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

Status: Moderate Concern. Abundance of natural spawners in most tributaries is fairly stable. However, basin-wide trends show increasing hatchery returns, with decreasing natural spawners, even within recent large runs.

Description: See the upper Klamath-Trinity rivers (UKTR) spring-run Chinook and Central Valley fall-run Chinook accounts in this report for detailed coverage of species description. Upper Klamath-Trinity rivers fall-run Chinook enter rivers as reproductively mature fish, exhibiting spawning colors.

Taxonomic Relationships: 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). 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 the distinctive adaptive life histories characterized by each group. See the UKTR spring-run Chinook salmon account in this report 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 (Strange 2005). Between 1925 and the early 1960s, the Klamathon Racks provided a counting facility and an egg collection station close to the current location of Iron Gate Dam. The earliest date that Chinook salmon passed this location between 1939 and 1958 was August 18, 1940; peak daily fish counts occurred during mid- and late-September and tapered off by late October (Shaw et al. 1997). More recent peak migration appears to occur one to four weeks later than the historic run timing recorded at the Shasta and Klamathon racks (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 September 18 and November 25 (Hampton 2006). They reach 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; use of smaller streams for spawning occurs later in the spawning season. Spawning on 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 has been documented to begin in mid-October (LaFaunce 1967). Spawning peaks during November in most Klamath and Trinity basin tributaries before tapering off in December (Leidy and Leidy 1984a).

Klamath River Chinook salmon have a lower fecundity and larger egg size than Chinook from the Sacramento River (McGregor 1922, 1923a). The average fecundity of Lewiston Hatchery fish is 3,732 eggs for 4-kg fish (Bartholmew and Henrikson 2006). Fry emerge from the 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 (Shaw et al. 1997).

The timing of juvenile emigration is highly variable and dependent on river rearing conditions, which are controlled largely by 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 the 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. 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).

Sullivan (1989) examined scales from returning fall-run adults to determine fry emigration patterns. Three distinct types of juvenile freshwater life history strategies for UKTR fall-run Chinook were identified: (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 the spawning areas quickly and forage along tributary and mainstem rivers for a short period, prior to emigrating during summer months. In the Shasta River, peak fry outmigration occurs in March or early April and from mid-April to mid-May in the Scott and Salmon rivers. Historically, in the mainstem Klamath River, Chinook juvenile emigration initiated in mid-March, before peaking in mid-June, and decreased by the end of July (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 into the mainstem during the spring and summer and rear there or in the estuary until 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 Weitchepec), naturally produced Chinook salmon emigration peaked around April 21, 2001. The first hatchery-produced Chinook salmon were not observed until six weeks later and emigration of these fish peaked in mid-October on the lower Trinity River (Naman et al. 2004). Juveniles of this life history strategy may remain in tributaries until fall rains. The first two types of juvenile rearing strategy are likely influenced by mainstem flows. Wallace and Collins (1997) found that, in low flow years, Chinook salmon (probably from multiple ESUs) were more abundant in the Klamath River estuary than during high flow years, suggesting that the second strategy may involve moving into cooler estuarine water sooner than under high flow conditions.

Although the vast of majority of UKTR Chinook salmon use one of the two strategies described above, a small portion of juveniles spend an entire year in the river, mainly in the larger tributaries, entering the ocean the following spring as yearlings (Sullivan 1989). From 1997-2000, these yearlings emigrated as smolts through the middle Klamath River between early May and mid-June, before the peak of 0+ wild juveniles in mid-June (USFWS 2001). Yearling Chinook were captured in Bogus Creek between mid-January and mid-May and at Big Bar, Presido Bar, and below the Scott River through mid-June (Shaw et al. 1997).

A fourth life history variation has recently been described. Recent surveys have observed mature parr in the Shasta River (C. Jeffres, pers. comm. 2011). Mature parr are reproductively mature males that have never left fresh water (M. Knechtle, pers. comm. 2011).

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 and Chinook recaptured from the Klamath River generally use ocean areas that maintain temperatures between 8° and 12°C (Hinke et al. 2005). Chinook salmon from the Klamath and Trinity hatcheries were observed in August, south of Cape Blanco (Brodeur et al. 2004).

