Long-Term Operation – Final Environmental Impact Statement

Chapter 12 – Fish and Aquatic Resources

November 2024

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Chapter 12 Fish and Aquatic Resources

This impact assessment is based on the background information and technical analysis documented in *Appendix O, Fish and Aquatic Resources Technical Appendix*, which includes additional information on fish and aquatic resource conditions and technical analysis of the effects of each alternative.

Using multiple lines of evidence, the analysis described below considers both context and intensity (40 CFR 1508.27) the alternatives may have on fish and aquatics resources.

12.1 Affected Environment

The Central Valley and Trinity River support a diverse number of special status, anadromous and recreationally important species (Table 12-1).

Table 12-1. Focal Fish Species in the Central Valley and Trinity River

Species or *Population*	**Federal Status**	**State Status**	**Tribal[1], Commercial[2], or Recreational Importance**	**Occurrence within Area of Analysis**
Chinook Salmon *Sacramento River Winter-Run ESU*	Endangered	Endangered	Yes	Sacramento River, Bay-Delta
Chinook Salmon *Central Valley Spring-Run ESU*	Threatened	Threatened	Yes	Clear Creek, Sacramento River, Bay-Delta
Steelhead *California Central Valley DPS*	Threatened	None	Yes	Clear Creek, Sacramento River, Lower American River, Stanislaus River, San Joaquin River, Bay-Delta
Green Sturgeon *Southern DPS*	Threatened	SSC	Yes	Sacramento River, Bay-Delta
Delta Smelt	Threatened	Endangered	Yes	Bay-Delta
Longfin Smelt *San Francisco Bay-Delta DPS*	Endangered	Threatened, SSC	Yes	Bay-Delta

[1] Tribal importance was noted based on Shilling et al. (2014:15–46).
[2] Commercially important species with Essential Fish Habitat under the Magnuson-Stevens Fishery Conservation and Management Act.

Species or *Population*	Federal Status	State Status	Tribal[1], Commercial[2], or Recreational Importance	Occurrence within Area of Analysis
Chinook Salmon *Central Valley Fall-Run/Late Fall–Run ESU*	None	SSC	Yes	Clear Creek, Sacramento River, Lower American River, Stanislaus River, Bay-Delta, San Joaquin River
White Sturgeon	Petitioned	Candidate	Yes	Sacramento River, Lower American River, Bay-Delta, San Joaquin River
Native Minnows (Sacramento Splittail, Hardhead, Sacramento Hitch)	None	SSC	Yes	Clear Creek, Sacramento River, Lower American River, Bay-Delta, Stanislaus River, San Joaquin River
Pacific Lamprey	None	SSC	Yes	Trinity River, Clear Creek, Sacramento River, Lower American River, Bay-Delta, Stanislaus River, San Joaquin River
Western River Lamprey	None	SSC	Yes	Sacramento River, Lower American River, Stanislaus River, Bay-Delta, San Joaquin River
Striped Bass	None	None	Yes	Sacramento River, Lower American River, Bay-Delta, Stanislaus River, San Joaquin River
American Shad and Threadfin Shad	None	None	Yes	Lower American River, Sacramento River, Bay-Delta, Stanislaus River, San Joaquin River
Black Basses (Largemouth, Smallmouth, Spotted)	None	None	Yes	Trinity Lake, Sacramento River, Lower American River, Bay-Delta, Stanislaus River, San Joaquin River
Starry Flounder	None	SSC	Yes	Bay-Delta
Coho Salmon *Southern Oregon/Northern California Coast ESU*	Threatened	Threatened	Yes	Trinity River
Chinook Salmon *Upper Klamath-Trinity River Spring-Run ESU*	Candidate	SSC	Yes	Trinity River
Chinook Salmon *Upper Klamath-Trinity River Fall-Run ESU*	Candidate	SSC	Yes	Trinity River
Steelhead *Klamath Mountains Province DPS*	None	SSC	Yes	Trinity River
Eulachon *Southern DPS*	Threatened	SSC	Yes	Lower Klamath River
Green Sturgeon *Northern DPS*	None	SSC	Yes	Trinity River, Lower Klamath River

Species or *Population*	Federal Status	State Status	Tribal[1], Commercial[2], or Recreational Importance	Occurrence within Area of Analysis
Coastal Cutthroat Trout	None	SSC	Yes	Lower Klamath River
Brown Trout	None	None	Yes	Trinity River, Lower Klamath River, Trinity Lake
Rainbow Trout	None	None	Yes	Trinity Lake
Kokanee Salmon (landlocked Sockeye Salmon)	None	None	Yes	Trinity Lake

ESU = evolutionary significant unit; DPS = distinct population segment; SSC = species of special concern

12.1.1 Trinity River

This section describes some of the focal fish species expected to occur in the Trinity River watershed including Trinity Reservoir. The Trinity River watershed also supports populations of Pacific lamprey, coastal cutthroat trout, brown trout, Kokanee, black basses, white catfish, and brown bullhead, as discussed in Appendix O.

12.1.1.1 Coho Salmon, Southern Oregon/Northern California Coast Evolutionarily Significant Unit

Coho salmon exhibit a three-year life cycle in the Trinity River during which they spend the first year in fresh water before migrating to the ocean. In the ocean, they spend the next two years maturing before returning to their natal stream to spawn and die. Juveniles remain in the river year-round. Adult coho salmon typically enter the Trinity River between August and January, with the year-specific timing influenced by genetics, stage of maturity, and river discharge. Coho salmon spawning occurs mostly in November and December in the mainstem Trinity River and its tributaries with peak coho salmon spawning activities in the mainstem Trinity River occurring between Lewiston Dam and the North Fork Trinity River. Spawning is concentrated in riffles or in gravel deposits at the downstream end of pools with suitable water depth, velocity, and substrate size.

Approximately 109 miles of coho salmon habitat in the Trinity Basin became inaccessible after construction of Lewiston and Trinity dams (National Marine Fisheries Service 2014a). To mitigate for the loss of upstream habitat, the Trinity River Salmon and Steelhead Hatchery was constructed near Lewiston Dam and produces coho salmon with an annual production goal of 500,000 yearling fish (California Hatchery Scientific Review Group 2012). Today, wild coho salmon are not abundant in the Trinity River, and most of the coho salmon that return to the river are of hatchery origin. The National Marine Fisheries Service (NMFS) (National Marine Fisheries Service; 2014a) considers this proportion of hatchery fish in the population a high-level risk factor for the continued existence of coho salmon in the Trinity River Basin.

In 2014, annual coho salmon production was reduced to 300,000 yearlings pending adoption of a Trinity River Hatchery Genetics Management Plan (HGMP). The HGMP for the operation of the

Trinity River Hatchery was approved by NMFS in 2019 and efforts began in 2021 to focus on natural environmental selection for the Trinity Coho salmon population and incorporating more natural origin fish into the breeding population at the Trinity River Hatchery (Hoopa Valley Tribe et al. 2022). In 2000, the Trinity River Restoration Program (TRRP) was created to improve aquatic habitat conditions on the 40-mile reach from Lewiston Dam downstream to the North Fork Trinity River confluence. The TRRP has implemented a variety of restoration actions to improve aquatic habitat conditions for coho salmon in the Trinity River that include flow management, channel rehabilitation, sediment management, watershed restoration, and adaptive management.

12.1.1.2 Chinook Salmon, Upper Klamath-Trinity River Spring-Run Evolutionarily Significant Unit

Adult spring-run Chinook salmon typically enter the Trinity River from April through September. Most fish have arrived at the mouth of the North Fork Trinity by the end of July. Spawning is concentrated in the reaches immediately downstream of Lewiston Dam to the mouth of the North Fork Trinity River. After entering fresh water, spring-run Chinook salmon remain in deep pools until the onset of the spawning season, which usually peaks in October but typically ranges from the third week of September through November. In the Trinity River, spring-run Chinook salmon fry emerge from the gravel beginning in December, and emergence can last into mid-April. Juvenile spring-run Chinook salmon typically out-migrate after less than a year of growth in the Trinity River. Peak out-migration occurs in May and June as based on monitoring in the lower Trinity River near the town of Willow Creek.

Historically, the spring-run Chinook salmon were the most abundant salmonid in the Trinity River (Snyder 1931; LaFaunce 1967). Spring-run Chinook salmon historically spawned in the Trinity River and several of its tributaries upstream of Lewiston Dam (e.g., East Fork Trinity River, Stuart Fork, Coffee Creek, Hayfork Creek [Gibbs 1956; Campbell and Moyle 1991]). Completion of dams on the Trinity River in the 1960s blocked access to 59 miles of adult holding, spawning, and nursery habitat (Moffett and Smith 1950).

To supplement the decline in population sizes of Chinook salmon, the Trinity River Hatchery below Lewiston Dam propagates Trinity River origin spring-run Chinook salmon. The TRRP has implemented a variety of restoration actions to improve aquatic habitat conditions for Chinook salmon in the Trinity River that included implementation of natural flow variability, temperature moderation, and elevated flows during fry emergence.

12.1.1.3 Fall-run Chinook Salmon, Upper Klamath-Trinity River Fall-Run Evolutionarily Significant Unit

Adult fall-run Chinook salmon typically enter the Trinity River from August through December. Spawning activity usually occurs between October and December with peak spawning activity occurring in November. Spawning activity typically begins just downstream of Lewiston Dam, then extends farther downstream as the season progresses. Fall-run Chinook salmon spawn throughout the mainstem Trinity River from Lewiston Dam to the Hoopa Valley (Myers et al. 1998). Similar to spring-run Chinook salmon, emergence of fall-run Chinook salmon fry begins in December and continues into mid-April. Juvenile fall-run Chinook salmon typically spend a few months rearing in the Trinity River before they out-migrate. Within the Trinity River near Lewiston Dam, out-migration occurs from March through May, with peak out-migration occurring in early May while out-migration farther downstream peaks in May and June.

Fall-run Chinook salmon historically were less abundant than spring-run Chinook in the Klamath-Trinity Basin. However, records from the previous century reveal that fall-run Chinook became the major component of Klamath salmon populations. Estimated run sizes ranged from 141,000 to 400,000 fall-run Chinook from 1912-1928 (Moyle 2002). However, overharvest and changes to the Klamath-Trinity watershed through the construction of dams greatly reduced the population size to an average of 3,000 fish from 1956-1969 (Moyle 2002). Production estimates of fall-run Chinook salmon was almost equally distributed between the Klamath and Trinity river basins.

Restoration of fall-run Chinook salmon populations included artificial supplementation of salmon from the Trinity River Hatchery. The TRRP has implemented a variety of restoration actions to improve aquatic habitat conditions for Chinook salmon in the Trinity River that included implementation of natural flow variability, temperature moderation, and elevated flows during fry emergence.

12.1.1.4 Steelhead, Klamath Mountains Province Distinct Population Segment

Spawning across the three run types in the Trinity River may occur anytime from December through May but occurs primarily from December through February. Adult summer-run steelhead enter the Klamath Basin between April and August and arrive in the Trinity River primarily in April and May (Moyle et al. 2017, Moyle et al. 2015, Pinnix et al 2007). Summer-steelhead hold until the spawning season, in deep pools within the mainstem or upper reaches of cool tributaries while they mature (Moyle 2002; Busby et al. 1996). Summer-run steelhead tend to spawn in smaller streams higher in the drainage network than fall- or winter-run steelhead (Roelofs 1983). Adult fall-run steelhead enter the Klamath River basin between July and November, arrive in the Trinity River primarily in July and August, and spawn primarily from January through May (Pinnix et al. 2007, Moyle et al. 2015, Moyle et al. 2017). Adult winter-run steelhead begin their upstream migration in the Klamath River from November through March (U.S. Fish and Wildlife Service 1997) and primarily spawn in the Trinity River from January through April (U.S. Fish and Wildlife Service 1997), with peak spawn timing in February and March (National Research Council 2004). Steelhead fry emerge in the spring, and juveniles remain in fresh water for up to three years. Most steelhead (86%) that return to the Klamath River basin are estimated to spend two years in freshwater before outmigrating to the ocean (Hopelain 1998).

Steelhead in the Trinity River exhibit two primary life history strategies, including a summer-run steelhead that matures after entering fresh water and a winter-run that matures in the ocean. The ocean maturing strategy is often further divided into a third group for fall-run steelhead based upon the timing of the adult migration. Steelhead also exhibit the “half-pounder” life history, which is limited to several rivers in northern California and southern Oregon, including both Klamath and Trinity rivers. Half-pounders are steelhead that return to fresh water in late summer through fall as immature fish after spending just three–five months at sea and support valuable freshwater fisheries. In the Trinity River, historically and at present, the half-pounder life history remains common among fall-run steelhead.

The TRRP has implemented a variety of restoration actions to improve aquatic habitat conditions for salmon and steelhead on the 40-mile reach from Lewiston Dam downstream to the North Fork Trinity River confluence that included implementation of natural flow variability, temperature moderation, and floodplain connectivity.

12.1.1.5 Green Sturgeon, Northern Distinct Population Segment

Green sturgeon in the Trinity River region belong to the Northern distinct population segment; however, data from the Trinity River are limited, so most information on life history characteristics for green sturgeon in the Trinity River is based on data from the Klamath River. Adult migration from the Pacific Ocean to the Trinity River occurs from March through July with most spawning taking place from the middle of April to the middle of June (National Research Council 2004). Green sturgeon spawn in deep pools in the lower section of mainstem Trinity River from the confluence with the Klamath River upstream to Grays Falls (Benson et al. 2007). After spawning, most green sturgeon hold in mainstem pools until the fall when they move downstream and leave the river system (Benson et al. 2007). A small proportion (around 25%) of green sturgeon migrate directly back to the ocean after spawning (Benson et al. 2007). Green sturgeon eggs hatch approximately a week after fertilization (van Eenennaam et al. 2005), and larvae rear in the river from March through September until they reach the juvenile stage (up to 150 cm TL). Juveniles slowly migrate downstream to rear in the lower Klamath River for up to a year (Moyle 2002, Mayfield and Cech, Jr. 2004). After moving downstream, juvenile green sturgeon may rear in larger river sections or in the Klamath River estuary for another year or two before they migrate to the Pacific Ocean (National Research Council 2004; Federal Energy Regulatory Commission 2007; Israel and Klimley 2008).

As of 2006, green sturgeon in the Trinity River Basin are Federally listed as a species of special concern. The green sturgeon historic range in the Trinity River is unknown, but the Trinity Dam and irrigation diversions are known to alter flow and water temperatures downstream (Benson et al. 2007) which could affect the species. In addition to downstream flow and temperature changes, green sturgeon face other potential threats in the Trinity River system including decreases in spawning habitat, lack of population data, and harvest impacts (Adams et al. 2002). However, the fact that the Trinity River spawning population occurs in a separate basin from the Klamath River spawning population helps to protect the nDPS green sturgeon from catastrophic events. A reduction in harvest and low entrainment risk in the Trinity River also help maintain the population (Adams et al. 2007).

12.1.1.6 Eulachon, Southern Distinct Population Segment

Eulachon are an anadromous smelt species that were important to local tribes and once supported a subsistence fishery on the lower Klamath River. The spawning migration period for adult eulachon in the Klamath River begins in December and continues until May, with peak migration occurring in March and April (Yurok Tribal Fisheries Program 1998; Larson and Belchik 1998). Eulachon can become sexually mature at two years but spawning typically occurs at ages three, four, or five (Scott and Crossman 1973). Spawning occurs in the lower reaches of rivers and tributaries. Eulachon are broadcast spawners and usually die after spawning.

Although specific spawning areas are unknown, adult eulachon are generally only observed in the lower 24 miles (40 kilometers) of the Klamath River, except during rare years when they are sometimes observed as high as Pecwan Creek and Weitchpec (Yurok Tribal Fisheries Program

1998). Eulachon eggs hatch in 20 to 40 days depending on water temperature, with cooler temperatures leading to longer incubation times. Once eggs hatch, larval eulachon are carried out to the ocean by river currents (Scott and Crossman 1973).

The current population status of eulachon in the Trinity River is unknown, and threats indicated in the recovery plan for Southern DPS eulachon were limited to major river basins. In the Klamath basin, dams and water quality were stated as moderate threats to the subpopulation (National Marine Fisheries Service 2017). Dam removals in the upper Klamath River, and ongoing efforts from TRRP for reduced sedimentation and temperature moderation will likely benefit spawning populations in the lower Klamath River.

12.1.2 Sacramento River

This section describes some of the focal fish species expected to occur in the Sacramento River watershed. The Sacramento River also supports populations of white sturgeon, native minnows, Pacific lamprey, Western River lamprey, striped bass, threadfin shad, American shad, black basses, and starry flounder, as discussed in Appendix O.

12.1.2.1 Chinook Salmon, Sacramento River Winter-Run Evolutionarily Significant Unit

Adult winter-run Chinook salmon return to fresh water entering the San Francisco Bay in November and migrate upstream past the former location of the Red Bluff Diversion Dam (RBDD) beginning in mid-December. Most of the run passes RBDD between January and May, with a peak mid-March (Hallock and Fisher 1985). Adults enter fresh water in an immature reproductive state, move upstream quickly, then hold in the cool waters downstream of Keswick Dam for an extended period before spawning above RBDD in the upper Sacramento River and tributaries in spring and summer. Juveniles spend five to nine months in the river and estuary systems before entering the ocean.

Access to approximately 58% of the original winter-run Chinook salmon habitat has been blocked by the existence of dams (Bureau of Reclamation 2008). The remaining accessible habitat occurs in the Sacramento River downstream of Keswick Dam and in Battle Creek. In addition, juveniles rear in the lower American River, lower Feather River, Mill Creek, Deer Creek, and the Delta before emigrating to the ocean (Phillis et al. 2018). Central Valley-wide escapement data indicate that the winter-run Chinook salmon population declined from levels in the 1970s to relatively low levels through the 1980s and 1990s, with a moderate rebound in the early 2000s (Azat 2023).

In 1998, the Livingston Stone National Fish Hatchery (LSNFH) was constructed to help boost the winter-run Chinook salmon population while conserving both genetic and life history diversity (U.S. Fish and Wildlife Service 2016). LSNFH releases up to 250,000 winter-run Chinook salmon a year, while working to minimize hatchery effects in the population by preferentially collecting wild adult winter-run Chinook salmon for brood stock (U.S. Fish and Wildlife Service 2011a). In addition to supplementing populations, restoration activities are being conducted to help improve instream and floodplain habitat for the species. Restoration within Battle Creek aims to create additional spawning and rearing habitat. The NMFS 2021 – 2025 priority actions identify several restoration efforts to help with the recovery of winter-run Chinook salmon, including but not limited to reintroduction of the species above Shasta Dam, improving management of Shasta Reservoir cold water storage, and improving Yolo Bypass fish habitat and passage.

