UPPER KLAMATH-TRINITY RIVERS SPRING-RUN CHINOOK SALMON
Oncorhynchus tshawytscha (Walbaum)

Critical Concern. Status Score = 1.6 out of 5.0. Small, self-sustaining populations occur in the Salmon and South Fork Trinity rivers, where they are highly vulnerable to climate change, introgression with hatchery fish, and other stressors.

Description: Upper Klamath-Trinity river (UKTR) spring-run Chinook salmon are nearly identical in appearance to fall-run Chinook salmon in the same basin. However, because these two run types differ in maturation, migration, and spawning, they have been reproductively isolated over time (Kinziger et al. 2008). As such, they are treated here in two separate accounts. Klamath River Chinook possess significant differences from Sacramento River Chinook in the number of gill rakers and pyloric caeca, with 12-13 rough, widely spaced gill rakers on the lower half of the first gill arch and 93-193 pyloric caeca (Snyder 1931, McGregor 1923). Dorsal fin ray, anal fin ray and branchiostegal counts are significantly different from Columbia River Chinook (Snyder 1931, Schreck et al. 1956). They have 10-14 major dorsal fin rays, 13-16 anal fin rays, 14-19 pectoral fins rays and 10-11 pelvic fin rays. Branchiostegal rays number 13-18 and there are 131-147 scales along the lateral line. For the 2015 run, mean fork length of all captured spring-run Chinook salmon at Junction City weir and Trinity River Hatchery was 66 cm (Kier and Hileman 2016).

Klamath River Chinook spawning adults are considered to be smaller, more rounded, and heavier in proportion to their length compared to Sacramento River Chinook (Snyder 1931). UKTR spring-run Chinook salmon enter natal streams during spring and early summer months as silvery, sexually immature adults that lack the breeding colors or elongated kype seen in fall-run Chinook salmon (Snyder 1931). They were historically likely the most abundant salmon run in the Klamath watershed and most important to native peoples, who esteemed them for their superior fat content and flavor (J. Saxon, Karuk Tribal Council, pers. comm. 2016).

Taxonomic Relationships: The UKTR Chinook salmon ESU includes all naturally spawned populations of Chinook salmon in the Klamath River basin, upstream from the confluence with the Trinity River (Waples et al. 2004). Within the UKTR Chinook ESU, genetic analyses have demonstrated that stock structure mirrors geographic distribution (Banks et al. 2000). Fall- and spring-run Chinook salmon from the same subbasin appear more closely related to one another than each is to fall or spring-run Chinook from adjacent basins (Pearse et al. 2015, Prince et al. 2016). Furthermore, fall- run Chinook salmon populations from the Klamath and Trinity subbasins appear more similar to the respective spring-run Chinook populations within a given subbasin than they are to fall-run Chinook in Lower Klamath River tributaries. Spring-run (stream-maturing ecotype) and fall-run (ocean-maturing ecotype) Chinook salmon have evolved repeatedly and independently in different geographic locations in a timeframe of perhaps less than about 1,000 years (Waples et al. 2004, Pearse et al. 2014). This pattern is distinct from Chinook in the Sacramento and Columbia rivers, where spring-run Chinook from different basins are more similar to one another than they are to fall-run Chinook within the same basin. It is hypothesized that the spring-run life history evolved first in California, and then radiated out and evolved more recently in more Northern populations (M. Miller, UC Davis, pers. comm. 2016).

UKTR spring-run Chinook are treated here as a distinct taxon because they represent a unique life history strategy that is supported by genetic variation on the Omy-5 locus of the genome, are an essential adaptive component of the ESU, and require separate management strategies for conservation than their fall-run counterparts in the same watersheds.

Life History: Similar to summer-run steelhead in the Klamath Mountains Province, UKTR spring-run Chinook salmon enter fresh water as immature fish, before their gonads are fully developed, and hold in cold water streams for 2-4 months before spawning. This life history strategy represents a relatively uncommon stream-maturing ecotype (Prince et al. 2015). Fish enter the Klamath estuary beginning in March and tapering off in July, with a peak between May and early June (Moffett and Smith 1950, Myers et al. 1998). A majority of late-entry fish are apparently of hatchery origin from the Trinity River Hatchery (TRH) (Barnhardt 1994, NRC 2004). Leidy and Leidy (1984) noted that adult Trinity River spring-run Chinook migration continued until October. However, given this late-entry timing, it is unclear if these fish are sexually mature and capable of spawning with spring-run Chinook adults already in the system. Because this late spring-run type is limited to the Trinity River, it is possible these fish represent hybrid spring and fall-run Chinook from hatchery stocks. Chinook salmon entering the Trinity River before October are considered to be spring-run Chinook, because the hatchery does not start processing adult fall-run Chinook until the day after Labor Day in most years (J. Hileman, CDFW, pers. comm. 2017). For harvest management of Chinook in the UKTR, September 1 is the date when regulations change to favor fall run fisheries (CDFW 2017). Moffett and Smith (1950) noted that spring-run Chinook migrated quickly through the watershed; more recent work (Strange 2005) has confirmed this rapid migration pattern. While migration occurs throughout the day and night, it peaks during the two hours following sunset (Moffett and Smith 1950).

Coded wire tags inserted into juvenile Chinook heads before release from Trinity River Hatchery reveal the age and run-timing composition of fall- and spring-run adults returning to the Trinity River each year for management purposes. Generally, the delineation in run-timing between fall- and spring-run fish falls between the last week of August and the first week of September, depending on flow conditions in a given year (J. Hileman, CDFW, pers. comm. 2017). This somewhat contradicts the management date of September 1 each year; returning adults are managed not necessarily on their run timing but out of convenience. Fish are counted and a portion are tagged as they pass the Junction City (Rkm 132.7) and Willow Creek weirs (Rkm 22.7) to give staff at the Trinity River Hatchery a benchmark to extrapolate run sizes and other important biological information (J. Hileman, CDFW, pers. comm. 2017).