While there is significant variability in age composition of Chinook spawners returning to the Klamath basin, a majority are fish age 3 or 4 years. Some age 5 fish are observed but they make up a smaller proportion of the total escapement than grilse. Grilse are small, mostly male, two-year-old spawners. Between 1978 and 2006, they constituted 2-51 percent of the number of annual Klamath River Chinook salmon (CDFG 2006). Sullivan et al. (1989) observed that, in 1986, a larger proportion of four year old Chinook returned to the Salmon River (24%) than to other subbasins. In 1986, 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).

Habitat Requirements: Upper Klamath-Trinity rivers 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 even 17°-20°C is detrimental (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; 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). Magneson (2006) reported water temperatures up to 14.5°C during spawner surveys in 2005. The Shasta River was historically the most reliable spawning tributary in the Klamath River system in terms of water temperatures (Snyder 1923), but diversions of cold water, combined with 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.

A majority of spawning habitat in this ESU is found in larger tributaries and in the mainstems of the Klamath and Trinity rivers. Spawning occurs primarily in habitats with large cobbles, loosely embedded in gravel, with sufficient subsurface infiltration of water to provide oxygen for developing embryos. On national forest lands in the Scott River basin, a significant portion of such Chinook spawning habitat is in poor condition (Olson et al. 1992). 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 water flow and cold temperatures. Redds in the mainstem Trinity River averaged 4.4m long and 2.3m wide (Moffett and Smith 1950), where the loosened gravels permitted infiltration of oxygenated water. For maximum embryo survival, water temperatures must be between 6-12°C, with oxygen levels close to saturation (Myrick and Cech Jr. 2004). 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. Water temperatures of 8°C were associated with initiation of fry emergence in the Scott and Shasta rivers (Bartholow and Hendrikson 2006).

Water temperatures above 15°C stimulate juvenile emigration, although temperatures above 15.6°C can increase risk of disease (McCollough 1999). Daily average temperatures above 17°C increase predation risks and impair smoltification, while temperatures over 19.6°C decrease growth rates (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 are important refuge habitats during the day (Belchik 1997). Stratified pools and subsurface flows at the base of old landslides and gravel bars are also important thermal refuges (Klamath National Forest, unpubl. report). Elevated river temperatures (>16°C) increase mortality from *Ceratomyxa shasta* infection in Chinook salmon released from Iron Gate Hatchery, in association with 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 that of the Scott River. These habitats have temperatures of 10°-21.5°C and provide refuges from temperatures lethal to emigrating juveniles (Belchik 1997). Belchik (1997) determined that fish abundance in these cool water areas was significantly related to the distance from Iron Gate Dam, proximity to the nearest cool water refuge area, and minimum temperature of each refuge area.

Distribution: UKTR Chinook salmon are found in all major tributaries above the confluence of the Klamath and Trinity rivers and are raised in hatcheries below Iron Gate and Lewiston dams. Upper Klamath-Trinity rivers fall-run Chinook salmon historically ascended to spawn in middle Klamath tributaries (Jenny Creek, Shovel Creek and Fall

Creek) 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 and further restricted by the completion of a series of dams on the Klamath, concluding with construction of Iron Gate Dam in 1964. As a result, salmon (and other anadromous fishes) were denied access to approximately 563 km of migration, spawning and rearing habitats in the upper Klamath River basin (Huntington 2006). Along 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 they remain among 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 between Bogus Creek and the Shasta River and between China Creek and Indian Creek (Magneson 2006).

Upper Klamath-Trinity rivers 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). Historically, the majority of UKTR fall-run Chinook spawning in the Trinity River occurred between the North Fork Trinity River 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). Above Lewiston Dam, the Stuart Fork was an important historic spawning tributary, as were Browns and Rush creeks below the dam (Moffett and Smith 1950). 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 Trinity River and Cedar Flat (Quihiullalt 1999**).** Additional tributaries that support Chinook salmon spawning in the Trinity River system include the North Fork, New River, Canyon Creek, and Mill Creek. In the South Fork Trinity River, fall-run UKTR Chinook historically spawned in the lower 48 km up to Hyanpom, and in the lower 4 km of Hayfork Creek (LaFaunce 1967).

