CALIFORNIA COASTAL CHINOOK SALMON
Oncorhynchus tshawytscha

High Concern. Status Score = 2.9 out of 5.0. Vulnerable to extinction in next 50-100 years if present trends continue and stream conditions deteriorate under climate change.

Description: Both male and female Chinook salmon have small black spots on the back, dorsal fin, and both lobes of the tail, though many adults can also have large, chevron-type spotting on the back and dorsal fin. Spotting on the caudal fin and the black coloration at the base of their teeth differentiate them from other sympatric salmonid species such as coho (*Oncorhynchus kisutch*), which have white at the base of the teeth. They have 10-14 major dorsal fin rays, 14-19 anal fin rays, 14-19 pectoral fins rays, and 10-11 pelvic fin rays. There are 130-165 scales along the lateral line. Branchiostegal rays number 13-19. They possess more than 100 pyloric caeca and have rough and widely spaced gill rakers, 6-10 on the lower half of the first gill arch.

Spawning Chinook adults are the largest Pacific salmonid, typically 75-80 cm SL, but lengths may exceed 140cm. California Chinook are usually smaller; Puckett (1972) found the average length of Eel River Chinook to be around 56 cm FL. The average weight is 9-10 kg, although the largest Chinook taken in California was 38.6 kg. Spawning adults may range in color from olive brown to dark maroon without streaking or blotches on the side. Males are often darker than females and develop a hooked jaw and slightly humped back during spawning. Juvenile Chinook have 6-12 parr marks, which often extend below the lateral line; the marks are typically equal to or wider than the spaces between them. Parr can also be distinguished from other salmon species by the adipose fin, which is pigmented on the upper edge, but clear at the base and center. Most fins are clear, though some parr begin to show spots on the dorsal fin as they grow. There are no morphological features to separate this Evolutionary Significant Unit (ESU) from other Chinook salmon ESUs, so separation is based on genetic data.

Taxonomic Relationships: The California Coastal Chinook salmon (CC Chinook) Evolutionary Significant Unit (ESU) includes Chinook salmon that spawn in coastal watersheds from Redwood Creek (Humboldt Co.) in the north to the Russian River (Sonoma Co.) in the south, inclusive. Chinook salmon found occasionally in coastal basins south of the Russian River (e.g., Lagunitas Creek, Marin Co.) are also under consideration to be in included in this ESU based on Williams et al. (2011), though no changes have been made to the ESU boundaries at this time. Recent genetic analyses demonstrate some differentiation among populations. Bjorkstedt et al. (2005) found that CC Chinook in the Eel River and northern watersheds differ from those on the Mendocino coast and in the Russian River. Differentiation among fish from different tributaries to the Eel River is low, suggesting high dispersal of Chinook in the basin. Generally, fish from the Russian River are genetically more similar to Chinook from the Eel River than to fish from the Central Valley fall Chinook ESU (Hedgecock et al. 2002, Bjorkstedt et al. 2005).

NMFS (2016b) divided the ESU into three groups through genetic analyses (Figure 1):

- 13 independent populations: Bear River, Big River, Garcia River, Humboldt Bay tributaries, Lower Eel River (Van Duzen River and Larabee Creek), Lower Eel River (South Fork and Lower mainstem Eel River) Little River, Mad River, Mattole River, Noyo River, Redwood Creek (Humboldt Co.), Russian River, and Upper Eel River;
- 3 supporting independent populations: Gualala River, Navarro River and Ten Mile River;
- 1 dependent population: Albion River

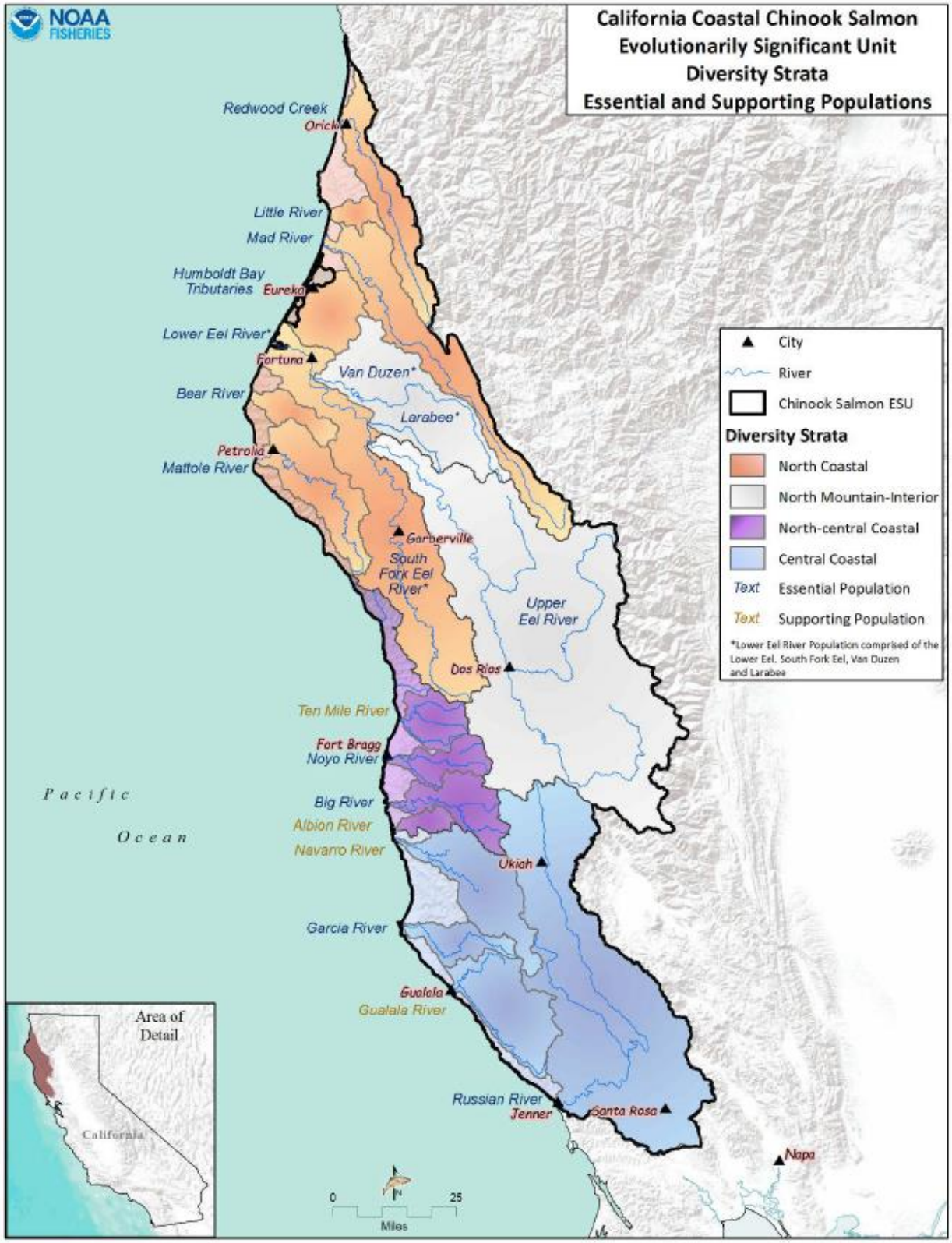

Figure 1. CC Chinook ESU boundaries and diversity strata. From NMFS 2016, Fig. 1. pg. 14.

Life History: Existing populations of CC Chinook in the ESU are characterized as a having a fall–run salmon based life history; the spring-run life history strategy has been lost throughout the ESU and represents a key source of genetic diversity loss in the ESU (NMFS 2016). There used to be significant natural variability in the timing of peak spawning runs of CC Chinook due to precipitation and its influence on stream flows and passage in relatively short coastal watersheds. For example, spring-run Chinook historically accessed streams in the Middle Fork and upper mainstem Eel River upstream of where Scott Dam now stands (J. Fuller, NMFS, pers. comm. 2017). CC Chinook typically return to their natal rivers between September and early November, often following large early winter storms. They are most abundant in open-estuary type systems throughout their range, and will stage in the lower reaches of rivers until cued upstream by hydrologic conditions (J. Fuller, NMFS, pers. comm. 2017). In smaller coastal watersheds or those with seasonal open estuaries, fall rains open the mouths by November (M. Sparkman, CDFW, pers. comm. 2016).

