CHUM SALMON
Oncorhynchus keta (Walbaum)

Extirpated or Critical Concern. Status Score = 1.6 out of 5.0. The status of chum salmon is poorly understood. If they have not already been extirpated as a self-sustaining species, their populations are so small as to be hard to detect.

Description: Chum salmon reach up to 1 m TL and 20.8 kg, but in California they are typically <65 cm TL. Unlike other salmon, except sockeye, they lack black spots on the back and fins. They have 10-14 rays in the dorsal fin, 13-17 in the anal fin, 14-16 in each pectoral fin, and 10-11 in each pelvic fin as well as 11-17 short, smooth gill rakers on the lower half of the first gill arch. The scales are tiny (124-153 in the lateral line) and branchiostegal rays are 12-16 on each side. Spawning male chum salmon have a slight hump and a hooked snout with conspicuous canine-like teeth; they are dark olive on the back and dark maroon on the sides, with irregular greenish vertical bars on the sides. Females are similar in color, although they are less maroon on the sides; they also lack a hump and the jaw is less hooked. Parr have 6-14 pale vertical bars (parr marks) that seldom extend below the lateral line, with light areas in between the marks being greater in width than the width of the marks themselves.

Taxonomic Relationships: The chum salmon forms a distinct evolutionary lineage within the genus *Oncorhynchus* with the pink (*O. gorbuscha*) and sockeye (*O. nerka*) salmon (Healey 1991). Chum salmon have strong homing tendencies (Salo 1991) which contributes to genetic isolation of spawners in different streams. No systematic genetic studies on chum salmon are available for California fish, so their relationship to more northern populations is not well understood. However, coastal populations in California, Oregon, and Washington are considered part of the "loosely defined" Pacific Coast ESU (Johnson et al. 1997, p. 105; NMFS 2005). DNA 'bar coding' of a single chum salmon taken from the San Joaquin River in 2013 indicated it was related to fish from British Columbia and Oregon (Root et al. 2015).

Life History: Because of their economic importance, life history, wide distribution, and habitat requirements chum salmon have been well studied in Asia, Alaska, and Canada (Salo 1991, Moyle 2002).

Although chum salmon have been recorded as migrating over 2,500 km up the Yukon River, Alaska, and the Amur River, Russia, they are not particularly strong swimmers for salmon and are easily stopped by low barriers. This results in most chum salmon spawning within 200 km of the ocean. Some populations even spawn in the intertidal reaches of streams. Chum salmon in the northern half of their range in North America tend to spawn in June through September, while more southern populations spawn in August-January. Adults are usually observed in California streams in December and January, but they can occur as early as August. In Mill Creek, a tributary to the Smith River, chums enter during mid-December, but only in years when stream flows are high. During years of low flow, the fish may be spawning instead in the mainstem Smith or in larger tributaries.

Adults home to natal streams where they spawn at 2-7 years of age, but primarily at ages 3-5 (Salo 1991, Moyle 2002). Each female digs a connected series of redds in which the eggs are deposited during spawning; the female guards the last redd until she dies. Males are sexually active for 10-14 days, spawning with multiple females. Large females produce over 4,000 eggs, but the average fecundity is 2,400-3,100 eggs. Fertilized eggs hatch after about 2-6 months of incubation, usually from December to February. Alevins absorb their yolk sac in 30-50 days, growing to approximately 35 mm TL before emerging from the gravel. Like pink salmon, fry spend only a short time in fresh water, moving into estuaries soon after emerging from the gravel. Depending on distance traveled, fry in fresh water are 35-70 mm TL. They may remain in estuaries, however, for several months before moving out into more oceanic waters. Movement of fry is mainly nocturnal, although they may migrate during the day if water clarity is low.

Fry may not feed in fresh water if their downstream migration is short; otherwise they feed on small aquatic invertebrates, primarily as drift. In estuaries, they feed mostly on benthic prey, such as copepods and amphipods. As they move into deeper water and grow larger, chums devour a wide variety of invertebrates as well as fishes. However, for subadults, gelatinous zooplankton, especially pteropods, seem to be especially important in their diet (Salo 1991). As a result of their short stay in fresh water compared to other salmon, their growth and survival is more closely tied to local ocean productivity than food availability in fresh and estuarine waters (NOAA Fisheries 2014).

Habitat Requirements: Chum salmon adults and maturing juveniles live in the open waters of the ocean, but juveniles are bottom oriented in rivers and streams. Optimal temperature ranges for freshwater portions of the life cycle are: adult migration, 7-11°C (range, 0-21°C); spawning, 7-13°C; incubation, 4-12°C; fry rearing/outmigration, 11-15°C, although fish can successfully live through periods of suboptimal temperatures (Moyle 2002, Richter and Kolmes 2005). Spawning takes place in gravel 1-10 cm in diameter but optimal gravel size seems to be 2-4 cm (Salo 1991). Relatively shallow depths (13-50 cm) for spawning are preferred.