The timing of spawning differs among watersheds throughout the UKTR basin. Spring-run Chinook generally enter the mouth of the Klamath River from late March to July in most years, and begin their migrations inland (W. Sinnen, CDFW, pers. comm. 2016). They reach the Trinity River in May-August and begin spawning in early September. In the mainstem Trinity River, spawning typically peaks 4-6 weeks earlier than that of fall-run UKTR Chinook in the same basin (Moffett and Smith 1950. However, in the upper reaches of the South Fork Trinity River, spawning peaks in mid-October, while in the Salmon River spawning begins in late September (LaFaunce 1967).

Overlap between fall- and spring-run Chinook spawning areas was historically minimal due to differences in temporal and spatial preferences and access to a wide variety of potential spawning habitat. In the South Fork Trinity River, the majority of spring-run Chinook salmon spawning occurred upstream of Hitchcock Creek, above Hyampom Valley, while fall-run

Chinook spawned below this point (LaFaunce 1967, Dean 1996). However, Moffett and Smith (1950) noted that spawning of fall and spring-runs overlapped in October on suitable spawning riffles between the East Fork Trinity River (now behind Lewiston Dam) and the North Fork Trinity River, which enters the mainstem about 64 Rkm downstream of Lewiston Dam. Dam creation and habitat degradation have decreased the amount of potential spawning habitat in the watershed over the last several decades.

Upper Klamath-Trinity rivers spring-run Chinook fry emerge from gravel from early winter (Leidy and Leidy 1984) until late-May (Olson 1996). With 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 Lewiston and Trinity dams were completed in 1963 and became the upper limit of spawning in the Trinity River, emergence upstream of Lewiston began in early January; Moffett and Smith (1950) speculated that these early fish were offspring of UKTR spring-run Chinook. More recent reports (Leidy and Leidy 1984) suggest emergence begins as early as November in the Trinity River and December in the Klamath River and lasts until February.

Unlike most spring-run Chinook north of the Klamath River (e.g., Columbia River), UKTR spring-run Chinook do not consistently display "stream type" juvenile life histories, where juveniles spend at least one year in streams before migrating to the ocean (Olson 1996). Juvenile emigration occurs primarily from February through mid-June (Leidy and Leidy 1984). Natural-spawned juvenile Chinook salmon were not observed emigrating past Big Bar (Rkm 91) earlier than the beginning of June, with a peak in mid-July from 1997-2000 (USFWS 2001). In the Salmon River, two peaks of juvenile emigration have been observed: spring/early summer and fall. Snyder (1931) examined scales from 35 adult spring-run Chinook and 83% displayed juvenile "ocean type" growth patterns, in which juveniles entered the ocean just a few months after emerging from the gravel. Other scale studies have found that over two-thirds of sampled spring-run Chinook salmon from the South Fork Trinity River expressed an ocean-type juvenile life history (Dean 1994). In the Salmon River, an otolith study (Sartori 2005) identified 31% of fall-emigrating juvenile Chinook salmon as having similar growth patterns to Salmon River spring-run Chinook, suggesting these were also 'ocean-type' juveniles.

Habitat Requirements: UKTR spring-run Chinook enter the Klamath estuary when river water temperatures are at optimal holding temperatures, typically around March or April (10-16°C; McCullough 1999). Spring-run Chinook use thermal refuges in the estuarine salt wedge and associated nearshore ocean habitats prior to entering fresh water (Strange 2003). Temperatures in the Lower Klamath River typically rise above 20°C in June and can reach 25°C during August, leading to a small migratory window for most fish. Strange (2005) found adult migration changed with different temperature trajectories; however volume of flow was the most important driver of timing of spring-run Chinook salmon migration (Strange et al. 2010). Under favorable flow and temperature conditions, spring Chinook in the UKTR may migrate up to 3.7 km/day (J. Hileman, CDFW, pers. comm. 2017).

When daily water temperatures are increasing, Chinook will migrate upstream until temperatures reached 22°C, but when temperatures are decreasing, fish will continue to migrate upstream at water temperatures of up to 23.5°C (Strange 2005). A cool water refuge at the confluence of Blue Creek (Rkm 64), the largest tributary on the lower Klamath, was used by 38% of spring- run Chinook for more than 24 hours in 2005 (Strange 2005). Optimal adult holding habitat is characterized by pools or runs >1 m deep with cool summer temperatures

(<20°C), all-day riparian shade, little human disturbance, and underwater cover such as bedrock ledges, boulders or large woody debris (West 1991). These habitats are similar to those preferred by holding summer steelhead in the basin (Nakamoto 1994); the two species are often found together in similar habitats (L. Cyr, USFS, pers. comm. 2016). Because the Salmon River and its forks regularly warm to summer daytime peaks of 21-22°C, the best holding habitats are deep pools that have cold water sources, such as those at the mouths of tributaries, areas with hyporheic flow from springs, or those deep enough to thermally stratify.

Spawning habitat is mainly comprised of low-gradient, gravelly riffles or pool tail-outs, and is typically found at higher elevations than areas utilized by fall-run Chinook. Spawning and redd construction appear to be triggered by a change in water temperature rather than an increase in flows. Therefore, redd superimposition may occur when flows are low, limiting suitable habitat to areas near holding pools. Redd superimposition and even hybridization among spring- and fall-run Chinook has been noted in the mainstem Trinity River (Kinziger et al. 2008), South Fork Trinity River (Dean 1995), and Salmon River, though spatial segregation is still obvious upstream of Matthews Creek (Olson et al. 1992). More recent studies hypothesize an important role of dams and habitat degradation constraining suitable spawning habitat for Chinook, but could not quantify the role of Lewiston Dam or the Trinity River Hatchery on observed rates of redd superimposition or hybridization (Kinziger et al. 2008). Juvenile habitat requirements for spring-run UKTR Chinook salmon are presumably similar to those of fall-run UKTR Chinook salmon.