Spawning in the larger basins peaks between late October and December, but in smaller watersheds it follows the timing of entrance into the natal stream more closely due to the more flashy streamflows that allow passage into these systems (J. Fuller, NMFS pers. comm. 2016). CC Chinook salmon may spawn immediately or may rest in holding pools for considerable time when early storms permit entrance to rivers but not access to preferred spawning habitat upstream. Most Chinook salmon migration activity occurs during a few distinct movement events per year, usually dictated by fall rains, increases in river flows, and cooler water temperatures between September and December on the Russian River (SCWA 2008). In Redwood Creek in 2016, 95% of the adults swam upstream within two weeks of the mouth opening to the ocean. In drought type water years, the migration is more prolonged (M. Sparkman, CDFW, pers. comm.. 2017). Mature Chinook females produce 2,000-17,000 eggs (Moyle 2002). Adults die within a few days after spawning and their carcasses become a source of food for a wide array of animals, including juvenile steelhead and coho salmon. They also fertilize riparian and stream ecosystems with marine-derived nutrients and trace elements, presumably increasing carrying capacity of the streams for their own young.

The vast of majority of CC Chinook salmon demonstrate an “ocean-type” juvenile life stage. Under this life history strategy, fry emerge from the gravel in the late winter or spring and initiate outmigration within a week to months of emergence when they are relatively small, about 30-50 mm FL. Emigration of smaller fish is likely a function of low stream carrying capacity, with later emerging fry only finding saturated habitats, forcing them to seek unclaimed rearing habitat. As they grow, the parr move into deeper and faster water to seek greater foraging opportunities, dispersing downstream as they opportunistically forage on drifting terrestrial and aquatic insects. Slow water habitats are still important to juvenile Chinook, but are used primarily during daytime, when the fish hide in deep cover to reduce predation and for energy conservation. In streams such as Redwood Creek, the peak month in emigration is typically June through lower river sections. Small numbers of “stream-type” parr will oversummer in the northern coastal watersheds of this ESU; these large (ca. 10+ cm FL) juveniles migrate out to sea when stream flows rise following large fall rainstorms (Bjorkstedt et al. 2005) or as yearlings in the spring (M. Sparkman, CDFW, pers. comm. 2016).

CC Chinook may reside in estuaries, lagoons, and bays for a few months to take advantage of feeding opportunities and grow in size, and then exit these habitats gradually over the summer (Healey 1991). Historically, estuaries with year-round access to the ocean were favorable juvenile habitat and fish had greater flexibility to leave or to remain in the estuaries

until fall/winter when habitat conditions change. The extended occupancy by smolts of these habitats suggests enhanced growth may benefit ocean survival (Williams 2006). In the Russian River, Cook (2005) observed Chinook to be habitat generalists found throughout the estuary. Juvenile Chinook were captured 38% of the time at tributary junctions within the estuary. At these locations they presumably fed on aquatic (drift) and terrestrial insects, supplied from the surrounding and upstream riparian corridors. Chinook presence in the Russian River estuary typically peaks in early June. Most juveniles have emigrated downstream past Sonoma County Water Agency's inflatable Mirabel Dam and diversion facility (Rkm 37), near Forestville, CA, by early July (CDFW 2007). Estuaries with summer-forming sandbars appear to have high juvenile mortality due to unfavorable summer estuarine water quality and habitat conditions. In 2007, large numbers of Chinook juveniles were observed in the Mattole River estuary in July, following a significant summer rain event. Although the estuary was closed to the ocean, by August very few Chinook were observed in the estuary or upstream habitats, suggesting mortality was very high due to the combination of lack of access to the ocean and inhospitable estuarine conditions (Mattole Salmon Group 2016).

Once they enter the ocean, CC Chinook salmon migrate along the California coast, often moving northward, where they mix with salmon from other river systems, including hatchery fish, and feed in the cool waters off of the Klamath-Trinidad region. Because salmon spend a majority of their lives at sea, shifts in ocean productivity play a large role in their survival, growth, and overall abundance. Chinook salmon are predators in the ocean, feeding on small fish and crustaceans such as copepods, anchovies, sardines, and krill. As their size increases, fish increasingly dominates their diet. This piscivorous diet provides for rapid growth on the order of 0.35-0.57mm/day (Healey 1991). CC Chinook salmon typically return after two to three years at sea; the most common ages-at-maturity for CC Chinook are three and four years. Five year and six year old fish contribute a small proportion to the spawning population, although their limited numbers may be due to effects of fisheries selectivity for larger individuals over the past century and in-river predation on the largest fish (Myers 1998).

Habitat Requirements: Habitat requirements for Chinook salmon are described in detail in Healey (1991) and Moyle (2002). Temperature is an important factor in Chinook salmon survival and growth, and tolerances vary with life history stage and by ESU (Table 1). Likewise, they are sensitive to dissolved oxygen levels, water clarity and other factors that indicate high water quality. For example, CC Chinook may not be as tolerant of warm temperatures as Central Valley Chinook salmon (J. Fuller, NMFS, pers. comm. 2017).

	Sub-Optimal	Optimal	Sub-Optimal	Lethal	Notes
Adult Migration	< 10ºC	10-20°C	20-21°C	> 21-24°C	Migration usually stops when temperatures climb above 21ºC, with partial mortality occurring at 22-24ºC. Lethal temperature under most conditions is 24ºC. Fish observed moving at high temperatures are probably seeking cooler refugia.
Adult Holding	< 10ºC	10-16°C	16-21°C	> 21-24°C	Adults experience heavy mortality above 21ºC under crowded conditions, but will survive temperatures up to 24ºC for short periods of time. In some holding areas, maximum temps exceed 20ºC for over 50 days in summer.
Adult Spawning	< 13ºC	13-16°C	16-19°C	> 19°C	Egg viability reduced with exposure to higher temperatures.
Egg Incubation	< 9°C	9-13°C	13-17°C	> 17°C	This is the most temperature sensitive phase of life cycle. American River salmon have 100% mortality >16.7°C; Sac. River fall-run salmon mortality exceeded 82% at temperatures >13.9°C.
Juvenile Rearing	< 13°C	13-20°C	20-24°C	> 24°C	*Past exposure (acclimation temperatures) has a large effect on thermal tolerance. Fish with high acclimation temperatures may survive 28-29ºC for short periods of time. Optimal conditions occur under fluctuating temperatures, with cooler temperatures at night. When food is abundant, juveniles that live under conditions that fluctuate between 16 and 24ºC may grow very rapidly.
Smolt Migration	< 10ºC	10-19°C	19-24°C	> 24°C	Smolts may survive and grow at suboptimal temperatures but are susceptible to predation; in the lab, optimal temperatures are 13-17ºC (Marine and Cech 2004), but observations in the wild suggest a greater range.

Table 1. Chinook salmon thermal tolerances in fresh water. All lethal temperature data is presented as incipient upper lethal temperatures (IULT), which is a better indicator of natural conditions because experimental designs use a slower rate of change (ca. 1°C/day). Fish living in the wild experience temperatures that fluctuate on a daily basis and rarely stay in warmer water for long. Information largely from McCullough (1999); this is a synthesis of data from throughout the range of Chinook salmon, so may not precisely reflect the tolerances of CC Chinook salmon.

Due to their large size, Chinook spawning use the largest substrate of any California salmonid for spawning, which consists of a mixture of small cobble and large gravel. Such coarse material has sufficient subsurface infiltration, which provides oxygen for developing embryos. As a result, the selection of redd sites is often a function of gravel permeability and subsurface water flow. For CC Chinook, a majority of suitable spawning habitat is in the upper main stems of rivers and lower reaches of coastal creeks. These habitats provide stable substrate and sufficient flows into late winter. Typically, redds are observed at depths from a few centimeters to several meters in water velocities of 15-190 cm/sec. Preferred spawning habitat seems to be at depths of 30-100 cm and at water velocities of 40-60 cm/sec. Redds are typically constructed over 2-15 m^2, where the loosened gravels permit steady access of oxygenated water (Healey 1991). Redd size is a function of female size as well as looseness of the substrate. For

maximum embryo survival, water temperatures must be between 5º and 13º C and oxygen levels must be close to saturation. Under optimal conditions, embryos hatch after 40-60 days and remain in the gravel as alevins for another 4-6 weeks, usually until the yolk sac is fully absorbed before emerging as fry (M. Sparkman, CDFW, pers. comm. 2017).