Trends in Abundance: It is likely that UKTR spring-run Chinook was historically the most abundant run in the Klamath and Trinity rivers (Snyder 1931, LaFaunce 1967) but, by the time records were kept, the spring run had been reduced to a minor component of Klamath salmon populations. Therefore, modern estimates of Chinook salmon numbers in the Klamath-Trinity system are generated primarily from UKTR fall-run Chinook. Snyder (1931) provided an early estimate for Klamath River Chinook runs of 141,000, based on the 1912 fishery catch of 1,384,000 pounds of packed salmon. Moffet and Smith (1950) estimated the Klamath River Chinook runs at 200,000 fish annually, using commercial fishery data collected between 1915 and 1943. USFWS (1979) combined these statistics to arrive at an annual catch and escapement of approximately 300,000 to 400,000 fish for the entire Klamath River system, during the period from 1915-1928. At the Klamathon Racks, a fish counting station proximate to 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). In 1965, 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 fish), Scott (8,000 fish), and Salmon (10,000 fish) rivers. Snyder (1931) noted that the Shasta River was the best spawning tributary in the basin; however, the number of returning spawners has markedly declined since that time. Leidy and Leidy (1984) estimated an annual average abundance of 43,752 Chinook from 1930-1937; 18,266 from1938-1946; 10,000 from 1950-1969; and 9,328 from1970-1976. A review of recent escapement into the Shasta River found an annual escapement of 6,032 fish from 1978-1995 and an escapement of 4,889 fish from 1995-2006 (CDFG 2006b). In the Scott River, fall Chinook escapement averaged 5,349 fish from 1978-1996 and 6,380 fish from 1996-2006. Analysis of natural spawner abundances suggests that numbers are fairly stable in several tributaries (Bogus Creek, Shasta River, Salmon River, Scott River, Trinity River) (Quiñones, unpublished data). Coots (1967) estimated the annual run of Klamath River Chinook salmon at 168,000, half of which ascended the Trinity River. Hallock et al. (1970) estimated 40,000 Chinook salmon entered the Trinity River above the South Fork. Burton et al. (1977 in USFWS 1979) estimated 30,500 Chinook 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).

In the 1980s, the Klamath River Chinook stocks accounted for up to 30% of the commercial Chinook salmon landings in northern California and southern Oregon, which averaged about 450,000 Chinook salmon per year (PFMC 1988). Between 1978 and 2006 the total in-river escapement of UKTR Chinook ESU ranged from 34,425 to 245,542 fish, with an average 5-year geometric mean of 112,317 fish (Figure 1). The mean number of natural spawners in the basin in recent years (2008-2012) was 79,187, which is equal to approximately 60% of the historical run of 300,000 spawners. The number of natural spawners in the basin appears to have remained steady since 1978 (Figure 1).

Hatchery operations have supplemented the abundance of UKTR Chinook salmon since completion of terminal mitigation hatcheries on the Klamath and Trinity rivers in the 1960s. The origins of hatchery stocks are principally from Klamath River fish and each hatchery relies on returning spawners for egg collection. Approximately 67% of hatchery releases have been fall-run Chinook from Iron Gate and Lewiston hatcheries (Myers et al. 1998), with between 7 and 12 million juveniles released annually (NRC 2004). Between 1997 and 2000, an average of 61% of the juveniles captured at the Big Bar out-migrant trap were hatchery-origin fish (USFWS 2001). At the Willow Creek out-migrant trap on the Trinity River, between 1997 and 2000, 53% and 67% of the Chinook captured in the spring and fall were hatchery-origin fish, respectively (USFWS 2001). Hatchery-origin adults also spawn in rivers, including all major tributaries (e.g., Shasta, Scott, Salmon rivers), although straying of hatchery fish is most pronounced in areas closest to the hatcheries (e.g., Bogus Creek and Shasta River in the Klamath drainage and upper main stem Trinity River).