Distribution: UKTR spring-run Chinook were once found throughout the Klamath and Trinity basins in suitable reaches of larger tributaries (e.g., Salmon River) or smaller tributaries with suitable flows for holding and spawning (Wooley Creek). Historically, they were the most abundant Chinook in the basin, and were found in major tributary basins such as the Salmon, Scott, Shasta, South Fork and North Fork Trinity rivers (Moffett and Smith 1950, Campbell and Moyle 1991). Their distribution is now restricted by dams on the Shasta (Dwinnell), Trinity (Lewiston), and Klamath (Iron Gate, Copco 1 and 2, and J.C. Boyle) rivers. Passage of spring-run Chinook through Upper Klamath Lake to access holding and spawning grounds in the Sprague, Williamson and Wood rivers, was blocked in 1918 by completion of Copco 1 Dam (Hamilton et al. 2005). Currently, only the Salmon and the South Fork Trinity rivers maintain self-sustaining populations with little hatchery influence (SRF 2016). Approximately 177 km of habitat is accessible to spring-run Chinook in the Salmon River (West 1991), but most of it is underutilized or unsuitable. The South Fork Salmon River supports the majority of the remaining spawning population, although redds have been found in some smaller tributaries of the Salmon River basin including Nordheimer, Knownothing, Methodist, and Wooley creeks. In addition, there are small populations of spring-run Chinook in Elk, Indian, Clear and creeks.

In the Trinity River basin, spring-run Chinook salmon historically spawned in the East Fork, Stuart Fork, Coffee Creek, Hayfork Creek and the snowmelt-fed mainstem upper Trinity River (Gibbs 1956, Campbell and Moyle 1991). The completion of Trinity Dam in 1962 and Lewiston Dam in 1963 blocked access to 56 km of what was considered to be prime spawning and nursery habitat (Moffett and Smith 1950). Currently, Trinity River spring-run Chinook are present in small numbers in the New River (mainstem Trinity River), Hayfork and Canyon creeks (South Fork Trinity River), and the North Fork Trinity River, but only the South Fork population appears to maintain itself through naturally spawned fish (W. Sinnen, CDFW, pers. comm. 2013). LaFaunce (1967) found spring-run Chinook spawning in the South Fork Trinity

River from about 3 km upstream of Hyampom and in Hayfork Creek up to 11 km above its mouth. However, decreases in water quality and increases in water temperature have been cited as leading to extirpation of spring-run Chinook in Hayfork Creek (A. Hill, CDFW, pers. comm. 2017).

Trends in Abundance: The UKTR spring-run Chinook population once likely totaled greater than 100,000 fish (Snyder 1931, Moyle 2002). The spring run was thought to be the main run of Chinook salmon in the Klamath River, but the stocks had been depleted by the early 20th century as the result of irrigation, overfishing, mining, and other causes (Snyder 1931). Historical run sizes were estimated by CDFW to be at least 5,000 fish annually in each of the following Klamath tributaries: Sprague and Williamson rivers (Oregon), Shasta River and Scott River (CDFG 1990). The runs in the Sprague, Wood, and Williamson rivers were extirpated after the construction of Copco 1 Dam in 1918. Healy (1963) estimated 7,000-10,000 spring-run Chinook spawned in the South Fork Trinity River, while LaFaunce (1964) estimated about 11,600 spring-run Chinook adults returned to spawn in 1964. Very low numbers (approximately 500 adults) returned to Iron Gate Hatchery (IGH) on the mainstem Klamath during the 1970s, but could not persist without cold water during summer; the last spring-run Chinook returned to IGH in 1978 (Hiser 1979). The run in the Shasta River, probably the largest in the middle Klamath drainage, disappeared in the early 1930s as the result of habitat degradation and blockage of upstream spawning areas by the construction of Dwinnell Dam in 1926. The smaller Scott River run was extirpated in the early 1970s, possibly earlier, from a variety of anthropogenic causes that depleted flows and altered habitats (Moyle 2002). In the middle reaches of the Klamath, spring-run Chinook have been extirpated from their historical habitats except the Salmon River and one of its tributaries, Wooley Creek (NRC 2004). Less than 10 spring-run Chinook have been annually observed in Elk, Indian, and Clear creeks (Campbell and Moyle 1991).

In the UKTR, spring-run Chinook abundance is highly variable over time. Large swings in abundance can be partially attributed to changes in habitat and survival of young: West (1991) noted that spring-run Chinook egg survival to emergence in the Salmon River ranged from 2-30% in 1990. The number of spring-run Chinook salmon adults appears to be decreasing in the Klamath River while increasing on the Salmon River, but continue to be a fraction of historical runs (Hamilton et al. 2011). Quiñones et al. (2014) found a correlation between spring-run Chinook returning to the Salmon River and TRH returns in the same year, but these trends may reflect similar responses of both wild and hatchery-reared fish to changing environmental conditions rather than hatchery supplementation. The US Forest Service has been collecting and compiling summer snorkel survey data on returning fish in the basin for many years, and have found small numbers of spring-run Chinook jacks (yearling male fish) that have either matured in fresh water or returned to spawning tributaries after spending only a few months in the ocean (NMFS 2016, Figure 1).