Once alevins emerge with their yolk sac absorbed, they become fry, which tend to aggregate along stream edges, seeking cover in bushes, swirling water, and dark backgrounds. As they grow larger and become increasingly vulnerable to avian predators, especially herons and kingfishers, they move into deeper (> 50 cm) water. Larger juveniles may wind up in the tails of pools or other moderately fast-flowing habitats where food is abundant and there is some protection from predators. As they move downstream, they use more open waters at night, while seeking protected pools during the day. Pools that are cooler than the main river, from upwelling or tributary inflow, may be sought out by the migrating juveniles as daytime refuges.

Juveniles and smolts that reach the estuary use food-rich tidal habitats, especially areas with overhanging cover or undercut banks. When given the opportunity, they will move into areas that have flooded either tidally or from freshets, to forage. Estuaries that present complex and variable habitats (i.e., that are not channelized, diked, and drained) are optimal for juvenile salmonids just before they go out to sea (Wallace et al. 2015).

In the ocean, habitats for the first few months are poorly documented, but it is assumed that the fish stay in coastal waters offshore of the Klamath-Trinidad region, where the cold California Current creates rich food supplies, especially small shrimp, by upwelling. During the day, they avoid surface waters. Subadult Chinook salmon hunt anchovies, sardines, herring, and other small fish, typically at depths of 20-40 m, moving offshore and into deeper waters in response to temperature, food availability, and predators, such as orcas and sea lions.

Distribution: This ESU includes Chinook salmon that spawn in coastal watersheds from Redwood Creek (Humboldt Co.) in the north to the Russian River in the south, inclusive (Figure 1). Chinook salmon found occasionally in coastal watersheds south of the Russian River (e.g., tributaries to Tomales Bay, Marin Co.) are also under consideration to become part of this ESU, but no new information has warranted that change (NMFS 2016). In general, small coastal streams within this range can support Chinook salmon spawning and rearing as long as they have timely open-estuary conditions with sandbar formations that are not constraining ocean connectivity during migratory periods. CC Chinook salmon south of the Eel River are typically present in year-round open-estuary systems (e.g. Garcia River) and rarely observed in systems impeded by sandbar formations (e.g. Gualala River). In general, timing of precipitation events and sandbar breaching in systems south of the Eel River occur too late to allow successful Chinook migration (J. Fuller, NMFS, pers. comm. 2017). California Coast Chinook salmon are distributed at the southern end of the species' North American range; only Central Valley fall Chinook are found spawning further south. NMFS identified four regions of this portion of the California coast with similar basin-scale environmental and ecological characteristics (Bjorkstedt et al. 2005). Sixteen watersheds were identified in these four regions that have minimum amount of habitat available to support independently viable populations.

In the North Mountain-Interior Diversity Strata, the Upper Eel and Middle Fork Eel rivers contain independent populations, while the Lower Eel and Van Duzen rivers have the potential to support dependent populations. Historically, Chinook were present in the North Fork Eel River up to a location known as the Asbill Roughs and Split Rock (USFS-USBLM 1996). Chinook are annually observed in the Middle Fork Eel River, in Black Butte River, and near

Williams Creek, though Scott Dam on Lake Pillsbury limits their upstream range. They continue to be observed annually in the Outlet Creek drainage and in small tributaries feeding Little Lake Valley (S. Harris, pers. comm. 2007). In the North Coastal Region, Redwood Creek and the Mad, Lower Eel, South Fork Eel, Bear and Mattole rivers all contain sufficient habitat for independent populations. On the Mad River, boulder roughs near Bug Creek (Rkm 80) precludes Chinook salmon passage upstream (Mad River Watershed Assessment 2010). Little River and Humboldt Bay tributaries may potentially host independent populations. In the North-Central Coastal Diversity Strata, numerous watersheds in Mendocino County contain small runs that are dependent upon self-sustaining stocks in Ten Mile, Noyo, and Big rivers. Big River, in particular, boasts a large, open estuary that could potentially support a self-sustaining population of Chinook, but without sufficient data to determine run sizes and timing, any Chinook returns are unpredictable at best (T. Daugherty, NMFS, pers. comm. 2017).

Along the Central Coastal Diversity Strata, the Navarro, Garcia and Gualala rivers historically had independent populations, but numbers have declined substantially. While some Chinook are seen annually in the Garcia River, the Navarro and Gualala further south have very limited information and few confirmed sightings of Chinook recently (J. Fuller, NMFS, pers. comm. 2017). Additionally, the Russian River supports a self-sustaining population of its own, although the historical and current influence of hatcheries and straying of fish from nearby basins is uncertain (Chase et al. 2007, CDFW 2007).

Seventeen additional watersheds were identified by NMFS to contain CC Chinook, but due to limited habitat were believed not to support persisting populations of these salmon (Good, et al. 2005). While Chinook salmon are also encountered in the San Francisco Bay region, these fish most likely originated from Central Valley populations that have been trucked from hatcheries downstream to bypass predation and entrainment threats in the Delta. These fish are then acclimated in pens near Carquinez Strait and other locations in the San Francisco Bay and are not included in the ESU. In the ocean, CC Chinook salmon are most frequently encountered in commercial fisheries from the Oregon border south to San Francisco Bay during the months of July and August (Satterthwaite et al. 2014).

Trends in Abundance: CC Chinook salmon abundance has declined to levels that are well below recovery targets and high-risk depensation thresholds, or reductions in egg survival and productivity due to shrinking effective spawning populations, established by NMFS (NMFS 2016). The remaining small population sizes have rendered the ESU vulnerable to stochastic processes, such as earthquakes, landslides, droughts, or flooding, and may lead to reductions in genetic diversity, altered breeding structure, and shifts in population dynamics (NMFS 2016). Yoshiyama and Moyle (2010) provide a history of salmon in the Eel River basin, which presumably reflects what has gone on in all watersheds in the region; they estimate that abundance of CC Chinook has decreased by more than 90% of historical numbers, though reliable population estimates for the Eel are severely lacking (J. Fuller, NMFS, pers. comm. 2017). In general, lack of long-term population monitoring across the ESU range, especially for the Upper and Lower Eel watershed and the Mad River populations, makes comparisons of current and historical abundance difficult (NMFS 2016). Returning numbers of adult CC Chinook over the last five years have shown a mix in population trends among regions: extremely low numbers exist in North-Central Coast and Central Coast Diversity Strata (NMFS 2016).

North Coastal Diversity Strata. CC Chinook that inhabit northern watersheds of the ESU (between Redwood Creek and the Mattole River) and Humboldt Bay appear to have runs of a few thousand spawners annually. On Redwood Creek, sonar estimates ranged from 1,600 to 3,400 returning adults per year, while the Mad River had an estimated 2,200 returning adults in 2016 (M. Sparkman, CDFW, pers. comm. 2017). Within Humboldt Bay, the smaller coastal tributaries also likely supported combined runs of several hundred fish. Presumably, CC Chinook runs in steep coastal tributaries such as Freshwater Creek are likely less than fifty adults per year, and the Elk River have been limited by spawning habitat, but expansive spring-flooded baylands and estuarine habitats may have resulted in high parr-to-smolt survival (M. Wallace, CDFW, pers. comm. 2007, M. Sparkman, CDFW, pers. comm. 2017), resulting in higher-than-expected numbers of returning adults. Chinook salmon have been observed in declining numbers in Freshwater Creek over the past decade. Adults continue to be captured at the Humboldt Fish Action Council's permanent weir in the lowest reach of Freshwater Creek, but in 1997- 2001, 30-70% of returning Chinook were of hatchery origin. Recent returns have fluctuated considerably and a recent adult population estimate (2002-2003) was 133 ± 63 Chinook entering Freshwater Creek (Ricker 2005). The Little River has small (on the order of 800-1,000) annual returning Chinook as well (M. Sparkman, CDFW, pers. comm. 2017). The Mattole River contains a CC Chinook population that contains perhaps a thousand adults based on counts of 300-400 redds per year from 2012-2015 (Mattole Salmon Group 2015).