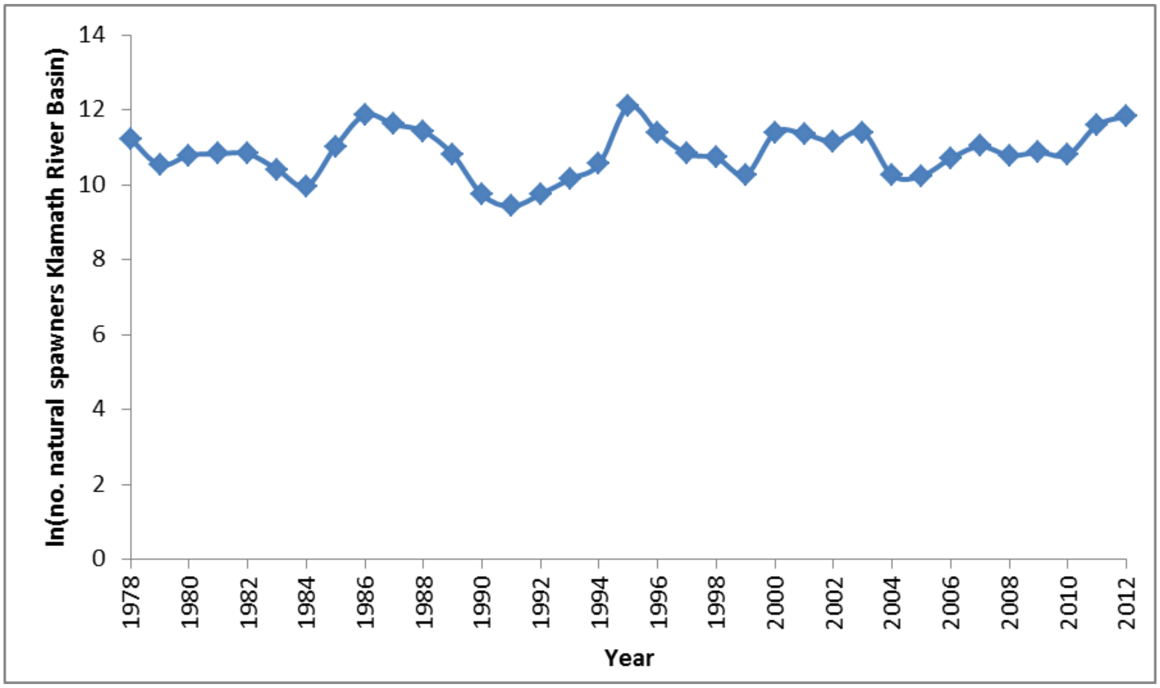

Figure 1. Number (ln) of UKTR fall-run natural spawners in the Klamath River basin, 1978-2012 (source data: CDFW 2012 Megatable). No trend in numbers was detected.

In general, historic numbers of wild UKTR fall-run Chinook probably ranged between 125,000 and 250,000 fish per year. While numbers over the past 25 years have often reached into that range, much lower numbers are typical and many fish are of hatchery origin. Of particular concern is the increasing trend of the proportion (%) of basinwide escapement made up of hatchery returns (Quiñones et al. 2013). However, factors influencing adult abundances include oceanic conditions and freshwater habitat quality; these factors differ by run and location (Quiñones 2011).

Nature and Degree of Threats: Numerous threats have influenced the status of UKTR Chinook salmon. Primary stressors include: dams, logging and other land uses, fisheries, hatcheries, and disease (Table 1).

Dams. Upper Klamath-Trinity rivers fall-run Chinook are primarily mainstem spawners, so Lewiston and Iron Gate dams negatively affected their population by changing downstream habitats (including altering seasonal flows and temperature regimes) and by blocking access to historic spawning area upstream. Iron Gate Dam and the chain of dams above it on the mainstem Klamath are used mainly for hydropower production, so they have had minimal impact on total flows below the dam (although water diversions to support agriculture in the upper Klamath basin reduce the amount of instream flow). However, dams have eliminated spawning gravel recruitment from upstream areas and reduced hydrologic variability. The lack of adequate flow releases is thought to have been a principal factor that caused a major fish kill in the lower Klamath river in September, 2002 (CDFG 2004).

Lewiston Dam and other dams on the Trinity River have substantially modified river flows and generally reduced the size and habitat complexity of the river channel. Starting in 1964, 75-90% of Trinity River flow was diverted to the Central Valley.

Declines of naturally-spawning fall-run Chinook populations were likely exacerbated by diversion of most of the river's water and corresponding reduction and degradation of spawning and rearing habitats. In 1984, Congress ordered restoration of the river to support salmon at historic levels (see http://www.trrp.net/). Little was accomplished until The Trinity River Mainstem Fishery Restoration EIS was completed and the Record of Decision (ROD) was signed on December 19, 2000. The EIS calls for numerous restoration actions, as well as a rough doubling of flows of the river mimicking the natural flow regime. Implementation is now underway (http://www.trrp.net/), after the commencement was delayed until 2004 by lawsuits.

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 Klamath River in Oregon, as well as from the Shasta and Scott rivers, reduces stream flows and increases temperatures, making many areas of formerly suitable habitat no longer suitable for salmon spawning or rearing. Because many farms use flood irrigation, return water flows back into the streams at high temperatures, further warming streams. 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 also reduces ground water tables and associated cold water inputs into rivers. 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.