Eggs and alevins occur primarily in fresh water, although spawning in intertidal areas occurs. The fry prefer shallow (< 1 m) water during their out-migration. An acclimation period to estuarine (10-15‰ salinity) conditions may be required prior to entering salt water. Juveniles can be killed by high suspended sediment loads (15.8-54.9 g l^{-1}) that abrade gills and prevent feeding (Moyle 2002).

Environmental tolerances have not been studied in California, the southern end of chum salmon range, but limiting factors are likely to be (1) temperatures >13°C for spawning and incubation, (2) intragravel dissolved oxygen in spawning areas at less than 90% saturation, (3) current velocities over spawning areas flowing at less than 30 cm/sec, (4) potential spawning areas dominated by gravel < 2 cm in diameter, (5) areas suitable for spawning that are < 50 cm deep, (6) streams containing high silt loads, (7) limited ocean access during fry outmigration periods, and (8) limited access of adults to spawning streams (Salo 1991).

Distribution: Chum salmon have the widest natural distribution of any Pacific salmon (NOAA Fisheries 2014). In Asia, the native range of spawning chum salmon seems to be streams from Korea north to the Arctic coast of Russia, although they are now raised in large numbers in hatcheries in northern Japan. In North America they range from the Mackenzie River on the Canadian Arctic coast southward into central California. Nineteenth century narratives generally have chum salmon occurring in coastal streams from San Francisco northward, albeit with no documentation of southern fish (Leidy 2007). They have been caught in the ocean as far south as San Diego, but the southernmost freshwater record is the San Lorenzo River, Santa Cruz County (Moyle 2002). At present, they become progressively less common in southern streams within their historical range (Moyle 2002). The southernmost populations for which annual spawning is documented appear to be in streams tributary to Tillamook Bay region in northern Oregon south to the Nestucca River (Johnson et al. 1997; NOAA Fisheries 2014).

Historically, they were considered to have small spawning runs in the Sacramento and Klamath (Trinity) rivers (Mills et al. 1997) and fish were commonly observed in other coastal rivers as well. During a ten-year (1949-1958) survey of the Sacramento River system, 68 chum salmon were recorded, leading Hallock and Fry (1967) to conclude that a very small run was present. A few spawners still are observed in the Sacramento River but not every year. In recent years, small numbers of adults have been recorded from two San Francisco Bay tributaries, and in 2004, 2005 and 2006 juveniles were collected from the Napa River estuary during a fish monitoring program (Stillwater Sciences 2006, Leidy 2007, Martin 2007). A single adult female was captured in an irrigation canal flowing into the San Joaquin River in December 2013 (Root et al. 2015) and small numbers (6 total in 2001-2004) have been observed ascending the Mokelumne River, which flows into the Delta (M. Workman, EBMUD, pers. comm. 2016).

Chum salmon are observed in the Klamath and Trinity rivers on a regular basis. The California Academy of Sciences has a small collection of parr taken from the Klamath River in 1944. Screw traps set in the rivers catch juvenile chum salmon on an annual basis, at least when they are looked for (Moyle 2002), suggesting small runs still exist. Adults are also occasionally seen but most are presumably overlooked. Thus a few adults have been observed annually in the South Fork Trinity River, the apparent remnant of a larger run that existed there prior to the 1964 flood (T. Mills, CALFED, pers. comm. 1995). One adult was seen in the Salmon River ca. 2007 (J. Grunbaum, USFS, pers. comm. 2009). Monitoring of Mill Creek, a tributary to the Smith River estuary, by J. Waldvogel (2006) suggests that chum salmon spawn there on a regular basis, based on the occurrence of adults, juveniles, and smolts (Stillwater Sciences 2002). They occur often enough to suggest that there may be a small annual run in the lower Smith River. Three adults were caught in the Rowdy Creek Hatchery trap (Smith River, one per year in three consecutive years (A. Van Scoyk, CDFW, pers. comm. 2009), 1994-1996. A single chum salmon was also identified in the headwaters of the North Fork Smith River in Oregon during spawning surveys in winter 2013-2014, the first known recording of this species so far upstream in this basin (Garwood, Larson, and Reneski 2014). Chum salmon are also observed on an irregular basis in other coastal streams, such as Redwood and Lagunitas creeks in Marin County (Ettlinger et al. 2005) and Prairie Creek in Humboldt County (R. Bellmer, CDFW, pers. comm. 2010). Regular surveys of spawning salmon on Lagunitas Creek since 1995 have observed 1-3 chum salmon every year, including individuals on redds (Ettlinger et al. 2005), although there has been no evidence of successful spawning (Ettlinger et al. 2015). Chum salmon have been observed in the Russian River in 6 of 16 years; a total of 16 fish were counted passing through a weir (S. Chase, SCWA, pers. comm. 2016). There is no evidence of spawning although the counting weir was well upstream of much potential spawning habitat.