North Mountain Interior Diversity Strata. The North Mountain Interior Diversity Strata encompasses all but the South Fork and lower Eel rivers. Steiner Environmental Consulting (1998) estimated historical Chinook abundance in the Eel River system based on cannery records compiled by Humboldt County (Humboldt Public Works 1991). From 1857-1921, SEC (1998) estimated that the average catch was 93,000 Chinook and coho salmon combined per year, with a peak of 585,000 fish in 1877. Similarly, Berg Associates (2002:107) stated, "from 1853 to 1922, fish packing and cannery records documented from 15,000 to 600,000 salmonids caught annually in commercial fisheries" (citing NMFS 2000). A large majority of these salmon were presumably Chinook salmon, as they are the most abundant and accessible to fishermen. There are no records of how many fish survived to spawn, but a conservative estimate would be that the annual runs of Chinook in the Eel River (catch plus escapement) in this early period were on the order of 100,000-600,000 fish per year (NMFS 2016b).

The early unrestricted fishery presumably greatly depleted the runs, but there are only scattered records to indicate run sizes after the canneries closed down. In 1965, CDFG suggested that the Eel River Chinook escapement approximated 88,000 adults. This number is presumably much lower than historical escapement. The Potter Valley Diversion Project on the Upper Mainstem Eel River had already been diverting water to the agricultural valleys of the Russian River watershed for almost forty years at the time, and Chinook were facing challenges from flow alteration, habitat degradation, pollution, and unregulated fishing (Shapovalov 1941). Benbow Dam, which was seasonally constructed across the South Fork of the Eel River, averaged approximately 12,000 Chinook between 1938 and 1952 (http://www.hits.org/salmon98/history/damrecords2.html), and multiple egg collection and hatcheries operated throughout the Eel River until the 1960s. During the last decade of the Benbow Dam fishway between 1965-1975 (Taylor 1978), average Chinook salmon counts declined to less than 5,000 fish annually and have continued in their decline. Chinook spawning was reported to occur in the South Fork Eel River between Bull Creek and Laytonville, and in the mainstem between Holmes and Van Arsdale Reservoir (Puckett and Hinton 1974).

In the Upper Eel River in 1975-76, an estimated 367 Chinook salmon entered Tomki Creek, the most productive upper mainstem tributary below Van Arsdale Reservoir (Brown 1976). By the 1990s, basin-wide escapement often numbered fewer than 5,000 fish, with numbers in the upper reaches dwindling to fewer than 50 fish in many years. The Van Arsdale Fish Station provides annual estimates of the Chinook entering the Upper Eel River; NMFS (2016) documented a significant positive trend in returns of CC Chinook passing the counting facility from 2000 through 2013 (Figure 2).

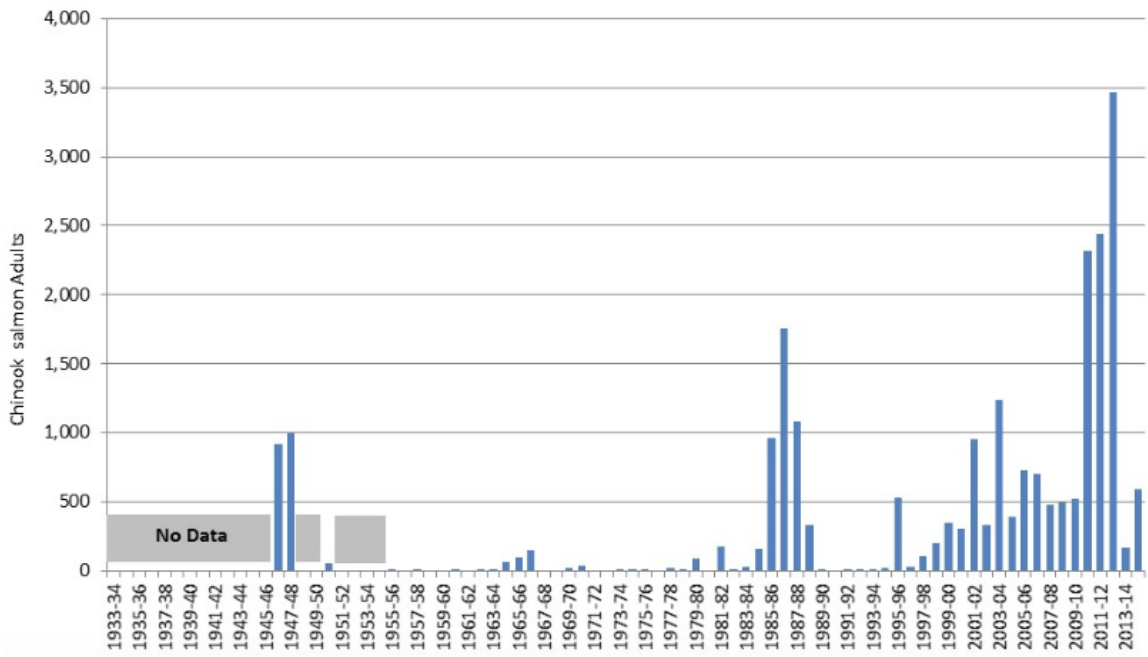

Figure 2. Adult Chinook salmon passing Van Arsdale Fish Station on the Upper Mainstem Eel River, 1933-2014. From NMFS 2016b, Fig. 1, pg. 91.

A number of the larger subbasins in the Eel River such as the Van Duzen, South Fork, and North Fork Eel rivers continue to support spawning runs, although monitoring data is limited and has only recently been improved through directed surveys in these watersheds. Redwood Creek, a small tributary to the lower South Fork Eel River once saw hundreds of Chinook returning annually, although numbers today fluctuate between 10 and 100 returning spawners (H. Vaughn, Eel River Salmon Restoration Project, pers. comm. 2016).

In recent years, there has been an upswing in numbers of returning adult Chinook to the Eel. Higgins (2015) estimated total run-size for the 2014-2015 to be 12,500-20,000 spawners, 14,900-25,000 in 2013-2014 and 20,000-50,000 in 2012-2013. These numbers are hopeful because the river had very low flows because of ongoing drought (2012-2016). There are several possible explanations for the recent positive trend: (a) the Eel River has been healing from the effects of the huge floods of 1955 and 1964, so there is more spawning gravel available in narrower channels, increasing survival of young; and (b) the estimates of Higgins (2015) are based on some of the most extensive snorkel surveys for salmon ever done in the river.

North-Central Coastal Diversity Strata. Monitoring data is sparse for coastal Mendocino watersheds such as Ten Mile, Noyo, Big, and Albion rivers. While CC Chinook are generally very low in abundance in these watersheds, generally numbering in the few hundreds of adults

per year, they have been regularly reported over time and may currently support small but viable populations (NMFS 2016). Early logging practices likely severely depressed CC Chinook stocks in these rivers by eliminating passage along the main stems by frequent use of splash dams and loss of rearing habitat from heavy sedimentation of both rivers and estuaries. Observations of Chinook in these watersheds indicate that spatial gaps among populations are not as great as once believed (NMFS 2016).

Central Coastal Diversity Strata. CC Chinook in the Central Coastal Diversity Strata range from the Navarro River in the north to the Russian River in the south. Russian River Chinook are of uncertain genetic origin following close to fifty years of inter-basin stocking in the river between the early 1950s and 1999. Between 1980 and 1996, CDFG stocked approximately 2.25 million juvenile Chinook from various inter and intra-basin locations to establish a self-sustaining hatchery run. Unfortunately, returns were very low (< 300 adults/year) during this time. Although the Chinook hatchery program ended in 1999, biologists working for the Sonoma County Water Agency have observed more Chinook Salmon in the Russian River than any other anadromous salmonids present in the basin. In the 2005-2006 spawning season, more than 2,563 Chinook salmon were counted swimming through SCWA's fish ladder, and 1,383 to 6,081 Chinook were observed migrating past Mirabel Dam (Rkm 37) during the 2000 to 2004 spawning runs. These fish spawn primarily in the mainstem between Cloverdale (Rkm 101) and the confluence of the East and West Branches of the Russian River (Rkm 150), but spawning has also been observed in Austin, Santa Rosa, Green Valley, Dry, Feliz, and Forsythe creeks, but this contribution is smaller than that observed on Dry Creek (NMFS 2016b). Returns of adult Chinook observed passing the Sonoma County Water Agency's Mirabel diversion, a few river kilometers downstream of the Dry Creek confluence near Healdsburg, have been variable since the turn of the century (Figure 3).