12.1.2.2 Chinook Salmon, Central Valley Spring-Run Evolutionarily Significant Unit

Upstream adult migration of spring-run Chinook salmon in the upper Sacramento River typically extends from mid-March through July with peak migration in late May and early June (California Department of Fish and Wildlife 1998). Individuals enter freshwater as immature fish and hold in deep cold pools near spawning areas until they are sexually mature. Spawning occurs from late-August through October and fry emerge from November through March (Williams 2006). Juvenile spring-run Chinook salmon rear in natal tributaries, the Sacramento River mainstem, and nonnatal tributaries to the Sacramento River (California Department of Fish and Wildlife 1998). Outmigration timing is highly variable, as they may migrate downstream as young of the year (YOY) or as juveniles or yearlings. The out-migration period for spring-run Chinook salmon extends from November to early May, with up to 69% of the YOY fish out-migrating through the lower Sacramento River and Delta during this period (California Department of Fish and Wildlife 1998).-Juveniles that remain in the Sacramento River over summer are confined to approximately 100 miles of the upper mainstem where dam releases maintain cool water temperatures.

Historically, spring-run Chinook salmon in the Sacramento River basin were found in the upper and middle reaches of the American, Yuba, Feather, Sacramento, McCloud and Pit rivers, as well as smaller tributaries of the upper Sacramento River downstream of present-day Shasta Dam (National Marine Fisheries Service 2009). Estimates indicate that 82% of the approximately 2,000 miles of salmon spawning and rearing habitat available in the mid-1800s are unavailable or inaccessible today (Yoshiyama et al. 1996). Spring-run Chinook salmon abundance in the Sacramento River mainstem has declined sharply since the 1970s. Operation of Feather River Fish Hatchery (FRFH) may pose threats to spring-run Chinook salmon stock genetic integrity (National Marine Fisheries Service 1998). A large portion of Central Valley spring-run Chinook salmon is of hatchery-origin, and naturally spawning populations may be interbreeding with both fall-run/late fall–run and hatchery raised spring-run Chinook salmon. Hatchery broodstock management has attempted to segregate the two runs; but despite these efforts, substantial hybridization has occurred, resulting in substantial genetic introgression (Clemento et al. 2014; Meek et al. 2016). Installation of NMFS-approved fish screens at the Tehama Colusa Canal diversion and implementation of monitoring, evaluating, and adaptively managing the new fish screens to ensure the screens are working properly and impacts to listed species are minimized was completed in 2013 (National Marine Fisheries Service 2009).

The development and implementation of a river flow management plan downstream of Shasta and Keswick dams that considers the effects of climate change, and flow and water temperature needs of spring-run Chinook salmon is ongoing. A recovery action that will operate and maintain temperature control curtains in Lewiston and Whiskeytown Reservoirs to minimize warming of water from the Trinity River and Clear Creek is authorized. The CVPIA long-term gravel augmentation plan will continue through 2024 with the goal of increasing and maintaining spawning habitat for spring-run Chinook salmon in the Sacramento River downstream of Keswick Dam.

12.1.2.3 Chinook Salmon, Central Valley Fall-Run and Late Fall-Run Evolutionarily Significant Unit

Fall-run Chinook salmon are an ocean-maturing type of salmon adapted for spawning in lowland reaches of big rivers, including the mainstem Sacramento River, and late fall–run Chinook salmon are mostly a stream-maturing type (Moyle 2002). Adult late fall–run Chinook salmon typically hold in the river for one to three months before spawning while fall-run Chinook salmon generally spawn shortly after entering fresh water. Fall-run Chinook salmon migrate upstream past RBDD on the Sacramento River between July and December, typically spawning in upstream reaches from October through March. Late fall–run Chinook salmon migrate upstream past RBDD from August to March and spawn from January to April (National Marine Fisheries Service 2009; Tehama-Colusa Canal Authority 2008). The primary spawning area for both runs is Keswick Dam downstream to RBDD. The majority of young fall-run Chinook salmon migrate to the ocean during the first few months following emergence, although some may remain in fresh water and migrate as yearlings. Late fall–run juveniles typically enter the ocean after seven to thirteen months of rearing in fresh water, at 150–170 millimeters (mm) in fork length, considerably larger and older than fall-run Chinook salmon (Moyle 2002).

Fall-run and late-fall run Chinook salmon are found throughout the Sacramento River and its tributaries from Keswick Dam down into the Delta. Spawning densities for both runs are generally highest between Keswick Dam and RBDD, individuals spawn downstream of RBDD to approximately Princeton Ferry (U.S. Fish and Wildlife Service 2003; California Department of Fish and Wildlife aerial redd survey unpublished data). Annual fall-run and late fall–run Chinook salmon escapement to the Sacramento River and its tributaries has generally been declining over the last decade, following peaks in the late 1990s to early 2000s (Azat 2023). Hatchery fall-run escapement was relatively consistent at approximately 50,000–60,000 fish during 2014–2018, with hatchery escapement of late fall–run Chinook salmon in recent years estimated to be greater than in-river numbers.

The Feather River Fish Hatchery, Coleman National Fish Hatchery, and Nimbus Fish Hatchery all produce fall run and or late-fall run Chinook salmon to serve as mitigation for loss of habitat, to enhance wild populations, and to support recreational and commercial fisheries in the region.

12.1.2.4 Steelhead, California Central Valley Distinct Population Segment

Steelhead are broadly divided into life history types based on the state of sexual maturity at the time of river entry. Only winter-run steelhead are currently found in Central Valley rivers and streams. Adult California Central Valley steelhead migrate into the Sacramento River from the Delta in late summer and throughout the winter, into early spring. Steelhead exhibit life histories in which they spawn within a few months of entering freshwater or stage in pools for more extended periods until the first high flows (Moyle 2002; Williams 2006). Unlike salmon, steelhead may live to spawn more than once and generally rear in freshwater streams for two to four years before out-migrating to the ocean. The Sacramento River functions primarily as a migration channel, although some rearing habitat remains in areas with setback levees (primarily upstream of Colusa) and flood bypasses (e.g., Yolo Bypass) (National Marine Fisheries Service 2009). Steelhead fry rear and migrate downstream in the Sacramento River during most months of the year, with peak emigration January to June, and juvenile steelhead can be rearing and migrating in the Sacramento River year-round (Hallock et al. 1961; McEwan 2001).

Central Valley steelhead are currently found in the Sacramento River downstream of the Keswick Dam and in the major tributaries and creeks of the Sacramento River watershed (Bureau of Reclamation 2023). Steelhead mostly use the Sacramento River as a migratory corridor for reaching other tributaries to spawn. Data on steelhead spawning in the mainstem Sacramento River is limited and likely restricted to the area upstream of Red Bluff (National Marine Fisheries Service 2009). Adult steelhead abundance in the upper tributaries of the Sacramento River are based on monitoring in Battle Creek and Clear Creek. Escapement estimates for Battle Creek ranged from 633 to 2,035 individuals from 2001 through 2004 but dropped below 500 individuals from 2005 through 2019 with the exception of 2013 and 2014 (Stanley et al. 2020).

The spawning distribution of steelhead in the upper Sacramento River is poorly known, but the suitability of spawning habitat is largely determined by instream flow and the availability of suitable spawning gravel (U.S. Fish and Wildlife Service 2011b, 2011c). In the upper Sacramento River during WY 2023, 24.5 acres of rearing habitat or spawning habitat were completed, on-going, or scheduled to start in the near future. Roughly 15.5 more acres are needed to meet the 40 to 60 acre goal by 2030 (Bureau of Reclamation 2024). The goal of 15,000 to 40,000 tons of gravel injected into the Sacramento River has been met each year and is anticipated to be met in WY 2024.

12.1.2.5 Green Sturgeon, Southern Distinct Population Segment

The Sacramento River provides habitat for southern DPS green sturgeon spawning, adult holding, foraging, and juvenile rearing. Suitable spawning temperatures and spawning substrate exist for green sturgeon in the Sacramento River upstream and downstream of RBDD (Bureau of Reclamation 2008). Although the upstream extent of historical green sturgeon spawning in the Sacramento River is unknown, the observed distribution of sturgeon eggs, larvae, and juveniles indicates that spawning occurs from Hamilton City upstream to Inks Creek confluence and possibly up to the Cow Creek confluence (Brown 2007; Poytress et al. 2013, 2015). California Department of Fish and Game (2002) indicated that green sturgeon spawn in late spring and early summer. Adult green sturgeon that migrate upstream in April, May, and June are completely blocked by the Anderson-Cottonwood Irrigation District diversion dam (74 Federal Register 52300–52351), rendering approximately three miles of spawning habitat upstream of the diversion dam inaccessible. The number of green sturgeon accessing the upper Sacramento River appears to have increased following the decommissioning of RBDD (Steel et al. 2018). Young green sturgeon appear to rear for the first one to two months in the Sacramento River between the Clear Creek confluence and Hamilton City (Heublein et al. 2017).

The current green sturgeon population status is unknown (Beamesderfer et al. 2007; Adams et al. 2007). Mora et al. (2018) employed acoustic telemetry and sonar studies to derive a total population size estimate of 17,548 individuals (95% confidence interval = 12,614–22,482)). The estimate does not include spawning adults in the lower Feather or Yuba Rivers (National Marine Fisheries Service 2019). Battaile et al. (2023) estimated lower adult green sturgeon abundance numbers from 2020-2022 (742 to 1,208 individuals).

The Central Valley Project (CVP) and CVPIA have begun habitat restoration, environmental water acquisitions, and fish screening projects that will benefit green sturgeon (National Marine Fisheries Service 2018). The construction of structures that will provide volitional passage for upstream migrating adults is an ongoing recovery action that began with the construction of the

Fremont Weir Adult Fish Passage Modification Project in 2018. The Yolo Bypass Salmonid Habitat and Fish Passage Project (Big Notch Project) is also a part of this recovery action and is expected to be constructed in 2024. The development of temperature and flow targets in accessible spawning, incubation, and rearing habitat through long-term monitoring is ongoing, as well as planned research to determine the effects from the operation of the Delta Cross Channel gates on green sturgeon.

12.1.3 Clear Creek

This section describes some of the focal fish species expected to occur in the Clear Creek watershed. Clear Creek also supports populations of native minnows and Pacific lamprey which are discussed in greater detail in Appendix O.

12.1.3.1 Chinook Salmon, Central Valley Spring-Run Evolutionarily Significant Unit

Central Valley spring-run Chinook salmon have re-established in Clear Creek following implementation of the Clear Creek Restoration Program (CCRP). Adult Central Valley spring-run Chinook salmon migrate upstream into lower Clear Creek beginning in early June and spawn in the uppermost reaches from September through early to mid-October. Rotary screw trap data on spring-run Chinook salmon outmigration from Clear Creek show spring-run Chinook juveniles emigrating during late October through late May (Schraml and Chamberlain 2019a, 2019b; Schraml et al. 2020). Peak emigration of spring-run Chinook salmon juveniles occurs in November, with fewer fish exiting each week through the end of May. The majority of the outmigrating juveniles are fry, generally under 40 mm fork length (Schraml et al. 2018).

Spring-run Chinook salmon utilize approximately 18 miles of habitat downstream of Whiskeytown Dam. Since 2000, Whiskeytown Dam has been the only remaining dam on Clear Creek, which provides cold water to sustain spring-run Chinook salmon spawning and rearing.

The CVPIA Clear Creek Adaptive Restoration Program is anticipated to begin in 2024 and will include gravel augmentation, wood supplementation, and channel rehabilitation translating to about 24 acres of floodplain habitat, 10 acres of perennial rearing habitat, 5 acres of new spawning habitat, 25 acres of new cover, and maintain 26 acres of existing spawning habitat (Bureau of Reclamation 2023). Water temperature criteria (maximum mean daily 56°F) in Clear Creek are set to be protective of spring-run Chinook salmon during spawning and incubation (September 15 to October 31) (Clear Creek Technical Team 2018). Since 2003, the USFWS has installed a temporary picket weir from late August through early November to allow spawning spring-run Chinook salmon to be spatially separated from fall-run Chinook salmon, which have an overlap in spawning timing (National Marine Fisheries Service 2014b). The Clear Creek Restoration Program (CCRP) identified and implemented a variety of actions to improve salmon and steelhead habitat. To combat the elimination of gravel recruitment from upstream of Whiskeytown Dam, spawning gravels have been added to Clear Creek downstream of Whiskeytown Dam every year since 2002.

12.1.3.2 Steelhead, California Central Valley Distinct Population Segment

Central Valley steelhead have re-established in Clear Creek following implementation of the CCRP, and adult Central Valley steelhead and non-anadromous rainbow trout (*O. mykiss*) are present in Clear Creek. *O. mykiss* >16 inches have been seen migrating upstream as early as

August and through February (Killam 2022). Based on the number of redds observed, most spawning appears to occur near to the confluence with the Sacramento River, with peak spawning occurring from December–January (Provins and Chamberlain 2019a, 2019b). Occurrence of yearlings and juveniles at the monitoring traps goes from November through June (Schraml and Chamberlain 2019a, 2019b, 2020, 2021).

Steelhead utilize approximately 18 miles of habitat downstream of Whiskeytown Dam. Since 2000, Whiskeytown Dam has been the only remaining dam on Clear Creek, which provides cold water to sustain steelhead spawning and rearing.

Since 1995, the CVPIA and later the CALFED Bay-Delta Program have conducted salmonid habitat and flow restoration in Clear Creek and re-established runs of California Central Valley steelhead. The CCRP identified and implemented a variety of actions to improve salmon and steelhead habitat, including increased minimum flows, summer water temperature control through flow management, removal of a low-head dam, large-scale stream and floodplain restoration, gravel augmentation, spring and early summer pulse flows, and erosion control (Clear Creek Technical Team 2018). To combat the elimination of gravel recruitment from upstream of Whiskeytown Dam, spawning gravels have been added to Clear Creek downstream of Whiskeytown Dam every year since 2002. The gravel augmentation program on Clear Creek continues to enhance the spawning habitat available to Central Valley fall- and spring-run Chinook salmon and Central Valley steelhead (Bureau of Land Management and National Park Service 2008).

12.1.3.3 Chinook Salmon, Central Valley Fall-Run and Late Fall-Run Evolutionarily Significant Unit

Clear Creek below Whiskeytown reservoir provides suitable spawning habitat for both fall-run and late fall-run Chinook salmon. Based on carcass surveys and juvenile outmigration trapping, fall-run Chinook salmon typically spawn in Clear Creek from late September through early December, and peak outmigration of juveniles occurs in January and February (Earley et al. 2013). Late-fall run Chinook salmon enter the upper Sacramento watershed in December and spawn through April (Vogel and Marine 1991), however based on the seasonal flows, turbidity, cold temperatures, and limited daylight, it can be difficult to survey spawning activity in tributaries (U.S. Fish and Wildlife Service 2008). Fall-run Chinook salmon spawn primarily in the lower 6.5 miles of the 8.5 lower alluvial segment of Clear Creek (U.S. Fish and Wildlife Service 2015).Chinook salmon and steelhead populations in Clear Creek are doing well relative to other Central Valley populations. Anadromous fish escapement, redd counts, and carcass indices in Clear Creek have either increased, remained stable, or decreased substantially less than their Central Valley counterparts in the years after implementation of habitat improvements.

Beginning in 1995, restoration actions in Clear Creek have had an effect on fall-run Chinook salmon populations. The actions have contributed to a near fourfold increase in escapement of fall-run Chinook salmon to Clear Creek (population estimates average 1,749 from 1967 to 1991 and 7,333 from 1992 to 2017) (Clear Creek Technical Team 2018).

12.1.4 Lower American River

This section describes some of the focal fish species expected to occur in the lower American River watershed. The lower American River also supports populations of white sturgeon, native minnows, Pacific lamprey, Western river lamprey, striped bass, black basses, threadfin shad, and American shad (Table 12-1), all of which are discussed in greater detail in Appendix O.

12.1.4.1 Steelhead, California Central Valley Distinct Population Segment

Adult steelhead enter the lower American River from November through April with a peak occurring from December through March (Surface Water Resources 2001). A spawning survey conducted in 2001–2007 indicates that steelhead spawning occurs in the lower American River from late December through early April, with peak occurrence in late February to early March (Hannon and Deason 2008). Redd count based population estimates indicated that there were approximately 200 to 500 in-river spawners in those years.

Prior to the construction of Folsom and Nimbus dams, steelhead would seek out coldwater refuges in higher elevation habitats of the basin and spawned only in the upper reaches (Sacramento Water Forum 2015). Although some spawning by steelhead in the lower American River occurs naturally (Hannon and Deason 2008), the population is supported primarily by the Nimbus Fish Hatchery (NFH). Lindley et al. (2007) classifies the listed (i.e., naturally spawning) population of lower American River steelhead at a high risk of extinction because it is reportedly mostly composed of winter-run steelhead originating from NFH; possibly up to 90% of spawners are of hatchery origin (Hannon and Deason 2008). NMFS considers the lower American River population to be important to the survival and recovery of the species (National Marine Fisheries Service 2009). Hatchery origin-fish from NFH are not considered part of the CCV steelhead DPS.

Currently, spawning density of steelhead in the lower American River is highest in the upper seven miles of the river, but spawning occurs as far downstream as Paradise Beach. About 90% of spawning occurs upstream of the Watt Avenue Bridge (Hannon and Deason 2008). The presence and operation of the dams reduce the recruitment of spawning gravel in the lower American River below Nimbus Dam. To mitigate those effects, in the lower American River, roughly 24 acres have been devoted to gravel augmentation, while approximately 50 acres have focused on side channel creation. Habitat restoration projects completed in October 2022 at Nimbus Basin and Lower Sailor Bar enhanced habitat for steelhead by laying approximately 41,000 cubic yards of clean gravel into the river and excavated side channel habitat (Water Forum 2022). Those projects have improved spawning habitat for both Chinook salmon and steelhead spawning in the lower American River. Reclamation's habitat programs will continue through separate environmental compliance and future restoration plans as independent programs.

12.1.4.2 Chinook Salmon, Central Valley Fall-Run Evolutionarily Significant Unit

Adult fall-run Chinook salmon enter the lower American River from mid-September through January, with peak migration from approximately mid-October through December (Williams 2001). Spawning occurs from about mid-October through early February, with peak spawning from mid-October through December. Chinook salmon spawning occurs within an 18-mile stretch from Paradise Beach to Nimbus Dam; however, most spawning occurs in the uppermost three miles (California Department of Fish and Wildlife 2012). Fall-run chinook salmon egg and alevin incubation occurs in the lower American River from about mid-October through April. There is high variability from year to year; however, most incubation occurs from about mid-October through February. Chinook salmon fry emergence occurs from January through mid-April, and juvenile rearing extends from January to about mid-July (Williams 2001). Most Chinook salmon out-migrate from the lower American River as fry between December and July, peaking in February to March (Snider and Titus 2002; Pacific States Marine Fisheries Commission 2014). There is evidence that late-fall run Chinook salmon presence in the lower American River is a result of straying from fish released from the Coleman National Fish Hatchery (Lasko 2012).

The lower American River historically supported fall-run and perhaps late fall–run Chinook salmon (Williams 2001). Both natural-origin and hatchery-produced Chinook salmon spawn in the lower American River. An analysis by Palmer-Zwahlen et al. (2018) found that constant fractional marking results from 2013 show that approximately 86% of the fall-run Chinook salmon spawners returning to Nimbus Hatchery were hatchery-origin. Further, 71% of fall-run Chinook salmon recorded at the Hatchery Weir and 65% of carcasses were identified as hatchery fish.

