainment risk stressor during the larval rearing period, the Proposed Action will export water from the Delta and lead to the storage and diversion of water which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al.

2009) and [2] fish routed/advected through water ways in the Delta where they may experience decreased survival. Longfin smelt larvae occur in the southern Delta due to adult utilizing spawning habitat in the South Delta resulting in larvae hatching in the region, entrainment into the region via hydrodynamic processes (e.g., negative OMR flows), or a combination of both (California Department of Fish and Game 2009). Entrainment is largely explained by OMR flows (Grimaldo et al. 2009).

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Freshwater flow stressors may increase for both eggs and larvae. During the larval rearing and migration period, the Proposed Action will store and divert water from the Delta and decrease the size and position of the LSZ. Young of the year longfin smelt tend to aggregate in the LSZ (Dege and Brown 2004). Longfin smelt may benefit when the LSZ coincides with the increased shallow water and marsh habitats in Suisun Bay, by allowing early-stage longfin smelt to maintain horizontal position and access food resources in higher quality habitat (Hobbs et al. 2006, Grimaldo et al. 2017). Increased freshwater flow also increases turbidity which can benefit longfin smelt by making them less visible to predators (Ferrari et al. 2014) and improve foraging efficiency (Hasenbein et al. 2013). Longfin smelt abundance is positively correlated with freshwater flow and the average position of X2 (Jassby et al. 1995, Kimmerer 2002, Kimmerer et al. 2009, Thomson et al. 2010, U.S. Fish and Wildlife Service 2022). The mechanism behind X2/freshwater flow and longfin smelt abundance may not only be related to salinity but could also be related to more dynamic aspects such as retention by estuarine circulation or transport to rearing areas (Kimmerer et al. 2013). Appendix J and Appendix K presents analysis.

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Food Availability stressors may increase for larvae. During the larval rearing the proposed storage and diversion of water associated with the Proposed Action will reduce Delta inflows and outflows. Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including Eurytemora affinis and Neomysis mercedis, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). Larval longfin smelt (< 18 mm) prey primarily on calanoid copepods such as Eurytemora affinis (Barros et al. 2022). Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix P analyzes zooplankton abundance near different types of habitats.

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CVP and SWP storage and diversion of water decreases Delta inflow, limiting the potential for dilution of contaminants. In the Delta, the potential for dilution of contaminants depends on sampling location (Stillway et al. 2021). Contaminants are likely local and have little response to CVP and SWP flows (Werner et al. 2010).

7.2.2.3 Juveniles Rearing and Migration

Juveniles are present.

Entrainment risk stressors may increase The proposed diversion of water may increase the entrainment risk stressor. During the juvenile rearing and migration period, Proposed Action will export water from the Delta and lead to the storage and diversion of water which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009) and [2] fish routed/advected through water ways in the Delta where they may experience decreased survival. Grimaldo et al. (2009) found OMR flow was the only variable that explained interannual salvage abundance for age-0 longfin smelt. Salvage of age-0 fish peaked in April – May (Grimaldo et al. 2009).

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Freshwater flow stressors may increase. CVP and SWP operations during the winter may reduce the size of the Low Salinity Zone at times and shift X2 eastward reducing access to suitable habitat. This reduces overlap with larger shoal and marsh habitats, and lower water velocities may reduce connectivity with higher habitat (Hobbs et al. 2006 and Grimaldo et al. 2017). Longfin smelt abundance is positively correlated with freshwater flow and the average position of X2 (Jassby et al. 1995, Kimmerer 2002, Kimmerer et al. 2009, Thomson et al. 2010, U.S. Fish and Wildlife Service 2022). The mechanism behind X2/freshwater flow and longfin smelt abundance may not only be related to salinity but could also be related to more dynamic aspects such as retention by estuarine circulation or transport to rearing areas (Kimmerer et al. 2013). Appendix J and Appendix K discuss this stressor in greater detail.

Water Temperature stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and 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 Bay-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 historical water temperatures do not exceed 68°F at Prisoner's Point (juvenile cellular stress response, Jeffries et al. 2016) in the early spring. There is uncertainty about whether the decreased inflow from reservoir operations would lead to increased Delta water temperatures; however, the correlations include wet years with flood operations. 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.

Food Availability stressors may increase. During the juvenile rearing and migration period the storage and diversion of water will reduce Delta inflows and outflows. Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis* and *Neomysis mercedis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). Larval longfin smelt (< 18 mm) prey primarily on calanoid copepods such as *Eurytemora affinis* and transition to feeding on larger mysids as they grow (> 25 mm) (Barros et al. 2022). Lojkovic-Burris et al. (2022) found longfin smelt fed on calanoid copepod prey when mysids were not readily available. Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix P analyzes zooplankton abundance near different types of habitats.

Predation stressors may increase. The increase is likely discountable and/or insignificant. During the juvenile rearing and migration period, the Proposed Action will store and divert water and reduce Delta inflows and outflow. 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 during operations of those that are CVP/SWP facilities, longfin smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Indirect effects of predation are described further in Appendix J – Spring Outflow Action, Appendix K, and Appendix I. Any residual effects of predation associated with the Proposed Action are considered insignificant.

Toxicity stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants. Contaminants have a short half-life and effects likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent.

7.2.3 Summer

In the summer, Reclamation and DWR’s proposed release and export of water will decrease Delta outflow on average. Decreased flows in the Bay-Delta may change stressors on longfin smelt.

7.2.3.1 Adults

Adults may be present. Longfin smelt are semelparous and die after spawning. During some years, adults are present in the North Delta and Suisun Bay region during the early summer (Appendix C).