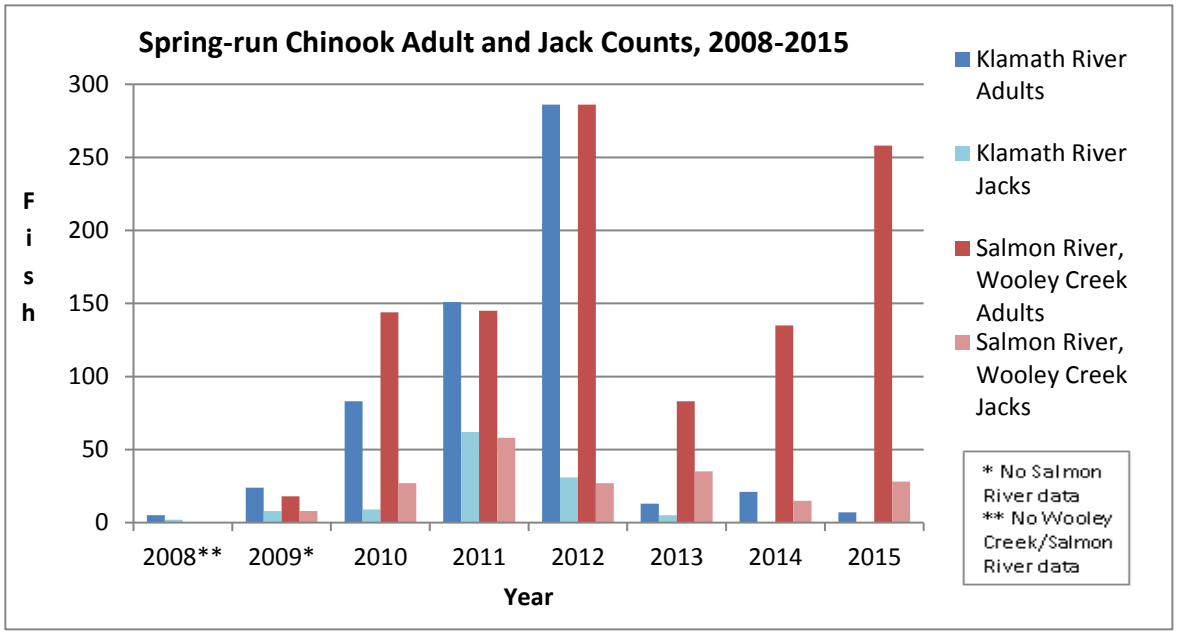

Figure 1. Snorkel survey counts of spring-run Chinook salmon adults and jacks in lower Klamath River tributaries, Salmon River, and Wooley Creek, 2008-2015. From L. Cyr, USFS, 2016.

Spring Chinook have been extirpated above Lewiston Dam on the Trinity River, but historically included more than 5,000 adults in the upper Trinity River and 1,000-5,000 fish in each of the Stuart Fork Trinity River, East Fork Trinity River, and Coffee Creek (CDFG 1990). For the 2015-2016, sampling year, 4,400 spring Chinook were estimated to migrate upstream of the Junction City weir, with only about a quarter (1,090 adults) estimated to be of natural origin (18% of the Trinity River Restoration Program target of 6,000 adults, Kier and Hileman 2016.) Over the last 30 years, an average of 263 fish were counted annually in the South Fork Trinity River (Hill et al. 2015).

While spring-run Chinook salmon are scattered throughout the lower Klamath and Trinity basins, the only viable wild populations appears to be limited to the Salmon, New, and South Fork Trinity rivers. The South Fork and New River remain the largest producers of spring Chinook abundances in the Trinity River tributaries (Hill et al. 2015). Mainstem Trinity River and nearby tributary numbers are presumably influenced by fish from the TRH, though this influence is likely small and decreases with distance from the hatchery (A. Hill, CDFW, pers. comm. 2017). Even if Trinity River tributary spawners are considered to be all wild fish, the total number of spring-run Chinook in the Trinity River rarely exceeds 1,000 fish, and may drop to < 300 in many years (Figure 2).

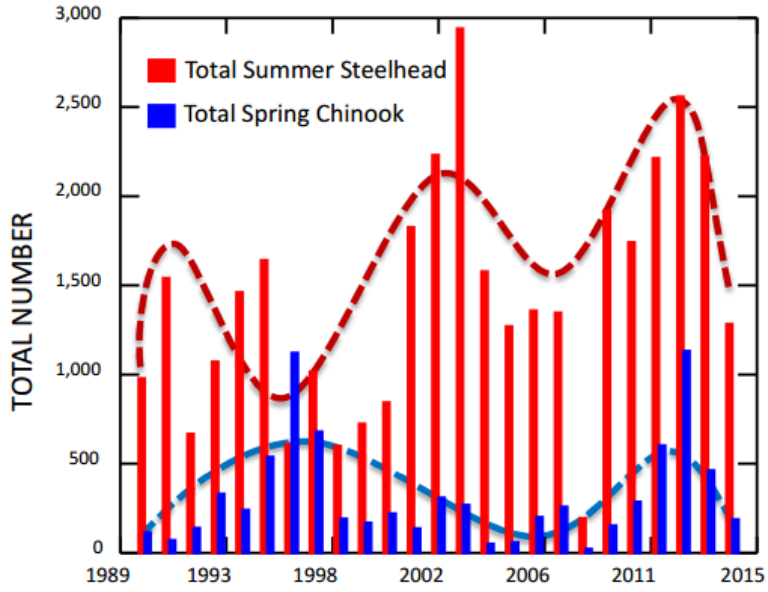

Figure 2. Spring-run Chinook salmon counted in summer snorkel surveys in Trinity River tributaries, 1990-2014. From Hill et al. 2015, Fig. 3, pg. 6.

In recent years, efforts have been made to compile all spring-run Chinook survey data by CDFW, from the U.S. Forest Service, CDFW, and others (Figure 3). The data include escapement and tribal/angler harvest of wild and hatchery fish in both the Klamath and Trinity basins. Since 1980, returns have fluctuated widely, but in most years, estimates are less than 3,000 individuals for the entire Klamath Basin. However, these numbers represent varying degrees of sampling effort among years, so are very imprecise and are best used to highlight trends rather than being actual numbers.