Restoration projects like the Upper River Bend Phase I and Nimbus Basin and Lower Sailor Bar aim to provide and enhance additional spawning habitat in the lower American River for anadromous species like the fall-run Chinook salmon.

12.1.5 Stanislaus River

This section describes some of the focal fish species expected to occur in the Stanislaus River watershed. The Stanislaus River also supports populations of native minnows, Pacific lamprey, Western River lamprey, striped bass, black basses, threadfin shad, and American shad (Table 12-1), all of which are discussed in greater detail in Appendix O.

12.1.5.1 Steelhead, California Central Valley Distinct Population Segment

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

On the Stanislaus River, the completion of Goodwin Dam in 1912 has excluded salmon and steelhead from 100 percent of their historical spawning and rearing habitat on the Stanislaus River (Lindley et al. 2006). Since that time, salmon and steelhead spawn downstream of Goodwin Dam on the Stanislaus River which experiences warmer water temperatures. None of the three dams on the Stanislaus River have a temperature control device, so the only mechanism for temperature management on the Stanislaus River is direct flow management. Reclamation currently operates New Melones Dam, located upstream of Goodwin Dam.

Past operational releases from New Melones Dam have influenced the extent of coolwater habitat available below Goodwin Dam. Since 2019, Reclamation has implemented a Stepped Release Plan (SRP) for the Stanislaus River. The SRP does not set water temperature standards for the Stanislaus River, but it does include minimum flow targets that are intended to benefit steelhead, including water temperature benefits and preservation of coldwater pool. Under the CVPIA 3406(b)(13) program, Reclamation's annual goal of gravel placement is approximately 4,500 tons in the Stanislaus River. Between 2009 and 2022, approximately 54,450 tons of gravel were added to the Stanislaus River for steelhead and salmon habitat restoration (Bureau of Reclamation 2022a). Reclamation proposes to construct an additional 50 acres of rearing habitat adjacent to the Stanislaus River by 2030 (Bureau of Reclamation 2024).

12.1.5.2 Chinook Salmon, Central Valley Fall-Run

The Stanislaus River provides important spawning habitat for fall-run Chinook salmon. The majority of fall-run Chinook salmon adults migrate upstream to the Stanislaus River between late September through December with peak migration from late October through early November. Most fall-run Chinook salmon spawning occurs between Riverbank and Goodwin Dam (Bureau of Reclamation 2012). By late October, the amount of spawning in downstream locations increases as water temperatures decrease, and the median redd location is typically around Knights Ferry (State Water Resources Control Board 2015). About 99% of salmon juveniles migrate out of the Stanislaus River January through May (Stanislaus River Fish Group 2004). Fry migration generally occurs from January through March, followed by smolt migration from April through May (Bureau of Reclamation 2012).

Historic spawning areas of the Stanislaus River are no longer reachable due to the development of the Goodwin Dam, however fall-run Chinook salmon can still access suitable spawning habitat between Riverbank and the Goodwin Dam. Flows through this viable spawning section of the river are supported by releases from the New Melones Dam. Additionally, gold and gravel mining activities have further degraded potential spawning and rearing habitat for salmonids in the Stanislaus.

To promote and enhance spawning habitat within the Stanislaus, Reclamation implemented the Goodwin Canyon Salmonid Spawning Gravel Placement Project, which helped improve spawning and rearing habitat for juvenile salmonids in the system. As mentioned above, the CVPIA has also played an important role in enhancing habitat within the Stanislaus River for salmonids, including fall-run Chinook salmon.

12.1.6 San Joaquin River

This section describes some of the focal fish species expected to occur in the San Joaquin River watershed. The San Joaquin River also supports populations of native minnows, striped bass, black basses, and threadfin shad (Table 12-1), all of which are discussed in greater detail in Appendix O.

12.1.6.1 Steelhead, California Central Valley Distinct Population Segment

The San Joaquin River is primarily documented as a migratory corridor for adult and juvenile steelhead. Adults entering the San Joaquin River Basin appear to have a later spawning run, entering the system starting in late October through December. Outmigration of juveniles from the San Joaquin River into the Delta is monitored through the Mossdale Trawl, and median passage is April through May (Columbia Basin Research, University of Washington 2024). The sampling trawls capture steelhead smolts, although usually in small numbers. Steelhead were historically present in the San Joaquin River, though data on their population levels are lacking (McEwan 2001). The current steelhead population in the San Joaquin River is substantially reduced compared with historical levels, although resident rainbow trout occur throughout the major San Joaquin River tributaries. Additionally, small populations of steelhead persist in the lower San Joaquin River and tributaries (e.g., Stanislaus, Tuolumne, and possibly Merced Rivers) (Zimmerman et al. 2009; McEwan 2001). Steelhead/rainbow trout of anadromous parentage occur at low numbers in all three major San Joaquin River tributaries. These tributaries have a higher percentage of resident rainbow trout compared to the Sacramento River and its tributaries (Zimmerman et al. 2009).

Reclamation has undertaken river restoration projects and provided in-stream flows for the San Joaquin River. The San Joaquin River Restoration Program is outside of this consultation.

12.1.6.2 Green Sturgeon, Southern Distinct Population Segment

From 2007 to 2012, anglers reported catching six green sturgeon in the San Joaquin River (Jackson and Van Eenennaam 2013). Although the reported presence of green sturgeon in the San Joaquin River coincides with the spawning migration period of green sturgeon within the Sacramento River, no evidence of spawning has been detected (Jackson and Van Eenennaam 2013). The current status and historic range of green sturgeon in the San Joaquin River is unknown, though anglers report seeing green sturgeon in the San Joaquin River (California Department of Fish and Wildlife 2023).

There are not specific protections in place for sDPS green sturgeon in the San Joaquin River.

12.1.6.3 Chinook Salmon, Central Valley Fall-Run

The San Joaquin River downstream of the Stanislaus River primarily provides upstream passage for adult fall-run Chinook salmon and downstream passage for juveniles and smolts as they out-migrate from the tributary spawning and rearing areas to the Delta and the Pacific Ocean. Weir counts in the Stanislaus River suggest that adult fall-run Chinook salmon in the San Joaquin River basin typically migrate into the upper rivers from late September to mid-November and spawn shortly thereafter (Pyper et al. 2006; Anderson et al. 2007; FISHBIO Environmental 2010, 2011). The juvenile fall-run Chinook salmon out-migration in the San Joaquin River basin typically occurs during winter and spring, primarily from January through May. The out-migration consists primarily of fry in winter and smolts in spring (FISHBIO Environmental 2007, 2013). Trawl sampling in the lower San Joaquin River from Mossdale to the Head of Old River (the Mossdale Trawl) captures Chinook salmon from February into July, with peak catches generally during April and May (Speegle et al. 2013).

Fall-run Chinook salmon are present in the San Joaquin River and its major tributaries upstream to and including the Merced River. Spawning and rearing occur in the major tributaries (Merced, Tuolumne, and Stanislaus rivers) downstream of the mainstem dams. Fall-run Chinook salmon are subject to the same potential impacts as other salmonids within the San Joaquin River system, which includes loss of important floodplain and estuarine habitat and water exports.

Programs like the San Joaquin River Restoration Program aim to restore flows to the San Joaquin River. While one of the main goals of this program is to restore spring-run Chinook populations, the program would also provide benefits to fall-run Chinook salmon and other native fish.

12.1.7 Bay-Delta

This section describes some of the focal fish species expected to occur in the Bay-Delta watershed. The Bay-Delta also supports populations of white sturgeon, native minnows, Pacific lamprey, Western River lamprey, striped bass, black basses, threadfin shad, American shad, and starry flounder (Table 12-1), all of which are discussed in greater detail in Appendix O.

12.1.7.1 Chinook Salmon, Sacramento River Winter-Run Evolutionarily Significant Unit

Winter-run Chinook salmon adults migrate through the Delta during winter and into late spring to spawning grounds in the mainstem Sacramento River downstream of Keswick Dam. Fry disperse from mid-June through mid-October to areas downstream for rearing (Vogel and Marine 1991) and juvenile occupancy in the greater Sacramento River and estuary system is expected to last between five to nine months prior to entering the ocean (California Department of Fish and Wildlife 1985, 1998). Phillis et al. (2018) demonstrated 82% of surviving winter-run Chinook salmon reared exclusively upstream of the Delta, suggesting less reliance on Delta habitats than previously recognized. Results of acoustic tagging studies indicate that migrating Chinook smolts can move through the Delta rapidly on the order of days to weeks (Perry et al. 2018). Telemetry studies of acoustically tagged, hatchery-origin winter-run juveniles indicate that migratory survival of smolts varies by route through the Delta and is a function of flow and temperature (Hance et al. 2022). The peak timing of the out-migration of juvenile winter-run Chinook salmon through the Delta is corroborated by recoveries of winter-run-sized juvenile Chinook salmon from the John E. Skinner Delta Fish Protective Facility, part of the State Water Project (SWP), and the Tracy Fish Collection Facility (CVP) in the south Delta (National Marine Fisheries Service 2009).

Winter-run Chinook salmon juveniles have been documented in many parts of the Delta: north (e.g., Sacramento River, Steamboat Slough, Sutter Slough, Miner Slough, Yolo Bypass, and Cache Slough complex); central (e.g., Georgiana Slough, Delta Cross Channel, Snodgrass Slough, and Mokelumne River complex below Dead Horse Island); south Delta channels, including Old and Middle rivers (OMRs), and the joining waterways between OMRs (e.g., Victoria Canal, Woodward Canal, and Connection Slough); and western central Delta, including the mainstem channels of the Sacramento and San Joaquin rivers and Threemile Slough (National Marine Fisheries Service 2009). Winter-run Chinook salmon exit the Delta at Chipps Island between December and May, with a peak in March (Brandes and McLain 2001; del Rosario et al. 2013).

Hatchery production at facilities like the Livingston Stone National Fish Hatchery help supplement the winter-run Chinook salmon population, which ultimately supports the population numbers found in the Bay-Delta. The Yolo Bypass Salmonid Habitat Restoration Project further supports benefits to Chinook salmon by improving connectivity with important floodplain habitats, which are valuable to salmonid rearing.

12.1.7.2 Chinook Salmon, Central Valley Spring-Run Evolutionarily Significant Unit

Adult spring-run Chinook salmon returning to spawn in the Sacramento River system enter the San Francisco Estuary from the ocean in January to late February and move through the Delta prior to entering the Sacramento River. Juvenile spring-run Chinook salmon show two distinct out-migration patterns in the Central Valley: migrating to the Delta and ocean during their first year of life as young of year (i.e., ocean-type life history), or holding over in their natal streams and migrating the following fall/winter as yearlings (i.e., stream-type life history) (Moyle 2002). YOY spring-run Chinook salmon presence in the Delta peaks during April and May, as suggested by the recoveries of Chinook salmon in the CVP and SWP salvage operations and in the Chipps Island trawls of a size consistent with the predicted size of spring-run Chinook salmon at that time of year. However, it is difficult to distinguish YOY spring-run Chinook salmon migration from that of fall-run Chinook salmon without employing genetic analysis due to the similarity in their spawning and emergence times and size. Typically, juvenile Spring-Run Chinook Salmon are not found in the channels of the eastern side of the Delta.

The Delta is an important migratory route for all remaining populations of Spring-run Chinook Salmon. Like all salmonids migrating up through the Delta, adult Spring-run Chinook salmon must navigate the many channels and avoid direct sources of mortality (e.g., fishing and predation), but also must minimize exposure to sources of nonlethal stress (e.g., high temperatures) that can contribute to prespawn mortality in adult salmonids (Budy et al. 2002; Naughton et al. 2005; Cooke et al. 2006; National Marine Fisheries Service 2009). Habitat degradation in the Delta caused by factors such as channelization and changes in water quality can present challenges for out-migrating juveniles. Additionally, out-migrating juveniles are subjected to predation and entrainment in the project export facilities and smaller diversions (National Marine Fisheries Service 2009).

The head of Old River agricultural barrier operations are constructed seasonally to maximize survival of spring-run Chinook salmon emigrating from the San Joaquin River. Closure of the Delta Cross Channel (DCC) radial gates is intended to minimize spring-run straying, but some southward net flow still occurs naturally in Georgiana and Threemile sloughs. Reclamation and DWR continue to implement projects that will improve passage and habitat conditions in the Stockton Deep Water Ship Channel. The Delta Tidal Habitat Restoration project that aims to restore 8,396 acres of tidal habitat by 2026 and the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (Big Notch Project) that aims to increase seasonal floodplain rearing habitat by 2030 will further support benefits to spring-run Chinook salmon.

12.1.7.3 Chinook Salmon, Central Valley Fall-Run and Late Fall-Run Evolutionarily Significant Unit

Adult fall-run Chinook salmon migrate through the Delta and into Central Valley rivers from June through December, whereas adult late fall–run Chinook salmon migrate through the Delta and into the Sacramento River from October through April. Adult Central Valley fall- and late fall–run Chinook salmon migrating into the Sacramento River and its tributaries primarily use the western and northern portions of the Delta, whereas adults entering the San Joaquin River system to spawn use the western, central, and southern Delta as a migration pathway. Most fall-run Chinook salmon fry rear in fresh water from December through June, with out-migration as smolts occurring primarily from January through June. Smolts that arrive in the estuary after rearing upstream migrate quickly through the Delta and Suisun and San Pablo Bays. A small number of juvenile fall-run Chinook salmon spend over a year in fresh water and migrate as yearling smolts the following November through April. Late fall–run fry rear in fresh water from April through the following April and migrate as smolts from October through February (Snider and Titus 2000a, 2000b, and 2000c). Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay (MacFarlane and Norton 2002).

Juvenile fall- and late fall–run Chinook salmon migrating through the Delta toward the Pacific Ocean use the Delta, Suisun Marsh, and Yolo Bypass for rearing to varying degrees, depending on their life stage (fry versus juvenile), size, river flows, and time of year. Movement of juvenile Chinook salmon in the estuarine environment is driven by the interaction between tidally influenced saltwater intrusion through San Francisco Bay and freshwater outflow from the Sacramento and San Joaquin rivers (Healey 1991). Survival of juvenile acoustically tagged, hatchery-origin late fall-run Chinook salmon from the Sacramento River varied among migration routes: fish routed to the interior Delta through either the Georgiana Slough or Delta Cross Channel exhibited lower survival than fish routed through Sutter Slough, Steamboat Slough, or the mainstem Sacramento River (Perry et al. 2018). In the Delta, tidal and floodplain habitat provide important rearing habitat for foraging juvenile salmonids, including fall-run Chinook salmon. Studies show juvenile salmon may spend two to three months rearing in these habitats.

Restoration of floodplain habitats from the Yolo Bypass Salmonid Habitat Restoration Project will provide access to rearing habitat for juvenile salmonids and supplementing wild populations with hatchery raised fish are done to enhance the population of fall-run and late-fall run Chinook salmon in the Bay-Delta and throughout the Central Valley.

12.1.7.4 Steelhead, California Central Valley Distinct Population Segment

Upstream migration of California Central Valley steelhead begins with estuarine entry from the ocean as early as July and continues through February or March in most years (McEwan and Jackson 1996; National Marine Fisheries Service 2009). Populations of steelhead occur primarily within the watersheds of the Sacramento River Basin, although not exclusively. Steelhead can spawn more than once, with post-spawn adults (typically females) potentially moving back downstream through the Delta after completion of spawning in natal streams. Upstream migrating adult steelhead enter the Sacramento River and San Joaquin River basins through their respective mainstem river channels. Steelhead entering the Mokelumne River system (including Dry Creek and the Cosumnes River) and the Calaveras River system to spawn are likely to move up the mainstem San Joaquin River channel before branching off into the channels of their natal rivers, although some may detour through the south Delta waterways and enter the San Joaquin River through the head of the Old River.

As mentioned in the San Joaquin River section above, steelhead entering the San Joaquin River Basin appear to have a later spawning run, indicating that migration up through the Delta may begin a few weeks earlier. During fall, warmwater temperatures in the south Delta waterways and water quality impairment because of low dissolved oxygen at the Port of Stockton have been suggested as potential barriers to upstream migration (National Marine Fisheries Service 2009). Reduced water temperatures, rainfall runoff, and flood control release flows provide the stimulus for adult steelhead holding in the Delta to move upriver toward their spawning reaches in the San

Joaquin River tributaries. Adult steelhead may continue entering the San Joaquin River basin through winter. Juvenile steelhead are recovered in trawls October through July at Chipps Island and Mossdale. Chipps Island catch data indicate a difference in migration timing between wild unmarked and hatchery-reared steelhead smolts from the Sacramento and east side tributaries. Hatchery fish are typically recovered at Chipps Island January through March, with a peak in February and March corresponding to the schedule of hatchery releases of steelhead smolts from the Central Valley hatcheries (Nobriga and Cadrett 2001; Bureau of Reclamation 2008). The timing of wild steelhead migration is more spread out, and based on salvage records at the CVP and SWP fish collection facilities, out-migration occurs over approximately six months with the highest levels of recovery in February through June (Aasen 2011, 2012).

The Yolo Bypass Project is intended to improve shallow water habitat and habitat connectivity for steelhead. Operations are expected to provide improved habitat connectivity for fish species to migrate between the Sacramento River and the Yolo Bypass. This enhanced habitat connectivity is expected to improve the ability of anadromous fish to access the Yolo Bypass, resulting in increased growth and decreased stranding events.

12.1.7.5 Green Sturgeon, Southern Distinct Population Segment

Adult green sturgeon move through the Delta from February through April, arriving at holding and spawning locations in the upper Sacramento River between April and June (Heublein 2006; Kelly et al. 2007). Following the initial spawning run upriver, adults may hold for a few weeks to months in the upper river before moving back downstream in fall (Vogel 2008; Heublein et al. 2009, Miller et al. 2020) or they may migrate back downstream through the Delta as early as the spring (Colborne et al. 2022). Adult green sturgeon have been tracked moving downstream past Knights Landing during summer and fall, typically in association with pulses of flow in the river, and congregate in the San Francisco Estuary (Heublein et al. 2009; Lindley et al. 2008). Juvenile green sturgeon are periodically, although rarely, collected from the lower San Joaquin River at south Delta water diversion facilities and other sites and salvaged from the SWP and CVP facilities (National Marine Fisheries Service 2009; Aasen 2011, 2012; Bureau of Reclamation 2008). Larvae and juveniles migrate downstream toward the Delta to rear for the first one to three years of their lives before moving out to the ocean. They are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, especially within the central Delta and Suisun Bay and Marsh (Bureau of Reclamation 2008). Miller et al. (2020) found that juvenile green sturgeon make short oceanic movements and return to the San Francisco Estuary before migrating out into the ocean as adults.

Green sturgeon are found in the Delta year-round, likely foraging and/or rearing before migrating into the ocean (Heublein et al. 2017). Juvenile green sturgeon are known to be in the Sacramento River upstream of Sherman Lake during all months of the year, but most abundantly in late-June through mid-September (Beccio pers. comm.). Their movements through and behavior in the Delta are not well known or studied.

According to the NMFS 2018 Green Sturgeon Recovery Plan, channel control structures, impoundments, predation, and climate change are the main threats to juvenile and adult green sturgeon in the Delta. Non-point source contaminants are an additional high threat to juveniles in the Delta. The Yolo Bypass Salmonid Habitat Restoration project (Big Notch Project) is expected to benefit green sturgeon by decreasing stranding and migration delays due to passage barriers (Bureau of Reclamation 2022b).