Entrainment stressors may increase. During the adult migration and spawning period, the Proposed Action will export water from the Delta and lead to the storage and diversion of water, which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP facilities where they may be pulled into diversions or the export facilities when adults move into freshwater regions for spawning; and [2] fish routed through specific migratory pathways in the Delta where they may experience decreased survival. Entrainment of adult longfin Smelt was highest in winter (Grimaldo et al. 2009), when adults move to freshwater regions to spawn. It is predicted that the position of the LSZ within the estuary would relatively predict the extent of adult longfin smelt spawning and, therefore, risk of entrainment (U.S. Fish and Wildlife Service 2022). Entrainment is largely explained by OMR flows (Grimaldo et al. 2009). Entrainment at the export facilities may result in direct mortality (Kimmerer 2008). Entrainment can lead to consistently high rates of pre-screen losses of fish in CCF due to predation (Castillo et al. 2012). MacWilliams and Gross (2013) demonstrated wind velocity and export rates affected residence time in the forebay and therefore exposure to predation. When fish are entrained into the south Delta, they are exposed to greater predation risk since the invasive aquatic macrophyte, *Egeria densa*, dominates the littoral zone in the south Delta (Durand et al. 2016) and provides habitat for the invasive largemouth bass (Brown and Michniuk 2007) which prey on other fish species. Multiple topic-specific appendices address aspects of adult migration through the Delta.

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

Freshwater flow stressors may increase. During the adult migration and spawning period, the Proposed Action will store and divert water from the Delta and change the size and position of the LSZ. Higher outflow increases connectivity to cooler, low salinity habitat which supports higher spawning effort and success further seaward of the Delta (Grimaldo et al. 2020) and Bay Area tributaries (Lewis et al. 2019). The Proposed Action may also move the LSZ further landward which would reduce the size of the LSZ and suitable spawning habitat for longfin smelt. This may also lead to entrainment of adult longfin smelt, which is discussed in the entrainment stressor. Modeling analyses indicated that freshwater flow had a positive association with the number of recruits per spawner for longfin smelt (Nobriga and Rosenfeld 2016). Appendix J and Appendix K presents analysis. **Water Temperature stressors** may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is positively correlated with Delta inflow in the winter and 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).

The range of potential reservoir operations 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 and meteorology (Vroom et al. 2017, Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures do not exceed 57.2°F at Prisoner’s Point (adult spawning temperature, Wang et al. 1986) in the winter and does exceed 57.2°F in some years in the spring. 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.

Food Availability stressors may increase. During the adult migration and spawning period, the proposed storage and diversion of water associated with the Proposed Action will reduce Delta inflows and outflows. Adult longfin smelt in the San Francisco Estuary feed primarily on mysids (U.S. Fish and Wildlife Service 2022) like other populations of longfin smelt in other regions (Sibley and Chigbu 1994), though they may rely more on copepod prey when mysids are less abundant (Feyrer et al. 2003). Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis* and *Neomysis mercedis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). *Neomysis mercedis* had a higher abundance as X2 was more seaward but since the invasion of the overbite clam, it now has higher abundances when X2 is more landward (Kimmerer 2002), but its abundance remains drastically reduced post-overbite clam invasion (Winder and Jassby 2011, Avila and Hartman 2020). Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix K analyzes the effect of summer and fall food actions on zooplankton abundance in the Delta. Appendix P analyzes zooplankton abundance near different types of habitats.

Predation stressors may increase. The increase is likely discountable and/or insignificant. During the adult migration and spawning period, the Proposed Action will store and divert water and reduce Delta inflows and outflow. 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 during operations of those that are CVP/SWP facilities, longfin smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Indirect effects of predation are described further in Appendix J – Spring Outflow Action, Appendix K, and Appendix I. Any residual effects of predation associated with the Proposed Action is considered insignificant.

Toxicity stressors may increase. The increase is likely discountable and/or insignificant. During the adult life stage, toxins may be mobilized through flooding of agricultural and urban areas; however, the seasonal operation of the CVP does not increase the flooding frequency. In the Delta, the potential for dilution of contaminants depends on sampling location (Stillway et al. 2021). Contaminants are likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).

7.2.3.2 Eggs and Larvae

Eggs are not present. Larvae are present.

Entrainment stressors is not anticipated to change for eggs and may increase for larvae. Eggs are not susceptible to entrainment risk stressors. The proposed diversion of water may increase the entrainment risk stressor during the larval rearing period, the Proposed Action will export water from the Delta and lead to the storage and diversion of water which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009) and [2] fish routed/advected through water ways in the Delta where they may experience decreased survival. Longfin smelt larvae occur in the southern Delta due to adult utilizing spawning habitat in the South Delta resulting in larvae hatching in the region, entrainment into the region via hydrodynamic processes (e.g., negative OMR flows), or a combination of both (California Department of Fish and Game 2009). Entrainment is largely explained by OMR flows (Grimaldo et al. 2009).

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Freshwater flow stressors may increase. During the larval rearing and migration period, the Proposed Action will store and divert water from the Delta and decrease the size and position of the LSZ. Young of the year longfin smelt tend to aggregate in the LSZ (Dege and Brown 2004). Longfin smelt may benefit when the LSZ coincides with the increased shallow water and marsh habitats in Suisun Bay, by allowing early-stage longfin smelt to maintain horizontal position and access food resources in higher quality habitat (Hobbs et al. 2006, Grimaldo et al. 2017). Increased freshwater flow also increases turbidity which can benefit longfin smelt by making them less visible to predators (Ferrari et al. 2014) and improve foraging efficiency (Hasenbein et al. 2013). Longfin smelt abundance is positively correlated with freshwater flow and the average position of X2 (Jassby et al. 1995, Kimmerer 2002, Kimmerer et al. 2009, Thomson et al. 2010, U.S. Fish and Wildlife Service 2022). The mechanism behind X2/freshwater flow and longfin smelt abundance may not only be related to salinity but could also be related to more dynamic aspects such as retention by estuarine circulation or transport to rearing areas (Kimmerer et al. 2013). Appendix J and Appendix K presents analysis.