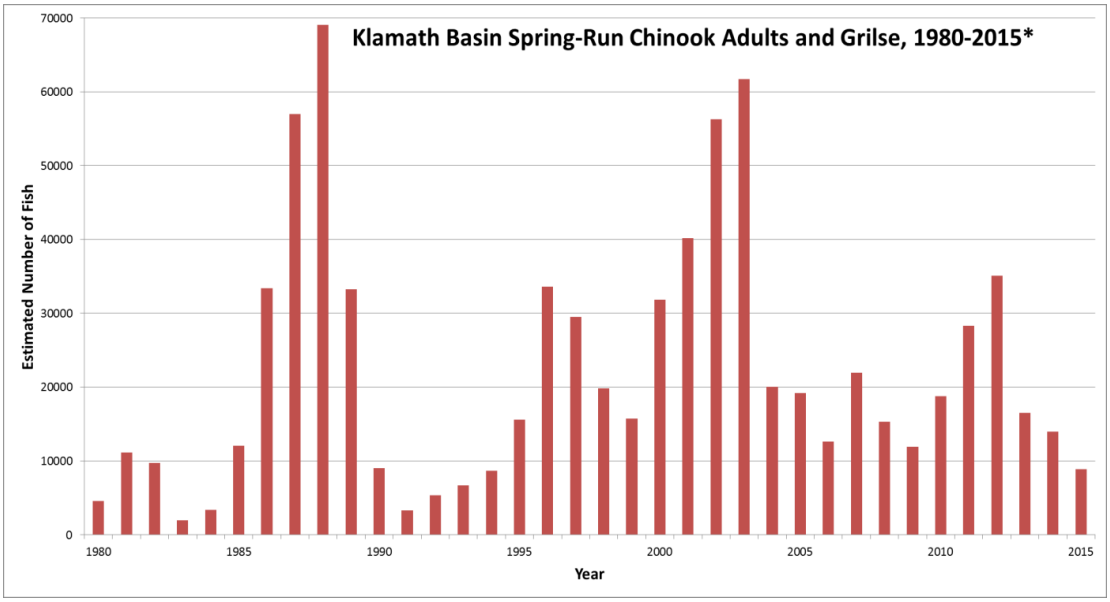

Figure 3. Estimates of Klamath Basin spring-run Chinook salmon adults and grilse, 1980-2015. Data from multiple sources and includes hatchery returns; all streams not surveyed every year. Data from CDFW 2016.

Factors Affecting Status: UKTR spring-run Chinook have been largely extirpated from their historical range because their distinctive life history makes them vulnerable to the combined impacts of climate change, dams, hatchery operations, and habitat degradation as well as other anthropogenic (Table 1) and natural factors (e.g., ocean conditions). UKTR spring-run Chinook have declined from being the most abundant run in the Klamath-Trinity system to one that is in danger of extinction in the near future. They may be the hardest species of all to recover because they migrate to spawning rivers in spring and are increasingly at risk to warm temperatures and low flows (Cannon 2016). In addition, climate change and ongoing (and more frequent) drought represent significant threats to the persistence of spring-run Chinook salmon in the Upper Klamath-Trinity rivers basin.

Dams. A significant portion of the historical UKTR spring-run Chinook range has been lost upstream of Iron Gate, Lewiston, and Dwinnell dams. These dams block access to about 970 km of upstream anadromous habitats of varying quality (Hamilton et al. 2005). They serve as barriers to adult holding and spawning habitats, as well as juvenile nursery areas, and have reduced resiliency of remaining small populations, reduced available habitat, and eliminated spatial segregation between spring and fall-run Chinook. This has likely led to significant interbreeding between fall- and spring-run Chinook in the Trinity River, to the detriment of each (Myers et al. 1998, Kinziger et al. 2008). Dams and diversions have also led to extirpation of spring-run Chinook in the Klamath and Shasta rivers due to alteration of water quality and temperature, channel simplification, and disconnection of mainstem river channels from floodplains (Lewis et al. 2004. Peak flow timing has also shifted a month earlier than prior to dam construction (Hamilton et al. 2011), further reducing viability of this life history strategy. In the Shasta River, spring-run Chinook historically entered during late May through early July; however, diversions of cold (11°C) water from Big Springs for irrigation created a thermal regime that could no longer support year-round juvenile rearing (Stenhouse et al. 2012). This situation has been partially rectified through purchase of Big Springs by The Nature Conservancy and CDFW in 2008 (Jeffres et al. 2009).

There is potential for UKTR spring-run Chinook salmon to be restored to large portions of their former range in the Klamath-Trinity basins through dam removal, especially on the mainstem Klamath. The four lowermost Klamath Dams (Copco 1 and 2, J.C. Boyle, and Iron Gate) are slated for removal beginning in 2020, which will restore access to significant potential holding a rearing habitat of unknown quality. Under the Klamath Basin Hydroelectric Agreement and Klamath Settlements, hundreds of kilometers of potential Chinook, coho, and steelhead habitat will be available in the future. The quality of the habitat upstream of these barriers is unknown, and significant, long-term restoration and monitoring will be required to allow anadromous salmonids to utilize the habitat in the future.

Agriculture. Most spring-run Chinook holding and rearing habitats are upstream of areas heavily influenced by agriculture (e.g., Scott and Shasta valleys); nonetheless, pasture and crops along the Shasta and Scott rivers utilize cold water that would otherwise be available for instream flow. Agricultural return waters are generally warm and often deliver pesticides, fertilizers and other pollutant to streams. These degrade the quantity and quality of habitat for spring-run Chinook, resulting in fewer successful spawning adults and hatching young in the watershed. With the legalization of marijuana cultivation in California under Proposition 64, more effort must be placed on understanding, quantifying, and reducing the extent and magnitude of impacts of this pervasive industry in the UKTR on spring-run Chinook. For a full

discussion of impacts of agriculture and marijuana cultivation on fishes in the watershed, see the Klamath Mountains Province winter steelhead account.

Logging. Logging and associated road building have dramatically altered aquatic habitats in the Klamath and Trinity River basins (NRC 2004). Intensive and widespread logging began in the mid-19th century and legacy effects continue to affect rivers and streams in this region. Historical logging and the development of most early access roads occurred with little regard for environmental impacts. The steep and unstable slopes of this region, combined with local geology, make them particularly prone to erosion following road development and timber harvest (NRC 2004). The low numbers of spring-run Chinook salmon currently using the heavily-logged South Fork Trinity River may be due to the catastrophic 1964 flood, which altered channel morphology and hydrology and triggered landslides that filled in holding pools and covered spawning beds. Primary and ongoing impacts from timber operations in the Klamath-Trinity province include: increased erosion rates (delivering large amounts of sediments into streams, which often imbed spawning areas and fill essential holding pools for spring Chinook needed by holding adults in the summer), increased surface run-off of precipitation (and corresponding and decreased aquifer recharge capacity, which decreases cool hyporheic flow during summer months and increases flash flooding, leading to increased frequency of flash flooding in streams), and increased summer stream temperatures due to lack of aquifer recharge and reduced canopy and riparian vegetation (instream shading, KNF 2002). Logging also removes trees that historically provided large wood that increased habitat complexity for all life history stages of all salmonids: its absence reduces the utility of remaining habitats.