12.1.7.6 Delta Smelt

Delta smelt have a mostly annual life cycle and are endemic to the Delta and the upper San Francisco Estuary (Moyle et al. 1992; Bennett 2005). Delta smelt are thought to spawn during winter and spring months over a wide area throughout much of the Delta, including the Sacramento River and San Joaquin River confluence, the upper Sacramento River, and Cache Slough as conditions allow (Brown et al. 2014; Murphy and Hamilton 2013). Substrates or habitats used for spawning by wild Delta smelt are unknown, but lab studies on wild fish have shown a preference for spawning over sandy or gravel substrates (Lindberg et al. 2019). During and after larval rearing in fresh water, many young Delta smelt move with river and tidal currents to remain in favorable rearing habitats, often moving increasingly into the low-salinity zone to avoid seasonally warm and highly transparent waters that typify many areas in the central Delta (Nobriga et al. 2008). Depending on hydrological conditions, this includes San Pablo Bay, the Napa River, Suisun Bay, Suisun Marsh, the Sacramento River and San Joaquin River confluence, and the lower Sacramento River (Merz et al. 2011; Murphy and Hamilton 2013). During summer and fall, many juvenile Delta smelt continue to grow and rear in the low-salinity zone, until maturing the following winter (Bennett 2005). During the winter, adult Delta smelt initiate upstream spawning migrations in association with "first flush" freshets (Sommer et al. 2011). Some Delta smelt also rear and complete their life cycle in freshwater upstream areas such as the Cache Slough complex and Sacramento Deep Water Ship Channel, depending on habitat conditions (Sommer and Mejia 2013).

Delta smelt persist in the upper San Francisco Estuary and Delta; however, portions of the historical tidal marsh–floodplain habitat once totaling approximately 300,000 acres has been diked and reclaimed for agricultural or other human use. Water conveyance projects and river channelization have altered the regional physical habitat by armoring levees with riprap, building conveyance channels like the DCC, storage reservoirs like Clifton Court Forebay, and by building and operating temporary barriers in the south Delta and permanent gates and water distribution systems in Suisun Marsh. Export and diversion of water for human uses can result in the entrainment of Delta smelt into unsuitable habitat or into water operation facilities. Channels in Suisun Bay and the Delta have been dredged deeper to accommodate shipping traffic and requires more freshwater outflow to maintain the low-salinity zone, an important Delta smelt rearing habitat, in the large Suisun Bay/river confluence region than was once required. Recent research combining long-term monitoring data with three-dimensional hydrodynamic modeling shows that the spatial overlap of several of the key habitat attributes, such as salinity and turbidity, increases as Delta outflow increases (Bever et al. 2016). Additionally, a wide variety of non-native plants and animals have been introduced and have altered habitat and the lower trophic food web (Cohen and Carlton 1998, Light et al. 2005, Winder and Jassby 2011). Important zooplankton prey have experienced long term declines (Winder and Jassby 2011, Kimmerer 2002).

Refugial populations of Delta smelt have been established at the UC Davis Fish Conservation and Culture Laboratory; the closed cycle is supplemented by wild broodstock collection. Recent supplementation efforts began in 2021 with experimental releases of cultured Delta smelt into the wild at various locations and have continued to the present day. Tidal habitat restoration projects in the Bay-Delta and the Suisun Marsh have also been ongoing meant to benefit native species including smelt. Additionally, several objectives and actions laid out in the 2016 Delta Smelt Resiliency Plan are ongoing including the north Delta food web adaptive management projects, outflow augmentation, Roaring River distribution system food production, and the above-mentioned Delta smelt supplementation.

12.1.7.7 Longfin Smelt, San Francisco Bay-Delta Distinct Population Segment

Longfin smelt populations occur along the Pacific Coast of North America, and the San Francisco Estuary (SFE) represents the southernmost population. Longfin smelt generally occur in the Delta; Suisun, San Pablo, and San Francisco Bays; and the Gulf of the Farallones, just outside San Francisco Bay. Longfin smelt are anadromous and migrate upstream to spawn in fresh or low salinity water in the Bay-Delta (Grimaldo et al. 2017), generally at 2 years of age, with most spawning occurring from November through April (Moyle 2002; California Department of Fish and Game 2009). Studies suggested that spawning occurs in the lower Sacramento River, the confluence of the Sacramento and San Joaquin rivers, and downstream of about Medford Island in the San Joaquin River (Moyle 2002). Other studies suggest hatching and early rearing occurs in a much broader region and higher salinity (2–12 parts per thousand) (Grimaldo et al. 2017), and that spawning distribution may also include portions of the south San Francisco Bay (Lewis et al. 2019), Suisun Marsh, and the Napa River (California Department of Fish and Game 2009) depending on hydrological conditions. Longfin smelt larvae are typically most abundant in the water column January through April (Bureau of Reclamation 2008). As larvae transition into the juvenile life stage, a portion of the population migrates out of the upper estuary and Delta by summer; the population is at least partially anadromous and is likely only one of several life history strategies in the population (Rosenfield and Baxter 2007; Garwood 2017).

Longfin smelt utilize the upper San Francisco Estuary and Delta as spawning and rearing habitat; however, portions of the historical tidal marsh–floodplain habitat once totaling approximately 300,000 acres has been diked and reclaimed for agricultural or other human use. Water conveyance projects and river channelization have altered the regional physical habitat by armoring levees with riprap, building conveyance channels like the DCC, storage reservoirs like Clifton Court Forebay, and by building and operating temporary barriers in the south Delta and permanent gates and water distribution systems in Suisun Marsh. Export and diversion of water for human uses can result in the entrainment of longfin smelt into unsuitable habitat or into water operation facilities. Channels in Suisun Bay and the Delta have been dredged deeper to accommodate shipping traffic and requires more freshwater outflow to maintain the low-salinity zone, an important larval and juvenile longfin smelt rearing habitat, in the large Suisun Bay/river confluence region. Additionally, a wide variety of non-native plants and animals have been introduced and have altered habitat and the lower trophic food web (Cohen and Carlton 1998; Winder and Jassby, 2011). Important zooplankton prey have experienced long term declines (Winder and Jassby 2011, Kimmerer 2002).

Ongoing efforts are continuing to develop a captive longfin smelt culture program at the UC Davis Fish Conservation and Culture Lab. Tidal habitat restoration projects in the Bay-Delta and the Suisun Marsh have also been ongoing meant to benefit native species including smelt.

12.1.8 Nearshore Pacific Ocean

Anadromous fish species use the Pacific Ocean as part of their life cycles. In addition, the Pacific Ocean supports the Southern Resident Killer Whale (SRKW) DPS, which relies on large anadromous fish in the ocean, particularly Chinook salmon, as preferred prey.

12.1.8.1 Killer Whale, Southern Resident Distinct Population Segment

The Pacific Ocean along the coast of northern California is part of the Southern Residents population's critical habitat. The potential effect of the action, however, is limited to potential changes in the number of Chinook salmon produced in the Central Valley and Trinity River regions entering the Pacific Ocean which may contribute an important component of the Southern Residents diet. Southern Residents are known to occur frequently in the inland waters of Washington, USA, and British Columbia, Canada, the outer coastal waters (within ~50 km of shore) from Haida Gwaii, Canada down the West coast of Vancouver Island, Washington, Oregon, and California as far south as Monterey Bay (National Marine Fisheries Service 2021).

According to the 2008 NMFS Recovery Plan for Southern Resident Killer Whales, prey availability is one of several threats to the species. Chinook salmon are SRKW preferred prey (Ford and Ellis 2006), and California Central Valley and Trinity River fall-run and spring-run Chinook salmon account for up to 19% of prey samples collected in outer coastal waters (Hanson et al. 2021). Several studies have identified correlations or connections between Chinook salmon abundance indices and Southern Residents health, survival, social cohesion, growth rate, body condition, and fecundity (Ward et al. 2009; Ayres et al. 2012; Ford et al. 2010; Fearnbach et al. 2011; Ward et al. 2013; Wasser et al. 2017; Fearnbach et al. 2020; Stewart et al. 2021). However, understanding demographic and health correlations with prey indices is complicated by differences in pod foraging patterns (Stewart et al. 2021); interactions with disturbance stressors (Ayres et al. 2012; Lacy et al. 2017); interaction with toxicant stressors (Lacy et al. 2017); residual demographic trends (Nelson et al. 2024); potential competition with the northern resident distinct population segment (Nelson et al. 2024); and inbreeding depression (Kardos et al. 2023).

12.2 Effects of the Alternatives

The impact assessment considers changes in fish and aquatic resources related to changes in CVP and SWP operations under the alternatives as compared to the No Action Alternative. This discussion describes some of the focal fish species; other fish species are described in greater detail in Appendix O including results from biological modeling. Attachments to Appendix O outline background, methods, results, assumptions and uncertainty, and references. Effects in this chapter describe beneficial and adverse impacts and not identify where impacts are negligible.

The No Action Alternative is based on 2040 conditions. The changes to fish and aquatic resources, such as changes in flow and temperature, that are assumed to occur by 2040 under the No Action Alternative conditions would be different than existing conditions because of the following non exhaustive list of factors:

- Climate change and sea-level rise

- General plan development throughout California, including increased water demands in portions of the Sacramento Valley

In the long term, it is anticipated that climate change, and development throughout California, could affect water supply deliveries.

Under the No Action Alternative, Reclamation would continue with the current operation of the CVP, as described in the 2020 Record of Decision and subject to the 2019 Biological Opinions. The 2020 Record of Decision for the CVP and the 2020 Incidental Take Permit for the SWP represent current management direction or intensity pursuant to 43 CFR Section 46.30.

Although the No Action Alternative included habitat restoration projects at a programmatic level, the 2020 ROD did not provide environmental coverage for these projects, and all of the habitat projects considered under the No Action required or will require additional environmental documentation. Thus, ground disturbance for habitat restoration projects did not materialize as a result of implementing the No Action Alternative. For the purpose of the analysis, these habitat restoration projects are considered independent projects that will be considered under cumulative effects.

The No Action Alternative is expected to result in potential changes to fish and aquatic resources, such as temperature and flow. These changes were described and considered in the 2020 LTO Record of Decision and associated documents. These changes are also described in Appendix O in the Cumulative Impacts section.

12.2.1 Trinity River

Different alternatives may import water from the Trinity River to the Sacramento River to a different extent in different years and on different patterns. Flows under the Trinity River Restoration Program Record of Decision (2000) are common to all alternatives; therefore, impacts occur as a result of different reservoir levels and rare safety of dam releases. The simulated CalSim 3 results are attributed to modeling assumptions for Alternative 1-4 described in Appendix F.

12.2.1.1 Southern Oregon/Northern California Coast coho salmon

For Southern Oregon/Northern California Coast coho salmon, outlined below are the expected responses to survival of incubating eggs and alevins, changes in rearing habitat for early life stages (fry and juveniles), and to spawning area from changes in operations primarily under each alternative relative to the No Action Alternative. The No Action Alternative would continue to improve coho habitat conditions (Appendix O). Appendix O provides detailed quantitative results of all model predictions.

- **Alternative 1** is expected to have spatially variable but negligible impacts of flow and water temperature on spawning and egg incubation and no adverse impacts on juvenile rearing habitat.
- **Alternative 2** is expected to have spatially variable impacts of flow and water temperature on spawning and egg incubation and juvenile rearing habitat, likely ranging from negligible to no adverse impacts.

- **Alternative 3** is expected to have spatially variable impacts of flow and water temperature on spawning and egg incubation and juvenile rearing habitat, likely ranging from negligible adverse to no adverse impacts.
- **Alternative 4** is expected to have no adverse impacts of flow and water temperature on spawning and egg incubation and juvenile rearing habitat.

Spring-run Chinook salmon

For upper Klamath-Trinity Rivers spring-run Chinook salmon, outlined below are the expected responses to survival of incubating eggs and alevins, changes in rearing habitat for early life stages (fry and juveniles), and to spawning area from changes in operations primarily under each alternative relative to the No Action Alternative. The No Action Alternative would continue to improve spring-run Chinook habitat conditions (Appendix O). Appendix O provides detailed quantitative results of all model predictions.

- **Alternative 1** is expected to have negligible impacts on spawning and egg incubation as well as rearing habitat.
- **Alternative 2** is expected to have negligible impacts on spawning and egg incubation as well as rearing habitat.
- **Alternative 3** is expected to have negligible impacts on spawning and egg incubation as well as rearing habitat.
- **Alternative 4** is expected to have no impacts on spawning and egg incubation as well as rearing habitat.

Fall-run Chinook salmon

For upper Klamath-Trinity Rivers fall-run Chinook salmon, outlined below are the expected responses to survival of incubating eggs and alevins, changes in rearing habitat for early life stages (fry and juveniles), and to spawning area from changes in operations primarily under each alternative relative to the No Action Alternative. The No Action Alternative would continue to improve fall-run Chinook habitat conditions (Appendix O). Appendix O provides detailed quantitative results of all model predictions.

- **Alternative 1** is expected to have spatially variable but negligible impacts of flow and water temperature on spawning and egg incubation and juvenile rearing habitat.
- **Alternative 2** is expected to have negligible impacts on spawning and egg incubation as well as rearing habitat.
- **Alternative 3** is expected to have negligible impacts on spawning and egg incubation as well as rearing habitat.
- **Alternative 4** is expected to have negligible impacts on spawning and egg incubation as well as rearing habitat.

Klamath Mountains Province steelhead

For Klamath Mountains Province steelhead, outlined below are the expected responses to survival of incubating eggs and alevins, changes in rearing habitat for early life stages (fry and juveniles), and to spawning area from changes in operations primarily under each alternative relative to the No Action Alternative. The No Action Alternative would continue to improve steelhead habitat conditions (Appendix O). Appendix O provides detailed quantitative results of all model predictions.

- **Alternative 1** is expected to have negligible adverse impacts from flow and water temperatures for all life stages.
- **Alternative 2** is expected to have negligible adverse impacts from flow and water temperatures for all life stages.
- **Alternative 3** is expected to have negligible adverse impacts from flow and water temperatures for all life stages.
- **Alternative 4** is expected to have negligible adverse impacts from flow and water temperatures for all life stages, and adverse flow impacts to adult holding habitat (up to approximately a 10% decrease) in wet years and above normal years.

12.2.1.2 Northern DPS green sturgeon

For Northern DPS green sturgeon, outlined below are the expected responses to survival of incubating eggs and yolk-sac larvae, changes in rearing habitat for early life stages, and to spawning area from changes in operations primarily under each alternative relative to the No Action Alternative. The No Action Alternative would continue contributing to the maintenance of suitable habitat conditions for green sturgeon (Appendix O). Appendix O provides detailed quantitative results of all model predictions.

- **Alternative 1** is expected to have negligible adverse to no adverse impacts from flow and water temperatures for all life stages.
- **Alternative 2** is expected to have negligible adverse to no adverse impacts from flow and water temperatures for all life stages.
- **Alternative 3** is expected to have negligible adverse to no adverse impacts from flow and water temperatures for all life stages.
- **Alternative 4** is expected to have negligible adverse to no adverse impacts from flow and water temperatures for all life stages.

Eulachon

For Southern DPS eulachon, outlined below are the expected responses to survival of incubating eggs and yolk-sac larvae, changes in rearing habitat for early life stages, and to spawning area from changes in operations primarily under each alternative relative to the No Action Alternative. The No Action Alternative would continue contributing to the maintenance of suitable habitat conditions for eulachon (Appendix O). Appendix O provides detailed quantitative results of all model predictions.

- **Alternative 1** is expected to have negligible adverse to no adverse impacts from flow and water temperatures for all life stages.
- **Alternative 2** is expected to have negligible adverse to no adverse impacts from flow and water temperatures for all life stages.
- **Alternative 3** is expected to have negligible adverse to no adverse impacts from flow and water temperatures for incubating eggs and larvae and rearing habitat impacts to juvenile emigration.
- **Alternative 4** is expected to have negligible adverse to no adverse impacts from flow and water temperatures for all life stages.

12.2.1.3 Other aquatic species

For aquatic species in the Trinity River not described above, including brown trout and Trinity Reservoir species, potential impacts range from adverse to no impact. There are little to no impacts on brown trout and coldwater reservoir species for Alternative 1-4. There are adverse impacts from flow and water temperature on warmwater species under Alternative 2 and Alternative 4 under some months and water year types.