Water Temperature stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and 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).

The range of potential reservoir operations 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 and meteorology (Vroom et al. 2017, Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures do not exceed 59°F at Prisoner's Point (temperature at which detrimental effects on larvae and embryo rearing were observed, Yanagitsuru et al. 2021) in the winter. Water temperature does exceed 59°F in some years in the spring. However, 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.

Food Availability stressors may increase. During the larval rearing the proposed storage and diversion of water associated with the Proposed Action will reduce Delta inflows and outflows. Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis* and *Neomysis mercedis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). Larval longfin smelt (< 18 mm) prey primarily on calanoid copepods such as *Eurytemora affinis* (Barros et al. 2022). Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix P analyzes zooplankton abundance near different types of habitats.

Predation stressors may increase. During the larval rearing and migration period, the Proposed Action will store and divert water and reduce Delta inflows and outflow. 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 during operations of those that are CVP/SWP facilities, longfin smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Indirect effects of predation are described further in Appendix J – Spring Outflow Action, Appendix K, and Appendix I. Any residual effects of predation associated with the Proposed Action is considered insignificant.

Toxicity stressors may increase and/or decrease. The increase and decrease is likely discountable and/or insignificant. Delta outflow in the summer is sometimes greater and sometimes less than outflow under environmental baseline conditions. CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants. Contaminants have a short half-life and effects likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).

CVP and SWP storage and diversion of water decreases Delta inflow, limiting the potential for dilution of contaminants. In the Delta, the potential for dilution of contaminants depends on sampling location (Stillway et al. 2021). Contaminants are likely local and have little response to CVP and SWP flows (Werner et al. 2010).

7.2.3.3 Juveniles Rearing and Migration

Juveniles and Sub-adults are present. While a majority of juveniles migrate to the ocean, some remain in the SFE.

Entrainment risk stressors may increase. During the juvenile rearing and migration period, Proposed Action will export water from the Delta and lead to the storage and diversion of water which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009) and [2] fish routed/advected through water ways in the Delta where they may experience decreased survival. Grimaldo et al. (2009) found OMR flow was the only variable that explained interannual salvage abundance for age-0 longfin smelt. Salvage of age-0 fish peaked in April – May (Grimaldo et al. 2009).

Multiple topic-specific appendices address aspects of adult migration through the Delta.

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Freshwater flow stressors may increase and/or decrease. CVP and SWP operations during the summer may reduce the size of the low salinity zone at times and shift X2 eastward reducing juvenile rearing habitat. CVP and SWP operations that reduce the size of the Low Salinity Zone and shift X2 eastward reduce access to suitable habitat, reducing access to high quality nursery habitat as a result (Grimaldo et al. 2020, Lewis et al. 2019). Appendix J and Appendix K presents analysis.

Water Temperature stressors may increase and/or decrease. The increase and/or decrease is likely discountable and/or insignificant. Delta outflow in the summer is sometimes greater and sometimes less than outflow under environmental baseline conditions. Delta water temperature is negatively correlated with Delta inflow (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). Inflow is largely controlled by operations during the summer and fall due to lower contributions from precipitation and snowmelt. However, in the Bay-Delta water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the increased summer inflow is a cause for decreased Delta water temperatures.

Food Availability stressors may increase and/or decrease. Changes to reservoir releases and diversion change the rate of Delta outflow. Delta outflow in the summer is sometimes greater and sometimes less than outflow under environmental baseline conditions. There is evidence for a negative relationship between outflow and mysid abundance in the summer (Kimmerer 2002) however mysid abundance has drastically declined since the introduction of the overbite clam (Winder and Jassby 2011). Lojkovic-Burris et al. (2022) found longfin smelt fed on calanoid copepod prey when mysids were not readily available. Abundances of historically important Delta smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). There is evidence for a negative relationship between outflow and mysid abundance in the summer (Kimmerer 2002). Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix P analyzes zooplankton abundance near different types of habitats.

Predation stressors may increase. The increase or decrease is likely discountable and/or insignificant. During the juvenile rearing and migration period, the Proposed Action will store and divert water and reduce Delta inflows and outflow. 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 during operations of those that are CVP/SWP facilities, longfin smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Indirect effects of predation are described further in Appendix J – Spring Outflow Action, Appendix K, and Appendix I. Any residual effects of predation associated with the Proposed Action are considered insignificant.

Toxicity stressors may increase. The increase is likely discountable and/or insignificant. Toxins may be mobilized through flooding of agricultural and urban areas; however, the seasonal operation of the CVP does not increase the flooding frequency. CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants. Contaminants have a short half-life and effects are likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).

7.2.4 Fall

In the fall, Reclamation and DWR's proposed release and export of water will decrease Delta outflow on average. Decreased flows in the Bay-Delta may change stressors on longfin smelt.

7.2.4.1 Adults

Adults are present.

