UPPER KLAMATH-TRINITY RIVERS FALL-RUN CHINOOK SALMON

Oncorhynchus tshawytscha (Walbaum)

Moderate Concern. Status Score = 3.1 out of 5.0. Abundance of natural spawners in most tributaries has declined from historical levels. The proportion of natural-origin spawners returning to the Upper Klamath-Trinity rivers basin has varied widely over the past decade, though a recent decreasing trend in the proportion of hatchery-origin adults returning to the Trinity River to spawn may signify a stabilization of the population.

Description: See the upper Klamath-Trinity rivers (UKTR) spring-run Chinook and Central Valley fall-run Chinook accounts in this report for detailed species descriptions. UKTR fall-run Chinook enter rivers as reproductively mature fish (ocean-maturing ecotype) exhibiting spawning colors (Kinziger et al. 2008, Prince et al. *In press*). 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)

Taxonomic Relationships: Fall- and spring-run Chinook salmon trace their evolutionary origins to geologic events during the Pleistocene, when changes on the landscape (mountain range formation, glaciations, volcanic activity) created spatial segregation among populations (Waples et al. 2008). Within California, spring- and fall-run Chinook life histories likely evolved independently and repeatedly in different basins over time, as evidenced by the fact that fish within basins are more closely related than those with shared life histories in other basins (Prince et al., *In press*). Further, fall- run Chinook salmon populations from Klamath and Trinity subbasins appear more similar genetically to the respective spring-run Chinook populations within a given subbasin than they are to fall-run Chinook in Lower Klamath River tributaries (M. Miller, UC Davis, unpubl. data 2016). Recent research indicates genetic variation on the GREB-1L and Omy-5 loci of the genome, which are associated with fat storage, sexual maturation, and run timing in *O. mykiss and O. tshawytscha*, largely differentiate fall-run and spring-run Chinook (M. Miller unpubl. data 2016, Prince et al. *In press*).

The UKTR Chinook salmon Evolutionarily Significant Unit (ESU) includes all naturally spawned populations of Chinook salmon in the Klamath River basin, upstream from the confluence of the Klamath and Trinity rivers. The UKTR Chinook salmon ESU is genetically distinguishable from other California Chinook ESUs (Waples et al. 2004, Kinziger et al. 2008). Although fall-run and spring-run Chinook salmon are both part of this ESU, the two runs are treated here as separate taxa due to their distinctive ecotypes, adaptive life histories, differing migration and foraging strategies at sea (Tucker et al. 2011), and discrete genetics (Kinziger et al. 2008, Prince et al. *In press*). See the UKTR spring-run Chinook salmon account for further details on taxonomy within this ESU.

Life History: Upper Klamath-Trinity rivers fall-run Chinook salmon show considerable variability in adult and juvenile life history strategies. This variability is characteristic of “ocean-type” Chinook salmon juveniles, which spend less than a year in fresh water before migrating to the ocean (see the Central Valley spring-run Chinook account for a more detailed discussion of ocean-type vs. stream-type life histories). Adult UKTR fall-run Chinook salmon enter the Klamath estuary from early July through September (Moyle 2002). They often hold in the estuary for a few weeks and initiate upstream migration as early as mid-July and as late as

October. Migration and spawning both occur under decreasing temperature regimes. Fall-run UKTR Chinook seem to hold extensively in, and travel slowly through, the lower Klamath River during their migration upstream (Strange 2005).

Between 1925 and the early 1960s, the Klamathon Racks provided a counting facility and egg collection station close to the current location of Iron Gate Dam. Chinook salmon historically passed this location in August between 1939 and 1958, with daily fish counts occurring during mid- and late-September and tapering off by late October (Shaw et al. 1997). More recently, peak migration appears to occur one to four weeks later than historical run timing (Shaw et al. 1997). In 2006, Chinook entered the Shasta River between mid-September and mid-December (Walsh and Hampton 2007) and Bogus Creek, adjacent to Iron Gate Hatchery, between mid-September and late-November (Hampton 2006). They reached spawning grounds in the Shasta and Scott rivers as early as September. Spawning in these tributaries tapers off in December, although snorkel surveys at the mouth of the Scott River found Chinook holding through mid-December (Shaw et al. 1997). Fall-run Chinook salmon migration occurs in the Trinity River between September and December, with early migrating fish entering larger tributaries first; spawning on smaller streams occurs later in the season. Spawning in the Trinity River begins earliest in suitable mainstem habitats immediately downstream of Lewiston Dam and extends into late November further downstream. Spawning in the South Fork Trinity River has been documented to begin in mid-October (LaFaunce 1967). In most other UKTR tributaries, spawning peaks during November before tapering off in December (Leidy and Leidy 1984).

Klamath River Chinook salmon have a lower fecundity and larger egg size than Chinook from the Sacramento River (McGregor 1922, 1923). The average fecundity of Lewiston Hatchery fish is 3,732 eggs for 4-kg fish (Bartholomew and Hendrikson 2006). Fry emerge from gravel in late winter or spring. The timing of fry emergence is dictated by water temperature, so the beginning of emergence may differ by over four weeks between years in the mainstem Trinity River (Shaw et al. 1997). The timing of juvenile emigration is highly variable and dependent on river rearing conditions, which are controlled largely by flows, water temperature and food availability. High winter flows, level of snowpack and subsequent spring runoff can reduce water temperatures (Minshall et al. 1989) and may contribute to annual variability in timing and duration of Chinook emigration. Once emigration begins, movement is fairly continuous, although high temperatures may cause emigrants to seek thermal refuges during the day and delay migration. Mean downstream movement rates for hatchery UKTR Chinook juveniles in the Klamath and Trinity rivers are 1.4 to 11.8 km per day (USFWS 2001).

While there is variability in age composition of fall-Chinook spawners returning to the Klamath basin, most fish are age-3, with a slightly smaller proportion of age-4 fish (CDFW 2016). Some age-5 individuals are also observed annually. Recently, CDFW samplers at Willow Creek Weir and in the Yurok/Hoopa Tribal fisheries have also confirmed a few rare age-6 fish (CDFW 2016). Age-2 fish (grilse) in some years can be a large proportion of the run; they are mostly male spawners that are much smaller than other spawners. From 1978 and 2006, grilse constituted 2-51% of all returning salmon to the Klamath Basin (CDFG 2006). In 1986, Sullivan et al. (1989) observed that a larger proportion of age-4 adults returned to the Salmon River (24%) than to other subbasins. During that year, the age structure of Chinook entering the estuary was composed of: two (23%), three (64%), four (12%), and five (1%) year old returns (Sullivan 1987). In 2004, the age structure of the Trinity River Hatchery (TRH) fall Chinook run was composed of: two (8%), three (78%), four (13%), and five (1%) year old fish (CDFG 2006a). In 2006, the Klamath River fall Chinook run was composed of: two (31%), three (21%), four (47%), and five (1%) year old individuals (KRTAT 2007) and these year class contributions have not changed much since (CDFW 2016).

Sullivan (1989) examined scales from returning fall-run adults to determine fry emigration patterns and identified three distinct juvenile freshwater life history strategies: (1) rapid emigration following emergence, (2) tributary or cool-water area rearing through the summer and fall emigration, and (3) longer freshwater rearing and overwintering before emigration. The first is the predominant strategy, where fry leave spawning areas quickly and forage in tributary and mainstem habitat for a short period before emigrating during summer months. In the spring-fed Shasta River, where water temperatures and flow are largely constant, peak fry outmigration occurs in March or early April, while in the snowmelt-fed Scott and Salmon Rivers, outmigration peaks from mid-April to mid-May. Historically, Chinook juvenile emigration initiated in mid-March in the mainstem Klamath River before peaking in mid-June (Shaw et al. 1997). More recently (1997-2000), wild juveniles were not observed in the lower river earlier than the beginning of June, with a peak in mid-July (USFWS 2001).

The second juvenile rearing strategy involves extended freshwater rearing with emigration to the ocean during fall to mid-winter (Sullivan 1989). Juveniles emigrate to the mainstem during spring and summer to rear or may remain in tributaries until fall rains and ocean entry. Multiple juvenile fish kills in July and August (1997, 2000) highlight the extensive use of the middle and lower Klamath River during summer months by juveniles (USFWS 2001). On the lower Trinity River (0.4 Rkm upstream of Weitchpec), naturally produced Chinook salmon emigration peak around mid-April. The first hatchery-produced Chinook salmon are not observed until six weeks later, and emigration of these fish peaks in mid-October on the lower Trinity River (Naman et al. 2004). The first two juvenile rearing strategies are likely influenced by mainstem flows. Wallace and Collins (1997) found Chinook salmon (probably from multiple ESUs) were more abundant in the Klamath River estuary in low flow years than during high flow years, suggesting that this strategy may involve moving into cooler and more productive estuarine water sooner than under high flow conditions.