Trends in Abundance: Chum salmon are abundant from Washington on north, with many runs supported by hatchery production (Johnson et al. 1997). They have probably always been uncommon in California; there is only limited evidence for spawning, although systematic efforts to find observe spawning or collect young have been few. There is evidence of spawning in the South Fork Trinity River. In the period 1985-1990, 1-3 adults were seen or captured every year except 1988 and juveniles were taken on at least six occasions; one pair was observed spawning in 1987, and one fish caught in 1990 was spawned out (Mills et al. 1997). USFWS sampling crews collected 21 chum juveniles and 2 fry in the Trinity River and 4 juveniles in the

Klamath Estuary during 1991 (T. Kisanuki, unpubl. data), but they are easy to overlook among the thousands of other salmon taken in the traps. In the West Branch of Mill Creek, a tributary of the Smith River, 1-8 spawning chums were observed in each of 10 years between 1980 and 2002, entering the stream with Chinook salmon during early to mid-December during high stream flows (Waldvogel 2006). In 2001-2002, both adults and juveniles were observed (Stillwater Sciences 2002). The fact that Mill Creek has had chum spawning reported for so many years is presumably in part a function of observers being present and in part a function of its estuarine position, an attractive location for chum salmon. Even though they are not observed every year, the frequency of observations suggests that alternate spawning areas may also be present in the main stem Smith River or its other tributary streams during years when spawning habitat is not accessible in Mill Creek.

There apparently was once a small run in the Sacramento River, with spawner estimates of 34-210 fish annually in the 1950s (Mills et al.1997). Subsequent records have been spotty (Moyle 2002) and they are rarely seen in salmon surveys. Curiously, chum salmon juveniles have been captured recently in the Napa River, indicating successful spawning (Martin 2007).

Overall, it appears chum salmon spawn, at least sporadically, in California streams from San Francisco Bay north to the Oregon border. Recent evidence suggests that the only California rivers used by chum salmon for spawning on a regular basis have been the South Fork Trinity, Klamath and Smith rivers, although the numbers of fish in each river is (was) small. It is highly likely that chum salmon were more abundant and widely distributed along the California coast in the past. However, chum salmon abundance has always been low in California compared to other salmon, few observers are aware of them, and juveniles are easy to overlook, so there are no reliable trend data available on their abundance. It is reasonable to think, however, that they once maintained small populations in the Sacramento River and various coastal rivers that have been extirpated in the last 50-70 years and that existing populations are likely to be extirpated in the near future, if they have not been already.

In Oregon, Nehlsen et al. (1991) list 10 populations at high or moderate risk of extinction, the closest to California being in the Elk River, in southwestern Oregon (Curry County). Johnson et al. (1997) indicate these populations have largely been extirpated with populations persisting in streams in the Tillamook region (NOAA Fisheries 2014).

Overall, chum salmon likely maintained a number of small populations in California, most of which were lost due to wide-scale changes in California rivers in the past 150 years. Today most occurrences in California are likely strays from the large populations that exist in the Pacific Northwest from both natural and hatchery production.

Factors Affecting Status: The apparent historical rarity of chum salmon in California makes it difficult to identify factors that have negatively affected their abundance. However, chum salmon historically spawned in the lower reaches of river systems in Oregon and California (Salo 1991) and these are the reaches most likely to be degraded by human activity, such as logging, road building, mining, channelization, and draining of estuarine marshes. There is so little information available on them in relation to chum salmon that no further discussion is merited beyond what is presented in Table 1.

If California populations are largely driven by fish ‘straying’ from more northern populations, especially those with large proportions of hatchery fish, then their abundance would also be related to factors such as ocean conditions, hatchery production, and status of populations in the northern part of their range.