Entrainment risk stressors may increase. During the adult migration and spawning period, the Proposed Action will export water from the Delta and lead to the storage and diversion of water, which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP facilities where they may be pulled into diversions or the export facilities when adults move into freshwater regions for spawning; and [2] fish routed through specific migratory pathways in the Delta where they may experience decreased survival. Entrainment of adult longfin Smelt was highest in winter (Grimaldo et al. 2009), when adults move to freshwater regions to spawn. It is predicted that the position of the LSZ within the estuary would relatively predict the extent of adult longfin smelt spawning and, therefore, risk of entrainment (U.S. Fish and Wildlife Service 2022). Entrainment is largely explained by OMR flows (Grimaldo et al. 2009). Entrainment at the export facilities may result in direct mortality (Kimmerer 2008). Entrainment can lead to consistently high rates of pre-screen losses of fish in CCF due to predation (Castillo et al. 2012). MacWilliams and Gross (2013) demonstrated wind velocity and export rates affected residence time in the forebay and therefore exposure to predation. When fish are entrained into the south Delta, they are exposed to greater predation risk since the invasive aquatic macrophyte, *Egeria densa*, dominates the littoral zone in the south Delta (Durand et al. 2016) and provides habitat for the invasive largemouth bass (Brown and Michniuk 2007) which prey on other fish species. Multiple topic-specific appendices address aspects of adult migration through the Delta.

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Freshwater flow stressors may increase. During the adult migration and spawning period, the Proposed Action will store and divert water from the Delta and change the size and position of the LSZ. Higher outflow increases connectivity to cooler, low salinity habitat which supports higher spawning effort and success further seaward of the Delta (Grimaldo et al. 2020) and Bay Area tributaries (Lewis et al. 2019). The Proposed Action may also move the LSZ further landward which would reduce the size of the LSZ and suitable spawning habitat for longfin smelt. This may also lead to entrainment of adult longfin smelt, which is discussed in the entrainment stressor. Modeling analyses indicated that freshwater flow had a positive association with the number of recruits per spawner for longfin smelt (Nobriga and Rosenfeld 2016). Appendix J and Appendix K presents analysis.

Water temperature stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion decreases Delta inflow. Delta water temperature is positively correlated with Delta inflow in the winter and 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).

The range of potential reservoir operations 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 and meteorology (Vroom et al. 2017, Daniels and Danner 2020). While there is uncertainty about whether the decreased inflow due to American River operations is a cause for changes in Delta water temperatures, historical water temperatures do not exceed 57.2°F at Prisoner's Point (adult spawning temperature, Wang et al. 1986) in the winter and does exceed 57.2°F in some years in the spring. 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.

Food Availability stressors may increase. During the adult migration and spawning period, the proposed storage and diversion of water associated with the Proposed Action will reduce Delta inflows and outflows. Adult longfin smelt in the San Francisco Estuary feed primarily on mysids (U.S. Fish and Wildlife Service 2022) like other populations of longfin smelt in other regions (Sibley and Chigbu 1994), though they may rely more on copepod prey when mysids are less abundant (Feyrer et al. 2003). Abundances of historically important longfin smelt zooplankton prey taxa in the LSZ, including *Eurytemora affinis* and *Neomysis mercedis*, generally exhibit a positive correlation with Delta outflow (Kimmerer 2002). *Neomysis mercedis* had a higher abundance as X2 was more seaward but since the invasion of the overbite clam, it now has higher abundances when X2 is more landward (Kimmerer 2002), but its abundance remains drastically reduced post-overbite clam invasion (Winder and Jassby 2011, Avila and Hartman 2020). Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix K analyzes the effect of summer and fall food actions on zooplankton abundance in the Delta. Appendix P analyzes zooplankton abundance near different types of habitats.

Predation stressors may increase. The increase is likely discountable and/or insignificant. During the adult migration and spawning period, the Proposed Action will store and divert water and reduce Delta inflows and outflow. 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 during operations of those that are CVP/SWP facilities, longfin smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Indirect effects of predation are described further in Appendix J, Appendix K, and Appendix I. Any residual effects of predation associated with the Proposed Action is considered insignificant.

Toxicity stressors may increase. The increase is likely discountable and/or insignificant. During the adult life stage, toxins may be mobilized through flooding of agricultural and urban areas; however, the seasonal operation of the CVP does not increase the flooding frequency. In the Delta, the potential for dilution of contaminants depends on sampling location (Stillway et al. 2021). Contaminants are likely local and have little response to CVP and SWP flows (Werner et al. 2010). CVP and SWP operations are not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).

7.2.4.2 Eggs and Larvae

Eggs and Larvae are not present in the fall.

7.2.4.3 Juveniles Rearing and Migration

Juveniles are present.

Entrainment risk stressors may increase. During the juvenile rearing and migration period, Proposed Action will export water from the Delta and lead to the storage and diversion of water which will reduce Delta inflows and outflows. OMR flows towards the central and south Delta will also increase. Entrainment is discussed in two ways: [1] fish encountering CVP and SWP facilities where they may be pulled into diversions or the export facilities as they follow net flows (Grimaldo et al. 2009) and [2] fish routed/advected through water ways in the Delta where they may experience decreased survival. Grimaldo et al. (2009) found OMR flow was the only variable that explained interannual salvage abundance for age-0 longfin smelt. Salvage of age-0 fish peaked in April – May (Grimaldo et al. 2009).

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- Appendix I presents analysis of "Old and Middle River Management" and "Delta Cross Channel Closure" conservation measures

Freshwater flow stressors may increase or decrease. The increase or decrease is likely discountable and/or insignificant. CVP and SWP storage and diversion of water increase Delta inflow in early fall and decrease inflow in late fall compared to the environmental baseline. CVP and SWP operations that reduce the size of the Low Salinity Zone and shift X2 eastward reduce access to suitable habitat, reducing access to high quality nursery habitat as a result (Grimaldo et al. 2020, Lewis et al. 2019). Appendix J and Appendix K presents analysis.