Although the vast of majority of UKTR Chinook salmon use one of these strategies, a small portion of juveniles spend an entire year mainly in larger tributaries, entering the ocean the following spring as yearlings (Sullivan 1989). From 1997-2000, these hatchery-reared yearlings emigrated as smolts through the middle Klamath River between early May and June, before the peak of 0+ wild juveniles emigrated in mid-June (USFWS 2001). A fourth life history strategy has also been observed, where parr mature in the spring-fed Shasta River (C. Jeffres, UC Davis, pers. comm. 2011). Mature parr are reproductively mature males that have never left fresh water and are known from the Sacramento and other major spawning rivers (Johnson et al. 2012).

In the ocean, Klamath River Chinook salmon (all runs) are found in the California Current system off the California and Oregon coasts. Salmon seem to follow predictable ocean migration routes to feed (Harding 2015).

Habitat Requirements: Sexually mature UKTR fall-run Chinook salmon enter the Klamath estuary for only a short period prior to spawning. Unfavorable temperatures may exist in the Klamath estuary and lower river during summer, and chronic exposure of migrating adults to temperatures of 17°-20°C is detrimental to their survival and spawning success (McCullough 1999). However, if water temperatures are decreasing, UKTR fall-run Chinook will migrate upstream in water temperatures as high as 23.5°C; water temperatures above 21°C generally seem to inhibit migration when temperatures are rising (Strange 2005). The thermal threshold for migration inhibition seems to be higher for UKTR fall-run Chinook than for Columbia River fall-run Chinook (> 21°C), due to adaptations to higher temperatures (McCollough 1999).

Optimal spawning temperatures for Chinook salmon are reported as less than 13°C (McCollough 1999). Water temperatures in the fall are usually within this range in the Trinity River (Quilhillalt 1999), though Magneson (2006) reported water temperatures up to 14.5°C during spawner surveys in 2005. With respect to water temperature, the spring-fed Shasta River was historically the most reliable spawning tributary in the Klamath River system (Snyder 1923), but agricultural diversions and warm irrigation return water have greatly diminished its capacity to support salmon. In addition, Ricker (1997) found that levels of fine sediment in 6 of 7 potential Shasta River and Park Creek spawning locations were high enough to significantly reduce fry emergence rates and embryo survival.

Most UKTR fall-run Chinook spawning habitat is found in the mainstem Klamath and Trinity Rivers and their larger tributaries. Spawning occurs primarily over large cobbles, loosely embedded in gravel, with sufficient subsurface infiltration of water to provide oxygen for developing embryos. In a survey of Trinity River redds, Evenson (2001) found embryo burial depths averaged 22.5-30 cm, suggesting minimum depths needed for spawning gravels. Regardless of depth, the keys to successful spawning are adequate flow and cold temperatures. For maximum embryo survival, water temperatures must be between 6-12°C, with oxygen levels close to saturation (Myrick and Cech Jr. 2004). Fry emergence in the Scott and Shasta rivers begin at water temperatures near 8°C (Bartholomew and Hendrikson 2006). With optimal conditions, embryos hatch after 40-60 days, and remain in gravel as alevins for another 4-6 weeks until the yolk sac is fully absorbed.

On the mainstem Klamath, McCollough (1999) suggests water temperatures above 15°C stimulate juvenile emigration, although temperatures above 15.6°C can increase risk of disease. For example, warmer temperatures favor *Ichthyophthirius multifiliis*, or “ich” disease, and transmission of the bacteria *Columnaris*, which is associated with higher mortality of pre-spawn salmonids that are exposed to above-optimal water temperatures in Northern California (Strange 2007, Power et al. 2015). Daily average temperatures above 17°C increase predation risks and impair smoltification, while temperatures over 19.6°C decrease growth rates and may impact behavior (Marine and Cech Jr. 2004). Temperatures up to 25°C are common in the middle Klamath River during the spring/summer juvenile emigration period, so cool water inputs at tributary confluences, such as Blue Creek, serve as important refuge habitats (Belchik 1997). Stratified pools, springs, and subsurface flows at the base of old landslides and gravel bars are also important thermal refuges (R. Quinones, USFS, unpubl. obs.). Elevated river temperatures (>16°C) increase mortality from *Ceratomyxa shasta* infection in Chinook salmon released from Iron Gate Hatchery, as well as lead to lethargic behavior, reduced body mass, and co-occurring bacterial infections from *Parvicapsula minibicornis*. Belchik (1997) identified 32 cool water refuge areas in the middle Klamath River mainstem; twenty-eight of these locations were tributary confluences, including the Scott River. These areas, although small in size, have temperatures of 10°-21.5°C and provide refuges from temperatures lethal to emigrating juveniles (Belchik 1997).

In the ocean, Chinook from California are caught in trawls in predictable currents off the Klamath-Trinidad region of California and Southern Oregon in water temperatures between 8° and 12°C (Hinke et al. 2005), which is suitable for their euphasiid and copepod prey (Harding 2015). In surveys, Chinook salmon and are most frequently encountered closer to shore than steelhead, and follow a latitudinal gradient: juveniles are mostly captured in the Gulf of the

Farallones, while adults are more commonly captured off of Northern California and Oregon (Harding 2015). Chinook salmon from the Klamath and Trinity hatcheries have been observed in August south of Cape Blanco, suggesting some regional differences in salmon distribution at sea (Brodeur et al. 2004). Recent research using coded wire tags on hatchery fish, has discovered that spring-run Chinook salmon smolts migrate faster and further north than fall-run Chinook salmon at sea, and older fish often range farther from their natal streams than younger fish (Tucker et al. 2011).

Distribution: UKTR Chinook salmon are found in all major tributaries above the confluence of the Klamath and Trinity rivers and are raised in Iron Gate Hatchery (Klamath) and Trinity River Hatchery. UKTR fall-run Chinook salmon historically spawned in middle Klamath tributaries (Jenny, Shovel, and Fall creeks) and in wetter years possibly into rivers in the upper Klamath Basin (Hamilton et al. 2005). Access to these tributaries was blocked in 1917 by construction of Copco 1 Dam, then Copco 2 Dam, J.C. Boyle Dam, and Iron Gate Dam in 1964. As a result, salmon and other anadromous fishes were denied access to approximately 563 km of spawning, passage, and rearing habitat in the upper Klamath River basin (Huntington 2006). In the lower Klamath River, numerous tributaries provide suitable spawning habitat including: Bogus, Beaver, Grider, Thompson, Indian, Elk, Clear, Dillon, Wooley, Camp, Red Cap, and Bluff creeks. The Salmon, Shasta and Scott Rivers historically supported large numbers of spawning Chinook salmon, and remain the most important spawning areas when sufficient flows are present. In the mainstem Klamath River, spawning consistently occurs between Iron Gate Dam and Indian Creek, with the two areas of greatest spawning density typically occurring near Bogus Creek and Indian Creek (Magneson 2006).

UKTR fall-run Chinook salmon once ascended the Trinity River above the site of Lewiston Dam to spawn as far upstream as Ramshorn Creek. Lewiston Dam was completed in 1963, eliminating 56 km of spawning habitat in the mainstem (Moffett and Smith 1950). The Stuart Fork was an important historical spawning tributary upstream of Lewiston Dam, as were Browns and Rush creeks below the dam (Moffett and Smith 1950). Historically, the majority of UKTR fall-run Chinook spawning in the Trinity River occurred between the North Fork and Ramshorn Creek; spawning now primarily occurs above Cedar Flat and, to a lesser extent, in downstream tributaries and the mainstem Trinity River (W. Sinnen, CDFW, pers. comm. 2011). The distribution of redds in the Trinity River is highly variable. While the reaches closest to the Trinity Hatchery support substantial spawning, there is a high degree of variability in spawning habitat utilization in reaches between the North Fork and Cedar Flat (Quihiullalt 1999). The North Fork, New River, Canyon Creek, and Mill Creek also continue to support spawning in the basin. In the South Fork Trinity River, fall-run Chinook historically spawned in the lower 48 km up to Hyampom, and in the lower 4 km of Hayfork Creek (LaFaunce 1967).