Factor	Rating	Explanation
Major dams	Low	Most populations well below major dams but altered flows could be an issue.
Agriculture	Medium	Estuaries highly altered for pasture, long-term degradation of watersheds.
Fire	Low	Fires may increase siltation of spawning areas.
Grazing	Low	Long-term degradation of watersheds increases siltation.
Rural/ residential development	Low	Most rivers where chum salmon are encountered are in rural areas, but impacts of residential development are unknown.
Urbanization	n/a	
Instream mining	Low	Gravel mining and gold dredging could alter habitat.
Mining	n/a	
Transportation	Medium	Roads are present or near most streams.
Estuary alteration	High	Loss of rearing habitat occurs in estuaries as habitat becomes degraded or constricted.
Logging	High	This has had a major impact on known spawning watersheds such as South Fork Trinity River.
Recreation	Low	Lower reaches of rivers where chum spawn are often a focus of fishing and other recreation.
Harvest	Low	Some commercial and recreational harvest; poaching may occur.
Hatcheries	Low	Some possibility that fish in California waters could be strays of hatchery origin.
Alien species	n/a	

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of chum 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 low. See methods for explanation.

Effects of Climate Change: Moyle et al. (2013) consider chum to be "critically vulnerable" to climate change, while admitting very little is known about likely effects. Climate change effects could be minimal on the freshwater portions of the life cycle because most spawning takes place in the lower reaches of rivers, in the coastal fog belt, which are likely to remain cool, except the South Fork Trinity River. On the other hand, even small changes in flows or temperatures and/or small changes in ocean conditions could eliminate small, fragile populations. Poor ocean conditions (e.g., reduced upwelling and food availability, higher temperatures) in particular could reduce survival in the ocean and reduce connections to more northern populations.

Status Score = 1.6 out of 5.0. Critical Concern or Extirpated. Johnson et al. (1997, p. 164) reported chum salmon as being extinct in California and all populations in Oregon as being "depressed or extinct." There is very limited evidence to support the presence of 2-3 very small self-sustaining populations (in Smith, Klamath, and Trinity rivers) in the state, which, if they exist, are all threatened with extinction. However, given the paucity of data, the certainty of the status of these populations is low (Table 2). The alternative, however, is to admit they are extirpated from the state as a viable species with records resulting entirely from fish straying from elsewhere. In this case, spawning in California streams would take place mainly when populations are high in the ocean and ocean conditions are favorable for fish to stray from more northern populations. At present, there is no hard evidence to support either hypothesis, so the conservative course of action is to assume chum salmon populations continue to exist in California and to take actions to enhance them as the southernmost populations of the species. Because California populations are not regarded as a distinct ESU, due to lack of information, chum salmon are not considered to be threatened in California by AFS (Jelks et al. 2008). The southernmost large runs, in the Columbia River and Hood Canal, Washington (summer run) are listed by NMFS as threatened (NOAA Fisheries 2014).

Metric	Score	Justification
Area occupied	2	If chum salmon are still maintaining populations, there are 2-3 (Smith, Trinity, Klamath rivers).
Estimated adult abundance	1	There is little evidence that any population is more than a handful of spawners, perhaps 6-20 in most years.
Intervention dependence	2	No effort is currently being made to specifically protect chum salmon runs; unlikely for species to persist in CA without intervention.
Tolerance	2	Southern populations have fairly narrow spawning habitat requirements; young require functioning estuarine habitats for rearing.
Genetic risk	1	California populations, if not already extirpated, are extremely small and vulnerable to inbreeding depression and other genetic problems. Genetic studies needed on CA populations.
Anthropogenic threats	2	2 High threats; severity of most threats unknown.
Climate change	1	Small changes in flows or temperatures and/or small changes in ocean conditions could eliminate the populations.
Average	1.6	11/7.
Certainty (1-4)	1	Information is very limited.

Table 2. Metrics for determining the status of chum salmon in California, 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 low. See methods for explanation.

Management Recommendations: The chum salmon is an enigmatic, cryptic species in California. Arguably, it is already too late to protect whatever spawning populations once existed and recent records all seem to be of individuals straying from more northern populations. However, surveys in the South Fork Trinity, Klamath, and Smith rivers should be conducted to determine if fish still spawn there. If present, they will benefit from maintaining suitable habitat, flow, and water quality to protect and enhance as a group the imperiled salmonids (including summer steelhead) in those rivers. Once key spawning areas are known, specific plans should be established for enhancing conditions. The management of Mill Creek in the Smith River system may be a model for management of similar streams that might support chum salmon (Stillwater Sciences 2002). However, in general, it is likely that chum salmon, like other salmon, will benefit from restoring the larger coastal estuaries, such as that of the Eel River, to more naturally functioning systems, away from their present state as diked and drained pastureland with narrow channels and breached lagoons.

Genetic studies on California and Oregon chum salmon are needed to determine if they are self-sustaining or are just part of the larger population in the ESU, with southern populations maintained by 'strays.'

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