Water Temperature stressors may increase or may decrease. The increase or decrease is likely discountable and/or insignificant. CVP and SWP storage and diversion of water increase Delta inflow in early fall and decrease inflow in late fall compared to the environmental baseline. Delta water temperature is negatively correlated with Delta inflow (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). Inflow is largely controlled by operations during the summer and fall due to lower contributions from precipitation and snowmelt. However, in the Bay-Delta water temperature is mainly driven by air temperature and meteorology (Vroom et al. 2017, Daniels and Danner 2020). There is uncertainty about whether the increased fall inflow is a cause for increased or decreased Delta water temperatures. 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.

Food Availability stressors may increase or decrease. Delta outflow in the fall is sometimes greater and sometimes less than outflow under environmental baseline conditions. Mysid abundance has drastically declined since the introduction of the overbite clam (Winder and Jassby 2011). Lojkovic-Burris et al. (2022) found longfin smelt fed on calanoid copepod prey when mysids were not readily available. Increased Delta inflows may increase critical allochthonous subsidies of alternate longfin smelt food resources (e.g., *Pseudodiaptomus forbesi*) through advection from more productive upstream areas to rearing habitats where local zooplankton productivity is severely impacted by competition with clams (Kimmerer et al. 2019, Hassrick et al. 2023) and limits subsidies when inflow is lower when compared to environmental baseline. Appendix J analyzes the effect of Spring Delta Outflow on food resources for native fishes. Appendix P analyzes zooplankton abundance near different types of habitats.

Predation stressors may increase. The increase is likely discountable and/or insignificant. CVP and SWP storage and diversion of water increase Delta inflow in early fall and decrease inflow in late fall compared to the environmental baseline. 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 during operations of those that are CVP/SWP facilities, longfin smelt 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 is widespread and exacerbated by disruption of habitat from land use and invasive aquatic vegetation, climate change, and altered predator dynamics from well-established invasive piscivorous non-native fish such as striped bass, largemouth bass and Mississippi silversides. Predation rates are a function of correlated variables such as predator presence, prey vulnerability, and environmental conditions (Grossman et al. 2013; Grossman 2016). Reduced turbidity from the Proposed Action can also increase predation risk (Ferrari et al. 2013, Schreier et al. 2016). Higher temperatures increase metabolic demands of fish which may cause longfin smelt to increase time spent foraging and exposure to predators. Effects of the Proposed Action on water temperature and food visibility that may interact with the predation stressor were analyzed in those sections. Indirect effects of predation are described further in Appendix J – Spring Outflow Action, Appendix K, and Appendix I. Any residual effects of predation associated with the Proposed Action are considered insignificant.

Toxicity stressors may increase or decrease. The decrease and increase are likely discountable and/or insignificant. CVP and SWP storage and diversion of water decreases Delta inflow and outflow limiting the potential for dilution of contaminants. Contaminants have a short half-life and effects likely local and have little response to CVP and SWP flows (Werner et al. 2010).

CVP and SWP operations is not a proximate cause of contaminants mobilized from the watershed, agricultural lands, and urban effluent (Guo et al. 2010).

7.3 Species Effects Determination

The seasonal operations of the CVP and SWP may affect and is likely to adversely affect longfin smelt. The seasonal operations of the CVP is likely to have beneficial effects. Deconstruction of the seasonal operations systematically evaluated each stressor identified by conceptual models. Stressors not linked to the operation of the CVP and SWP were identified as "are not anticipated to change." Stressors that were insignificant or discountable were documented above. Stressors with a material effect on the fitness of species were identified, and the seasonal operations incorporate minimization and/or compensation through conservation measures.

Stressors on adults influenced by the seasonal operations include:

- Entrainment risk may increase from export operations because of migratory patterns. Adverse effects are minimized by implementing real time OMR management.
- Salinity stressors will increase as the low-salinity zone is shifted eastward from decreased Delta outflow. Adverse effects are minimized by implementing Spring Delta Outflow and Summer Fall Habitat Action.
- Food availability: May be reduced from decreased net Delta outflows on average resulting from seasonal operations. Adverse effects are minimized by increasing food availability through tidal habitat restoration and Summer Fall Habitat Action.

Stressors on eggs and larvae influenced by the seasonal operations include:

- Entrainment (only Larvae) risk and transport direction risk may increase from decreased inflows to the Delta on average. Adverse effects are minimized by implementing real time OMR management.
- Salinity stressors will increase as the low-salinity zone is shifted eastward from decreased Delta outflow. Adverse effects are minimized by implementing Spring Delta Outflow and Summer Fall Habitat Action.
- Food availability: May be reduced from decreased net Delta outflows on average resulting from seasonal operations. Adverse effects are minimized by increasing food availability through tidal habitat restoration and Summer Fall Habitat Action.

Stressors on juveniles influenced by the seasonal operations include:

- Entrainment risk and transport direction: May increase from export operations. Adverse effects are minimized by implementing real time OMR management.
- Salinity stressors will increase as the low-salinity zone is shifted eastward from decreased Delta outflow. Adverse effects are minimized by implementing Spring Delta Outflow and Summer Fall Habitat Action.

- Food availability: May be reduced from decreased net Delta outflows on average resulting from seasonal operations. Adverse effects are minimized by increasing food availability through tidal habitat restoration and Summer Fall Habitat Action.

7.4 Critical Habitat Physical and Biological Features

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7.5 Critical Habitat Effect Determination

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8 Southern Resident Killer Whales

Southern resident killer whales, *Orcinus orca*, are a population of fish-eating killer whales found in the coastal waters of the northeastern Pacific Ocean from Haida Gwaii, Canada to Monterey Bay, California.