Trends in Abundance: It is likely that the spring-run Chinook run was historically the most abundant in the UKTR Basin (Snyder 1931, LaFaunce 1967). However, by the time records were kept, spring run had been reduced to a minor component of Klamath salmon populations. Recent estimates of Chinook salmon in the Klamath-Trinity system are primarily from fall-run fish. There are several historical estimates of Chinook salmon abundance in the UKTR Basin: Snyder (1931) estimated 141,000 in 1912, Moffett and Smith (1950) estimated 200,000 at that time, and USFWS (1979) estimated approximately 300,000 to 400,000 fish from 1915-1928. At the Klamathon Racks, a fish counting station near Iron Gate Dam, an estimated annual average of

12,086 Chinook spawned in the upper basin from 1925-1949, and declined to an average of 3,000 from 1956-1969 (USFWS 1979). At this time, the Klamath River basin was believed to contribute 66% (168,000) of the total number of Chinook salmon spawning in California's coastal basins (CDFG 1965). This production was nearly equally distributed between the Klamath (88,000 fish) and Trinity (80,000 fish) basins, with approximately 30% of the Klamath basin's fish originating in the Shasta (20,000), Scott (8,000), and Salmon (10,000) rivers.

Hatchery operations have supplemented UKTR Chinook runs since the completion of Iron Gate Hatchery on the Klamath and Trinity Hatchery on the Trinity rivers in the 1960s. In the 1980s, Klamath Basin Chinook accounted for up to 30% of the commercial Chinook salmon landings in northern California and southern Oregon, which averaged about 450,000 salmon per year (PFMC 1988). From 1978 through 2006, the average in-river escapement of UKTR Chinook was 112,317 fish. By 2015, the average number of returning adults basin-wide each year increased to approximately 129,000 (Figure 1).

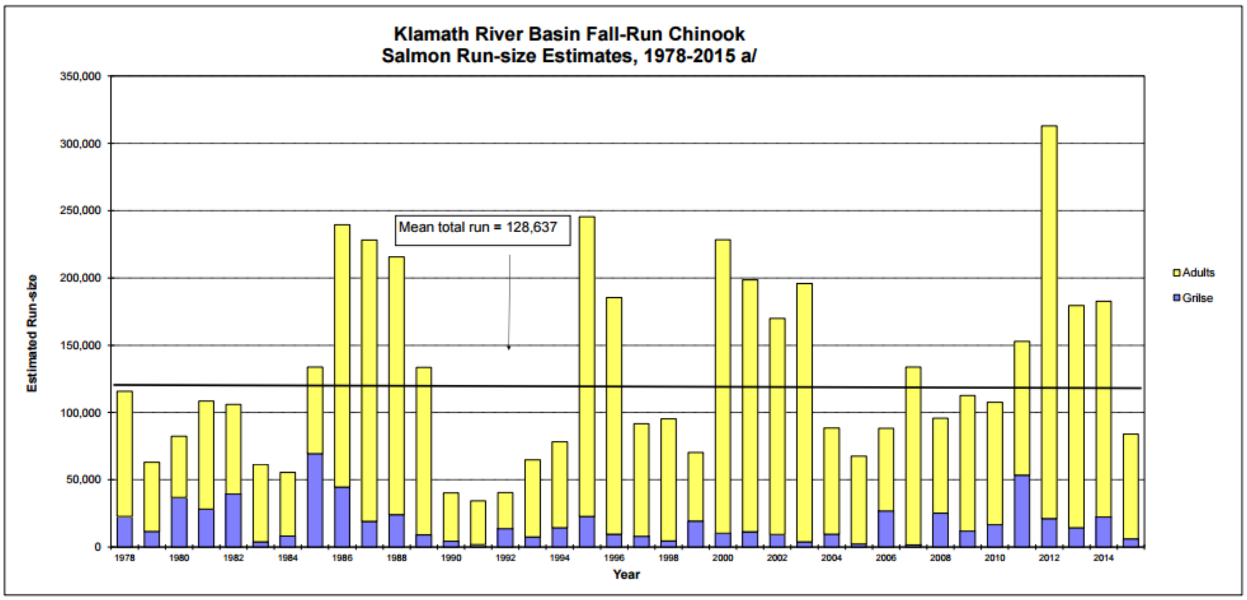

Figure 1. UKTR fall-run Chinook escapement, 1978-2015. From CDFW 2016, Fig. 1, pg. 14.

However, these totals have a high proportion of returning fish of hatchery origin. Since 1978, natural escapement has only surpassed 100,000 adults in four of 38 years, though there is an upward trend in natural escapement from 2004 to 2014 (Figure 2).

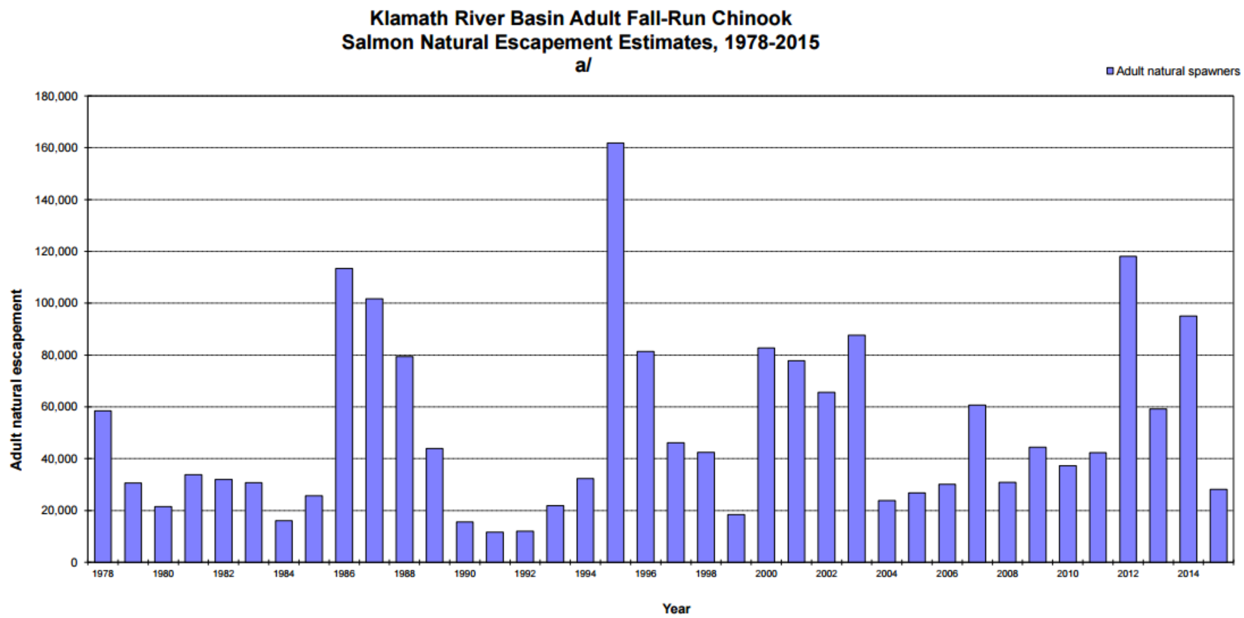

Figure 2. Natural UKTR fall-run Chinook escapement, 1978-2015. From CDFW 2016, Fig. 2, pg. 14.

Between 7 and 12 million juvenile Chinook are released annually from both hatcheries combined (NRC 2004). Between 1997 and 2000, about 60% of juveniles captured at Big Bar were hatchery-origin fish (USFWS 2001). Hatchery-origin adults also spawn in all major Klamath tributaries (e.g., Shasta, Scott, Salmon rivers), although straying of hatchery fish is pronounced closest to the hatcheries (e.g., Bogus Creek and Shasta River, Upper Mainstem Trinity River). On the mainstem Klamath from Iron Gate Hatchery to the Shasta River confluence, the contribution of hatchery fish to the total run in each year class has fluctuated widely since 2001 (Figure 3).

Year	Estimated hatchery-origin proportion	Escapement estimate	
		Total	Hatchery only
2001	11.8%	7,828	925
2002	14.2%	14,394	2,043
2003	3.8%	12,958	489
2004	1.2%	4,715	58
2005	26.6%	4,585	1,222
2006	22.7%	3,587	815
2007	39.8%	5,523	2,201
2008	37.0%	4,894	1,810
2009	25.1%	4,427	1,112
2010	48.1%	2,572	1,238
2011	40.9%	4,880	1,995
2012	45.3%	12,626	5,726

Figure 3. Mainstem Klamath spawner escapement estimates, Iron Gate Dam to Shasta River confluence. From Gough and Som 2015, pg. 22, Table 8.

Snyder (1931) noted that the Shasta River was historically the best spawning tributary in the basin. Adult escapement into the Shasta River was estimated to be 6,032 fish from 1978-1995, and 4,889 fish from 1995-2006 (CDFG 2006b). The Shasta River (~23%), mainstem Klamath River from Iron Gate Dam to Shasta River confluence (~21%), Bogus Creek (16%), and Scott River (~15%) accounted for the most fish, respectively, in the 2014 year-class in the Klamath Basin, with age-4 adults making up the majority of the run (Figure 4).