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, roaded and mined. As a result, the Klamath River is regarded as impaired because of its nutrient loads, high temperatures, and low levels of dissolved oxygen. See the UKTR spring-run Chinook account in this report for further discussion on impacts from logging and other land uses.

Grazing. Livestock are grazed on many 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, resulting in stream incision, reduction of riparian cover, and silting of spawning gravels.

Rural residential. 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 throughout these basins. Widespread rural development results in increased sediment delivery to streams, particularly in the steep, mountainous terrain of this region, effluent from septic tanks and other pollutants, water diversion, deforestation and habitat fragmentation.

	Rating	Explanation
Major dams	High	Much former habitat is above dams; dams have decreased habitat quality downstream
Agriculture	High	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	Medium	Cumulative effects of numerous roads and rural development can negatively affect salmon habitats
Urbanization	Low	Urban areas are few, small, and restricted to main rivers
Instream mining	Medium	Legacy effects are still severe in some areas, while dredge mining can alter habitat and disturb fish (currently banned)
Mining	Low	Legacy effects of hard-rock mining are potentially severe in localized areas
Transportation	Medium	Roads present along many streams; sources of sediment and pollutant input along with habitat fragmentation
Logging	Medium	Both legacy effects and ongoing impacts degrade aquatic habitats; much greater historical impact
Fire	Medium	Fires predicted to become more frequent and severe, potentially degrading important headwater tributary habitats
Estuary alteration	Low	The Klamath River estuary is less altered than most north coast estuaries
Recreation	Low	Human use of rivers may impact behavior of spawning fish and juveniles
Harvest	Medium	Legal and illegal harvest, combined, may be negatively affecting abundance
Hatcheries	Medium	Principal run raised in Iron Gate and Trinity hatcheries
Alien species	Low	Few alien species in range, although brown trout present in Trinity River

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of UKTR fall-run Chinook salmon in California. 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 section for descriptions of the factors and explanation of the rating protocol.

Mining. Mining has dramatically altered river and stream habitats in the Klamath-Trinity Province, with lasting legacy impacts in many 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 was heavily altered in the Scott River Valley and remains so today, where a degraded river winds through immense piles of dredge tailings. Historic 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 (J. West, U.S.F.S., pers. comm. 1995). Mining and its legacy effects have disconnected and constricted juvenile salmon habitats, filled in adult holding habitats, degraded spawning grounds and altered the 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 adults and rearing juveniles (West 1991, Elder et al. 2002).

Suction dredging for gold can also negatively affect fall-run UKTR populations, although there is currently a moratorium in place. See the UKTR spring-run Chinook account in this report for more details.

Transportation. Roads are present along many streams, resulting in sediment or pollutant inputs; many roads in this region were constructed to provide access for timber harvest and mining and 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. Wild fires 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.

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. The Pacific Fisheries Management Council (PFMC) has paid particular attention to upper Klamath and Trinity River Chinook salmon in recent years because annual escapement goals have not met the Council's minimum escapement objective for natural adult spawners in 17 out of 35 years. In November, 2006, the PFMC accepted new fisheries guidelines that are intended to result in annual natural spawning escapements of 22,000 -35,000 fish. This was considered a compromise to account for: (1) recent critically low spawner abundances in consecutive years (2005-2006); (2) the risk that populations were dropping below critical genetic thresholds; (3) prevailing ocean conditions; and (4) Federal Endangered Species Act recovery actions for other species (PFMC 2007). Poor ocean conditions can severely impact escapement, especially when combined with high rates of harvest. In 2008, the minimum escapement goal was raised to 40,700 fish, partly to account for recent high returns. Harvest goals are often difficult to set because consistently poor conditions in freshwater, coupled with reliance on hatchery fish to support the fishery, means that ocean conditions become increasingly important in determining levels of adult returns. This results in extreme population fluctuations, as evidenced in recent years.