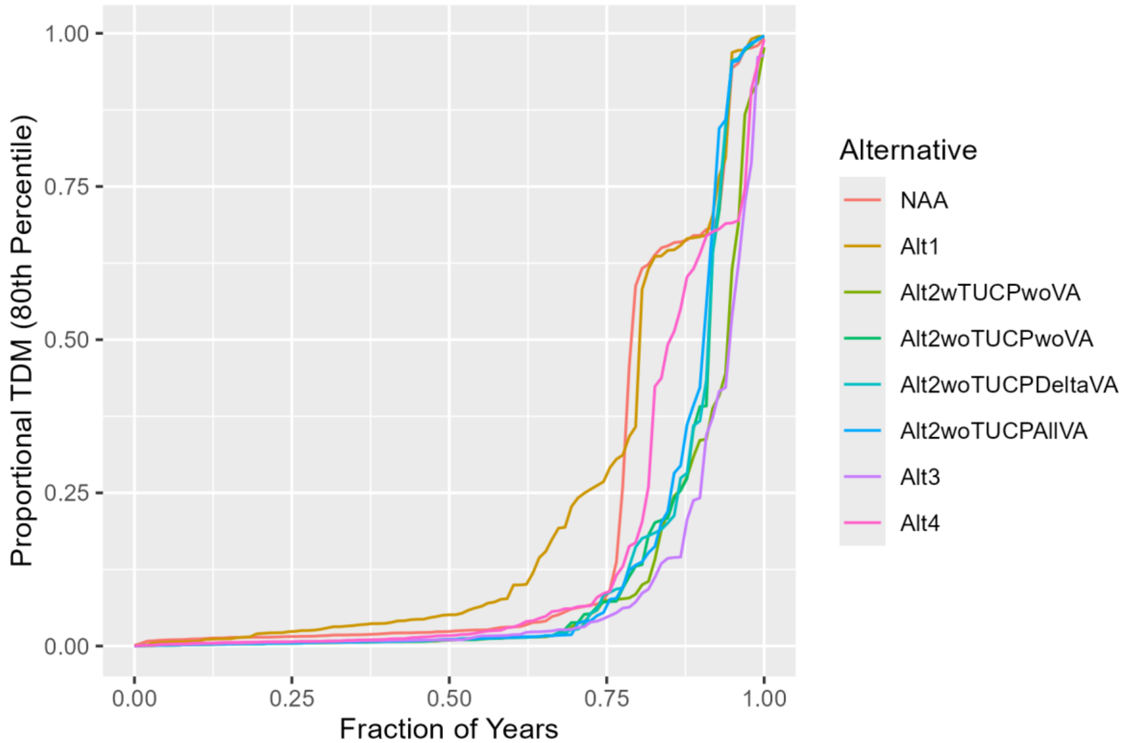
12.2.2 Sacramento River

12.2.2.1 Winter-run Chinook salmon

For winter-run Chinook salmon, outlined are expected responses to survival for incubating eggs and alevins and for early life stages from changes in summer / fall water temperature management operations under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models may vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on spawning and egg incubation that varies by the component.
- **Alternative 1** is expected to have adverse impact resulting from decreased egg survival and increased temperature dependent mortality (Anderson predicted mean proportional TDM estimate, range of all non-critically dry water year types and critically dry water year type: 0.021 - 0.286 and 0.811; Martin TDM estimate, range of all non-critically dry water year types and critically dry water year type: 0.021 - 0.234 and 0.690; Figure 12-1), minimal impacts from less fry stranding. and little to no impact on fry and juvenile rearing (range of predicted mean instream rearing habitat quantities across all water year types: 30.66 (July) – 60.82 (October) acres), increases in redd dewatering potential during critically dry water year types, decreases in fry survival, and beneficial impacts on juvenile survival (average mean annual survival, range of all non-critically dry water year types and critically dry water year type: 14.45 – 26.19 and 9.64; Figure 12-2). Alternative 1 carries over less water in storage to contribute to the next year's cold water pool.
- **Alternative 2** is expected to have minimal to beneficial impact on egg survival resulting from decreased temperature dependent mortality (Anderson predicted mean proportional

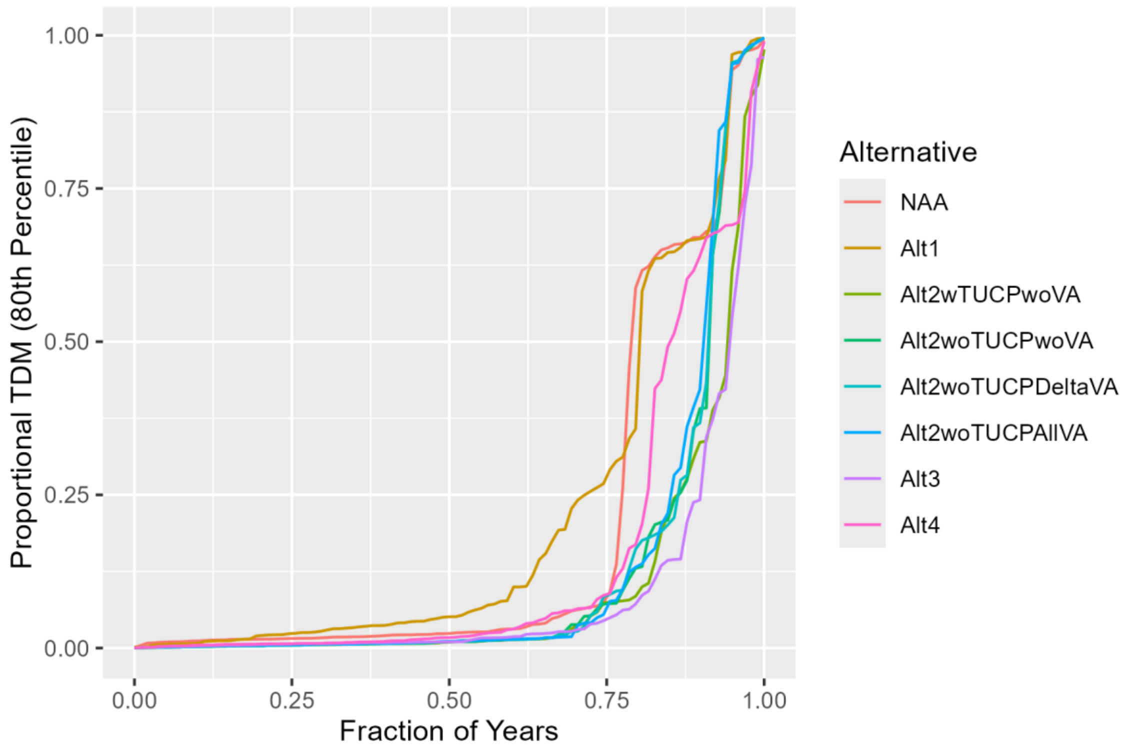
TDM estimate, range of all non-critically dry water year types and critically dry water year type: 0.001 - 0.061 and 0.472; Martin TDM estimate, range of all non-critically dry water year types and critically dry water year type: 0.007 - 0.102 and 0.561;



- Figure 12-1), increased egg to fry survival, generally less fry stranding, increases or reductions in redd dewatering potential during critically dry water year types (depending on the phase), and little to no impact on fry and juvenile rearing (range of predicted mean instream habitat quantities across all water year types: 31.02 (July) – 60.59 (October) acres), and beneficial impact on juvenile survival particularly in critically dry water year types (average mean annual survival, range of all non-critically dry water year types and critically dry water year type under the four phases: 11.9 – 26.12 and 7.19 – 11.46; Figure 12-2). Alternative 2 requires more storage in Shasta Reservoir for higher releases.

- **Alternative 3** is expected to have adverse to beneficial impacts resulting decreased egg to fry survival and generally decreased temperature dependent mortality except wet water year types (Anderson predicted mean proportional TDM estimate, range of all non-critically dry water year types and critically dry water year type: 0.005 - 0.042 and 0.312; Martin TDM estimate, range of all non-critically dry water year types and critically dry water year type: 0.011 - 0.077 and 0.389; Figure 12-1), less fry stranding and higher fry survival particularly in critically dry water year type, and little to no impact on fry and juvenile rearing (range of predicted mean instream rearing habitat quantities across all water year types: 32.87 (July) – 60.96 (October) acres), reduction in redd dewatering potential during critically dry water year types, and beneficial impact on juvenile survival except adverse in below normal and dry water year types (average mean annual survival, range of all non-critically dry water year types and critically dry water year type: 11.76 – 28.91 and 7.32; Figure 12-2). Alternative 3 combines additional Delta outflow with measures to improve drought protection and temperature management through increased reservoir carryover storage.

- **Alternative 4** is expected to have adverse to beneficial impacts resulting from no impact on egg survival except an increase in survival in critically dry water years, decreased egg to fry survival, and generally decreased temperature dependent mortality except wet water year types (Anderson predicted mean proportional TDM estimate, range of all non-critically dry water year types and critically dry water year type: 0.007 - 0.123 and 0.608; Martin TDM estimate, range of all non-critically dry water year types and critically dry water year type: 0.015 - 0.129 and 0.585;



- Figure 12-1), less fry stranding, reduction in redd dewatering potential in critically dry water year types, and lower fry survival, increases and decreases in rearing habitat (range of predicted mean instream habitat quantities across all water year types: 31.25 (July) – 61.26 (October) acres), and beneficial impact on juvenile survival (average mean annual survival, range of all non-critically dry water year types and critically dry water year type: 15.12 – 26.08 and 7.05; Figure 12-2). Alternative 4 releases from Shasta Reservoir for water service contract deliveries to achieve an EOS storage of 2.0 MAF in Shasta Reservoir based on the 90% forecast unless a less conservative forecast requires more releases.

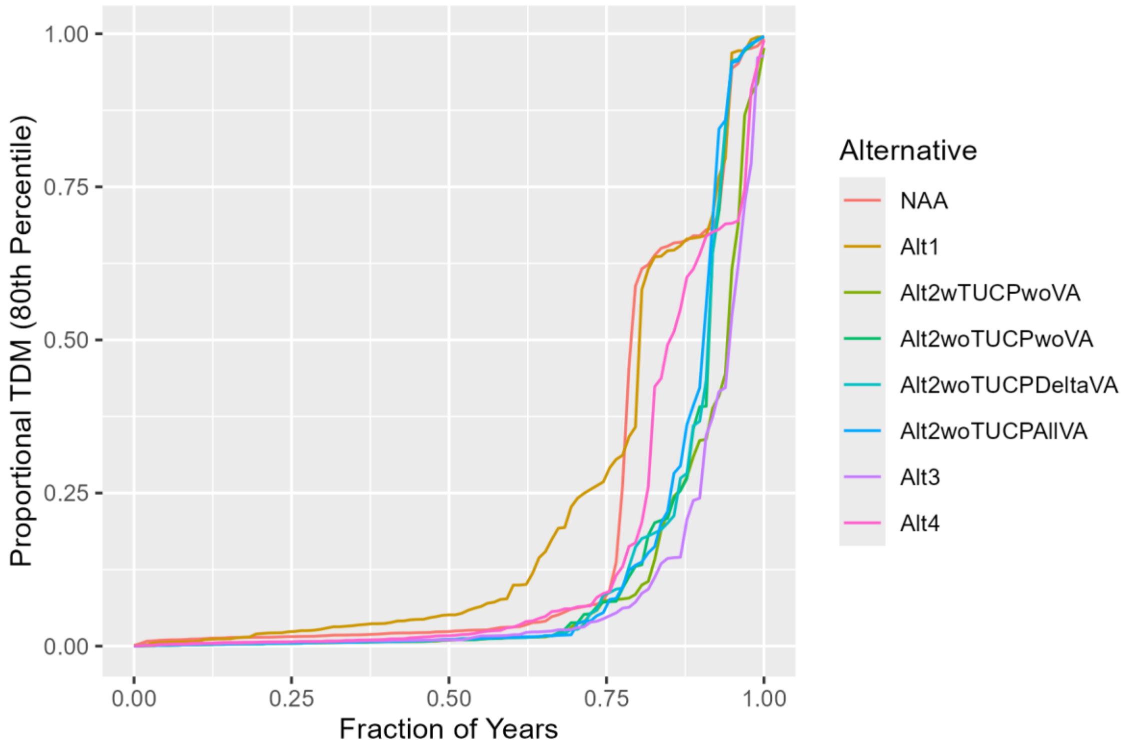


Figure 12-1. Exceedance plots of proportional Temperature Dependent Mortality (TDM) estimates across all water year types for the Martin TDM model, calculated using the 80th percentile of TDM for each water year type (Attachment L.2 *Egg-to-fry Survival and Temperature Dependent Mortality*).

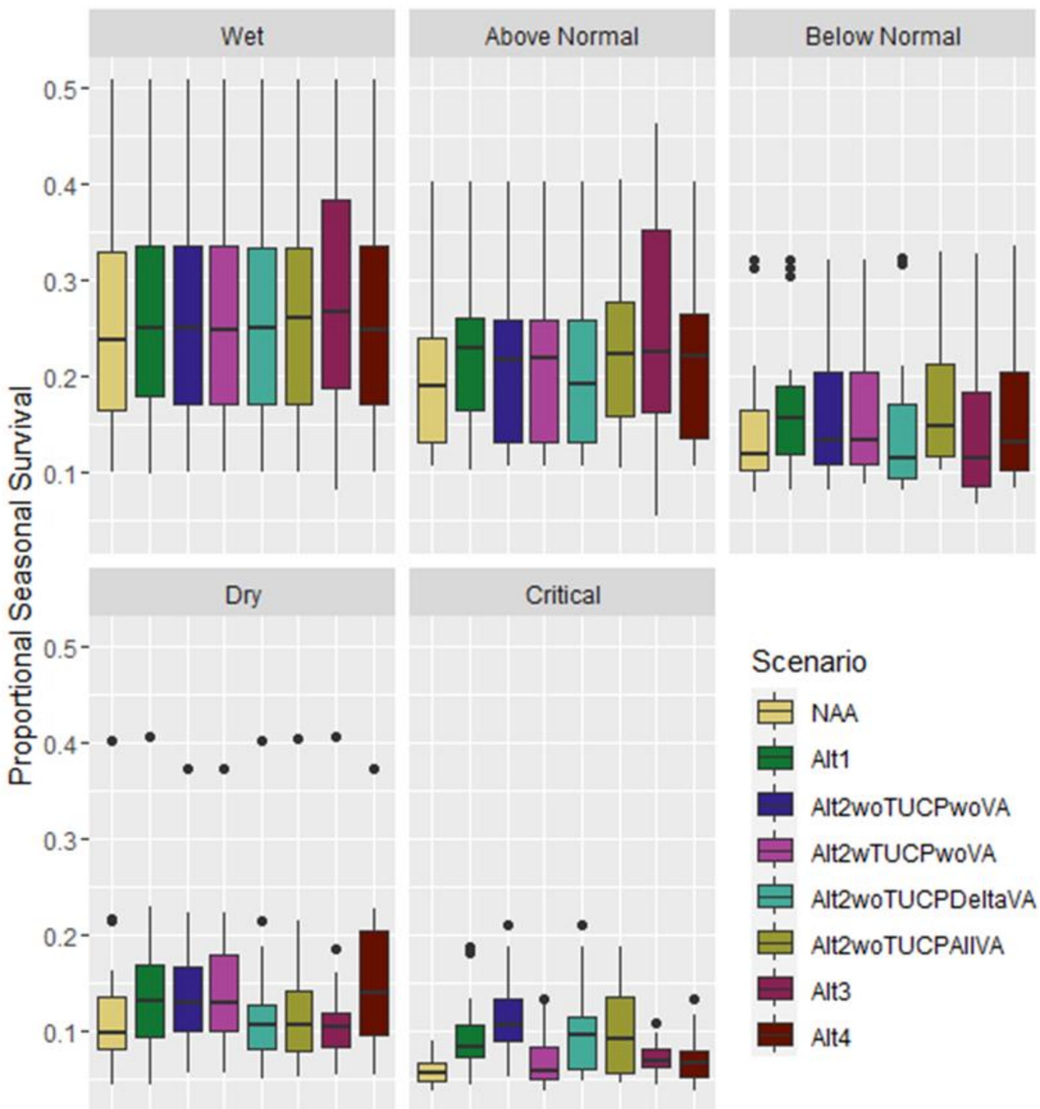


Figure 12-2. Boxplots of annual mean seasonal March 15th through June 15th probability of juvenile Chinook salmon survival in the Sacramento River, between the confluence of Deer Creek and Feather River, for each water year type (Attachment J.5 *Flow Threshold Salmon Survival*).

12.2.2.2 Spring-run Chinook salmon

For spring-run Chinook salmon, outlined are expected responses to survival for incubating eggs and alevins, survival for early life stages, and changes to rearing habitat and stranding from changes in summer/fall water temperature management operations under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models may vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.
- **Alternative 1** is expected to have negligible impacts from changes to flow on spawning, spawner abundance, and egg/alevin incubation, adverse impacts on redd dewatering during wet and above normal water year types from reductions in flow to store water in the winter, adverse and beneficial impacts from changes to the pattern of flow on rearing habitat (range of predicted mean instream rearing habitat quantities across all water year types: 61.54 (November) – 39.45 (June) acres), beneficial impact on juvenile survival (average mean annual survival, range of all non-critically dry water year types and critically dry water year type: 14.45 – 26.19 and 9.64; Figure 12-2), adverse impacts on juvenile stranding except in critically dry years, and adverse and beneficial impacts from water temperature on growth, smoltification, and predation vulnerability, depending on index value, life stage and location). Alternative 1 carries over less water in storage to contribute to the next year's cold water pool.
- **Alternative 2** is expected to have little impact from changes to flow on spawning, spawner abundance and egg/alevin incubation, beneficial impacts on redd dewatering potential in critically dry water year types, adverse and beneficial impacts from water temperature on spawning and egg/alevin incubation, adverse and beneficial impacts from changes to the pattern of flow on rearing habitat (range of predicted mean instream habitat quantities across all water year types: 58.96 (November) – 42.1 (June) acres, beneficial impact on juvenile survival (average mean annual survival, range of all non-critically dry water year types and critically dry water year type under the four phases: 11.9 – 26.12 and 7.19 – 11.46; Figure 12-2), adverse and beneficial impacts on juvenile stranding depending on the phase and water year type, and adverse and beneficial impacts from water temperature on juvenile and yearling growth, smoltification, and predation vulnerability. Alternative 2 requires more storage in Shasta Reservoir for higher releases and implements spring pulses.
- **Alternative 3** is expected to have adverse to beneficial impacts from changes to flow on spawning, spawner abundance, impacts on redd dewatering, and egg/alevin incubation, negligible impacts from water temperature on spawning and egg/alevin incubation, impacts from changes to the pattern of flow on rearing habitat and stranding (range of predicted mean instream rearing habitat quantities across all water year types: 60.58 (November) – 46.16 (June) acres), beneficial impact on juvenile survival except adverse in below normal and dry water year types (average mean annual survival, range of all non-critically dry water year types and critically dry water year type: 11.76 – 28.91 and 7.32; Figure 12-2), and adverse and beneficial impacts from water temperature on juvenile rearing and emigration, except below Keswick Dam where there would be an adverse impact on both juvenile and yearling life stages. Alternative 3 combines additional Delta outflow with measures to improve drought protection and temperature management through increased reservoir carryover storage and implements spring pulses.
- **Alternative 4** is expected to have impacts from changes to flow on spawning, spawning habitat, spawner abundance, and egg/alevin incubation, beneficial impacts on redd dewatering potential in critically dry water year types, adverse to beneficial

impacts from water temperature on spawning and egg/alevin incubation, adverse to beneficial impacts from changes to the pattern of flow on rearing habitat (range of predicted mean instream rearing habitat quantities across all water year types: 58.34 (November) – 41.61 (June) acres), adverse and beneficial impacts on juvenile stranding depending on the water year type, beneficial impact on juvenile survival (average mean annual survival, range of all non-critically dry water year types and critically dry water year type: 15.12 – 26.08 and 7.05; Figure 12-2), and expected adverse and beneficial impacts from water temperature on juvenile rearing and emigration (depending on index value, life stage, and location). Alternative 4 releases from Shasta Reservoir for water service contract deliveries to achieve an EOS storage of 2.0 MAF in Shasta Reservoir based on the 90% forecast unless a less conservative forecast requires more releases.

12.2.2.3 California Central Valley steelhead

For steelhead, outlined are expected responses to changes in rearing habitat and stranding from changes in operations under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models may vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have changes in flow that result in adverse and beneficial impacts, with a -1.2% to 1.9% difference in rearing habitat area depending on water year type. Changes in flow are also expected to have a adverse impact on fry stranding, with up to a 16.1% difference during wetter water year types, and a beneficial impact with up to 12.6% difference on fry stranding during drier water year types. Changes to water temperature are expected to have a beneficial impact on juvenile rearing and emigration. Alternative 1 carries over less water in storage to contribute to the next year's coldwater pool.

- **Alternative 2** is expected to have changes in flow that result in adverse and beneficial impacts, with a -1.4 % to 5.8% difference in rearing habitat area depending on water year type. Changes in flow are also expected to have general beneficial impacts on fry stranding, with a 30% reduction in below normal water year types, but may have adverse impact in critically dry water year types with up to 8.8% increase in fry stranding. Changes to water temperature are expected to have a beneficial impact on juvenile rearing and emigration. Alternative 2 requires more storage in Shasta Reservoir for higher releases.

- **Alternative 3** is expected to have changes in flow that result in adverse and beneficial impacts, with a -1.6% to 5.6% difference in rearing habitat area depending on water year type. Changes in flow are also expected to have adverse impacts on fry stranding during above normal/below normal water year types with up to a 25% increase, and beneficial impact on fry stranding during dry water year types with a 4.3% decrease. Changes to water temperature are expected to have frequent beneficial impacts on juvenile rearing and emigration. Alternative 3 combines additional Delta outflow with measures to improve drought protection and temperature management through increased reservoir carryover storage.