Escapement & Harvest	AGE 2	3	4	5	Total Adults	Total Run
Hatchery Spawners						
Iron Gate Hatchery (IGH)	1,039	12,864	11,276	160	24,300	25,339
Trinity River Hatchery (TRH)	221	3,653	3,271	51	6,975	7,196
Hatchery Spawner subtotal	**1,260**	**16,517**	**14,547**	**211**	**31,275**	**32,535**
Natural Spawners						
Salmon River Basin	527	865	1,674	167	2,706	3,233
Scott River Basin	2,051	2,977	7,159	283	10,419	12,470
Shasta River Basin	3,945	4,064	10,265	83	14,412	18,357
Bogus Creek Basin	323	6,119	6,448	40	12,607	12,930
Klamath River mainstem (IGH to Shasta R)	1269	6491	8847	114	15,451	16,720
Klamath River mainstem (Shasta R to Indian Cr)	575	2932	4010	50	6,992	7,567
Klamath Tributaries (above Trinity River)	1,498	1,649	4,987	241	6,877	8,375
Blue Creek	332	105	1,108	32	1,245	1,577
Klamath Basin subtotal	10,520	25,202	44,498	1,010	70,709	81,229
Trinity River (mainstem above WCW)	6,576	10,261	12,011	1,004	23,276	29,852
Trinity River (mainstem below WCW)	74	115	135	11	262	336
Trinity Tributaries (above Reservation; below WCW)	47	123	361	31	515	562
Hoopa Reservation tributaries	52	135	398	34	568	620
Trinity Basin subtotal	6,749	10,634	12,905	1,080	24,621	31,370
Natural Spawners subtotal	**17,269**	**35,836**	**57,403**	**2,091**	**95,330**	**112,599**
Total Spawner Escapement	**18,529**	**52,353**	**71,950**	**2,302**	**126,605**	**145,134**

Figure 4. UKTR fall-run Chinook escapement, 2014. From KRRT 2015, Table 5, pg. 10.

Hallock et al. (1970) estimated that 40,000 fall-run Chinook salmon historically entered the Trinity River above the South Fork. Burton et al. (1977 in USFWS 1979) estimated 30,500 Chinook returned below Lewiston Dam on the Trinity River between 1968 and 1972. The average fall Chinook run for the Trinity River between 1978 and 1995 was 34,512; this average declined between 1996 and 2006 to 23,463 fish (CDFG 2007). Recently, escapement goals for the Trinity River Hatchery for fall-run Chinook were set at 62,000 total fish annually (Kier and Hileman 2016). In 2016, an estimated 10,365 adult fall-run Chinook made it past Willow Creek weir, representing less than a quarter of the annual average run size from 1977-2015. Jacks represented about 27% and 7% of all fall-run Chinook at Willow Creek weir and Trinity River Hatchery, respectively (Kier and Hileman 2016). With the exception of 2014 (Figure 5), the percentage of hatchery fish contributions to the total run upstream of the Willow Creek weir have decreased below the 25-year average of about 50% since 2007.

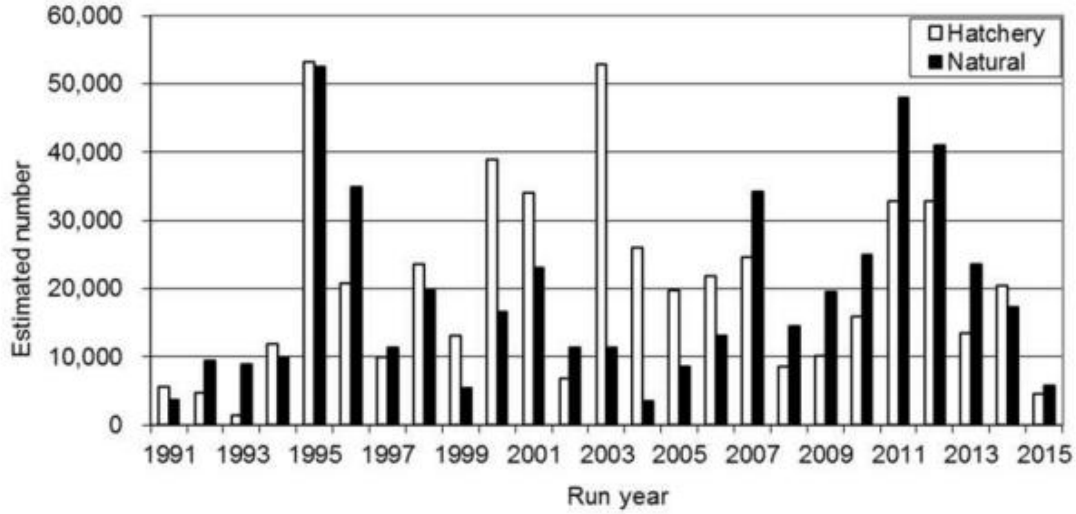

Figure 5. Natural and hatchery-origin fall-run Chinook salmon upstream of Willow Creek Weir on the Trinity River, CA, 1991-2015. From Kier and Hileman 2016 Fig. 13, pg. 33.

Each year, the Pacific Fisheries Management Council works with management partners to make annual run size predictions to determine harvest limits in the ocean, recreational, and tribal fishery sectors. These forecasts are based on hatchery releases from Iron Gate and Trinity, prior escapement estimates, scale sampling, length-at-age data, past harvest, and anticipated survival in the ocean. However, ocean conditions are extremely variable, and tend to shift on the order of decades in relation to Pacific Decadal Oscillation (PDO), which can significantly impact marine survival of salmonids (Mantua 2015).

In fact, poor marine conditions off the coast of California in 2005 and 2006 led to high mortality of juvenile Chinook salmon entering the ocean, and drove the collapse and subsequent closure of the commercial salmon fishery in California and southern Oregon in 2008-2009 (Lindley et al. 2009). In 2015, nearly 120,000 fall-run Chinook were forecast to return to the Klamath Basin, but only an estimated 78,000 (65%) returned, highlighting the significant challenges inherent in predicting return runs during ongoing drought and poor ocean conditions. The majority of these fish returned to Iron Gate Hatchery (19%), mainstem Trinity River above Willow Creek weir (16%), and the Shasta River basin (16%), respectively (CDFW 2016).

The proportion of natural-origin fall-run Chinook returning to the Trinity River has fluctuated while hatchery releases have mostly been constant since 2001. This shift has presumably come in response to Record of Decision environmental flow block adjustments and significant rearing habitat restoration in the mainstem Trinity River, which began in 2005 (Kier 2016). The proportion of natural-origin fall-run Chinook has surpassed 50% in 6 of 8 years since 2007, which had previously only happened once (2002) in the previous 6 years (Kier 2016). More monitoring over time will help elucidate the impacts of habitat and natural flow improvements over the last decade on numbers of returning adults to the Trinity Basin.

Factors Affecting Status: Numerous threats continue to stress UKTR fall-run Chinook salmon. Primary stressors include dams, logging and other land uses, fisheries, hatcheries, and disease.

Dams. UKTR fall-run Chinook are primarily mainstem spawners, so Lewiston and Iron Gate dams negatively affect populations by prohibiting access to upstream habitats and altering seasonal flows and temperature regimes in remaining downstream habitat. Iron Gate, Copco 1 and 2, and J.C. Boyle dams are used mainly for hydropower production and minimally impact total flows downstream in themselves, although agricultural water diversions in the upper Klamath basin do measurably reduce the amount of instream flow. However, dams have eliminated spawning gravel recruitment from upstream areas, reduced hydrologic variability, and significantly shifted peak flows in the basin (Hamilton et al. 2011). On the Shasta River, Dwinnell Dam blocks migrating salmon. The lack of adequate flow releases from Iron Gate and Lewiston dams, and resulting poor water quality and high water temperatures, are principal factors that caused a major kill of adult salmon in the lower Klamath River in September 2002 (CDFG 2004). Poor water quality in the lower Klamath is a major limiting factor on juvenile survival to outmigration, especially during drought years, as high water temperatures and low flows exacerbate stressors on fish and cause increased susceptibility to disease and associated mortality (USFWS 2015).

Lewiston Dam on the Trinity River has substantially modified river flows and generally reduced the size and habitat complexity of the river channel (A. Hill, CDFW, pers. comm. 2016). Starting in 1964, 75-90% of Trinity River flow was diverted to the Central Valley. Declines of naturally-spawning fall-run Chinook populations were exacerbated by diversion of most of the river's water and corresponding reduction in spawning gravels and degradation of habitat. In 1984, Congress ordered restoration of the river to support salmon at historical levels (see http://www.trrp.net/). In 2000, a Record of Decision (ROD) was signed that called for numerous restoration actions, as well as a rough doubling of flows of the river mimicking the natural flow regime. Implementation is now underway: block water releases have been mandated and implemented, and large-scale restoration of spawning and rearing habitat has occurred on the mainstem Trinity River (Kier 2016).