Because the status of both Central Valley and Klamath River salmon stocks is highly variable, the ocean fishery (and probably the inland sport fishery as well) is 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 spawning stocks in the mainstem Trinity and Klamath rivers are increasingly supported by hatcheries. 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 rearing and releasing fall-run Chinook in 1914. 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. A significant proportion of mainstem spawning now occurs between Shasta River and Iron Gate Dam. The proportion of hatchery returns to total escapement has increased from 0.18 from 1978-82 to 0.26 from 1991-95 and 0.29 from 2001-2006 (CDFG 2007, Myers et al. 1998). 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). Similar observations have been made on the Trinity River. Historically, most fall 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 monitoring traps were fish clipped at hatcheries. This proportion increased to more than two-thirds during the fall monitoring period (USFWS 2001), although this may attributed to the fact that most naturally produced Chinook in the basin are ocean type and emigrate in the spring and summer and hatchery releases of yearling fish occur in October. Large numbers of hatchery fish in the Klamath-Trinity system may impact naturally produced Chinook juveniles through competition, predation, and/or disease transmission. 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), which may also increase the incidence of disease transmission. Wild populations are also threatened with reduced fitness through interbreeding with hatchery fish (Quiñones et al. 2013).

Hatchery returns are likely replacing natural escapement of at least some wild populations of UKTR fall-run Chinook. The proportion (percent of basin-wide escapement) of fall-run Chinook natural escapement has significantly decreased ($p = 0.001$), concurrent with significant increases in hatchery returns to IGH and TRH. Since the 1980s, returns of Chinook salmon to IGH significantly increased ($p = <0.0002$), as did the number of hatchery strays throughout the basin ($p = 0.013$). Basin-wide fall-run Chinook adult abundance was significantly correlated to returns to both hatcheries ($r(27) =0.53$, $p = <0.05$). Fall-run Chinook natural escapement to Bogus Creek was significantly correlated to returns to both IGH ($r(27) = 0.60$, $p = <0.05$) and TRH ($r(27) = 0.58$, $p = <0.05$). Fall-run Chinook natural escapement to the Salmon River was significantly correlated to returns to IGH ($r(27) = 0.36$, $p = <0.05$). Fall-run Chinook natural escapement to the Trinity River was significantly correlated to returns to both IGH ($r(27) = 0.41$, $p = <0.05$) and TRH ($r(27) = 0.72$, $p = <0.05$) (Quiñones et al. 2013). These patterns suggest increasing dependence on hatchery propagation but may, alternately, signal similar responses of natural and hatchery spawners to environmental conditions. In either case, 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. See the Central Valley fall-run Chinook account in this report for further discussion on hatchery effects.

Synergistic impacts. Recent large scale die-offs of UKTR salmon and other fish in the Klamath River provide examples of how multiple factors can affect salmon runs. Chinook salmon in the Klamath and Trinity basins emigrate as juveniles and return to spawn as adults when water temperatures and minimum flows begin to approach their limits of tolerance, increasing their susceptibility to disease. In September, 2002, between 30,000 and 70,000 predominantly UKTR fall-run Chinook adult salmon perished in the lower Klamath River. The immediate cause of death was infection by ich disease (caused by the ciliated protozoan *Ichthyopthirus multifilis*) and columnaris disease (caused by the bacteria *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. In response to high water temperatures and low flows, fish apparently ceased migration and concentrated in large numbers in pools. These conditions allowed for a disease epidemic to sweep through the population of highly stressed fish. The contribution of low flows to this unfortunate and highly publicized event is underscored by the finding that increased base flows likely reduce pathogen transmission risk during Chinook salmon migration (Strange 2007).

In juvenile UKTR Chinook salmon, high water temperatures and low flows can also increase susceptibility to a number of other diseases. While the myxozosporean parasites common to the Klamath River, *Ceratomyxa shasta* and *Parvicapsula minibicornis* are often present, they are not always abundant nor do the conditions necessary for infecting large numbers of Chinook salmon occur regularly. *C. shasta* is known to occur in the mainstem and upper Klamath River, Copco reservoir, both Klamath and Agency lakes and the lower reaches of the Williamson and Sprague rivers (Buchanan et al. 1989, Hendrickson et al. 1989). It is likely that UKTR fall-run Chinook were historically infected by these diseases at low levels, but rarely did widespread epidemics occur because contributing factors such as high temperatures, low flows, poor water quality and lack of access to upper watersheds (greater spatial distribution and lower concentration of spawners) did not exist to the extent they do now. Although *C. shasta* does not appear to occur in the Shasta, Scott, and Trinity rivers (Foott et al. 2004), Trinity River smolts become infected with *C. shasta* while migrating through the lower Klamath River and a majority of those infected salmon later die of Ceratomyxosis (Foott et al. 2002). When high densities of infected fish and warm temperatures exist in combination, *C. shasta* infection appears to be accelerated (Foott et al. 2003). Large releases of hatchery fish may, therefore, be particularly susceptible and spread disease to wild fish. *P. minibocornis* appears to be more infectious than *C. shasta* and was detected in 23% of juveniles in the Klamath estuary and 95% of juveniles in the Klamath River (Nichols et al. 2003). 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, therefore, ultimately select for juvenile UKTR Chinook that emigrate at times when temperatures in the main river are cooler, increasing the potential for more frequent disease outbreaks.