Hatcheries. The Trinity River Hatchery below Lewiston Dam is the only hatchery in the Klamath basin that still raises spring-run Chinook salmon. The impacts of hatchery propagation on wild spring-run fish in the Trinity basin may be substantial. Most naturally spawning fish are considered to be of wild origin, though there is a component of hatchery fish that spawn in natural areas, particularly close to the Lewiston Dam (W. Sinnen, CDFW, pers. comm. 2017). Mixed runs of wild and hatchery-reared fish tend to segregate themselves above Junction City (Rkm 127), with a significant portion of hatchery fishes returning to TRH. However, artificial selection in a hatchery has been demonstrated to reduce fitness in fish reproducing in the wild (Araki et al. 2007, 2009). Hatchery spring-run Chinook hybridize with fall-run fish on the Trinity due to reductions in habitat and shifts in run timing (Kinziger et al. 2008). Attempts to ameliorate these impacts to the extent possible are reflected in a TRH hatchery genetics management plan (J. Hileman, CDFW, pers. comm. 2017).

Rural/ residential development. The long history of mining and logging in the Klamath and Trinity basins has left an extensive network of roads, which continue to provide access to many remote areas, facilitating rural development. Rural development, particularly in the steep, mountainous terrain that characterizes this region, may have substantial impacts on streams through increased surface run-off, sedimentation, effluent from septic tanks and other pollutants, water diversion, deforestation and habitat fragmentation. Over time, these increasing human pressures on watersheds exacerbate other problems.

Fire. Altered forests in the region have also become more prone to large-scale catastrophic fires and increased erosion. For example, over 50% of the Salmon River watershed has been severely burned in the past 100 years (NRC 2004). Portions of UKTR watersheds are subject to intense fires (e.g., Forks, Salmon, and Corral complex fires, 2013), and are likely to increase in frequency under predicted climate change scenarios. Fires can increase water temperatures of important holding and rearing habitat, cause landslides, increase sediment

loading, and remove shading canopy cover, all to the detriment of salmonids. Large rainfall events in these areas can quickly mobilize debris from the steep, fragile slopes and bury spawning and rearing habitats in headwater reaches.

Mining. Mining has dramatically altered river and stream habitats in the Klamath-Trinity Province, with lasting legacy impacts in many areas form historical activity. Intensive hydraulic and dredge mining for gold occurred in the 19th century, causing severe stream degradation and alteration to channel morphology. In fact, mining was a principal cause of decline of spring-run Chinook in the Scott River and large areas in the Trinity River, followed by some recovery after large-scale mining ceased (Cramer et al. 2010). Spring-run Chinook once swam through Scott Valley; now, only a degraded river winds through immense piles of dredge tailings (SRRC 2009). Historical mining impacts still affect the Salmon River spring-run Chinook population as the estimated 16 million cubic yards of sediment disturbed between 1870 and 1950 are slowly transported through the basin (J. West, USFWS, pers. comm. 1995). Legacy effects include disconnected and constricted juvenile salmon habitats, filled-in adult holding habitats, degraded spawning grounds, and altered annual hydrograph of many streams. Pool in-filling is a particular problem because high stream temperatures have been demonstrated to reduce survival of both holding spring adults and rearing juveniles (Elder 2002).

Although suction dredging has been banned since 2009 (CDFW 2016), historical dredging has been particularly damaging to spring-run Chinook habitats. Of particular concern, in the Klamath, Salmon, and Scott rivers and their tributaries is the creation of piles of suction dredge tailings in the past that may be utilized by spawning salmonids. Although these tailing piles are often comprised of suitable substrates for salmon redd creation and successful spawning, they are likely to be mobilized during high flows, greatly reducing survival of embryos within the gravel.

Harvest. Both legal harvest of spring-run Chinook in the ocean and illegal harvest of adults in-river can limit abundance of spawning populations. Because UKTR spring- and fall-run Chinook are indistinguishable when encountered at sea and belong to the same ESU under federal law, they are taken legally in sport and commercial fisheries in the ocean. Recreational and tribal harvest of both wild and hatchery-origin spring-run adults is also allowed in the lower Klamath and upper Trinity rivers under special regulations. Spring-run Chinook are subject to special harvest restrictions from the South Fork Trinity River and mainstem Klamath reaches upstream of Weitchpec, during their migration season (W. Sinnen CDFW, pers. comm. 2017). Based on management and regulatory mechanisms rather than biological reasons, regulations stipulate that Chinook in the Klamath-Trinity rivers before August 31 are considered spring-run and no more than 2 fish per day may be taken per angler, per day; Chinook in the river after September 1 are considered fall-run and are managed by an annual quota set by the Pacific Fishery Management Council. No harvest of spring-run Chinook is allowed in the South Fork Trinity or Salmon rivers (CDFW 2016).

Holding adults are vulnerable to poaching due to their reliance on deep pools with cold water, although the extent to which poaching affects populations is largely undocumented. Recreational angling may strain small populations through inadvertent hooking mortality.

Recreation. Spring-run Chinook may be absent from many suitable areas because of repeated disturbance by humans. Gold dredgers, swimmers, and boaters may stress and displace fish, particularly holding adults (P. Moyle and R. Quiñones, pers. obs. 2000). Displacement from suitable habitats may make spring-run Chinook less able to survive natural periods of stress (e.g., high temperatures) or survive to spawning. Increased and unnatural movements of fish make

them more noticeable, potentially increasing incidence of poaching. Not surprisingly, spring-run Chinook tend to persist mostly in the most remote canyon pools in their watersheds, in some of the same habitats utilized by summer steelhead.