8.1 Conceptual Lifecycle Models

The southern resident killer whales (*Orcinus orca*) are known to occur frequently in the outer coastal waters (within ~50 km of shore) and inland waters of Washington, USA, and British Columbia, Canada, down the West coast of the United States to the coastal waters off California. Southern resident killer whales forage on fish. Chinook salmon are their preferred prey; however, they will eat other salmonids, some groundfish, and, rarely, other types of fish and cephalopods (Hanson et al. 2021). They tend to diversify their diet more in the wintertime to include steelhead, chum, lingcod and halibut but Chinook salmon remain their preferred prey when available (Hanson et al. 2021). Fall-run and Spring-run Chinook salmon that originate from the Central Valley and Trinity River of California make up some of the prey consumed by southern resident killer whales (Hanson et al. 2021) with a higher proportion of CV Chinook (19%) identified in prey samples collected in outer coastal waters and a smaller proportion of CV Chinook (<5%) identified in prey samples collected in Puget Sound. About two percent of samples in the outer coast waters and no samples from Puget Sound were from the Klamath River watershed. This is consistent with studies that show Chinook salmon of Central Valley and Klamath River watershed origin can occur as far north as the coastal waters off British Columbia during their ocean-going life-history phase; however, the majority of them do not travel further north than central Oregon (Weitkamp 2009; Shelton et al. 2019).

The SRKW population comprises three pods (J, K, and L) which each contain several matrilines. J pod matrilines are not documented in the coastal waters off California and Oregon and occur mostly in the Salish Sea and off the west coast of Vancouver Island. Photoidentification studies

(Center for Whale Research [CWR] 2022), satellite tagging studies (National Oceanic and Atmospheric Administration Fisheries and Cascadia Research unpublished data), prey studies (Hanson et al. 2021), contaminant studies (Krahn et al. 2007; Krahn et al. 2009), passive acoustic monitoring (Hanson et al. 2013), as well as land-based and boat-based sighting networks indicate that J pod individuals rarely, if ever, travel beyond the coastal waters off Washington and British Columbia and rarely forage on salmon originating from the Central Valley or Klamath River watershed (National Marine Fisheries Service 2008; 2021). K and L pods also occur frequently in the Salish Sea and off the west coast of Vancouver Island but also make frequent excursions to the coastal waters off Oregon and occasionally off the coast of California. K and L pods members have been observed as far south as the coastal waters off Monterey Bay (Monterey Bay Whale Watch 2003, National Marine Fisheries Service 2008, 2021). Excursions to coastal California happen more often in February but have been documented, albeit rarely, in December, January, March, and April. The same group of studies listed above indicate that K and L pods forage more often on salmon originating from California than J pod. Therefore, the CVP and SWP operations are likely to have little to no effect on members of J pod but may affect members of K and L pod.

8.2 Species Effects Deconstruction

Because the conceptual model assumes that southern resident killer whales of all ages travel, forage, and prey share with their matrilines, southern resident killer whales of all ages are combined into the discussion of each stressor and how operations would or would not affect that stressor in the coastal waters off California. Also, because J Pod has never been observed south of the coast of Washington, the analysis focuses on K and L Pods.

8.2.1 Winter

K and L pods occur mostly in waters off the west coast of Vancouver Island, Canada and Washington and Oregon, USA, during the winter including occasional excursions to the Salish Sea as well as the coastal waters off California in February and more rare excursions to the waters off coastal California in December and January.

Prey Availability Stressors may increase. The increase is likely discountable or insignificant. The proposed storage, diversion, blending, and releasing of water may increase the prey availability stressor by decreasing the number of natural-origin Chinook salmon that make it to the ocean and grow into adults. The analysis for this is in Chapters 5, 6, and 7 for winter-run, spring-run, and steelhead, where impacts to these fisheries are expected. Additionally, Appendices D – Seasonal Operations Deconstruction, G, I, J – Winter and Spring Pulses and Delta Outflow, L- Shasta Cold Water Pool Management, M – Folsom Cold Water Pool Management, and Q – Georgiana Slough Barrier address impacts to prey. CV Chinook salmon make up a small percent of the total amount of Chinook salmon available to K and L pods in the Pacific Ocean (Bellinger et al. 2015) but as K and L pod whales move south, the proportion of CV Chinook salmon of the total abundance in the ocean increases; therefore, more Chinook salmon originating from the Central Valley would be most important to southern resident killer whales in the winter, particularly February. If the operations of the CVP and SWP affect abundance of large Chinook salmon in the ocean in February, then changes in the operations may have adverse effects on K and L pod whales but are not likely to reduce the likelihood of survival and recovery because other Chinook salmon stocks are prioritized higher, CV Chinook make up a small percentage of Chinook salmon in the ocean, and there is likely a short amount of time when CV Chinook stocks would make up a significant part of K and L pod diets (i.e., they make short excursions to areas with higher percent abundances of CV Chinook).

National Oceanic and Atmospheric Administration Fisheries and the Washington Department of Fish and Wildlife (WDFW) prioritized the importance of Chinook salmon stocks to southern resident killer whales based on three factors: 1) Observed part of southern resident diet, 2) Consumed during times of poor body condition or diversified diet, 3) Degree of spatial/temporal overlap. Based on these factors, CV Chinook salmon runs were assigned a medium level of importance with Spring-run CV Chinook salmon prioritized higher than fall-run CV Chinook and late fall-run CV Chinook salmon, which were both prioritized higher than winter-run CV Chinook salmon (National Oceanic and Atmospheric Administration Fisheries and Washington Department of Fish and Wildlife 2018).

Bellinger et al. (2015) estimated that CV Chinook salmon made up about 22 percent of the Chinook salmon sampled off the Oregon coast and about 50 percent of those sampled off the California coast (south to Big Sur). While this apex predator certainly eats a variety of other species as well, CV Chinook salmon (all runs) can be estimated to make up approximately 40 percent of the southern resident killer whale diet when these mammals are off the California coast, and 18 percent of the southern resident killer whale diet when they are off the Oregon coast.