Agriculture. Much of the water diverted from the Trinity River is used for agriculture in the Central Valley. Diversion of water for agriculture from the headwaters of the Klamath River in Oregon, as well as from the Shasta and Scott rivers in California, reduces streamflows and increases water temperatures, reducing suitable habitat for spawning or rearing. Many farms use flood irrigation, whereby return water flows back into the streams at high temperatures, carrying nutrients and fertilizers, further warming streams and degrading water quality. These impacts are particularly acute during summer and early fall months, when ambient temperatures are highest and natural flow inputs are lowest. Pumping from wells adjacent to waterways also reduces groundwater tables and associated coldwater inputs into rivers, which are especially critical for Chinook salmon during the summer and fall months. The Shasta River, for example, has been converted by agricultural diversions from a cold river that supported year-round salmon production to one with degraded water quality, including temperatures too high to support salmon in summer. With the passage of Proposition 64 in California in November 2016, marijuana cultivation for private use has become legalized, which may put increasing pressure on limited water resources within the UKTR Basin. It remains to be seen if this legalization will impact the geography of grow operations in the future, which are currently centered in the UKTR basin and surrounding counties. More effort must be placed on understanding, quantifying, and reducing the extent and magnitude of these impacts on fall-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. The majority of spawning and rearing habitat for UKTR Chinook salmon is surrounded by public lands in the Klamath and Shasta-Trinity National Forests, which have been heavily logged and covered in associated networks of roads. As a result, the Klamath River is regarded as impaired under the Clean Water Act because of high nutrient and sediment loads, high temperatures, and low levels of dissolved oxygen. See the UKTR spring-run Chinook account for further discussion on impacts from logging and other land uses in the UKTR Basin.

Grazing. Livestock grazing is widespread on public and private lands throughout the Klamath-Trinity system. Grazing impacts occur mainly on tributary streams, where livestock can cause severe bank damage and reduce riparian vegetation through trampling, compaction, and grazing, resulting in stream incision and silting of spawning gravels. After decades of ranching, feral cattle continue to degrade riparian vegetation and trample streambanks in the Trinity and Klamath basins (Beesley and Fiori 2008).

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 results in increased sediment delivery to streams in the steep, mountainous terrain of this region, effluent from septic tanks and other pollutants, water diversion, deforestation and habitat fragmentation. These impacts are often most acute on small headwater streams; while not critical spawning habitats for fall-run Chinook, these are important sources of cold water and flows for all salmonids.

Mining. Mining has dramatically altered river habitats in the UKTR Basin, with lasting legacy impacts in many inland areas. Intensive hydraulic and dredge mining occurred in the 19th century and, depending on location, these activities caused severe stream degradation and alteration to channel morphology. Mining was a principal cause of decline of UKTR Chinook in the Scott River and large areas in the Trinity River, followed by some level of recovery after large-scale mining ceased. The Scott River Valley remains heavily altered, with immense piles of dredge tailings marking its history. Historical mining impacts still affect the Salmon River Chinook population, as the estimated 16 million cubic yards of sediment disturbed between 1870 and 1950 are slowly transported through the basin. Mining and its legacy effects have disconnected and constricted juvenile salmon habitat, filled in adult holding habitat, degraded spawning grounds, and altered the annual hydrograph of numerous streams. Pool in filling is a particular problem because high stream temperatures have been demonstrated to reduce survival of both holding adults and rearing juveniles (West 1991, Elder et al. 2002). In general, the productive capacity of the Scott River has been significantly reduced as a result of extensive mining in the watershed (Cramer Fish Sciences 2010).

While banned since 2009, suction dredging for gold has likely negatively affected fall-run UKTR populations through disturbance of spawning gravel, siltation, and sedimentation. See UKTR spring-run Chinook account in this report for more details.

Transportation. Roads are widespread along many UKTR streams, and increase sediment and pollutant inputs into waterways due to erosion. Many timber and mining roads were built at a time when little attention was paid to environmental impacts. Many roads have been improved and/or closed to public access, but impacts to stream habitats and water quality remain. Culverts and other passage structures often create migration barriers, although restoration projects have mitigated many of these impediments.

Fire. Wildfires are predicted to become more frequent and severe under climate change scenarios, so may pose increasing threats to spawning and holding habitats, as well as contribute to increasing water temperatures and sediment input that can fill pools, smother spawning habitat, and degrade water quality during rainstorms following fires. The UKTR area is prone to large wildfires as a result of decades of past fire exclusion practices.

Recreation. Water sports have a presumably minimal impact on UKTR juveniles and adults; however, widespread use of motorized boats in the lower Klamath River may affect adult spawner behavior and movement patterns. See the UKTR spring-run Chinook account in this report for more detail on potential recreational impacts.

Harvest. Unlike most other salmon runs in California, the UKTR fall-run Chinook run supports substantial commercial, tribal, and recreational fisheries. Harvest may be selecting for smaller and faster-maturing fish over time, as larger and older fish are removed from the population year after year. Snyder (1931) noted a decline in the proportion of age 4 and 5 Chinook in the estuary, which was most likely the result of harvest focused on larger fish. The Pacific Fisheries Management Council (PFMC), which regulates commercial fishing on the West Coast, has paid particular attention to UKTR Chinook returns because these fish account for a considerable proportion of the harvest of salmon in California and southern Oregon each year. The breakdown of in-river harvest and total escapement, those fish that were not caught in commercial fisheries at sea for the 2014 year-class, is shown below (Figure 6).

	Age 2	Age 3	Age 4	Age 5	Total Adults	Total Run
Recreational Harvest						
Klamath River (below Hwy 101 bridge)	268	249	775	69	1,093	1,361
Klamath River (Hwy 101 to Weitchpec)	2,847	365	1,438	71	1,875	4,722
Klamath River (Weitchpec to IGH)	75	728	759	9	1,496	1,571
Trinity River Basin (above WCW)	168	358	355	45	758	926
Trinity River Basin (below WCW)	3	26	26	3	55	58
Subtotals	**3,361**	**1,726**	**3,353**	**198**	**5,277**	**8,638**
Tribal Harvest						
Klamath River (below Hwy 101)	153	2,262	16,668	1,108	20,039	20,192
Klamath River (Hwy 101 to Trinity mouth)	130	593	2,785	56	3,434	3,564
Trinity River (Hoopa Reservation)	65	524	1,804	111	2,439	2,504
Subtotals	**348**	**3,379**	**21,257**	**1,277**	**25,913**	**26,260**
Total Harvest	**3,709**	**5,105**	**24,610**	**1,475**	**31,190**	**34,898**
Totals						
Harvest and Escapement	22238	57458	96560	3777	157,794	180032
Recreational Angling Dropoff Mortality 2.04%	69	35	68	5	108	177
Tribal Net Dropoff Mortality 8.7%	30	294	1,848	111	2,253	2,283
Klamath River disease testing	11	50	234	4	288	299
Total River Run	**22,348**	**57,837**	**98,710**	**3,897**	**160,444**	**182,792**

Figure 6. Recreational and Tribal harvest estimates of UKTR fall-run Chinook, 2014. From KRTT 2015, Table 5, pg. 10.

Poor ocean conditions can severely impact adult escapement, especially when combined with high rates of harvest that this run has historically sustained. Harvest goals are often difficult to set because poor ocean conditions can devastate several year classes of fish at once. The difficulties are compounded by consistently poor conditions in fresh water and reliance on hatchery fish to support the fishery. This leads to extreme population fluctuations, resulting in complete commercial salmon fishery closures in California for the 2008 and 2009 fishing seasons (Lindley et al. 2009, CDFW 2010). In 2016, the Council cited a substantially low forecast of fall-run Chinook returns to the UKTR and Central Valley, primarily due to ongoing drought and poor ocean conditions associated with El Nino, as the driver for fishery constraints in Oregon and California (PFMC 2016). Fisheries for UKTR fall-run Chinook salmon are likely to be periodically restricted to prevent overharvest of wild fish, unless a mark-selective fishery is instituted [e.g., all hatchery fish are marked and all non-marked (wild) fish are released].

Hatcheries. Although most tributary spawning stocks are apparently comprised mainly of wild fish, the mainstem Klamath River is increasingly supported by hatchery returns. Hatchery operations have likely influenced the age of maturation and spawning distribution of UKTR Chinook salmon and reduced life history diversity in the Klamath-Trinity basin. Hatcheries first began operating on the Klamath River for fall-run Chinook in 1914. A significant proportion of mainstem spawning now occurs between Shasta River and Iron Gate Dam. In 1999, 73% of redds were located between Iron Gate Hatchery and the Shasta River and this proportion has increased over time (Bartholomew and Hendrikson 2006).