- **Alternative 4** is expected to have changes in flow that result in adverse and beneficial impacts, with a -0.8% to 3.9% difference in rearing habitat area depending on water year type. Changes in flow are also expected to have beneficial impacts on fry stranding with up to a 23.4% decrease during dry water year types. Changes to water temperature are expected to have beneficial impacts on juvenile rearing and emigration. Alternative 4 releases from Shasta Reservoir for water service contract deliveries to achieve an EOS storage of 2.0 MAF in Shasta Reservoir based on the 90% forecast unless a less conservative forecast requires more releases.

12.2.2.4 Fall-run Chinook salmon

For fall-run Chinook salmon, outlined are expected responses to survival for incubating eggs and through the alevin life stage, to spawning, and changes to rearing habitat and stranding from changes in operations under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models may vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have changes in flow that result in adverse and beneficial impacts; with up to a 4.2% increase in spawning habitat area in above normal water year types, a 6.8% reduction in redd dewatering potential in critically dry water year types, a -2.6% to 0.1% difference in rearing habitat area, up to a 19% increase fry stranding during wetter water year types, and up to a 13.7% decrease in fry stranding in critically dry water year types. Changes in water temperature are expected to have frequent adverse impacts on spawning initiation, and adverse and beneficial impacts on juvenile rearing and emigration. Alternative 1 carries over less water in storage to contribute to the next year's coldwater pool.

- **Alternative 2** is expected to have changes in flow that result in adverse and beneficial impacts; with a -2.1% to 1.5% difference in spawning habitat area depending on water year type, a 0.6% reduction to a 15.6% increase in redd dewatering potential in critically dry water year types (depending on the phase), a -1.8% to 2.8% difference in rearing habitat area depending on water year type, and more frequent reductions in fry stranding that are greater than a >10% difference (compared to increases in fry stranding). Changes in water temperature are expected to have adverse impacts on spawning initiation, and adverse and beneficial impacts on juvenile rearing and emigration. Alternative 2 requires more storage in Shasta Reservoir for higher releases.

- **Alternative 3** is expected to have changes in flow that result in adverse and beneficial impacts; with a -2.5% to 2.5% difference in spawning habitat area depending on water year type, 12.7% increase in redd dewatering potential during critically dry water year types, a -2.3% to 3.5% difference in rearing habitat area depending on water year type, and a -6% to 12.5% difference in fry stranding depending on water year type. Changes in water temperature are expected to have negligible impacts on spawning and egg incubation, and adverse and beneficial impacts on juvenile rearing and emigration. Alternative 3 combines additional Delta outflow with measures to improve drought protection and temperature management through increased reservoir carryover storage.

- **Alternative 4** is expected to have changes in flow that result in adverse and beneficial impacts; with a -1.4% to 1.1% difference in spawning habitat area, a 6.8% increase in redd dewatering potential in critically dry water year types, a -0.9% to 2% difference in rearing habitat area, and reductions in fry stranding in all water year types (up to a -7.2% difference). Changes to water temperature are expected to have negligible impacts on spawning and egg incubation. Changes to water temperature are expected to have adverse and beneficial impacts on juvenile rearing and emigration. Alternative 4 releases from Shasta Reservoir for water service contract deliveries to achieve an EOS storage of 2.0 MAF in Shasta Reservoir based on the 90% forecast unless a less conservative forecast requires more releases.

12.2.2.5 *Late fall-run Chinook salmon*

For late fall-run Chinook salmon, outlined are expected responses to survival for incubating eggs and through the alevin life stage, to spawning, and changes to rearing habitat and stranding from changes in operations under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models may vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have changes in flow that result in adverse and beneficial impacts; with reductions in spawning habitat area in all water year types (up to a 7.4% reduction in above normal water years), a 0.2% reduction in redd dewatering potential in critically dry water year types, a -3.5% to 1.3% difference in rearing habitat area depending on water year type, up to a 26.3% increase in fry stranding during critically dry water years, and up to a 17% reduction in fry stranding in below normal water years. Changes in water temperature are expected to have frequent beneficial impacts to spawning/egg incubation/fry emergence, and adverse and beneficial impacts for juvenile rearing and emigration. Alternative 1 carries over less water in storage to contribute to the next year's coldwater pool.

- **Alternative 2 is** expected to have changes in flow that result in adverse and beneficial impacts; with -2.0% to 0.4% difference in spawning habitat area depending on water year type, a 20.2% increase to a 39.2% reduction in redd dewatering potential during critically dry water years (depending on the phase), a -1.7% to 2.8% difference in rearing habitat area depending on water year type, up to a 41.4% increase in fry stranding during critically dry water years, and up to a 31.4%

reduction in fry stranding in below normal water years. Changes in water temperature are expected to have frequent beneficial impacts on spawning/egg incubation/fry emergence, and adverse and beneficial impacts on juvenile rearing and emigration. Alternative 2 requires more storage in Shasta Reservoir for higher releases.

- **Alternative 3** is expected to have changes in flow that result in adverse and beneficial impacts; with up to a 5.9% reduction in spawning habitat area in above normal water year types, up to a 35.5% increase in redd dewatering potential during critically dry water years, a -1.2% to 5.6% difference in rearing habitat area depending on water year type, and up to a 29% increase in fry stranding during above normal water years. Changes in water temperature are expected to have frequent beneficial impacts to spawning and incubation, and adverse and beneficial impacts for juvenile rearing and emigration. Alternative 3 combines additional Delta outflow with measures to improve drought protection and temperature management through increased reservoir carryover storage.

  Alternative 4 is expected to have changes in flow that result in adverse and beneficial impacts; with -1.4 to 1.1% difference in spawning habitat area, a 15.6% increase in redd dewatering potential during critically dry water years, a -0.3% to 5.7% difference in rearing habitat area depending on water year type, and reductions in fry stranding in all water year types with up to a 21.8% reduction during dry water years. Changes in water temperature are expected to have frequent beneficial impacts to spawning and incubation, and adverse and beneficial impacts to juvenile rearing and emigration. Alternative 4 releases from Shasta Reservoir for water service contract deliveries to achieve an EOS storage of 2.0 MAF in Shasta Reservoir based on the 90% forecast unless a less conservative forecast requires more releases.

12.2.2.6 Southern DPS green sturgeon

For green sturgeon, outlined are expected responses for spawning adults and incubating eggs from changes in operations under each alternative relative to the No Action Alternative. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have a adverse impact of flows decreasing up to 6% resulting in a potential impact on spawning habitat across all water year types and beneficial impacts from water temperature on spawning and egg incubation. Alternative 1 carries over less water in storage to contribute to the next year’s coldwater pool.

- **Alternative 2** is expected to have beneficial impact of flows increasing up to 26% resulting in a potential impact on spawning habitat in critically dry years, and negligible impacts in all other water year types and adverse and beneficial impacts from water temperature on spawning and egg incubation. Alternative 2 requires more storage in Shasta Reservoir for higher releases.

- **Alternative 3** is expected to have a beneficial to adverse impact of flows decreasing up to 10% or increasing up to 8% depending on water year type resulting in a potential impact on spawning habitat and beneficial to adverse impacts from water temperature on spawning and egg incubation depending on index value and location. Alternative 3 combines additional Delta outflow with measures to improve drought protection and temperature management through increased reservoir carryover storage.

- **Alternative 4** is expected to have negligible impacts of flow on spawning habitat across all water year types and beneficial or adverse impacts from water temperature on spawning and egg incubation depending on depending on index value and location. Alternative 4 releases from Shasta Reservoir for water service contract deliveries to achieve an EOS storage of 2.0 MAF in Shasta Reservoir based on the 90% forecast unless a less conservative forecast requires more releases.

12.2.2.7 Other aquatic species

For aquatic species in the Sacramento River not described above, potential impacts range from adverse to beneficial, including no impacts, depending on species, life stage, month, and water year type. For example, Alternative 1 is expected to have no impact to beneficial impacts to white sturgeon, Alternative 2 and Alternative 4 are expected to have no impacts, and Alternative 3 is expected to have adverse and beneficial impacts. Alternative 1, Alternative 2, and Alternative 3 are expected to have adverse to beneficial impacts on Pacific lamprey and striped bass, whereas Alternative 4 is expected to have negligible to adverse impacts.

12.2.3 Clear Creek

12.2.3.1 Spring-run Chinook salmon

For spring-run Chinook salmon, outlined below are the expected responses to survival of incubating eggs and alevins, changes to spawning area, and changes to rearing habitat for early life stages from changes in operations primarily under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have adverse impacts on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 1,134 - 1,200 and 1,017), fry rearing habitat (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 24,942 - 25,959 and 24,500), and juvenile (sub-yearling to yearling) rearing habitat, negligible impacts from water temperature on spawning and egg incubation, and negligible impacts from water temperature for juvenile and yearling criteria. Alternative 1 provides minimum instream flows and water temperature management and does not include specific pulse flows.

- **Alternative 2** is expected to have adverse impacts on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 4,530 - 5,064 and 4,123 - 4,577), beneficial impacts on fry rearing habitat (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 28,803 - 29,758 and 26,915 - 26,928), adverse impacts on juvenile (sub-yearling to yearling) rearing habitat, no anticipated impacts from water temperature on spawning and egg incubation, and negligible impacts from water temperature for juvenile and yearling criteria. Alternative 2 provides releases to emulate natural processes, water temperature management, and pulse flows.
- **Alternative 3** is expected to have adverse impacts on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 4,457 - 4,532 and 4,184), beneficial impacts on fry rearing habitat (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 28,746 - 29,716 and 27,116), and an adverse impact on juvenile (sub-yearling to yearling) rearing habitat, no anticipated impacts from water temperature on spawning or egg incubation, no anticipated impacts from water temperature on juvenile and yearling rearing criteria. Alternative 3 provides releases to emulate natural processes, water temperature management, and pulse flows.
- **Alternative 4** is expected to have adverse impacts on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 4,766 - 5,046 and 4,516), beneficial impacts on fry rearing habitat (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 28,874 - 29,838 and 27,007), adverse impact on juvenile (sub-yearling to yearling) rearing habitat, no anticipated impacts from water temperature on spawning and egg incubation, and negligible impacts from water temperature for the juvenile and yearling criteria. Alternative 4 provides releases to emulate natural processes, water temperature management, and pulse flows.

12.2.3.2 California Central Valley steelhead

For steelhead, outlined below are the expected responses to survival of incubating eggs and alevins, changes to spawning area, and changes to rearing habitat for early life stages from changes in operations primarily under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.
- **Alternative 1** is expected to have an adverse impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 14,338 - 15,690 and 13,957), adverse impact on fry and juvenile rearing habitat area (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 18,696 - 18,788 and 18,696), beneficial impacts from water temperature on spawning and egg incubation, and

negligible impacts from water temperature on juvenile rearing and emigration. Alternative 1 provides minimum instream flows and water temperature management and does not include specific pulse flows.

- **Alternative 2** is expected to have a beneficial impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 14,338 - 15,690 and 13,957), a negligible impact on fry rearing habitat (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 17,564 - 17,708 and 17,240 - 17,275), an adverse impact on juvenile rearing habitat, negligible impacts from water temperature on spawning and egg incubation, and no anticipated impacts from water temperature on juvenile rearing and emigration. Alternative 2 provides releases to emulate natural processes, water temperature management, and pulse flows.
- **Alternative 3** is expected to have a beneficial impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 42,512 - 43,515 and 38,594), a negligible impact on fry rearing habitat (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 17,639 - 17,794 and 17,382), an adverse impact on juvenile rearing habitat, negligible impacts from water temperature on spawning and egg incubation, and negligible impacts from water temperatures for juvenile rearing and emigration. Alternative 3 provides releases to emulate natural processes, water temperature management, and pulse flows.
- **Alternative 4** is expected to have a beneficial impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 42,469 - 43,589 and 38,610), a negligible impact on fry rearing habitat (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 17,665 - 17,822 and 17,325), an adverse impact on juvenile rearing habitat, similar adverse and beneficial impacts from water temperature on egg incubation, negligible adverse and beneficial impacts from water temperature on spawning, and no anticipated impacts from water temperature on juvenile rearing and emigration. Alternative 4 provides releases to emulate natural processes, water temperature management, and pulse flows.

12.2.3.3 Fall-run Chinook salmon

For fall-run Chinook salmon, outlined below are the expected responses to survival of incubating eggs and alevins, changes to spawning area, and changes to rearing habitat for early life stages from changes in operations primarily under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.
- **Alternative 1** is expected to have an adverse impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and

critically dry water year type: 112,033 - 114,579 and 81,290), an adverse impact on fry and juvenile rearing habitat area (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 44,136 - 44,681 and 44,680), adverse impacts from water temperature on spawning and egg incubation, and no anticipated impacts from water temperature on juvenile rearing and emigration. Alternative 1 provides minimum instream flows and water temperature management and does not include specific pulse flows.

- **Alternative 2** is expected to have a beneficial impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 197,831 - 201,120 and 141,779 - 145,932), adverse impacts on fry and juvenile rearing habitat (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 37,731 - 38,409 and 39,855), no anticipated impacts from water temperature on spawning and egg incubation, and negligible impacts from water temperature on juvenile rearing and emigration. Alternative 2 provides releases to emulate natural processes, water temperature management, and pulse flows.
- **Alternative 3** is expected to have a beneficial impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 196,781 and 154,459), an adverse impact on fry and juvenile rearing habitat (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 37,604 - 38,299 and 39,832), no anticipated impacts from water temperature on spawning and egg incubation, and no anticipated impacts from water temperature on juvenile rearing and emigration. Alternative 3 provides releases to emulate natural processes, water temperature management, and pulse flows.
- **Alternative 4** is expected to have beneficial impacts on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 200,941 - 201,120 and 143,347), a adverse impact on fry rearing habitat (expected WUA for fry rearing, range of all non-critically dry water year types and critically dry water year type: 37,731 - 38,409 and 39,855), adverse impact on juvenile rearing habitat, no anticipated impacts from water temperature on spawning and egg incubation, and no anticipated impacts from water temperature on juvenile rearing and emigration. Alternative 4 provides releases to emulate natural processes, water temperature management, and pulse flows.

12.2.3.4 Other aquatic species

For aquatic species in Clear Creek not described above, including hardhead and Pacific lamprey, potential impacts range from adverse to beneficial, including no impacts, depending on species, life stage, month, and water year type. Alternative 1 and Alternative 2 are expected to have negligible impacts to hardhead, whereas Alternative 3 and Alternative 4 are expected to have negligible impacts on migrating and spawning hardhead, and adverse impacts to juvenile and non-spawning adults. Alternatives 1-4 would have negligible to beneficial impacts to Pacific lamprey depending on month and water year type.

12.2.4 Lower American River

12.2.4.1 California Central Valley steelhead

For steelhead, outlined below are the expected responses to survival of incubating eggs and alevins, changes in rearing habitat for early life stages (fry and juveniles), and to spawning area from changes in operations primarily under each alternative relative to the No Action Alternative. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have a adverse impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 28,692 - 96,053 and 105,814), an adverse impact on redd dewatering potential, adverse impact on rearing habitat area, adverse (5-20% unfavorable conditions) and beneficial (3.3-6.7% favorable conditions) impacts from water temperature on spawning and egg incubation, and adverse (1.7-12% unfavorable conditions) and beneficial (1.7-10% favorable conditions) impacts from water temperature on juvenile rearing and emigration. Alternative 1 consists of minimum instream flows and water temperature management with no spring pulses or redd dewatering adjustments.

- **Alternative 2** is expected to have an adverse impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 29,222 - 108,278 and 115,178 - 116,689) and redd dewatering potential, an adverse or beneficial impact on rearing habitat area depending on the month in critically dry water year types, adverse (3.3-6.7% unfavorable conditions) to beneficial (3.3-6.7% favorable conditions) impacts from water temperature on spawning and egg incubation, and adverse (1.7-5% unfavorable conditions) to beneficial (1.7-6.7% favorable conditions) impacts from water temperature on juvenile rearing and emigration. Alternative 2 consists of a minimum release requirement, spring pulses, releases to limit potential steelhead redd dewatering, and water temperature management.

- **Alternative 3** is expected to have an adverse impact or beneficial impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 28,596 - 110,040 and 122,231), beneficial impact on redd dewatering potential, an adverse or beneficial impact on rearing habitat area, adverse (3.3-15% unfavorable conditions) and beneficial (3.3% favorable conditions) impacts from water temperature on spawning and egg incubation, and adverse (1.7-10% unfavorable conditions) to beneficial (1.7-5% favorable conditions) impacts from water temperature on juvenile rearing and emigration. Alternative 3 consists of minimum release requirements prioritizing minimum flows then storage, and winter and spring pulses.

- **Alternative 4** is expected to have an adverse impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 29,392 - 107,547 and 117,633) and a beneficial impact on redd dewatering potential, an adverse impact on rearing habitat area, adverse (3.3-15.0% unfavorable conditions) to beneficial (3.3% favorable conditions) impacts from water temperature on spawning and egg incubation, and adverse (1.7-6.7% unfavorable conditions) to beneficial (1.7-6.7% favorable conditions) impacts from water temperature on juvenile rearing and emigration. Alternative 4 consists of a minimum release requirement, spring pulses, releases to limit potential steelhead redd dewatering, and water temperature management.

12.2.4.2 Fall-run Chinook salmon

For fall-run Chinook salmon, outlined below are the expected responses to survival of incubating eggs and alevins, changes in rearing habitat for early life stages (fry and juveniles), and to spawning area from changes in operations primarily under each alternative relative to the No Action Alternative. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have an adverse impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 104,927 - 123,537 and 123,463), adverse impacts on redd dewatering potential, an adverse or beneficial impact on rearing habitat area, beneficial (2.9-13.3% favorable conditions) and adverse (2.9-13.3% unfavorable conditions) impacts from water temperature on spawning andegg incubation, and adverse (8-20% unfavorable conditions) and beneficial (4-12% favorable conditions) impacts from water temperature on juvenile rearing and emigration. Alternative 1 consists of minimum instream flows and water temperature management with no spring pulses or redd dewatering adjustments.

- **Alternative 2 is** expected to have an adverse impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 108,538 - 139,838 and 123,661 - 126,791), adverse impacts from increases in redd dewatering potential, an adverse or beneficial impact on rearing habitat area, adverse (2.9-3.3% unfavorable conditions) to beneficial (2.9-3.3% favorable conditions) impacts from water temperature on spawning and egg incubation, and adverse (4-8% unfavorable conditions) to beneficial (4-8% favorable conditions) impacts from water temperature on juvenile rearing and emigration. Alternative 2 consists of a minimum release requirement, spring pulses, releases to limit potential steelhead redd dewatering, and water temperature management.

- **Alternative 3** is expected to have an adverse and beneficial impact on spawning habitat area depending on water year type (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 109,743 - 137,595 and 131,242), beneficial impacts from reduced redd dewatering potential, an adverse impact on rearing habitat area (depending on the month), beneficial impact in dry years, adverse (2.9-11.4% unfavorable conditions) and beneficial (2.9-3.3% favorable conditions) impacts from water temperature on spawning and egg incubation, and adverse (8-12% unfavorable conditions) and beneficial (4-8% favorable conditions) impacts from water temperature on juvenile rearing and emigration. Alternative 3 consists of minimum release requirements prioritizing minimum flows then storage, and winter and spring pulses.

