BULL TROUT
Salvelinus confluentus

Extinct in California. Status Score = 0.0 out of 5.0. Bull trout are extinct in their range in California; the last known individual was captured on the McCloud River in 1975. Bull trout were likely in decline for most of the 20th century prior to their eventual extirpation.

Description: The bull trout is a large, piscivorous salmonid that typically thrives in habitats with abundant juvenile salmonids such as salmon or steelhead fry or parr (Brenkman et al. 2007). It has fine scales (110 along the lateral line) and has white or cream leading edges on the pelvic, pectoral and anal fins. Live fish are olive green in color with tiny yellowish spots on the back and small red spots on the sides. The body usually has a few yellow spots at the base of the tail. In adults, the head is broad, flat between the eyes, and long, making up more than 25 percent of the body length in adults. The eyes are close to the top of the head to suit its ambush stalking tactics. The mouth is large, with conspicuous sharp teeth; the maxillary bone of the upper jaw extends beyond the eye. The lower jaw has a fleshy nob at its tip that fits into a notch on the top of the upper jaw (between the premaxillary bones). The adipose fin is large, making up about 50–85 percent of the depth of the caudal peduncle. For McCloud River fish, the branchiostegal rays numbered 13-15 per side; the mandibular pores, 7-9 per side; and the gill rakers, 15-18 per arch, with visible teeth on the anterior margin of each (Cavender 1997).

Taxonomic Relationships: Bull trout are part of the Arctic char (*Salvelinus alpinus*) complex, which includes species of the genus *Salvelinus* such as the Eastern Brook "trout." Bull trout were once considered to be the same species as Dolly Varden char (*S. malma*), a largely anadromous coastal species, and all three species have been lumped into once great taxon (Behnke 2002). However, studies by Cavender (1978), Hass and McPhail (1991), and others have eliminated doubts about their distinctiveness and species status (Behnke 2002). Museum specimens of California bull trout are distinct morphologically from other populations (Moyle 2002), so if they were still present they would probably be treated as an Evolutionary Significant Unit (ESU) confined to California.

Life History: Bull trout in California were largely unstudied until they became extinct (Wales 1939, Sturgess and Moyle 1978, Rode 1990) and the information summarized here is from other regions, as presented by Moyle 2002. Bull trout can be a) adfluvial, where adults live in lakes and spawn and rear in streams, b) fluvial, where all stages live in streams, but adults migrate up tributaries for spawning), c) stream resident fish with no separation of life history stages, or d) anadromous, where immature fish and adults undertake repeated estuary and/or ocean migrations to attain large sizes and seek more abundant sources of prey (Brenkman, Corbett, and Volk 2007). Most resident populations remain in small streams, and it is possible that many, if not all, are remnants of once-fluvial populations (e.g., populations in Klamath Basin tributaries in Oregon). The population was apparently once fluvial in the McCloud River, with adults

concentrating in pools in the lower reaches of the river, migrating upstream to spawn in higher-gradient reaches below Lower Falls (Rode 1990).

Juvenile bull trout (<11 cm TL) feed heavily on aquatic insects, and fish gradually become more important in their diet as they grow larger. Bull trout more than 25 cm TL are primarily piscivorous, with juvenile trout, salmon, sculpins, and their own young making up the bulk of the diet. Frogs, snakes, mice, and ducklings have also been found in their stomachs. Bull trout are ambush predators, typically lying in wait underneath a log or ledge and opportunistically grabbing passing fish. High bull trout densities are often associated with concentrations of small fish from migratory populations. Presumably, Chinook salmon eggs and juveniles rearing in the McCloud River year-round were once a major source of food for bull trout.

Bull trout grow slowly and are long-lived for salmonids, with lifespans up to 20 years. As a result, they are capable of achieving large sizes. They typically reach 5-8 cm TL in their first year, 10-14 cm in their second, and 15-20 cm in their third. Growth is slowest afterward in resident populations, and fastest in adfluvial populations, where individuals may reach 40-45 cm TL in 5-6 years. The largest bull trout on record, from Lake Pend Oreille, ID, measured 103 cm TL (14.5 kg). Bull trout from the McCloud River were purported to reach over 7.3 kg (ca. 70 cm TL), and the California angling record is a fish from McCloud Reservoir that weighed about 5.1 kg. A fish that lived for 19 years in the Mt. Shasta hatchery weighed around 6 kg at the time of death. The last two bull trout caught from the McCloud River (in 1975) measured 37 cm SL and 42 cm SL and were 4-6 years old (Sturgess and Moyle 1978).