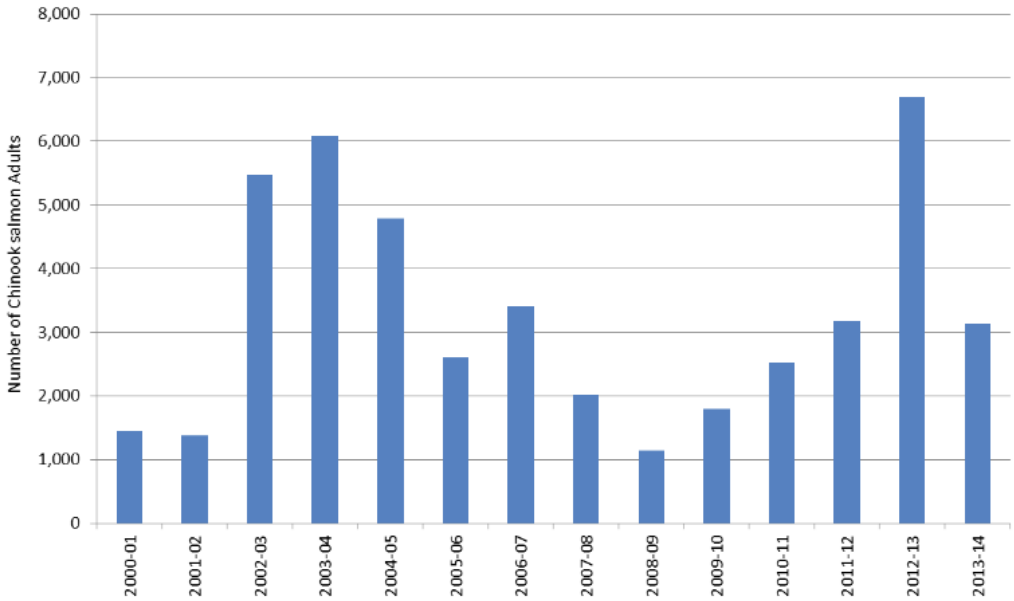

Figure 3. Minimum counts of adult Chinook salmon passing Mirabel diversion facility video station, Russian River (Sonoma Co.) 1980-2014. From NMFS 2016b Fig. 3, pg. 459.

Overall. CC Chinook salmon are now much less abundant across the ESU than they were historically, although monitoring has been always been sparse. It is reasonable to assume

that in 'good' years, historic runs were on the order of 600,000 fish combined in the ESU, perhaps dropping to 30,000-50,000 in 'bad' years. Present numbers (even in good ocean years), based on insufficient data, seem to total about 5,000-20,000 fish annually. There are concerns about the extremely low returns of adult Chinook in the North-Central Coast and Central Coast strata, and the diminished connectivity among populations in the ESU that results from very small abundance in key watersheds (NMFS 2016).

Factors Affecting Status: The factors affecting CC Chinook salmon are multiple and interactive but somewhat different for each watershed (Moyle 2002). This multiple population structure provides some resilience to CC Chinook populations overall (portfolio effect). NMFS (2016b) found that broadly, the anthropogenic factors most likely to threaten the continued existence of CC Chinook are: channel modification, impacts from roads and railroads, and logging and wood harvesting. These and other threats are discussed more specifically below.

Dams. Dams and diversions affect water quality and quantity in both rural and urban watersheds. The main withdrawal of water in the ESU is the inter-basin transfer from the upper Eel River into the upper Russian River for Pacific Gas & Electric's Potter Valley Project. This project transfers less than 3% of the Eel River's total flows to the Russian River (Potter Valley Water 2016) via a 1.6 km tunnel to supply water during fall and spring for vineyard irrigation and municipal uses, which presumably indirectly helps to sustain all CC Chinook life stages in the mainstem Russian River. The transfer of water has presumably contributed to declines in Eel River CC Chinook runs by reducing flows available for out-migration by juveniles and for upstream spawning migration by adults. Water withdrawals from the Eel River likely affect water temperatures in the upper mainstem Eel, creating thermal barriers that restrict juvenile emigration to earlier in the spring. Dams on the Mad, Eel and Russian rivers have also influenced geomorphic regimes and decreased the quality of spawning habitat downstream through reduced flows and gravel recruitment. Ruth Dam on the Mad River is capable of drawing up to 75 million gallons of water daily, and can reduce flows during the low flow period between August and October, which overlaps with early migration of fall Chinook into the lower portion of the river. While the overall percentage of river water diverted is not very high, the timing of these diversions, and associated reductions in streamflow, have important consequences for salmonids. CDFW is currently working with Humboldt Bay Municipal Water District to ensure more water can be available for migrating and rearing fish during September and October if there is not much rain during this critical portion of the season (M. Sparkman, CDFW, pers. comm. 2017).

Despite the challenges posed by dams, reservoir operations that capture and store coldwater pool in critically dry years (2013-2015) can benefit salmonids downstream when released strategically (J. Fuller, NMFS, pers. comm. 2017). Scott Dam and the Potter Valley Project, which cut off between 291-463 km for steelhead and 89-127 km for Chinook salmon (Cooper et al., 2017, *in progress*), limit streamflows during certain times of the year, and reduces water in the Eel River through diversions to the Russian River.

Water quality and quantity is reduced by operation of Scott Dam (Eel River) and Coyote Valley Dam (Lake Mendocino, Russian River), which were near record-low levels from 2013-2015. Low storage levels led to reduced summer flows with high temperatures (> 20°C) and turbidities downstream of the dams. In particular, a chronic challenge with managing coldwater pool and reducing the high turbidity flows exists at Coyote Valley Dam, to the detriment of salmonids in the Russian River (J. Fuller, NMFS, pers. comm. 2017). Low releases from these dams can reduce diversity of benthic invertebrates, an important food of juvenile Chinook and

degrade spawning and rearing habitat for both salmon and steelhead, and delay juvenile Chinook out-migration (NMFS 2016). Low releases can have negative impacts on salmonids in the mainstem Russian and Eel rivers as well, especially during fall and early winter months (J. Fuller, NMFS, pers. comm. 2017). In addition, illegal diversions for marijuana cultivation have increased exponentially significantly threatening populations of CC Chinook, especially in Humboldt and Mendocino counties, through altering or dewatering creeks, use of pesticides, poisons, and fertilizers that degrade water quantity and quality (Bauer et al. 2015, NMFS 2016).

Urbanization. Urbanization presents multiple problems for CC Chinook in many parts of the ESU, especially in the lower portions of watersheds where they are most likely to spawn. Water quality is often degraded by urban pollution and runoff. The use of land around rivers and creeks for towns and farms has led to channelization, construction of levees, removal of instream habitat, and channel erosion. Increasing urbanization and other development through the southern portion of the ESU is straining the capacity for water agencies to meet municipal needs and this is likely to further increase water withdrawals and negatively impact CC Chinook.

While there are still issues to be resolved with parasites and toxic algae in the Eel River (Bouma-Gregson and Higgins, 2015), recent emphasis by the State Water Resources Control Board and the Environmental Protection Agency on water quality standards has generally improved water quality throughout the ESU since the last NMFS status update was completed in 2011. Development and implementation of total maximum daily load (TMDLs) limits on pathogens, heavy metals, salts, nutrients, turbidity, and temperature have protected clean water for wildlife (NMFS 2016), with presumably positive, if unmeasured, impacts on salmonids.