Based on the *Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement, Inland Harvest, and ocean Harvest in 2020*, 29% of the fall-run Chinook salmon that return to natural spawning areas are natural-origin salmon. While 13% of fall-run Chinook salmon that return to hatcheries are natural-origin salmon. Combining these two results to represent the total population of salmon that returned comes to 21% natural-origin fall-run Chinook salmon. This percentage can represent the percentage of natural-origin salmon along the California coast and subsequently the percentage of southern resident killer whale diet.

With estimates of 50% of K and L pod's diet consisting of CV salmon along the California coast and with 21% of CV salmon being natural-origin salmon, the percentage of natural-origin CV salmon in K and L pod's diet is 10.5%, while along the California coast. That leaves 39.5% being hatchery produced CV Chinook salmon. The Proposed Action is not impacting hatchery operations and the impacts to the out migration of hatchery produced salmon is considered insignificant due to release strategies. Therefore, the Proposed Action impacts up to 10.5% of K and L pod's diet for potentially up to 5 months of the year, on the years they do travel far south. As the southern resident killer whale travels north, this percentage reduces.

Pollution and Contamination Stressors are not anticipated to change. Three identified classes of persistent organ pollutants are found at high concentrations in the blubber of southern resident killer whales: Dichlorodiphenyltrichloroethane (DDT and metabolites, mainly DDE), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs) (Mongillo et al. 2016). Toxins bioaccumulate in animal fat stores and biomagnify up the food chain and, in mammals, are passed from mother to offspring through lactation. During their time spent in coastal waters, adult Chinook salmon, primary prey for southern resident killer whales, are not expected to experience increased exposure to contaminants. CVP and SWP operations are not a proximate cause of contaminant stressors in Chinook salmon off the coast of California.

Underwater Noise and Vessel Traffic Stressors are not anticipated to change. Although underwater noise and vessel traffic are identified as stressors to southern resident killer whales in the Pacific northwest, underwater noise and vessel traffic have not been identified as significant stressors for southern resident killer whales in coastal waters off California (National Marine Fisheries Service 2008) and vessel traffic around the whales is presumed to be substantially lower in this area due to the difficulty in finding and tracking the whales when they are in coastal waters versus the narrower passages of the Salish Sea in the Pacific northwest. CVP and SWP operations are not a proximate cause of underwater noise or vessel traffic stressors off the coast of California.

8.2.2 Spring

K and L pods occur mostly in waters off the west coast of the USA and Canada during the spring including rare excursions to the waters off coastal California in March and early April.

Prey Availability Stressors may increase. The increase is likely discountable and/or insignificant. The Proposed Action may affect prey components of critical habitat and could result in individual-level effects on killer whale that could include changes in areas searched for prey and consequent changes in energy expended for such searches, resulting in changes in energy intake. Changes in energy consumption and nutritional stress could lead to changes in body size, condition, and growth; and changes in reproductive and survival rates for adults (National Marine Fisheries Service 2019). However, K and L pods make excursions to California only rarely and for brief durations in the spring. The operations of the CVP and SWP may affect abundance of large Chinook salmon in the ocean in spring, but K and L pods are less likely to forage on CV Chinook in the spring and the effects would be insignificant to the population.

Pollution and Contamination Stressors are not anticipated to change. Three identified classes of persistent organ pollutants are found at high concentrations in the blubber of southern resident killer whales: Dichlorodiphenyltrichloroethane (DDT and metabolites such as DDE), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs) (Mongillo et al. 2016). Toxins bioaccumulate in animal fat stores and biomagnify up the food chain and, in mammals, are passed from mother to offspring through lactation. During their time spent in coastal waters, adult Chinook salmon, primary prey for southern resident killer whales, are not expected to experience increased exposure to contaminants. CVP and SWP operations are not a proximate cause of contaminants stressors off the coast of California.

Underwater Noise and Vessel Traffic Stressors are not anticipated to change. Although underwater noise and vessel traffic are identified as stressors to southern resident killer whales in the Pacific northwest, underwater noise and vessel traffic have not been identified as significant stressors for southern resident killer whales (National Marine Fisheries Service 2008) in coastal waters off California and vessel traffic is presumed to be substantially lower in this area due to the difficulty in finding the whales when they are in coastal waters versus the narrower passages of the Salish Sea. CVP and SWP operations are not a proximate cause of underwater noise or vessel traffic stressors off the coast of California.

8.2.3 Summer

K and L pods occur mostly in the coastal and estuarine waters of northwestern USA and southwestern Canada during the summer with no documented excursions to the waters off coastal California.

8.2.4 Fall

K and L pods occur mostly in the coastal and estuarine waters of northwestern USA and southwestern Canada during the fall with no documented excursions to the waters off coastal California.

8.3 Species Effects Determination

The seasonal operations of the CVP and SWP may affect, but is not likely to adversely affect southern resident killer whale. Deconstruction of the seasonal operations systematically evaluated each stressor identified. Stressors not linked to the operation of the CVP and SWP were identified as "are not anticipated to change." The stressor that was insignificant or discountable was documented above.

8.4 Critical Habitat Physical and Biological Features

On September 1st, 2021, NMFS revised the critical habitat designation for southern resident killer whales. The final rule maintains the previously designated, but not in the action area, critical habitat in inland waters of Washington and expands it to include certain coastal waters off Washington, Oregon, and California. The revision adds to critical habitat approximately 15,910 square miles of marine waters between the 6.1-meter and 200-meter depth contours from the U.S.-Canada border to Point Sur, California (86 FR 41668). The three essential physical or biological features did not change in the most recent critical habitat revision.