- **Alternative 4** is expected to have an adverse impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 109,148 - 139,916 and 126,721), adverse impacts in wet water year types and beneficial impacts in critically dry water year types on redd dewatering potential, negligible impacts on rearing habitat area except in critically dry water year types when there would be both adverse and beneficial impacts, beneficial (3.3% favorable conditions) and adverse (5.7-6.7% unfavorable conditions) impacts from water temperature on spawning and egg incubation, and adverse (4% unfavorable conditions) and beneficial (4% favorable conditions) impacts from water temperature on juvenile rearing and emigration. Alternative 4 consists of a minimum release requirement, spring pulses, releases to limit potential steelhead redd dewatering, and water temperature management.

12.2.4.3 Other aquatic species

For aquatic species in the lower American River not described above, potential impacts range from adverse to beneficial, including no impacts, depending on species, life stage, month, and water year type. For example, Alternative 1 is expected to have negligible to beneficial impacts American shad, Alternative 2 is expected to have adverse to beneficial impacts, Alternative 3 is expected to have beneficial impacts, Alternative 4 is expected to have negligible to adverse impacts. Impacts for some species in the lower American River would be consistent among alternatives. For example, Alternatives 1-4 are expected to have no impacts to white sturgeon, negligible to adverse impacts to native minnows, and adverse to beneficial impacts to Pacific lamprey.

12.2.5 San Joaquin River

12.2.5.1 California Central Valley steelhead

For steelhead, outlined below are the expected responses to adult migration and juvenile emigration from changes in operations under each alternative relative to the No Action Alternative. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is not expected to result in additional impacts that those discussed in the environmental compliance for the San Joaquin River Restoration Project. Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision.

- **Alternative 1** is expected to have negligible impacts on juvenile emigration and beneficial impacts on adult migration and holding (an increase of flows at Vernalis of up to 7% between July and September). Alternative 1 continues implementation of the San Joaquin River Restoration Program as an independent related activity.

- **Alternative 2** is expected to have negligible impacts on juvenile emigration and beneficial impacts on adult migration and holding (an increase of flows at Vernalis of up to 3% between July and September). Alternative 2 continues implementation of the San Joaquin River Restoration Program as an independent related activity.
- **Alternative 3** expected to have negligible impacts on juvenile emigration and negligible impacts on adult migration and holding. Alternative 3 continues implementation of the San Joaquin River Restoration Program as an independent related activity.
- **Alternative 4** is expected to have negligible impacts on juvenile emigration and beneficial impacts on adult migration and holding (an increase of flows at Vernalis of up to 3% between July and September). Alternative 4 continues implementation of the San Joaquin River Restoration Program as an independent related activity.

12.2.5.2 Fall-run Chinook salmon

For fall-run Chinook salmon, outlined below are the expected responses to adult migration and juvenile emigration from changes in operations under each alternative relative to the No Action Alternative. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is not expected to result in additional impacts that those discussed in the environmental compliance for the San Joaquin River Restoration Project. Reclamation will operate the Friant Division consistent with the San Joaquin River Restoration Program Record of Decision.
- **Alternative 1** is expected to have negligible impacts on juvenile emigration and beneficial impacts on adult migration and holding. Alternative 1 continues implementation of the San Joaquin River Restoration Program as an independent related activity.
- **Alternative 2 is** expected to have negligible impacts on juvenile emigration and beneficial impacts on adult migration and holding. Alternative 2 continues implementation of the San Joaquin River Restoration Program as an independent related activity.
- **Alternative 3** expected to have negligible impacts on juvenile emigration and negligible impacts on adult migration and holding. Alternative 3 continues implementation of the San Joaquin River Restoration Program as an independent related activity.
- **Alternative 4** is expected to have negligible impacts on juvenile emigration and beneficial impacts on adult migration and holding. Alternative 4 continues implementation of the San Joaquin River Restoration Program as an independent related activity.

12.2.5.3 Other aquatic species

For aquatic species in the San Joaquin River not described above, potential impacts range from adverse to beneficial, including no impacts, depending on species, life stage, month, and water year type. For example, Alternative 1, Alternative 2, and Alternative 4 are expected to have beneficial impacts to green sturgeon adults in the San Joaquin River, whereas Alternative 3 is expected to have no impacts. Alternative 1, Alternative 2, and Alternative 4 are expected to have negligible impacts to native minnows in the San Joaquin River, whereas Alternative 3 is expected to have negligible to adverse impacts. Alternatives 1-4 are expected to have no impacts to white sturgeon adults in the San Joaquin River. Alternative 1, Alternative 2, and Alternative 4 is expected to have a beneficial to negligible impact on black basses in the San Joaquin River, whereas Alternative 3 is expected to have adverse to beneficial impacts.

12.2.6 Stanislaus River

12.2.6.1 California Central Valley steelhead

For steelhead, outlined below are the expected responses to survival of incubating eggs and alevins and for fry and juveniles rearing habitat from changes in operations primarily in the winter and spring under each alternative relative to the No Action Alternative. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have an adverse impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 314,401 - 528,577 and 609,693), a adverse or beneficial impact on juvenile and fry rearing habitat area (depending on the water year type), beneficial impacts from water temperature on spawning/egg incubation/fry emergence, and beneficial impacts from water temperature on juvenile emigration. Alternative 1 includes minimum instream flows and does not operate to pulse flows.

- **Alternative 2** is expected to have an adverse or beneficial impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 360,125 - 645,747 and 700,988 - 701,832), a adverse or beneficial impact on juvenile and fry rearing habitat area (depending on the water year type), adverse impacts from water temperature on spawning/egg incubation/fry emergence, and adverse impacts from water temperature on juvenile emigration. Alternative 2 includes minimum instream flows and pulse flows during the winter and fall seasons.

- **Alternative 3** is expected to have an adverse impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 277,294 - 528,713 and 715,068), an adverse or beneficial impact on juvenile and fry rearing habitat area (depending on the water year type), beneficial impacts from water temperature on spawning/egg incubation/fry emergence, and beneficial impacts from water temperature on juvenile emigration. Alternative 3 includes minimum instream flows, fall pulse flows, and unimpaired flow as minimum instream flows during the spring and winter seasons.

- **Alternative 4** is expected to have an adverse or beneficial impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 360,466 - 637,263 and 701,836), an adverse or beneficial impact on juvenile and fry rearing habitat area (depending on the water year type), negligible impacts from water temperature on spawning/egg incubation/fry emergence, and negligible impacts from water temperature on juvenile emigration. Alternative 4 includes minimum instream flows and pulse flows during the winter and fall seasons.

12.2.6.2 Fall-run Chinook salmon

For fall-run Chinook salmon, outlined below are the expected responses to survival of incubating eggs and alevins and for fry and juveniles rearing habitat from changes in operations primarily in the winter and spring under each alternative relative to the No Action Alternative. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have a beneficial impact on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 694,035 - 980,894 and 917,477), an adverse or beneficial impact on juvenile and fry rearing habitat area (beneficial particularly during critically dry water year types), adverse impacts from water temperature on spawning and egg incubation, and beneficial and adverse impacts from water temperature on juvenile emigration. Alternative 1 includes minimum instream flows and does not operate to any pulse flows.

- **Alternative 2 is** expected to have adverse or beneficial impacts on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 653,205 - 891,602 and 920,810 - 921,084), beneficial impacts on juvenile and fry rearing habitat area (depending on the water year type), no anticipated impacts from water temperature on spawning and egg incubation, and beneficial and adverse impacts from water temperature on juvenile emigration. Alternative 2 includes minimum instream flows and pulse flows during the winter and fall seasons.

- **Alternative 3** is expected to have beneficial impacts on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 678,174 - 888,506 and 929,620), beneficial impacts on juvenile and fry rearing habitat area (depending on the water year type), adverse impacts from water temperature on spawning and egg incubation, and adverse impacts from water temperature on juvenile emigration. Alternative 3 includes minimum instream flows, fall pulse flows, and unimpaired flow as minimum instream flows during the spring and winter seasons.

- **Alternative 4** is expected to have negligible impacts on spawning habitat area (expected WUA for spawning, range of all non-critically dry water year types and critically dry water year type: 653,428 - 889,816 and 921,089), beneficial impacts on juvenile and fry rearing habitat area (depending on the water year type), negligible impacts from water temperature on spawning and egg incubation, and beneficial and adverse impacts from water temperature on juvenile emigration. Alternative 4 includes minimum instream flows and pulse flows during the winter and fall seasons.

12.2.6.3 Other aquatic species

For aquatic species in the Stanislaus River not described above, potential impacts range from adverse to beneficial, including no impacts, depending on species, life stage, month, and water year type. For example, Alternatives 1-4 are expected to have adverse to beneficial impacts on Pacific lamprey, Western River lamprey, and striped bass in the Stanislaus River. Alternative 1 is expected to have adverse to beneficial impacts to American shad in the Stanislaus River, whereas Alternative 2, Alternative 3, and Alternative 4 are expected to have negligible impacts.

12.2.7 Bay-Delta

12.2.7.1 Winter-run Chinook salmon

For winter-run Chinook salmon, outlined are expected changes in survival and entrainment from changes in water project operations under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on juvenile and adult life stages that varies by the component.

- **Alternative 1** is expected to have an adverse impact from increased entrainment of juvenile LAD winter-run Chinook salmon (predicted average December through April monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 2 - 78 fish, 1 - 15 fish), negligible impact on proportion of juveniles salvaged, and adverse and beneficial impacts on survival (predicted December through April monthly through-Delta survival across all routes range, all non-critically dry water year types and critically dry water year type: 0.415 - 0.664, 0.372 - 0.468; Figure 12-3). Alternative 1 does not include Old and Middle River criteria resulting in lower Delta outflows and exports are not adjusted to minimize entrainment of fish and protection of critical habitat.

- **Alternative 2** is expected to have an adverse or beneficial impact from increased and decreased entrainment of juvenile LAD winter-run Chinook salmon (predicted average December through April monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 1 - 43 fish, 1 - 9 fish), negligible impact on proportion of juveniles salvaged, and adverse and beneficial impacts on survival (predicted December through April monthly through-Delta survival across all routes range, all non-critically dry water year types and critically dry water year type: 0.442 - 0.645, 0.372 - 0.468; Figure 12-3). Alternative 2 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

- **Alternative 3** is expected to have a beneficial impact resulting from decreased entrainment of juvenile LAD winter-run Chinook salmon (predicted average December through April monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 0 - 24 fish, 0 - 6 fish), negligible impact on the predicted proportion of juveniles salvaged, and adverse and beneficial impacts on survival (predicted December through April monthly through-Delta survival across all routes range, all non-critically dry water year types and critically dry water year type: 0.453 - 0.665, 0.383 - 0.469; Figure 12-3). Alternative 3 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.
- **Alternative 4** is expected to have an adverse impact from increased entrainment of juvenile LAD winter-run Chinook salmon (predicted average December through April monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 1 - 23 fish, 1 - 10 fish), negligible impact on the predicted proportion of juveniles salvaged, and adverse and beneficial impacts on survival (predicted December through April monthly through-Delta survival across all routes range, all non-critically dry water year types and critically dry water year type: 0.444 - 0.664, 0.373 - 0.470; Figure 12-3). Alternative 4 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

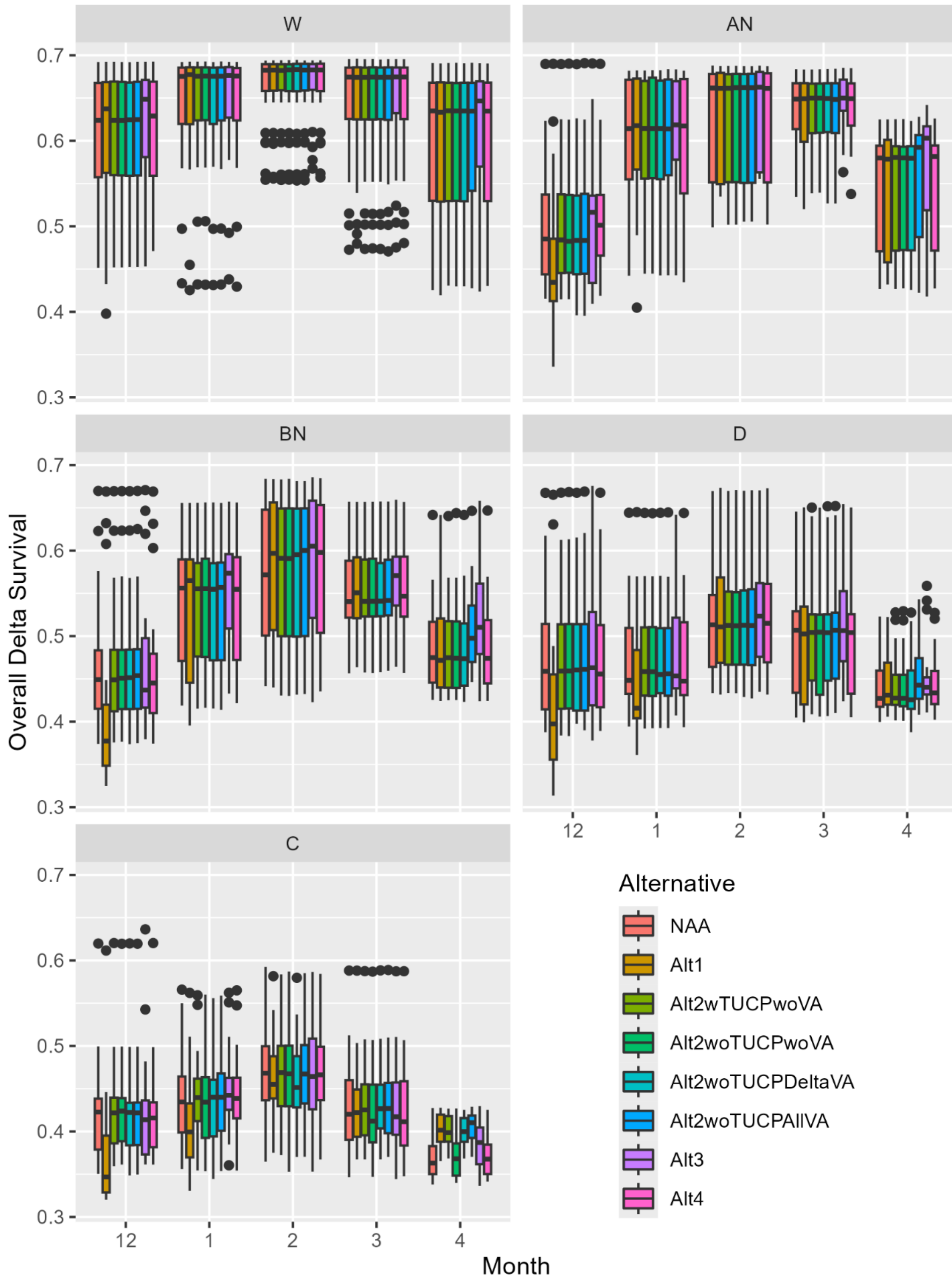


Figure 12-3. Boxplots of predicted mean through-Delta survival across all routes for relevant migratory months, box edges represent 25th and 75th percentiles, whiskers are the product of the interquartile range and 1.5, for each water year type (Attachment I.5 *Survival, Travel Time, and Routing Simulation Model*).

12.2.7.2 Spring-run Chinook salmon

For spring-run Chinook salmon, outlined are expected changes in survival and entrainment from changes in water project operations under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models may vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on juvenile and adult life stages that varies by the component.

- **Alternative 1** is expected to have an adverse impact from increased entrainment of juvenile spring-run Chinook salmon (predicted average March through June monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 2 – 3,264 fish, 21 – 108 fish) and a negligible to beneficial impact on survival of outmigrating juveniles (mean predicted survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.179 – 0.326, 0.139). Alternative 1 does not include Old and Middle River criteria resulting in lower Delta outflows and exports are not adjusted to minimize entrainment of fish and protection of critical habitat.
- **Alternative 2** is expected to have beneficial and adverse impacts from decreased and increased entrainment (predicted average March through June monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 1 – 3,544 fish, 7 – 105 fish) and a negligible to beneficial impact on survival of outmigrating juveniles (mean predicted survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.181 – 0.328, 0.134 – 0.143). Alternative 2 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.
- **Alternative 3** is expected to have a beneficial impact from decreased entrainment (predicted average March through June monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 0 – 593 fish, 4 – 53 fish) and a beneficial impact on survival of outmigrating juveniles (mean predicted survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.191 – 0.356, 0.141). Alternative 3 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.
- **Alternative 4** is expected to have an adverse impact from increased entrainment (predicted average March through June monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 1 – 3,106 fish, 9 – 105 fish) and a negligible impact on survival of outmigrating juveniles (mean predicted survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.182 – 0.326, 0.133). Alternative 4 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

12.2.7.3 California Central Valley steelhead

For steelhead, outlined are expected changes in survival and entrainment from changes in water project operations under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models may vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have an adverse impact resulting from increased entrainment (predicted average December through June monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 65 – 11,661 fish, 18 – 1,716 fish) and a beneficial impact with a smaller proportion routed to Interior Delta between December and March, particularly in OMR groupings more negative than -5,500. Alternative 1 does not include Old and Middle River criteria resulting in lower Delta outflows and exports are not adjusted to minimize entrainment of fish and protection of critical habitat.

- **Alternative 2** is expected to have adverse and beneficial impacts from increased and decreased entrainment (predicted average December through June monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 23 – 8,549 fish, 13 – 500 fish) and adverse and beneficial impacts on survival of outmigrating juvenile steelhead in the winter and spring, dependent on OMR conditions. Alternative 2 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

- **Alternative 3** is expected to have a beneficial impact from decreased entrainment (predicted average December through June monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 5 – 2,962 fish, 3 – 270 fish) and adverse and beneficial impact on survival of outmigrating juvenile steelhead, dependent on OMR conditions. Alternative 3 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

- **Alternative 4** is expected to have adverse and beneficial impacts from increased and decreased entrainment (predicted average December through June monthly salvage at the Delta fish collection facilities range, all non-critically dry water year types and critically dry water year type: 15 – 9,545 fish, 12 – 590 fish) and adverse and beneficial impacts on survival of outmigrating juvenile steelhead, dependent on OMR conditions. Alternative 4 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

12.2.7.4 Southern DPS green sturgeon

For green sturgeon, outlined are expected changes in entrainment from changes in operations under each alternative relative to the No Action Alternative. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.
- **Alternative 1** is expected to have a negligible impact on entrainment at both Delta fish collection facilities. Alternative 1 does not include Old and Middle River criteria resulting in lower Delta outflows and exports are not adjusted to minimize entrainment of fish and protection of critical habitat.
- **Alternative 2** is expected to have a negligible impact on entrainment at both Delta fish collection facilities. Alternative 2 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.
- **Alternative 3** is expected to have a negligible impact on entrainment at both Delta fish collection facilities. Alternative 3 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.
- **Alternative 4** is expected to have a negligible impact on entrainment at both Delta fish collection facilities. Alternative 4 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

12.2.7.5 Fall-run and late fall-run Chinook salmon

For fall-run Chinook salmon and late fall-run Chinook salmon, outlined are expected changes in entrainment and survival from changes in water project operations under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models may vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. Appendix O provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.
- **Alternative 1** is expected to have an adverse and beneficial impact on both fall-run and late fall-run Chinook salmon from increased and decreased entrainment at both fish facilities (predicted fall-run Chinook salmon average monthly salvage at Banks range, all non-critically dry water year types and critically dry water year type: 0 – 15,130 fish, 0 – 357 fish; predicted fall-run average monthly salvage at Jones range, all non-critically dry water year types and critically dry water year type: 0 – 4,927 fish, 0 – 238 fish; predicted late fall-run Chinook salmon average monthly salvage at Banks range, all non-critically dry water year types and critically dry water year type: 0 – 1,182 fish, 0 – 339 fish; predicted late fall-run average monthly salvage at Jones

range, all non-critically dry water year types and critically dry water year type: 0 - 225 fish, 0 - 36 fish) and an adverse impact for both fall-run and late fall-run Chinook salmon except for a beneficial impact in a critically dry water year type for fall-run Chinook salmon (mean predicted fall-run Chinook salmon survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.157 – 0.250, 0.129; mean predicted late fall-run Chinook salmon survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.144 – 0.254, 0.131). Alternative 1 does not include Old and Middle River criteria resulting in lower Delta outflows and exports are not adjusted to minimize entrainment of fish and protection of critical habitat.