Agriculture. Likewise, many tributaries are facing increasingly frequent water withdrawals to expand and irrigate vineyards, marijuana, and other crops and to provide frost protection for grape vines, especially in Sonoma and Mendocino counties. Sonoma County's recently adopted Vineyard Erosion and Sediment Control Ordinance (VESCO) in 2012 will seek to control sediment discharge into streams and minimize potential erosion, but stops short of analyzing expanding vineyard operation impacts on future water diversions (NMFS 2016).

Ironically, flows diverted from the Eel River, via the Potter Valley Project, and stored in Mendocino Reservoir (Coyote Valley Dam) increase summer flows in the Russian River and may be responsible for improving consistent spawning flows for salmon in the river. Pacific Gas and Electric's Potter Valley Project implemented spring block water releases in 2012, 2014, and 2015 to encourage emigration of juvenile Chinook and benefit rearing steelhead with improved habitat accessibility (NMFS 2016). In addition, the Russian River watershed recently became NMFS's first national Habitat Focus Area to help improve water management by decreasing withdrawals for irrigation and by creating conditions that support juvenile salmonid use of the estuary (https://www.habitatblueprint.noaa.gov/habitat-focus-areas/russian-river-california/).

Logging. CC Chinook require intact and interacting riparian, freshwater and estuarine ecosystems to support critical growth during the freshwater and estuarine portions of their life cycle. Historical and current land use practices related to logging and its associated road construction continue to increase the vulnerability of CC Chinook to extirpation within all watersheds in this ESU, but especially in the smaller watersheds. In general, populations in such watersheds are imperiled due to reduction of spawning, incubation, and rearing habitats, mainly resulting from sedimentation. The biggest blows to their habitats occurred in 1955 and 1964, when record rainfall acting on hillsides denuded by years of logging, grazing, and road building caused large-scale erosion as huge, 1,000-year floods ripped through the basins (Yoshiyama and Moyle 2010). "The result was massive landslides, which filled streambeds and pools with loose

gravels throughout the drainages. Enormous flows greatly widened stream channels and eliminated most riparian vegetation. Habitat for anadromous salmonids was greatly reduced when sections of stream subsequently became too warm and shallow for juveniles during the summer (Moyle 2002, p. 57)." See discussion of logging effects in the SONCC coho salmon account for a more complete historical perspective of the destructive 1964 flood that largely filled in the South Fork Trinity River (A. Hill, CDFW, pers. comm. 2017).

Continued erosion from abandoned logging area and increases in rural residential roads have created chronic sediment loads far above natural levels. This causes coarse substrate to become imbedded in fine sediment, which makes redd construction by spawning Chinook difficult and creates conditions unfavorable for embryo survival (Opperman et al. 2005). Large amounts of sediment reduce oxygen and metabolite exchange within redds and may entomb embryos. Sedimentation and loss of riparian tree cover (from floods, logging, and other factors) in combination reduce stream habitat complexity, simplifying aquatic food webs and reducing food for juvenile salmonids. Increased sediment has also been shown to reduce juvenile survival by altering feeding success through increased turbidity, reducing prey visibility, and irritation of gills. These factors can also create widened, shallow channels, in which existing high temperatures can be exacerbated and depths too shallow to support Chinook salmon juveniles. Finally, legacy impacts of logging have led to lack of large woody debris in streams that serves as important cover for all life stages of salmonids and high sediment loads from yarding practices that will take decades to recover (NMFS 2016).

Two major landholders, Humboldt Redwoods Company and Green Diamond Resource Company, are implementing habitat conservation plans to benefit salmonids and other species on their properties. Such activities include decommissioning priority road sites, riparian protection, replacing fish barriers at road crossings, replanting exposed soil, fisheries monitoring, adaptive management, and reporting turbidity and temperature data to improve conditions for salmonids (NMFS 2016). The rapid implementation and expansion of such practices across all holdings of these two major companies has the potential to significantly benefit salmonids and other species.

Estuarine alteration. Estuaries, bays, and lagoons are increasingly being recognized as critical rearing habitats for various salmonids, especially those found in Humboldt Bay (Humboldt Co.) (Wallace et al. 2015), and Redwood Creek (Humboldt Co.). Numerous lagoons form at the mouth of rivers and creeks in this ESU when summer flows become too low to wash out mouth bars. While the timing of large flow events to open sandbars may be more important, this factor is exacerbated by upstream diversions. Lagoons become marginal habitat for juvenile Chinook salmon through the cumulative effects of sedimentation, habitat degradation, and poor water quality. CC Chinook juveniles presumably were once able to over-summer in these habitats. The Mattole River Estuary is the most obvious example of this and conditions in the estuary seem to increase mortality of CC Chinook and steelhead smolts that enter the estuary after its mouth has closed (Mattole Salmon Group 2016). In addition, once productive estuarine marsh habitats have been drained and diked for pasture, greatly reducing habitat available for rearing of juveniles, such as in the Eel River estuary. Redwood Creek, tributaries to Humboldt Bay, and the Eel River all have lost this estuarine complexity, contributing to the decline of salmon populations (Coastal Watershed Planning and Assessment Program 2017).

Mining. Gravel mining still continues today in the Mad, Eel, Van Duzen, and Russian rivers and in Redwood Creek. These operations have been increasingly regulated to minimize impacts in the mainstems of these rivers. The removal of coarse sediment may be beneficial to reduce impacts from increased bedload movement resulting from harmful upstream land

practices, but if improperly undertaken, mining can create barriers to migration, increase spawning in channel areas that lack necessary flows for incubation, and decrease water quality from pollution and sedimentation. Gravel mining also creates seasonal barriers during critical migratory periods and can cause stranding of adult Chinook trying to enter tributaries.

Harvest. While CC Chinook are listed as threatened under the Endangered Species Act, they are the target of significant fishing pressure at sea as they become mixed with Chinook from other ESUs, including hatchery fish from the Klamath-Trinity system. NMFS (2016) admits that the effect of the fishery on CC Chinook populations is not known, but estimates that exploitation rates of CC Chinook are low following implementation of Pacific Fishery Management Council regulations targeted to protect large Klamath adults and undersized (< 56cm) sub-adults meant to reduce incidental harvest of CC Chinook and listed Central Valley winter- and spring-run Chinook. Despite these measures, in the absence of reliable sampling that can determine origins of Chinook caught at sea, ocean harvest rates of CC Chinook in some years may be underestimated (J. Fuller, NMFS, pers. comm. 2017). Some mortality undoubtedly occurs on CC Chinook during catch and release at sea; mortality estimates range from about 12-42% depending on methods and location. However, mortality is difficult to quantify because unmarked fish can belong to either the Klamath or CC Chinook ESUs (NMFS 2016).

In fresh water, a catch and release fishery is allowed for CC Chinook by CDFW in the Eel River. This fishery may cause some level of post-release mortality, especially if adults are targeted during periods of low flow (NMFS 2016). In order to combat this, NMFS and CDFW have worked together to impose low-flow fishing closures on many coastal rivers throughout Humboldt, Mendocino, and Sonoma counties under Title 14, Section 8, if stream flows are inadequate for salmonids to passively move upstream (NMFS 2016). The closure was due in part to protect fish that were exhibiting stressed behavioral responses due to low flow conditions and were forced to hold in sub-optimal reaches for extended periods of time (J. Fuller, NMFS, pers. comm. 2016). Poaching, especially under such low flow conditions, has been documented to be a major concern in the Mad, Eel, Garcia, and Russian river watersheds and angler outreach campaigns have been enacted to raise awareness and increase compliance when water levels are low, especially during summer and fall months during drought (e.g., 2012-2016).

Alien species. Predatory alien fish species are significant problems mainly in the Eel and Russian river drainages. In the Eel River, Sacramento pikeminnow (*Ptychocheilus grandis*) were introduced illegally in 1979 and spread throughout much of the watershed (Brown and Moyle 1997). Their populations have fluctuated over time but it is highly likely that they are suppressing Chinook salmon populations through predation on emigrating juveniles (NMFS 2016); this impact is compounded by other factors discussed above. Sacramento pikeminnow are native to the Russian River, but are not as abundant as they are in the Eel River. Salmonids also face predation from abundant smallmouth bass (*Micropterus dolomieu*) in the Russian River. The effect of these predators is not known, but likely negative (J. Fuller, NMFS, pers. comm. 2017). Striped bass (*Morone saxatilis*) also occur in the lower Russian River at times, and may consume juvenile salmonids (NMFS 2016). However, over the past decade, the abundance of striped bass has declined to the point that recreational anglers that used to target them in the lower river no longer do (J. Fuller, NMFS, pers. comm. 2017).