Historically, most fall-run Chinook in the Trinity River spawned between the North Fork and Ramshorn Creek (Moyle et al. 2008). More than 50% of out-migrating smolts observed between 1999 and 2000 at the Willow Creek weir were of hatchery origin; this proportion increased to more than two-thirds during the fall monitoring period (USFWS 2001). While the contribution of hatchery-origin fish to the total annual run is trending downward over the last decade (Kier 2016), they still have impacts on natural-origin fish. Most naturally produced Chinook in the basin are ocean-type and emigrate in the spring and summer, while Trinity River Hatchery releases yearlings in October. Large numbers of hatchery fish in the Klamath-Trinity system may impact naturally produced Chinook through competition, hybridization, predation, redd superimposition, and/or disease transmission. Wild populations face reduced fitness through interbreeding with hatchery fish (Araki et al. 2007, 2009, Kinziger et al. 2008).

Competition and predation may be enhanced when releases of large (compared to wild fish) hatchery juveniles occupy shallow water refuge habitats used by naturally spawned juveniles (NRC 2004). Naman and Sharpe (2012) conducted a review of predation impacts of hatchery-origin steelhead on wild juvenile salmonids in the Trinity Basin, and found predation rates were orders of magnitude higher than found in other watersheds throughout the Pacific Northwest. Over 6% of natural-origin Chinook and coho subyearlings in the year class were consumed by hatchery-origin juvenile steelhead in the study reach below Trinity River Hatchery. Hatchery steelhead are released on March 15 every year near thousands of redds, from which fry have recently emerged and before they have emigrated, creating conditions that favor high predation rates.

Hatchery returns are likely replacing natural escapement of at least some wild populations of UKTR fall-run Chinook. The proportion of fall-run Chinook natural escapement has significantly decreased over time, concurrent with significant increases in hatchery returns to IGH and TRH since the 1980s (Quiñones et al. 2013). These patterns suggest increasing dependence on hatchery propagation and perhaps signal similar responses of natural and hatchery spawners to environmental conditions. More research is needed to understand the full extent of hatchery influence on natural production and genetics of fall-run Chinook in the Klamath-Trinity system, especially with removal of the four lowermost dams on the Klamath River and significant restoration and reintroduction efforts looming in 2020. See the Central Valley fall-run Chinook account for further discussion on hatchery effects on wild stocks.

The large-scale die-off of over 60,000 UKTR salmon and other fish in the Klamath River in 2002, and near-repeat again in 2014, provide examples of how multiple factors can create synergistic impacts that are capable of decimating salmon runs (Lynch and Riley 2003). Chinook salmon in the Klamath and Trinity basins migrate when water temperatures and minimum flows begin to approach their limits of tolerance, increasing their susceptibility to stress and disease. In

September 2002, between 30,000 and 70,000 predominantly UKTR fall-run Chinook adult salmon perished in the lower Klamath River due to infection by "ich" disease (caused by *Ichthyopthirus multifilis*) and columnaris disease (*Flavobacter columnare*) (Lynch and Riley 2003). Factors that led to this massive die-off are still not fully understood, but were likely a combination of: (1) high water temperatures, (2) crowded conditions, and (3) low flows. These conditions allowed for a disease epidemic to sweep through the population of highly stressed fish concentrated in pools. Increased base flows likely reduce pathogen transmission risk during Chinook salmon migration (Strange 2007). High water temperatures and low flows can also increase salmonid susceptibility to a number of other diseases, such as *Ceratomyxa shasta* and *Parvicapsula minibicornis*. It is likely that UKTR fall-run Chinook were historically infected by these diseases at low levels, but widespread epidemics rarely occurred because contributing factors such as high temperatures, low flows, and poor water quality throughout the lower Klamath River during summer months did not exist to the extent they do now. When high densities of infected fish and warm temperatures exist in combination, *C. shasta* infection is accelerated (Foott et al. 2003). Large releases of hatchery fish may therefore be particularly susceptible to infection and spread disease to wild fish. It is also likely that most juvenile Chinook from the Scott and Shasta rivers do not survive their exposure during emigration through the lower Klamath, and these diseases may exert selection pressures by killing juvenile UKTR Chinook that emigrate at times when temperatures in the main river are too warm.

While many threats act in concert to reduce abundance and resiliency in salmon populations in California, perhaps none are more important or less understood than the forces that dictate early marine survival of salmon. Population productivity and persistence are often determined during this critical early marine life stage, and low abundance increases susceptibility of salmon to environmental forcing, such as Pacific Decadal Oscillation and El Nino events (Kilduff et al. 2014).

Alien species. Alien species are at best a minor problem to UKTR Chinook salmon. Predation by brown trout (*Salmo trutta*) on juvenile Chinook, coho, or steelhead juveniles in the system appears to have negligible effects compared to other predation. Brown trout may also compete with other native salmonids at all life stages for food, rearing and spawning habitat (NMFS 2014), but effects are likely to be small and localized.

Factor	Rating	Explanation
Major dams	High	Much former habitat is above dams; dams have significantly reduced remaining habitat quality downstream.
Agriculture	Medium	Habitats have been degraded through diversions, warm return water, and associated pollutant inputs.
Grazing	Medium	Livestock are pervasive on public and private lands; impacts concentrated in smaller tributary streams.
Rural/ residential development	Low	Cumulative effects of numerous roads and rural development can negatively affect salmon.
Urbanization	Low	Urban areas are few, small, and restricted to main rivers.
Instream mining	Medium	Legacy effects are still severe in some areas and have altered stream productivity, such as on the Scott and Salmon Rivers.
Mining	Low	Legacy effects of hard-rock mining are potentially severe in localized areas, such as the Salmon and Trinity rivers.
Transportation	Medium	Roads present along many streams and contribute sediment and pollutants along with habitat fragmentation.
Logging	Medium	Both legacy effects and ongoing impacts degrade aquatic habitats, but impacts are much lesser than historical impact.
Fire	Medium	Fires predicted to become more frequent and severe across the Basin, potentially degrading important headwater habitats.
Estuary alteration	Low	The Klamath River estuary is less altered than most North Coast estuaries.
Recreation	Low	Human uses such as boating may impact behavior of spawning fish and juveniles, especially in the lower Klamath River.
Harvest	Medium	Legal and illegal harvest may be negatively affecting abundance.
Hatcheries	Medium	Iron Gate and Trinity hatcheries contribute significantly to returning adults and may impact genetic integrity of wild fish.
Alien species	Low	Brown trout are present in the Trinity River, are known competitors and predators of juvenile salmon.

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of UKTR fall-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. A factor rated “n/a” has no known negative impact. Certainty of these judgments is moderate. See methods for explanation.

Effects of Climate Change: Moyle et al. (2013) rated the UKTR fall-run Chinook as “highly vulnerable” to extinction in the next 100 years as the result of the added impacts from climate change. The ‘ocean’ life history strategy of UKTR fall-run Chinook makes them least vulnerable of all runs to climate change. However, warm temperatures in the lower Klamath River during summer and fall months are already a substantial threat to migrating fish, and are likely to exacerbate problems with disease outbreaks and die-offs, such as those associated with "ich" disease and *C. shasta*. Elevated water temperatures have been identified as a factor limiting anadromous salmonid abundance in the Klamath River basin, especially UKTR spring-run Chinook salmon, as the result of the impacts of multiple land and water use impacts being compounded by climate change. Water temperatures in UKTR Basin rivers have increased approximately 0.5°C/decade, and have resulted in the loss of about 8.2 km of cool summer water in the mainstem each decade (Bartholomew and Hendrikson 2006). Bartholomew and Hendrikson (2006) documented that the timing of high temperatures potentially stressful to Chinook has moved forward seasonally by about one month in spring, and therefore extended the amount of time that stressful conditions exist in the lower Klamath. These temperature changes are consistent with measured basin-wide air temperature increases. The resulting spatial and temporal loss of rearing habitat may also reduce the survival of UKTR fall-run Chinook. See the UKTR spring-run Chinook account for further information on potential climate change impact to salmon populations in this region.