Alien species. Alien species are rare in the UKTR system, although brown trout (*Salmo trutta*) may pose some predation and competition risk to juvenile salmon in the upper and North Fork Trinity River.

While not alien species, native California black bear (*Ursus americanus californiensis*) are known predators on spring Chinook in the Trinity River watershed (J. Hileman, CDFW, pers. comm. 2017). River otters (*Lontra canadensis*) will prey on summer-run steelhead in the Klamath-Trinity basins, suggesting they could also impact spring-run Chinook salmon, especially during periods of low flows while fish are concentrated in pools (M. Sparkman, CDFW, pers. comm. 2016). However, natural predation rates are not well documented.

Factor	Rating	Explanation
Major dams	High	Large portions of historical range are blocked by dams.
Agriculture	Medium	Agriculture reduces habitat quality and quantity through diversions, warm return waters, and pollutants.
Grazing	Medium	Grazing and irrigated pasture pervasive on public and private lands.
Rural /residential development	Low	Cumulative effects of roads and widespread rural development pose ongoing and chronic threats.
Urbanization	Low	Urban areas are few and restricted to main rivers.
Instream mining	Medium	Dredge mining currently banned but legacy effects remain in many areas; gravel mining may cause localized impacts.
Mining	Medium	Legacy effects of intensive and widespread gold mining remain severe in some areas.
Transportation	Medium	Roads present along many streams; impacts from increased run-off, sedimentation and habitat fragmentation.
Logging	High	Both legacy and ongoing impacts have dramatically altered and degraded salmon habitats.
Fire	Low	Climate change may contribute to increased fire frequency and intensity, affecting headwater holding areas.
Estuarine alteration	Low	Klamath River estuary is less altered than most on the North Coast.
Recreation	Medium	May be a chronic source of disturbance for some populations.
Harvest	Medium	Legal and illegal harvest takes many fish; evidence of poaching is annually found in the Salmon River basin.
Hatcheries	High	Spring Chinook stocks are supplemented by TRH production. Potential reduction in fitness through spring-/fall-run interbreeding.
Alien species	Low	Few alien fishes co-occur with the salmon.

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of UKTR spring-run 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. Certainty of these judgments is moderate. See methods for explanation.

Effects of Climate Change: Climate change is likely the greatest threat to the long-term persistence of stream-maturing life history expression in UKTR spring-run Chinook salmon. Moyle et al. (2013) rated the UKTR spring-run Chinook salmon as "critically vulnerable" to extinction because of the added effects of climate change on top of diminished populations. Climate change is already reducing stream volume, increasing stream temperatures, and altering seasonal flow patterns of water, which will likely lead to further reductions in suitable upper watersheds that spring-run Chinook use to oversummer. Increased protection and restoration efforts to improve stream flows, allowing accessibility to prime holding and spawning habitat, and maintenance of cool temperatures in headwater tributaries for both spring Chinook salmon and summer steelhead, are essential for recovery. Recent (2012-2016) drought in California may have contributed to higher pre-spawn mortality of spring-run Chinook in the basin, because lower flows and higher water temperatures are associated with increased pre-spawn mortality rates, which are typically less than 30% across Chinook salmon in California (Bowerman et al. 2016). Since 2012, the Bureau of Reclamation has augmented flow releases downstream of Trinity and Lewiston dams in August and September to reduce die-off of fall-run Chinook in the lower Klamath associated with high water temperatures and disease outbreaks (USBOR 2016). The impact of these releases on spring-run Chinook is unknown at this time.

Climate change is predicted to decrease snowpack (reduce instream flows), increase water temperatures, and alter flow timing. Lower flows are of particular concern in the spring and summer, because remaining water can reach daytime temperatures of 24-26°C in the Klamath, rendering them unusable to spring-run fish. The Salmon River already reaches summer temperatures of 21-23°C, approaching lethal thresholds for salmonids. 1-2°C increases in stream temperatures by 2100, as forecasted in moderate climate model projections, will greatly reduce the amount of suitable habitat available for spring-run Chinook. Reduced reservoir recharge may limit thermal stratification and the amount of cold water pool available for environmental flows via dam releases, which may be particularly acute in the Klamath River. The frequency and intensity of both drought and flash floods are likely to increase as well. Studies similar to Nakamoto's (2004) study of habitat use by summer steelhead in the New River should be undertaken to determine how emerging temperature/hydrologic regimes in the UKTR impact salmonid habitat use, survival, and productivity.

Climate change may also increase the incidence of disease outbreaks due to warmer water temperatures and further stress adult salmon. For example, warmer temperatures favor epizootic outbreaks of *Ichthyophthirius multifiliis* and transmission of the bacteria *Columnaris*, which is associated with higher mortality of pre-spawn salmonids that are exposed to above-optimal water temperatures (Strange 2007, Power et al. 2015).

Status Score = 1.6 out of 5.0. Critical Concern. The principal self-sustaining wild populations of UKTR spring-run Chinook exist in the Salmon and South Fork Trinity rivers. The largest component of the run, the hatchery-influenced upper Trinity River portion, was derived from original stocks, which migrated past Lewiston Dam historically (W. Sinnen, CDFW, pers. comm. 2017). UKTR spring-run Chinook are considered a Sensitive Species by the USDA Forest Service and a Species of Special Concern by CDFW (2015). The spring-run Chinook salmon of

the Central Valley was listed as threatened under the California Endangered Species Act in 1999, but this designation has not yet been made for fish in the Upper Klamath-Trinity rivers basin (CDFW 2016). Genetic risk from low populations and interaction with TRH fish, climate change impacts, and anthropogenic threats plague UKTR spring-run Chinook salmon and make them vulnerable. Without significant human intervention in the form of changing logging practices, updating hatchery operations, and especially removal and restoration of the four lowermost Klamath dam sites, this run of fish is likely to become extirpated within 50 years.