Hatcheries. Local groups have operated small-scale hatcheries on Freshwater Creek (Humboldt Fish Action Council), Yager Creek (Pacific Lumber Company), Redwood Creek (S. Fork Eel River; Eel River Salmon Restoration Program), Hollow Tree (Salmon Restoration Association), and the Mattole River (Mattole Salmon Group), and the Mad River Hatchery

(CDFW). These efforts have been shuttered since 2007 (NMFS 2016) in part because of concern over their negative impacts on the ESU and low returns. It appears that such hatcheries did not increase returns of adult CC Chinook; they may even have increased risks of extirpation in some watersheds when adult Chinook were being removed for hatchery use but returns of fish of hatchery origin were below replacement (Good et al. 2005; NMFS 2007). Williams and colleagues (2011) found that hatchery-origin Chinook Salmon straying into the Russian River were equally likely to be from the Central Valley fall-run as from other CC Chinook watersheds, indicating the CC Chinook are susceptible to competition from hatchery fish of diverse origins.

It is possible that a conservation hatchery could be used for a short time to bolster CC Chinook populations in small coastal rivers in Mendocino County, which could speed local recovery of the ESU, provided major habitat restoration programs were taking place at the same time. In addition, net pens have been proposed for use off of the Humboldt/ Mendocino coast to acclimate juveniles and increase survival to adulthood (J. Fuller, NMFS, pers. comm. 2017). However, there are major concerns with such an approach, because net pen usage tends to significantly increase straying rates to other watersheds, and may concentrate parasites.

Factor	Rating	Explanation
Major dams	Medium	Dams on the Eel and Russian rivers reduce spawning, rearing, and migration habitat and flows.
Agriculture	Medium	Irrigation diversions in tributary streams reduce flows, especially from illegal diversions for marijuana cultivation.
Grazing	Medium	Chronic stream bank alteration in many areas.
Rural /residential development	Low	Rural and residential development is expanding in the region as large landholders continue to subdivide and sell parcels.
Urbanization	Medium	Mad and Russian rivers provide water for urban use. Urban areas of Sonoma and Mendocino counties have altered water quality in lower Russian River. Not a problem on Eel.
Instream mining	Low	Gravel mining in Russian and Eel rivers may reduce habitat for juvenile salmon.
Mining	Low	Hardrock mining limited.
Transportation	Medium	Roads create sediment and erosion (see logging).
Logging	Medium	Legacy effects and road-building create impacts.
Fire	Low	Causes siltation of streams, some loss of shade to cool water.
Estuary alteration	Medium	Estuaries highly altered with reduced rearing habitat and connectivity among habitats.
Recreation	Low	Boating, rafting, swimming, fishing likely have little impact.
Harvest	Medium	Subject to mixed stock commercial fishery at sea, which includes hatchery fish, though harvest levels closely managed.
Hatcheries	Low	Seven hatcheries once operated in the ESU range but have all been closed since 2007; possibility of a conservation hatchery for Mendocino Coast populations. Net pen proposals offshore may have major consequences for Chinook salmon if approved.
Alien species	Low	Sacramento pikeminnow in Eel are assumed to be a problem for juvenile Chinook; basses (*Micropterus and Morone spp*.) may pose predation threat to juveniles in Russian River.

Table 2. Major anthropogenic factors limiting, or potentially limiting, viability of populations of California Coastal Chinook salmon. Factors were rated on a five-level ordinal scale where a factor rated "critical" could push a species to extinction in 3 generations or 10 years, whichever is less; a factor rated "high" could push the species to extinction in 10 generations or 50 years whichever is less; a factor rated "medium" is unlikely to drive a species to extinction by itself but contributes to increased extinction risk; a factor rated "low" may reduce populations but extinction is unlikely as a result. A factor rated "n/a" has no known negative impact. Certainty of these judgments is moderate. See methods for explanation.

Effects of Climate Change: Climate change in Northern California is predicted to result in warmer temperatures, diminished snowpack, more variable precipitation, increased ocean acidity, sea level rise, altered estuary dynamics, and altered marine and freshwater food webs; these factors together will cause reductions in salmonid distribution, growth, behavior, and survival (Williams et al. 2016).

CC Chinook were rated as "highly vulnerable" (score of 18/30) to climate change by Moyle et al. (2012), suggesting under the right circumstances at least some of the population can adapt to or find refuge from climate change. The biggest challenge facing this ESU may be adjusting to changes in flow timing and variability, which are functions of reservoir management in some streams that seek to provide water deliveries, reliable streamflow, and coldwater pool to support fall migrations of adult salmonids (J. Fuller, NMFS, pers. comm. 2017). In the majority of CC Chinook watersheds, natural flows unimpeded by dams are still the major requirement for embryo and juvenile survival. Without sufficient early fall storms, Chinook often will spawn in the accessible lower portion of a river's mainstem, rather than higher upstream. Thus, the relationship between timing of storms/flows and spawner migration timing is critical, and large storms following small ones can lead to significant loss of spawning productivity. This is believed to have occurred in Mattole River and Redwood Creek in recent years. In these locations, low counts of outmigrating juveniles despite high spawner abundance estimates have followed dry fall seasons, when flows needed to allow adults to reach spawning areas in middle and upper watersheds did not occur. Rapid declines in flows during spring may also strand juveniles in reaches where water becomes too warm for over-summering. Logging, urbanization, agriculture, and other factors also increase the amount and magnitude of run-off from storms, increasing their potential for negative effects on Chinook redds and juveniles.

Under the most likely future climate change scenarios for California, variability in timing and amount of precipitation is likely to increase, leading to more common and prolonged drought for much of the state. The historic "hot drought" in California (2012-2016) saw well below average precipitation every year, coupled with record high temperatures in three of the four years (NMFS 2016). This drought was ranked as the worst in perhaps 1,000 years in the state (Williams et al. 2016), and led to record low snowpack in 2015, anomalously high sea surface temperatures, and an over-reliance on groundwater pumping and illegal stream diversions to make up the deficit, robbing watersheds with important flows for salmonids during the warm summer and fall months. Future drought is an especially critical concern for CC Chinook salmon because the coastal watersheds they rely on are fed primarily by rain and not snowmelt, as the upper and Middle Forks of the Eel are, and the periods of lowest summer baseflows coincide with the time of greatest demand for irrigation water in the region (Williams et al. 2016). Further, both freshwater and saltwater survival are generally found to be lower across almost all salmon and steelhead populations on the West Coast during warmer years, suggesting

populations may have declined during the ongoing drought (Williams et al. 2016). In fact, poor ocean survival has been identified as one of several drivers (along with reservoir operations and poor habitat quality during critically low water years) of decline in salmon abundance in California over the last decade (NMFS 2016). However, reductions in survival for juveniles during this time will only be confirmed in returning numbers of adults in the following 3-4 years (one generation).

Status Score = 2.9 out of 5.0. High Concern. CC Chinook are vulnerable to extinction in next 50 years, especially if climate change strongly affects both stream and ocean conditions. Katz et al. (2012) scored the status as 2.4/5.0 (vulnerable). The CC Chinook Salmon ESU was initially listed as threatened under the federal Endangered Species Act on September 16, 1999, but this was rescinded in 2002, due to the court case *Alsea Valley Alliance v. Evans*. In this action, the U.S. District Court in Eugene, Oregon, set aside the 1999 listing due to its exclusion of hatchery fish. A status review of the CC Chinook ESU and 15 additional ESUs was completed in 2005 (Good et al. 2005), and the CC Chinook ESU was again listed as threatened on June 28, 2005. The 2010 review concluded the status had not changed but that endangered status was likely in the future (NMFS 2012). Over the last five years, poor ocean conditions, drought (2012-2016, and exploding marijuana cultivation practices throughout the ESU range have had significant negative impacts on the CC Chinook ESU (NMFS 2016), and they remain listed as threatened.