- **Alternative 2** is expected to have an adverse and beneficial impact on both fall-run and late fall-run Chinook salmon from increased and decreased entrainment at both fish facilities (predicted fall-run Chinook salmon average monthly salvage at Banks range, all non-critically dry water year types and critically dry water year type: 0 – 15,229 fish, 0 – 336 fish; predicted fall-run average monthly salvage at Jones range, all non-critically dry water year types and critically dry water year type: 0 – 4,970 fish, 0 – 244 fish; predicted late fall-run Chinook salmon average monthly salvage at Banks range, all non-critically dry water year types and critically dry water year type: 0 – 700 fish, 0 - 269 fish; predicted late fall-run average monthly salvage at Jones range, all non-critically dry water year types and critically dry water year type: 0 - 210 fish, 0 - 67 fish) and negligible impacts on through-Delta survival of both fall-run and late fall-run Chinook salmon (mean predicted fall-run Chinook salmon survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.157 – 0.250, 0.123 – 0.131; mean predicted late fall-run Chinook salmon survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.151 – 0.264, 0.136 – 0.138). Alternative 2 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.
- **Alternative 3** is expected to have an adverse and beneficial impact on both fall-run and late fall-run Chinook salmon from increased and decreased entrainment at both fish facilities (predicted fall-run Chinook salmon average monthly salvage at Banks range, all non-critically dry water year types and critically dry water year type: 0 – 6,987 fish, 0 – 291 fish; predicted fall-run average monthly salvage at Jones range, all non-critically dry water year types and critically dry water year type: 0 – 1,466 fish, 0 – 49 fish; predicted late fall-run Chinook salmon average monthly salvage at Banks range, all non-critically dry water year types and critically dry water year type: 0 - 461 fish, 0 – 131 fish; predicted late fall-run average monthly salvage at Jones range, all non-critically dry water year types and critically dry water year type: 0- 138 fish, 0 - 36 fish) and beneficial impacts on through-Delta survival of both fall-run and late fall-run Chinook salmon (mean predicted fall-run Chinook salmon survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.163 – 0.272, 0.130; mean predicted late fall-run Chinook salmon survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.129 – 0.272, 0.141). Alternative 3 includes Old and Middle River Flow

Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

- **Alternative 4** is expected to have an adverse and beneficial impact on both fall-run and late fall-run Chinook salmon from increased and decreased entrainment at both fish facilities (predicted fall-run Chinook salmon average monthly salvage at Banks range, all non-critically dry water year types and critically dry water year type: 0 – 14,888 fish, 0 – 357 fish; predicted fall-run average monthly salvage at Jones range, all non-critically dry water year types and critically dry water year type: 0 – 4,987 fish, 0 – 220 fish; predicted late fall-run Chinook salmon average monthly salvage at Banks range, all non-critically dry water year types and critically dry water year type: 0 - 644 fish, 0 - 237 fish; predicted late fall-run average monthly salvage at Jones range, all non-critically dry water year types and critically dry water year type: 0 - 197 fish, 0 - 65 fish) and negligible impacts on through-Delta survival of both fall-run and late fall-run Chinook salmon (mean predicted fall-run Chinook salmon survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.158 – 0.249, 0.122; mean predicted late fall-run Chinook salmon survival to Chipps Island range, all non-critically dry water year types and critically dry water year type: 0.150 - 0.262, 0.138). Alternative 4 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

12.2.7.6 Delta smelt

For Delta smelt, outlined are expected changes in entrainment, habitat, and population abundance from changes in water project operations under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models may vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. *Appendix O* provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have adverse to beneficial impacts to larvae resulting from increased and decreased entrainment of larvae (Neutrally buoyant particle fate by inflow bin entrained at exports: 62% hihi – 94% himed; neutrally buoyant particle fate by OMR bins entrained at exports 73% at -2,000 cfs – 86% at -5,000 cfs). For juvenile summer-fall rearing habitat, there are expected adverse impacts on juveniles (Habitat Suitability Index [HSI] without temperature threshold of non-critically dry water year types and critically dry water year type: 0.48 – 0.543 and 0.404 and HSI with temperature threshold: 0.148 – 0.428 and 0.124). For population abundance, there is an expected negative impact on the population growth rate (LCME: Geometric mean [a type of average that accounts for data volatility] of predicted population growth rate of wet and above normal water year types and below normal, dry, and critically dry water year types: 0.96 (Wet and Above Normal), 0.52 (Below Normal, Dry, and Critically Dry), Figure 12-4). Alternative 1 does not include Old and Middle River criteria resulting in lower Delta outflows and exports are not adjusted to minimize entrainment of fish and protection of critical habitat.

- **Alternative 2** is expected to have adverse to beneficial impacts to larvae resulting from increased and decreased entrainment of larvae (Neutrally buoyant particle fate by inflow bin entrained at exports: 60% hihi – 89% hilo; neutrally buoyant particle fate by OMR bins entrained at exports 73% at -2,000 cfs – 85% at -5,000 cfs). For rearing habitat, there are expected adverse to beneficial impacts on juveniles (HSI without temperature threshold of non-critically dry water year types and critically dry water year type: 0.513 – 0.65 and 0.402 – 0.424 and HSI with temperature threshold: 0.203 – 0.525 and 0.129 – 0.137). For population abundance, there are expected adverse to beneficial impacts on the population growth rate (each of the phases show variation in the geometric mean LCME: Geometric mean of predicted population growth rate of wet and above normal water year types and below normal, dry, and critically dry water year types: 1.21 (Wet and Above Normal) – 1.24 (Wet and Above Normal), 0.74 (Below Normal, Dry, and Critically Dry,) 0.70 – 0.73 (Below Normal, Dry, and Critically Dry), Figure 12-4). Alternative 2 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.
- **Alternative 3** is expected to have beneficial to negligible impacts to larvae resulting from decreased entrainment of larvae (Neutrally buoyant particle fate by inflow bin entrained at exports: 19% medhi – 88% hilo; neutrally buoyant particle fate by OMR bins entrained at exports 72% at -2,000 cfs – 88% at -5,000 cfs). For rearing habitat, there are expected adverse to beneficial impacts on juveniles (HSI without temperature threshold of non-critically dry water year types and critically dry water year type: 0.544 – 0.613 and 0.415 and HSI with temperature threshold: 0.199 – 0.459 and 0.126. For population abundance, there is an expected positive impact on the population growth rate (LCME: Geometric mean of predicted population growth rate of wet and above normal water year types and below normal, dry, and critically dry water year types: 1.53 (Wet and Above Normal), 0.90 (Below Normal, Dry, and Critically Dry), Figure 12-4). Alternative 3 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.
- **Alternative 4** is expected to have adverse to negligible impacts larvae resulting from increased entrainment of larvae (Neutrally buoyant particle fate by inflow bin entrained at exports: 77% lolo – 90% hilo; neutrally buoyant particle fate by OMR bins entrained at exports 75% at -2000 cfs – 86% at -5000 cfs). For rearing habitat, there are expected negligible to adverse impacts on juveniles (HSI without temperature threshold of non-critically dry water year types and critically dry water year type: 0.483 – 0.638 and 0.387 and HSI with temperature threshold: 0.201 – 0.516 and 0.126). For population abundance, there is an expected negative impact on the population growth rate (LCME: Geometric mean of predicted population growth rate of wet and above normal water year types and below normal, dry, and critically dry water year types: 1.18 (Wet and Above Normal), 0.68 (Below Normal, Dry, and Critically Dry), Figure 12-4). Alternative 4 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

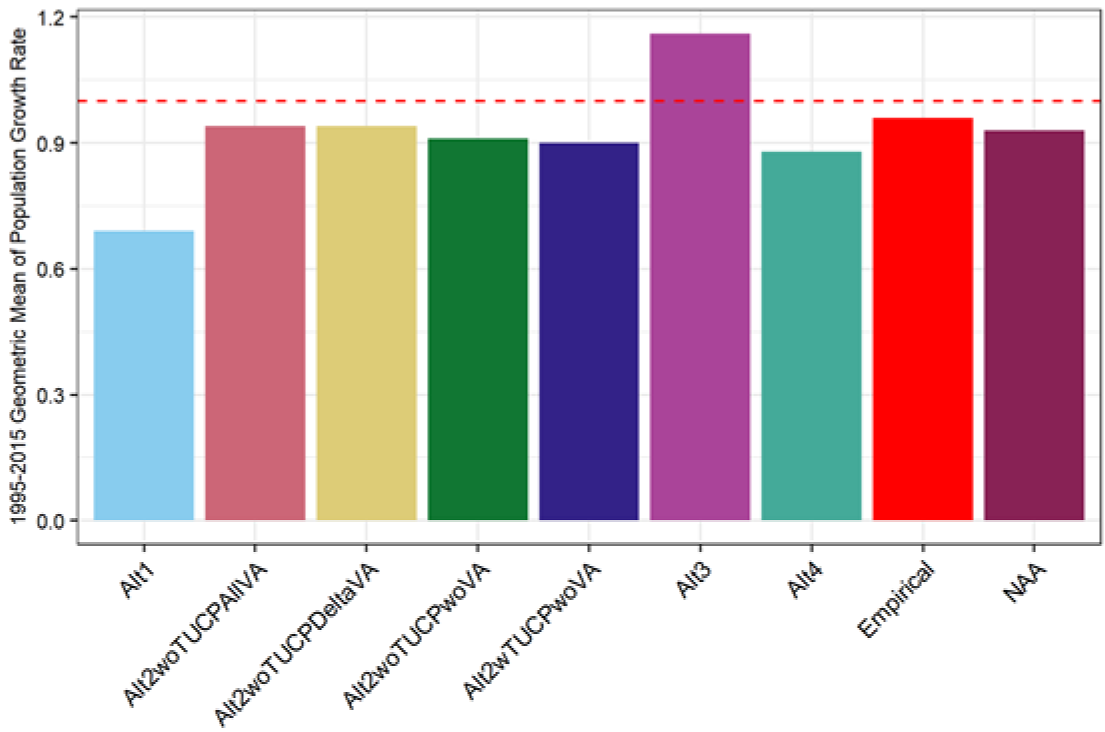


Figure 12-4. Mean population growth rates aggregated across the years. Bar plot demonstrating the geometric mean of population growth rate (lambda) from 1995 to 2015 for the various alternatives. Dashed line indicates lambda of 1 which suggests a stable population (neither growth or decline, Attachment F.4 *Delta Smelt USFWS LCM*).

12.2.7.7 Longfin smelt

For longfin smelt, outlined are expected changes in entrainment, and population abundance from changes in water project operations under each alternative relative to the No Action Alternative. In some cases, the direction of conclusions from multiple models may vary due to a differing suite of input variables, time-step of input data, or performance metric threshold. *Appendix O* provides detailed quantitative results of all model predictions.

- **No Action Alternative** is expected to have an adverse to beneficial impact on all life stages that varies by the component.

- **Alternative 1** is expected to have adverse to negligible impacts to larvae resulting from increased and decreased entrainment (Neutrally buoyant particle fate by inflow bin entrained at exports: 74% hihi – 97% hilo; neutrally buoyant particle fate by OMR bins entrained at exports 79% at -2000 cfs – 95% at -5500 cfs), and substantial adverse impacts to juveniles resulting from increased entrainment (April – May predicted juvenile longfin smelt salvage range, all non-critically dry water year types and critically dry water year type: 2390 – 5280 fish, 1226 fish). For population abundance, there is an expected adverse impact on juveniles (Means of annual posterior predictive means for the FMWT index of longfin smelt abundance range, all non-critically dry water year types and critically dry water year type: 88.2 – 664.2, 72.3). Alternative 1 does not include Old and Middle River criteria resulting in lower Delta outflows and exports are not adjusted to minimize entrainment of fish and protection of critical habitat.

- **Alternative 2** is expected to have negligible to beneficial impacts to larvae (Neutrally buoyant particle fate by inflow bin entrained at exports: 71% hihi – 92% medlo; neutrally buoyant particle fate by OMR bins entrained at exports 78% at -2000 cfs – 97% at -5500 cfs) and adverse to beneficial impacts to juveniles resulting from increased and decreased entrainment (April – May predicted juvenile longfin smelt salvage range, all non-critically dry water year types and critically dry water year type: 1403 – 3757 fish, 1110 – 1170 fish). For population abundance, there are expected adverse to beneficial impacts to juveniles (Means of annual posterior predictive means for the FMWT index of longfin smelt abundance range, all non-critically dry water year types and critically dry water year type: 95.2 – 727.1, 75.9 – 79.6). Alternative 2 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

- **Alternative 3** is expected to have negligible to beneficial impacts to larvae resulting from decreased entrainment (Neutrally buoyant particle fate by inflow bin entrained at exports: 36% medhi – 78% hilo; neutrally buoyant particle fate by OMR bins entrained at exports 80% at -2000 cfs – 96% at -5500 cfs), and substantial beneficial impacts on juveniles resulting from decreased entrainment (April – May predicted juvenile longfin smelt salvage range, all non-critically dry water year types and critically dry water year type: 109 – 449 fish, 447 fish). For population abundance, there is an expected positive impact on juveniles (Means of annual posterior predictive means for the FMWT index of longfin smelt abundance range, all non-critically dry water year types and critically dry water year type: 116.8 – 1015.7, 91.0). Alternative 3 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

- **Alternative 4** is expected to have negligible impacts on larvae resulting from increased to decreased entrainment (Neutrally buoyant particle fate by inflow bin entrained at exports: 86% lolo – 92% medlo; neutrally buoyant particle fate by OMR bins entrained at exports 81% at -2000 cfs – 95% at -5500 cfs), and substantial adverse impacts on juveniles resulting from increased entrainment (April – May predicted juvenile longfin smelt salvage range, all non-critically dry water year types and critically dry water year type: 2124 – 3813 fish, 1114 fish). For population abundance, there is an expected negligible impacts on juveniles (Means of annual posterior predictive means for the FMWT index of longfin smelt abundance range, all non-critically dry water year types and critically dry water year type: 95.3 – 728.6, 75.6). Alternative 4 includes Old and Middle River Flow Management which adjusts exports to minimize entrainment of fish and protection of critical habitat.

12.2.7.8 Other aquatic species

For aquatic species in the Bay-Delta not described above, potential impacts range from adverse to beneficial, including no impacts, depending on species, life stage, month, and water year type. For example, Alternative 1, Alternative 2, and Alternative 4 are expected to have beneficial to negligible impacts from seasonal operations on Pacific lamprey in the Bay-Delta, whereas Alternative 3 is expected to have adverse to beneficial impacts from seasonal operations. Alternative 1 is expected to have beneficial to negligible impacts from seasonal operations on striped bass, Alternative 2 and Alternative 3 are expected to have adverse and beneficial impacts, and Alternative 4 is expected to have beneficial impacts. Alternative 1 is expected to have adverse impacts from entrainment on striped bass, Alternative 2 and Alternative 4 are expected to have adverse and beneficial impacts, and Alternative 3 is expected to have beneficial impacts. Alternative 1-4 are expected to have negligible impacts from seasonal operations to threadfin shad, although impacts from entrainment are more variable. Alternative 1, Alternative 2, and Alternative 4 are expected to have adverse and beneficial impacts from entrainment, whereas Alternative 3 is expected to have beneficial impacts.

12.2.8 Nearshore Pacific Ocean

12.2.8.1 Southern Resident Killer Whale's Chinook Salmon prey

Changes in water operations under the alternatives could have the potential to impact Chinook salmon prey for Southern Residents relative to the No Action Alternative. The No Action Alternative is predicted to have negligible to no impacts on Southern Residents and the Central Valley and Trinity Rivers would continue to contribute about the same amount of Chinook salmon to the compilation of adult Chinook salmon in the Pacific Ocean available as prey to Southern Residents. Outlined below are expected changes in Southern Residents prey. *Appendix O* provides detailed quantitative results of all model predictions.

Alternatives 1-4 are expected to have minimal impact on the number of Chinook that would be produced by the Trinity River watershed and survive to adulthood in the ocean becoming prey available to Southern Residents.

Alternative 1, Alternative 2, and **Alternative 4** are expected to have minimal impact on the number of Chinook that would be produced by the Central Valley and survive to adulthood in the ocean becoming prey available to Southern Residents. **Alternative 3** would benefit Central Valley Chinook salmon that survive to adulthood in the ocean and are available as Southern Residents' prey.

12.3 Mitigation Measures

Appendix D includes a detailed description of mitigation measures identified for fish and aquatic resources per alternative. These mitigation measures include avoidance and minimization measures that are part of each alternative and, where appropriate, additional mitigation to lessen impacts of the alternatives. These measures include water temperature and storage management, minimum instream flows, ramping rates, pulse flows, fall and winter baseflows, rice decomposition smoothing, OMR management, increased Delta outflow, salinity management, a drought plan and toolkit, flow and non-flow measures from the Voluntary Agreements, rebalancing between CVP reservoirs, water supply reductions and allocations to conserver storage, modifying water transfers, coordinating on refuge needs to conserve storage, adjustments of minimum release requirements for redd dewatering purposes, DCC gates closures, pumping plant operations specific to timing and fish screening, and Delta smelt supplementation.

12.4 Cumulative Impacts

The No Action Alternative would continue with the current operation of the CVP and may result in potential effects to fish and aquatic resources storing, diverting, blending and releasing water. The action alternatives will also result potential effects to fish and aquatic resources storing, diverting, blending and releasing water. The magnitude of the changes is dependent on alternative, species present and water year type. Therefore, the No Action Alternative and action alternatives may contribute to cumulative effects to some of the species and life stages analyzed in this EIS, as described in *Appendix O*, *Fish and Aquatic Resources* and Appendix Y, *Cumulative Impacts Technical Appendix*.