Marine survival plays an important role in abundance trends over time in Pacific salmonids, but the factors that contribute to changes in survival are only recently becoming clear. Researchers at NMFS' Southwest and Northwest Fisheries Science Centers have found that a complex interaction of physical and biological processes, including temperature, upwelling, lower-trophic level production, competition, and predation impact survival of juvenile salmonids at sea (Sharma et al. 2013). Increases in sea surface temperatures, such as those associated with climate change and El Nino Southern Oscillation (ENSO) events, reduce salmonid survival across populations, and play a significant role in predicting salmon abundance from the Klamath Basin to southeast Alaska. Generally, as sea surface temperatures increase, upwelling decreases, and the composition of prey offshore, such as euphasiid species that Chinook prey on, also shift. Based on historical analyses of changing sea surface temperatures and survival, Sharma and colleagues (2013) estimate that a 1°C increase in average sea surface temperatures in the spring and early summer, while juvenile salmon transition from freshwater to salt, could result in 1-4% reductions in survival across their range. Such increases are well within the expected bounds of sea surface temperature increases due to climate change by 2100 (Mantua 2015).

In addition to these predictable outcomes, greater forces such as the North Pacific Gyre Oscillation, which shifts on timeframes of decades, has recently been shown to be highly correlated with survival of salmonids from Alaska to California (Mantua 2015). This oscillation of cool and warm periods in the North Pacific, where most salmon migrate to feed, interact in complex ways with climate change that are not currently well understood. However, there is evidence that as hatchery-influenced runs from the southern edge of the salmon range in North America lose genetic diversity and life history variability, their survival in changing ocean environments has also become synchronized, resulting in greater population fluctuations (Hayes et al. 2016). This is in contrast to the more diverse, wild-origin runs at the northern edge of the range, which have generally enjoyed higher survival through poor growing conditions at sea over time (Mantua 2015). In short, greater diversity in run timing, life history adaptation, and genetic variability can help salmon runs reduce their risk of poor survival in the face of shifting ocean conditions and climate change. This bet-hedging survival tactic employed by anadromous salmonids through expression of various life history strategies so that entire year classes are not devastated by poor conditions at sea, known as the portfolio effect, is akin to how a diversified portfolio of investments can reduce catastrophic losses in the event of a stock market crash (Satterthwaite and Carlson 2011).

Status Score = 3.1 out of 5.0. Moderate Concern. UKTR fall-run Chinook are not in immediate danger of extinction, although their numbers have declined in recent decades. There is increasing reliance on hatcheries to maintain fisheries and returns of hatchery-origin fish may be masking a decline of wild production in the Klamath-Trinity basins. The UKTR Chinook salmon ESU was determined to not warrant listing under the Federal Endangered Species Act on March 9, 1998. However, they are considered a Sensitive Species by the U.S. Forest Service and a Fish Species of Special Concern by CDFW (CDFW 2015). CDFW manages the run for sport in fresh water, while the Pacific Fishery Management Council manages tribal, ocean sport and commercial fisheries.

Metric	Score	Justification
Area occupied	5	Widely distributed in Klamath and Trinity basins.
Estimated adult abundance	4	Abundant, with several large populations, but hatchery contributions a problem.
Intervention dependence	3	Major intervention is required to maintain fisheries, primarily through hatchery propagation and flow regulations.
Tolerance	3	Moderate physiological tolerance.
Genetic risk	3	Genetically diverse population but heavily influenced by hatcheries.
Climate change	2	Vulnerable to increasing temperatures in mainstem rivers, changes in flow regimes in tributaries, and variable ocean conditions.
Anthropogenic threats	2	1 "High" and 8 "Medium." A highly managed population.
Average	3.1	22/7. No immediate threat of extinction but declines likely.
Certainty (1-4)	4	Most studied of Klamath River Chinook runs.

Table 2. Metrics for determining the status of UKTR fall-run Chinook salmon, where 1 is a poor value and 5 is excellent. Each metric was scored on a 1-5 scale, 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: While UKTR fall-run Chinook salmon seem to be decreasing in abundance over time, significant actions have been undertaken to aid their populations, perhaps slowing decline. The Trinity River Restoration Program (TRRP) is focused on maintaining and recovering populations of UKTR Chinook salmon by taking a holistic approach to restoration in the form of flow manipulations, focused restoration activities, and implementation of conservative fisheries management actions. In the Trinity Basin, annual monitoring and assessment of returning fish by CDFW and Hoopa Tribal Fisheries are working to adaptively manage Trinity River flows, as set out in the Trinity River Restoration Program's stated objectives (Kier and Hileman 2016). Restoration activities, such as those that deploy spawning gravel in known spawning reaches, are presumably decreasing competition for limited usable spawning habitat, reducing redd superimposition and interbreeding of fall-run and spring-run Chinook below Trinity River Hatchery (Kier and Hileman 2016). Where possible, spatial and temporal overlap between predators (e.g., hatchery-origin steelhead) and prey (subyearling Chinook and coho salmon) should be reduced by hatchery operations to reduce high rates of predation observed in the Trinity River. In addition, block water releases are being used for adult attraction flows and spring runoff events to aid in juvenile outmigration, especially with the prevalence of poor water quality conditions in the lower Klamath River. Overall, restoration objectives for the TRRP provide reasonable targets for ameliorating limiting factors and increasing suitable habitat quantity and quality in the Trinity River. They need to continue to be implemented and managed adaptively.

A similar program needs to be implemented as part of the Klamath River Restoration Program. Planned removal of the four lowermost Klamath Dams is scheduled to begin in 2020, marking the beginning of the largest river restoration project in North America. This will return the river to a more natural flow regime in part, although summer flows are likely to be lower due to upstream removals of water (in Oregon). While the Salmon River and some smaller watersheds in the Klamath National Forest remain in relatively good condition, the Shasta and Scott rivers need large-scale restoration efforts and improved flows to protect salmon populations and ensure successful re-colonization of newly accessible historical habitat after dam removal. For example, restoration of the highly productive Shasta River, with its constant spring-fed cold water from Big Springs Creek, may be prioritized in the short-term to boost natural-origin salmon populations that could volitionally re-colonize the upper Klamath River.

Protecting and restoring cool water habitats throughout the Klamath and Trinity watersheds will be essential to conserving fall- and spring-run Chinook in the Basin. A changing thermal regime in the Klamath River, which is exacerbated by ongoing drought and climate change, could rapidly eliminate UKTR Chinook spawning habitat in the mainstem and create thermal barriers to migration, effectively disconnecting critical spawning tributaries from the lower mainstem on the Klamath River. Both adult immigrants and juvenile emigrants are often exposed to water temperatures that are bioenergetically suboptimal or even lethal, leading to increased incidence of disease outbreaks.

The behavioral and life history plasticity displayed by Chinook salmon indicates strong potential for management strategies that increase juvenile survival through maintenance of multiple life history patterns. In mainstem habitats, Belchik (1997) demonstrated that UKTR Chinook use cool water areas as refuges; use of such habitats increases adult spawner and juvenile outmigrant survival and should be catalogued and monitored, at a minimum, and expanded where possible through adaptive water management and restoration. For example, the Western Rivers Conservancy and the Yurok Tribe have partnered to purchase the majority of the Blue Creek watershed from the Green Diamond Resource Company and to place it under Yurok Tribal stewardship in perpetuity as a salmon sanctuary. Innovative partnerships such as these should be expanded wherever appropriate in the UKTR. Partnerships with Tribes, private landowners, resource companies, municipalities, and others that conserve and restore cold water and flows to UKTR tributaries, such as the Shasta, Salmon, Scott, and South Fork Trinity Rivers will be critical to the recovery and persistence of robust runs of salmonids in the basin. Safe Harbor Agreements, where assurances are given from management agencies on Endangered Species Act and other environmental regulations to private landowners that willingly engage in conservation efforts on their properties, should be replicated and expanded where possible.

Many of the recommendations for conservation of UKTR spring-run Chinook also apply to fall-run Chinook (see UKTR spring-run Chinook account). In particular, hatchery operations at Iron Gate Hatchery and Trinity Hatchery are likely reducing productivity, survival, and persistence of wild salmon in the basin, and should be examined critically to find ways to reduce competition, predation, loss of genetic diversity, and loss of life history diversity (Tucker et al. 2011). In the short-term, managers should consider limiting harvest to a mark-selective fishery for 100% adipose fin-clipped fall-run Chinook to separate hatchery fish from wild fish and better understand the impacts of the fishery on natural-origin stocks. This could be done experimentally for 5-10 generations, as a learning tool. In addition, the benefits and risks associated with employing a new conservation hatchery on the upper mainstem Klamath River should be carefully considered to help re-establish populations of Chinook salmon in the upper watershed.

New References:

Hileman, J. 2016. Pers. comm. CDFW Environmental Scientist, Northern Region.

Hill, A. 2016. Pers. comm. CDFW Environmental Scientist, Northern Region.

Jeffres, C. 2016. Pers. comm. UC Davis Fisheries Ecologist.