Historic runs of Chinook salmon in the Eel River probably ranged between 100,000 and 800,000 fish per year, declining to roughly 1,000 fish per year in the 1990s and 2000s (Yoshiyama and Moyle 2010). Higgins (2015) noted an apparent increase in Chinook numbers spawning in the Eel in 2012-15 to as many as 25,000 fish, but this may not reflect a permanent upward trajectory. Overall, the CC Chinook have likely suffered declines in excess of 90% in the past 100 years. Whether or not the decline is continuing or abating is equivocal because of inadequate surveys in all rivers except Redwood Creek (NMFS 2016).

Metric	Score	Justification
Area occupied	3	ESU occupies 5 major watersheds.
Estimated adult abundance	3	All populations are under 1,000 spawners in most years but some mixing among populations; there have been recent increases in the Eel River population, but reliable data are lacking.
Intervention dependence	3	Long-term declines indicate intervention needed, especially in improved flows and habitat in the Russian and Eel rivers.
Tolerance	3	Fall-run life history allows for moderate tolerance of environmental conditions encountered.
Genetic risk	3	Major watersheds may have distinct populations, all threatened by small size and similar genetic issues. The loss of spring-run life history strategy was a major loss of diversity within the ESU.
Climate change	2	Likely to accelerate declines, especially in reservoir-dominated systems with reduced flows and altered channels.
Anthropogenic effects	3	8 Medium threats.
Average	2.9	20/7.
Certainty (1-4)	3	Fairly well studied.

Table 3. Metrics for determining the status of California Coastal Chinook salmon, where 1 is a major negative factor contributing to status, 5 is a factor with no or positive effects on status, and 2-4 are intermediate values. Certainty of these judgments is high. See methods for explanation.

Management Recommendations: CC Chinook are one of the few non-hatchery dependent ESUs of Chinook salmon remaining on the California coast, so management efforts to increase numbers need to focus on habitat/watershed restoration on a large scale and on marking all hatchery fish in other ESUs so they can be differentiated. The NMFS Coastal Multispecies Recovery Plan for the CC Chinook ESU assesses the biology, threats, and conservation considerations that will be part of such a recovery strategy for the ESU (NMFS 2016b). Included in this recovery plan are an estimated 2,630 km of stream habitat and 65 square km of estuarine habitats, which were designated as critical habitat on September 2, 2005. However, the designation has not improved returns of adult CC Chinook in most rivers. Considerable efforts to preserve and restore spawning and rearing habitat, fish passage, water conservation, monitoring, and outreach to local groups have been undertaken over the past two decades, to the tune of $250 million spanning 3,500 restoration projects through the California Fisheries Restoration Grant Program (FRGP) (http://www.dfg.ca.gov/fish/Administration/Grants/FRGP/FundSummary.asp). Under this program, coordinated projects have tackled fish passage, water conservation, improving instream habitats, watershed monitoring, education and organizational support to watershed groups.

Pressing water quantity and quality issues need to be resolved in most of the ESU's basins to protect and restore habitat for salmonids. A balance of water sharing between the Russian and Eel rivers will influence the abundance of CC Chinook in these basins and is integral to recovery of both populations. While it appears that Chinook are able to exist within the historical and current hydrograph of the Russian River (Chase et al. 2007) and the lower Eel River, recovery of CC Chinook in the upper mainstem Eel River may benefit from restoration of the original hydrograph, which has been altered by operation of Scott and Van Arsdale dams. The Eel River likely supported multiple subpopulations of CC Chinook, but ecological changes in the Eel's mainstem now seem to favor species such as Sacramento pikeminnow.

The recently released NMFS Coastal Multispecies Recovery Plan (NMFS 2016b) lays out general goals to aid in the recovery of the CC Chinook ESU and de-listing from ESA: 1) Reduce the destruction, modification, or curtailment of habitat or range; 2) Ameliorate utilization for commercial, recreational, scientific, or educational purposes; 3) Abate disease and predation; 4) Adequately employ existing regulatory mechanisms for protecting CC Chinook salmon; 5) Ensure the status of CC Chinook salmon is at a low risk of extinction based on abundance, growth rate, spatial structure and diversity. A conservation strategy, drawing from the updated recovery plan (NMFS 2016b) for CC Chinook salmon, should:

- Develop a strategic land acquisition program to protect spawning habitats throughout the ESU. This should focus holistically on watersheds because sedimentation can only be ameliorated through watershed-wide reductions and groundwater pumping far from riparian habitats negatively impacts summer baseflows.
- Mark all hatchery salmon from outside the ESU that enter the mixed stock fishery off the California coast and/or set up a genetic/genomic recognition program to determine the origins of salmon in the fishery, such as Genetic Stock Identification (GSI) monitoring of all Pacific salmon to determine origins of and mortality on Chinook in ocean fisheries for management. As a starting point, the Eel and Russian rivers could stand in as indicator

watersheds for the CC Chinook ESU as a whole and help evaluate exploitation rates based on returns to these systems, in combination with GSI monitoring.

- Develop and implement an extensive monitoring program for the entire Eel watershed to monitor recovery progress and adaptively manage restoration projects.
- Restore estuarine marshes and floodplains and improve lower river riparian corridors to increase juvenile-to-smolt survival. This is particularly important for the Eel River, Redwood Creek, and other rivers with historically extensive tidal and lagoon habitats.
- Establish a managed flow regime, similar to the historical hydrograph in volume and timing, for the Eel River below Scott and Van Arsdale dams and the Russian River below Coyote Valley dam to provide necessary migration of Chinook into upper portions of spawning habitat, and for juveniles to successfully migrate to sea. The entire operation of the water system that diverts Eel River water into the Russian River (Potter Valley Project), including the presence and operation of Van Arsdale and Scott dams, needs to be carefully evaluated to develop conservation strategies that prioritize reliable flows of high quality water at appropriate times to benefit CC Chinook Salmon in both rivers.
- Improve operation of Ruth Dam on the Mad River to benefit all anadromous fishes.
- Increase water allocated from Mendocino and Sonoma reservoirs for fish in the Russian River, in conjunction with reducing flows from the Potter Valley Project.
- Improve agricultural and forestry practices to reduce sedimentation, improve water quality, increase stream habitat complexity, and increase flows. Current logging harvest rates reduce viability of CC Chinook in multiple watersheds. Of particular importance is reducing amounts of water diverted for irrigation (or pumped from wells adjacent to streams) in small tributaries of regulated rivers and throughout the watersheds of undammed rivers (e.g., South Fork Eel).
- Conduct annual monitoring of spawner abundance and juvenile and smolt abundance for all major, remnant populations within the ESU.
- Promote municipal, industrial, agricultural outreach programs that conserve water, reduce pollution, and create awareness about CC Chinook as an indicator of healthy waters.
- Develop a Fishery Management and Evaluation Plan (FMEP) that will continue to allow for legal catch-and-release fishing of CC Chinook in the Eel River (NMFS 2016), and that covers Tribal fishing rights, in order to allow take of ESA-listed fish. As part of such a plan, consider closure of the mouths of CC Chinook rivers during certain portions of the commercial ocean fishery.
- Promote and expand application of the State Water Resources Control Board Policy for Maintaining Instream Flows that includes principles for water right administration and conservation from the Mattole River south to San Francisco Bay (NMFS 2016).
- Supply adequate funding for implementing and expanding use of the California Coastal Monitoring Program beyond the Russian and Eel watersheds to determine changes in population structure and dynamics.
- Address illegal diversions in all watersheds but especially the Eel and Russian rivers.
- Enforce special fishing regulations to protect Chinook, coho, and steelhead, especially in the Eel, Garcia, and Russian Rivers.
- Enforce Assembly Bill 2121 (1259.2 and 1259.4 in the California Water Code) to ensure protective flows remain instream for salmonids (NMFS 2016).

- Explore the feasibility of strategically using a temporary broodstock conservation hatchery along the Mendocino Coast to establish and bolster populations of CC Chinook in the short-term.

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