Effects of Climate Change: The 'ocean' life history strategy of UKTR fall-run Chinook makes them least vulnerable of all runs to climate change, although warm temperatures in the Klamath River are already a substantial threat. Elevated water temperatures have been identified as a factor limiting anadromous salmonid abundance in the Klamath River basin, as the result of multiple land and water use impacts, combined with climate change. Water temperatures have increased approximately 0.5°C/decade and has resulted in the loss of about 8.2 km of cool summer water in the mainstem each decade (Bartholow and Hendrikson 2006). Bartholow and Hendrikson (2006) documented that the timing of high temperatures potentially stressful to Chinook has moved forward seasonally by about one month. These temperature changes are consistent with measured basin-wide air temperature increases. Resultant loss of rearing habitat, both temporally and spatially, may also influence the survival of UKTR fall-run Chinook. See the UKTR spring-run Chinook account in this report for further information on potential climate change impact to salmon populations in this region. 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.

Status Determination Score = 3.0 - Moderate Concern (see Methods section, Table 2). 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 hatchery production may be masking a decline of wild production in the Klamath-Trinity basins, which does not bode well for the longer-term persistence of wild salmon stocks (Quiñones 2011). The UKTR Chinook salmon ESU was determined to not warrant listing under the Federal Endangered Species Act on March 9, 1998. Upper Klamath-Trinity rivers fall-run Chinook are a U.S. Forest Service Sensitive Species. They are managed by CDFW for sport and ocean fisheries, and by PFMC for 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 minimum escapement goal is not always met
Intervention dependence	3	Major intervention is required to maintain fisheries, primarily through hatchery propagation and flow regulations
Tolerance	3	Moderate physiological tolerance
Genetic risk	2	One 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	Two threats rated “high” and eight “medium” (Table 1)
Average	3.0	21/7
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 major negative factor contributing to status, 5 is a factor with no or positive effects on status, and 2-4 are intermediate values. See methods section for further explanation.

Management Recommendations: There are many ongoing, as well as potential, management options for the Klamath and Trinity rivers to benefit UKTR Chinook salmon. The Trinity River Restoration Program (TRRP) is focused on maintaining and recovering populations of UKTR Chinook salmon by taking a holistic approach to restoration. The TRRP approach involves flow manipulations and focused restoration activities to meet the habitat requirements of Chinook and other keystone aquatic species. A similar program should be implemented as part of the Klamath River Restoration Program. Models evaluating limiting factors and habitat availability for UKTR Chinook salmon suggest that crucial short-term actions are required to increase UKTR fall-run Chinook spawners and prevent further declines (Bartholow and Henrikson 2005). Restoration objectives for the TRRP provide reasonable targets for ameliorating limiting factors and increasing suitable habitat quantity and quality in the Trinity River. 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.

Water temperatures may be more important to UKTR Chinook salmon than a restored natural flow regime per se, although the two are often interrelated. Protecting and restoring cool water habitats throughout the Klamath and Trinity watersheds will be essential to conserving these fish. Bartholow (2005) modeled a changing thermal regime in the Klamath River that could eventually eliminate UKTR Chinook spawning in the mainstem and disconnect critical spawning tributaries from the lower mainstem, an important migratory corridor. Both adult immigrants and juvenile emigrants are often exposed to water temperatures that are bioenergetically suboptimal or even lethal, especially in relation to increased incidence of disease outbreaks. The behavioral plasticity displayed by Chinook salmon indicates strong potential for management strategies that increase juvenile survival through maintenance of multiple life history patterns, rather than reliance upon hatchery production which may lead to loss of life history diversity. In main-stem habitats, Belchik (1997) demonstrated that UKTR Chinook use cool water areas as refuges; use of such habitats increases adult spawner and juvenile outmigrant survival. These key habitats should be conserved, monitored and, where possible, expanded. Many of the recommendations for conservation of UKTR spring-run Chinook also apply to fall-run Chinook (see UKTR spring-run Chinook account in this report).

Figure 2. Distribution of upper Klamath-Trinity rivers fall-run Chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), in California.