The physical biological features for southern resident killer whale are:

8.4.1 Water Quality to Support Growth and Development

Water quality supports Southern Resident killer whales' ability to forage, grow, and reproduce free from disease and impairment. Southern Resident killer whales are highly susceptible to biomagnification of pollutants, such that chemical pollution is considered one of the prime impediments to their recovery (National Marine Fisheries Service 2008). Water quality is essential to the whales' conservation, given the whales' present contamination levels, small population numbers, increased extinction risk caused by any additional mortalities, and geographic range (and range of their primary prey) that includes highly populated and industrialized areas. Water quality is especially important in high-use areas where foraging behaviors occur and contaminants can enter the food chain. The absence of contaminants or other agents of a type and/or amount that would inhibit reproduction, impair immune function, result in mortalities, or otherwise impede the growth and recovery of the Southern Resident population is a habitat feature essential for the species' recovery. Exposure to oil spills also poses additional direct threats as well as longer-term population level impacts. Therefore, the absence of these chemicals is essential to Southern Resident conservation and survival.

There are no operation effects on water quality.

8.4.2 Prey Species of Sufficient Quantity, and Availability to Support Individual Growth, Reproduction, and Development, as well as Overall Population Growth

Southern Resident killer whales need to maintain their energy balance all year long to support daily activities (foraging, traveling, resting, socializing) as well as gestation, lactation, and growth. Maintaining their energy balance and body condition is also important because when stored fat is metabolized, lipophilic contaminants may become more mobilized in the bloodstream, with potentially harmful health effects (Mongillo et al. 2016). Southern Resident killer whales are top predators that show a strong preference for salmonids in inland waters, particularly larger, older age class Chinook (age class of 3 years or older) (Ford and Ellis 2006, Hanson et al. 2010). Samples collected during observed feeding activities, as well as the timing and locations of killer whales' high-use areas that coincide with Chinook salmon runs, suggest the whales' preference for Chinook salmon extends to outer coastal habitat use as well (Hanson et al. 2017, Shelton et al. 2018, Hanson et al. 2021). At some low Chinook abundance level, the prey available to the whales will not be sufficient to forage successfully leading to adverse effects on body condition or fecundity (National Marine Fisheries Service 2020). Habitat conditions should support the successful growth, recruitment, and sustainability of abundant prey to support the individual growth, reproduction, and development of Southern Resident killer whales.

Age, size, and caloric content all affect the quality of prey, as do contaminants and pollution. The availability of key prey is also essential to the whales' conservation. Availability of prey along the coast is likely limited at particular times of year due to the small run sizes of some important Chinook salmon stocks, as well as the distribution of preferred adult Chinook salmon that may be relatively spread out prior to their aggregation when returning to their natal rivers. Availability of Chinook salmon to the whales may also be impacted by sound from vessels or other sound sources if they raise average background noise within the animal's critical bandwidth to a level that is expected to chronically or regularly reduce echolocation space (Joy et al., 2019, Veirs et al. 2016), and by competition from other predators including other resident killer whales, pinnipeds, and fisheries (Chasco et al. 2017).

The species effect determination found related potential stressors of:

- Prey Availability

There are no additional operations effects on "prey species of sufficient quantity" when species are not present.

8.4.3 Passage Conditions to Allow for Migration, Resting, and Foraging

Southern Resident killer whales are highly mobile, can cover large distances, and range over a variety of habitats, including inland waters and open ocean coastal areas from the Monterey Bay area in California north to Southeast Alaska. The whales' habitat utilization is dynamic. Analyses of Southern Resident killer whales' movement patterns on the outer coast from satellite tag data have revealed preferred depth bands and distances from shore that suggest potential travel corridors, and variations in travel speed or duration of occurrence that may indicate different behavioral states (Hanson et al. 2017). Southern Resident killer whales require open waterways that are free from obstruction (e.g., physical, acoustic) to move within and migrate between important habitat areas throughout their range, find prey, communicate, and fulfill other life history requirements. As an example of an ''acoustic obstruction,'' killer whale occurrence in the Broughton Archipelago, Canada declined significantly when acoustic harassment devices were in use at a salmon farm, and returned to baseline levels once the devices were no longer used (Morton and Symonds 2002), indicating the introduction of this chronic noise source into the environment acted as an acoustic barrier and/or deterrent to the whales' use of the area. The passage feature may be less likely to be impacted in coastal ocean waters compared to the more geographically constricted inland waters because the whales may be able to more easily navigate around potential obstructions in the open ocean, but these passage conditions are still a feature essential to the whales' conservation and which may require special management considerations or protection.

There are no operation effects on passage conditions.

8.5 Critical Habitat Effect Determination

The seasonal operation may affect, but is not likely to adversely affect critical habitat for southern resident killer whale.

- Decreased prey availability

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9.2 Personal Communications

Colborne, S. Lead Manuscript Author. University of California, Davis. November 18, 2021 – email to Josh Israel, Chief, Science Division, U.S. Bureau of Reclamation, Bay Delta Office and Kristin Arend, Fish Biologist, U.S. Bureau of Reclamation, Bay Delta Office.

Poytress, Bill, Program Manager, Red Bluff Fish & Wildlife Office, Email communication to Josh Israel, Chief, Science Division, U.S. Bureau of Reclamation, Bay-Delta Office and Kristin Arend, Fish Biologist, U.S. Bureau of Reclamation, Bay-Delta Office, regarding egg, larval, and juvenile green sturgeon presence at Red Bluff Diversion Dam and middle Sacrament River. 12/27/2021