Metric	Score	Justification
Area occupied	2	Only Salmon River and South Fork Trinity River support wild, self-sustaining populations.
Estimated adult abundance	2	A few hundred natural spawners support the population, with attendant impacts of small populations and hatchery influence.
Intervention dependence	2	Hatchery stocks maintain the mainstem Trinity run; Klamath dam removal in Klamath needed to restore access to historical range.
Tolerance	2	Narrow temperature tolerance (<20ºC) during migrations; temperatures and other factors limiting in summer holding areas.
Genetic risk	1	Hybridization with fall-run and/or hatchery spring-run is occurring in Trinity River; fitness reduction may result from hybridization.
Climate change	1	Increased temperatures, density of adults and juveniles and disease outbreaks, and reduction in suitable habitats will limit populations.
Anthropogenic threats	1	3 High, 7 Medium factors.
Average	1.6.	11/7.
Certainty (1-4)	3	Fairly well-studied.

Table 2. Metrics for determining the status of UKTR spring-run 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 moderate. See methods for explanation.

Management Recommendations: UKTR spring-run Chinook are an indicator of ecosystem health due to their narrow tolerance to water temperature and quality and presence in upstream reaches of river during warm summer months when flows are reduced. The rarity of cool water refuges throughout the UKTR during their migration period is already a significant threat to long-term persistence.

Monitoring of spring-run Chinook by several agencies occurs annually throughout the Klamath-Trinity system. However, data need to be compiled and standardized to be most useful for managers. Existing surveys demonstrate that suitable habitat exists for adult holding and spawning in the UKTR, yet spring-run Chinook abundance continues to fluctuate at low numbers. Spring-run Chinook may be particularly susceptible to warming trends, especially in the face of predicted climate change impacts and ongoing drought, which has reduced flows during summer and fall months since 2012. To combat reduced flows and increased temperatures in the mainstem Trinity and Klamath rivers, the U.S. Bureau of Reclamation increased flows up to 1,300 cfs out of Lewiston Reservoir in 2012-2016 (USBOR 2016). The goal of these augmentation flows was to keep density- and flow-dependent disease of fall-run Chinook at bay

in the lower Klamath River. Disease was implicated in the 2002 die-off and may have had unintended consequences on spring-run Chinook in the Trinity River. The effects of these flows are unknown at this time. Restoration activities in the Salmon and South Fork Trinity rivers, two spring-run Chinook strongholds, should be prioritized (SRF 2016). For example, plans to place hundreds of whole trees with intact root wads via helicopter into the South Fork Trinity River in the snowmelt-fed Hayfork Valley should be replicated and expanded to other key spring-run habitats (J. Smith *in* SRF 2016).

Of all salmonids in this drainage, spring-run Chinook would likely benefit the most from increased access to cold-water habitats. Reconnecting historical habitats in the upper watersheds of the Klamath and Trinity rivers, with their tributaries fed by spring sources and snowmelt, are critical after dam removal for long-term persistence of this run. Habitat for spawning and rearing should be restored as quickly as possible to avoid potential negative impacts on salmonids immediately following dam removal (Quiñones et al. 2014). Literature suggests that these activities will increase diversity of life histories and increase resiliency of anadromous fish populations by offering the ability to differentiate spatially and temporally over the habitat (Hodge et al. 2015). However, restoration and volitional re-colonization of historical habitats may not be enough to recover the run. The tradeoffs of employing hatcheries to raise ocean-maturing and stream-maturing Chinook ecotypes should also be carefully weighed and considered, as hatchery selection pressures may negatively impact genetic integrity and variation in colonizing salmon (Quiñones et al. 2014). However, these potential impacts may be outweighed by bolstering wild runs with greater numbers of fish to increase genetic diversity in the short-term and avoid inbreeding depression or founder's effect (Fraser 2008). Other specific recommendations to restore UKTR spring-run Chinook salmon include:

- Restore the Shasta River as a cold-water refuge for all salmonids in the Klamath basin by recapturing spring flows in the river, reducing ground water extraction and exploration of potential for developing fish passage over Dwinnell Dam to spawning habitat.
- Protect and restore Blue Creek watershed to maintain critical coldwater flows in summer and fall months for migrating spring-run Chinook, as the Yurok Tribe and Western Rivers Conservancy have committed to do.
- Manage the Salmon River as a spring-run Chinook and summer steelhead refuge by restricting extractive use of the river in summer by promoting alternative sources of water for agriculture and human consumption and amending regulations to protect holding fish.
- Develop restoration actions and priorities for reducing the impacts of sediment inputs from roads, logging and other activities into rivers of the Klamath-Trinity system, especially on public lands. In addition, determination of effects of diversions, stream alterations, and pesticides/herbicides associated with illegal marijuana cultivation should be undertaken and increased under funding provisions associated with recent passage of Proposition 64.
- Develop a program to investigate impact(s) of the Trinity River Hatchery on spring-run Chinook populations (e.g., number of hatchery-reared fishes spawning in the wild, genetic shifts in population) and manage hatchery production accordingly. Rates of hybridization between spring-run and fall-run Chinook, and relative fitness of the offspring, should be paid particular attention.
- Investigate whether spring Chinook from a conservation hatchery built expressly for this purpose can play a role in facilitating re-colonization of Klamath River tributaries after dam removal occurs (after Kinziger et al. 2008). If such an approach is explored, efforts

must be made to reduce genetic impacts of founder's effects and inbreeding/outbreeding depression.

- Manage downstream reaches below dams to favor conditions for out-migrating smolts.
- Limit recreational in-river harvest to a mark-selected, fishery for 100% adipose fin-clipped TRH-produced spring-run Chinook to keep them separate from wild fish.
- Increase enforcement focus of fishing and land use regulations in over-summering areas, especially related to groundwater pumping, illegal diversions, marijuana cultivation, etc. Proceeds from taxation of legalized marijuana could help fund expansion of staff for targeted enforcement and administrative management of such illicit activities.

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