Kier, M. C. 2016. Pers. comm. CDFW Environmental Scientist, Northern Region.

Sinnen, W. 2016. Pers. comm. CDFW Supervisory Environmental Scientist, Northern Region.

Beesley, S. and R. Fiori. 2008. “Cooperative Restoration of Tribal Trust Fish and Wildlife Habitat in Lower Klamath River Tributaries.” 37pp. http://www.yuroktribe.org/departments/fisheries/documents/YTFP2008CooperativeRestorationofLKTribsFINALReport_PartI.pdf. Accessed 12/1/2016.

CDFW. 2010. “Salmon Emergency.” Web: http://www.fgc.ca.gov/public/reports/DFGissues/Salmon%20Emergency.pdf. 1pp. Accessed 11/16/2016.

CDFW. 2015. “Fish Species of Special Concern: Upper Klamath-Trinity Fall-Run Chinook Salmon.” Web: https://www.wildlife.ca.gov/Conservation/SSC/Fishes. Accessed 11/16/2016.

CDFW. 2016. “Fall Megatable: Klamath River Basin Fall Chinook Salmon Spawner Escapement, In-River Harvest and Run-Size Estimates, 1978-2015.” Web: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=122850&inline. Accessed 11/2/2016.

Cramer Fish Sciences, Philip Williams & Associates, and Siskiyou Resource Conservation District. 2010. “Scott River Spawning Gravel Evaluation and Enhancement Plan.” 116pp. Web: http://www.fishsciences.net/reports/2010/ScottRiverFinal10Dec2010.pdf. Accessed 8/20/2016.

Gough, S. and N. Som. 2015. “Fall Chinook Salmon Run Characteristics and Escapement for the Mainstem Klamath River, 2012.” U.S. Fish and Wildlife Service. Arcata Fisheries Data Series Report DS 2015–46, Arcata, California. 38pp. Web: https://www.fws.gov/arcata/fisheries/reports/dataSeries/2012%20klamath%20carcass%20survey%20report%20FINAL.pdf. Accessed 11/15/2016.

Harding, J. 2015. “Cruise Report for OS1401, Juvenile Salmon Ocean Ecology.” R/V OCEAN STARR, Cruise: OS1401, July 5-24, 2014. Fisheries Ecology Division, NOAA, NMFS, SWFSC. Web:https://swfsc.noaa.gov/uploadedFiles/Divisions/FED/Salmon_Ecology/resources/cruise_report_OS1401.pdf. Accessed 9/10/2016.

Hassrick, J. et al. (*In prep.*). “Physical and Environmental Determinants of Juvenile Chinook Salmon Dispersal in the Northern California Current.”

Hayes, S. et al. 2016. “Half pounders, Climate Change and Blob, Blob, Blob.” NOAA Southwest Fisheries Science Center. Presentation for the 2016 Pacific Coast Steelhead Management Meeting, Pacific Grove, March 2016. Web: www.psmfc.org/steelhead/2016/hayes_PSMFC_Hayes_steelhead_talk.pdf. Accessed 9/1/2016.

Johnson, J., Johnson, T. and T. Copeland. 2012. “Defining Life Histories of Precocious Male Parr, Minijack, and Jack Chinook Salmon Using Scale Patterns.” *Transactions of the American Fisheries Society* 141(6): 1545-1556.

Kier, M. C. and J. Hileman. 2016. “Annual Report: Trinity River Basin Salmon and Steelhead Monitoring Project: Chinook and Coho Salmon and Fall-Run Steelhead Run-Size Estimates Using Mark-Recapture Methods, 2016-17 Season.” Report to the Trinity River Restoration Program (U.S. BOR Agreement R13AC20027). California Department of Fish and Wildlife, Redding, CA. 96pp. http://odp.trrp.net/Data/Documents/Details.aspx?document=2299. Accessed 11/16/2016.

Kier, M. C. 2016. “Escapement and Proportion of Natural Origin Salmonids Contributing to Total Escapement.” Trinity River Restoration Program (TRRP) Performance Measure. TRRP, Weaverville, California. http://odp.trrp.net/Data/Documents/Details.aspx?document=2285. Accessed 11/16/2016.

Kinziger et al. 2008. “Hybridization between Spring- and Fall-Run Chinook Salmon Returning to the Trinity River, California.” *North American Journal of Fisheries Management* 28:1426-1438.

Klamath River Technical Team (KRRT). 2015. “Klamath River Fall Chinook Salmon Age-Specific Escapement, River Harvest, and Run Size Estimates, 2014 Run.” Presentation to the Pacific Fishery Management Council, March 2, 2015. 19pp. Web: http://www.pcouncil.org/wp-content/uploads/2015/03/krtt.age_.comp_.final_.02Mar2015.pdf. Accessed 11/15/2016.

Klamath River Technical Team. 2016. “Klamath River Fall Chinook Salmon Age-Specific Escapement, River Harvest, and Run Size Estimates, 2015 Run.” 19pp. Web: http://odp.trrp.net/Data/Documents/Details.aspx?document=2280. Accessed 11/16/2016.

Lindley, S. et al. 2009. “What Caused the Sacramento River Fall Chinook Stock Collapse?” NOAA Technical Memorandum: NOAA-TM-NMFS-SWFSC-447. 125pp. Web: https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-447.PDF. Accessed 12/1/2016.

Mantua, N. 2015. “Shifting Patterns in Pacific Climate, West Coast Salmon Survival Rates, and Increased Volatility in Ecosystem Services.” *Proceedings of the National Academy of Sciences* 112(35): 10823-10824.

Naman, S. and C. Sharpe. 2012. “Predation by Hatchery Yearling Salmonids on Wild Subyearling Salmonids in the Freshwater Environment: A Review of Studies, Two Cast Histories, and Implications for Management.” *Environmental Biology of Fishes* 94:21-28.

NMFS. 2014. “SONCC Coho Final Recovery Plan: Upper Trinity River Population.” Web: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/southern_oregon_northern_california/SONCC%20Final%20Sept%202014/sonccfinal_ch39_uppertrinityriver.pdf. Accessed 12/1/2016.

Pearse, D. et al. 2016. “Rapid Parallel Evolution of Standing Variation in a Single, Complex, Genomic Region is Associated with Life History in Steelhead/Rainbow Trout.” *Proceedings of the Royal Society* 281: 20140012.

PFMC. 2016. “Council Announces 2016 Salmon Seasons.” http://www.pcouncil.org/2016/04/41860/council-announces-2016-salmon-seasons/. Accessed 12/2/2016.

Power, M. et al. 2015. “The Thirsty Eel: Summer and Winter Flow Thresholds that Tilt the Eel River of Northwestern California from Salmon-Supporting to Cyanobacterially-Degraded States.” *Copeia: Fish out of Water Symposium*. August 29, 2008. 35pp. Web: http://eelriverrecovery.org/documents/Thirsty%20Eel%20August%2029-1.pdf. Accessed 11/7/2016.

Prince, D. et al. *In press*. “The Evolutionary Basis of Premature Migration in Pacific Salmon Highlights the Utility of Genomics for Informing Conservation.” BioRxiv pre-print work. 18pp.

Satterthwaite, W. and S. Carlson. 2011. “Weakening portfolio effect strength in a hatchery-supplemented Chinook salmon population complex.” *Canadian Journal of Fisheries and Aquatic Sciences* 72: 1860–1875. Web: https://nature.berkeley.edu/carlsonlab/wp-content/uploads/2016/01/Satterthwaite_Carlson_2015_CJFAS.pdf. Accessed 1/18/2017.

Sharma, R. et al. 2013. “Relating Spatial and Temporal Scales of Climate and Ocean Variability to Survival of Pacific Northwest Chinook Salmon (*Oncorhynchus tshawytscha*).” *Fisheries Oceanography* 22(1): 14-31.

Tucker, S. et al. 2011. “Life History and Seasonal Stock-Specific Ocean Migration of Juvenile Chinook Salmon.” *Transactions of the American Fisheries Society* 140: 1101–1119.

USFWS. 2015. “Proceedings of the Klamath River Fish Health Workshop.” March 24, 2015. Karuk Community Center, Yreka, CA. 18pp. Web: https://www.fws.gov/arcata/fisheries/reports/KRFHW_2015_agenda_abstracts.pdf. Accessed 11/18/2016.

Waples et al. 2008. “Evolutionary History of Pacific Salmon in Dynamic Environments.” *Evolutionary Applications* (3):189-206.

Western Rivers Conservancy. 8/12/2014. “Yurok Stewardship of Klamath’s Blue Creek Bodes Well for Fish.” Web: http://www.westernrivers.org/blog/entry/yurokstewardshipofklamathsbluecreekbodeswellforfish/. Accessed 11/16/2016.