Bull trout spawn for the first time in their fourth or fifth year at lengths of 40 cm TL or more. Fish from resident populations spawn at smaller sizes (25-30 cm TL) and presumably younger ages. They usually migrate upstream to spawn in gravel riffles of clear, cold streams. Migrations of 150-250 km are not unusual in adfluvial populations where passage facilitates such movement. Spawning migrations can begin in July or August, but spawning does not begin until water temperatures have dropped below 9-10°C in early fall (September and October) in the McCloud River. Female spawners choose sites that have relatively low gradients, expanses of loose gravel, groundwater or spring inflow, and nearby cover, such as pools. Spawning behavior is similar to that of brook trout, although males may spawn with multiple females. Small jack males are present among the spawners as well. Each female, depending on size, lays 1,000-12,000 eggs. Embryos are buried at a depth of 10-20 cm and hatch in 100-145 days. They remain in the gravel for another 65-90 days, absorbing their yolk sacs. They begin feeding while still in the interstices of the gravel and emerge at 23-28 mm TL to fill their air bladders, usually in April or May. Young-of-year bull trout spend much of their first summer along stream edges or in backwaters until they reach about 50 mm TL, when they move out into faster and deeper water to seek greater foraging opportunities.

Habitat Requirements: According to Moyle (2002) streams containing bull trout require exceptionally cold, clear water, often originating from springs. They are rarely found in streams that have maximum temperatures greater than 18°C, though Behnke (2002) suggests 15°C is the upper thermal tolerance. Optimum temperatures appear to be 12-14°C (10-12°C according to Behnke 2002) for adults and juveniles, and 4-6°C for embryo incubation. Prior to the construction of McCloud Dam, the McCloud River

provided near-ideal temperatures for bull trout, with its major source (Big Springs) flowing in at 7.5°C year-round and temperatures in the lower river rarely exceeding 13°C during the summer (Rode 1990). The river also had other characteristics favorable to bull trout: good spawning and rearing habitat below Lower Falls, deep pools in the lower river for adults, and abundant prey in the form of juvenile Chinook salmon.

Adult bull trout in rivers and smaller streams prefer to live on the bottom in deep pools. Adfluvial populations thrive in large coldwater lakes and reservoirs (e.g., Flathead Lake and Hungry Horse Reservoir, MT). In California, bull trout populations in both McCloud and Shasta reservoirs were unable to maintain themselves. Juvenile trout up to 20 cm TL are strongly bottom-oriented, hanging out near or under large rocks and large woody debris, in stream reaches with coarse, silt-free substrates. They seem to prefer pockets of slow water near faster-moving water that can deliver food. As they grow larger, they move into pools.

Distribution: In California, bull trout were found in nearly 100 km of the McCloud River (Shasta and Siskiyou counties), from its mouth to Lower Falls (Rode 1990). They may also have occurred in spring-fed tributaries to the Upper Sacramento and Pit Rivers, but records are lacking. According to Moyle (2002), this was historically the southernmost distribution of the species. Today the southernmost populations are found in the Jarbridge River, NV, and small streams in the upper Klamath Basin, OR. The northernmost populations are found in the headwaters of the Yukon River, British Columbia. The easternmost populations are found in Columbia River tributaries in Alberta and Montana. They are widely scattered in the Columbia River system, in the headwaters of coastal rivers of British Columbia, and in interior drainages of British Columbia and Alberta (Saskatchewan, Athabasca, and Peace Rivers). The presence of many disjointed populations at present indicates a wider distribution in the Pleistocene period, under wetter and cooler conditions than exist now.

Trends in Abundance: Bull trout are extinct in California. The last known bull trout caught in California was captured by University of California, Davis graduate student Jamie Sturgess in 1975, by hook and line. It was tagged and released but not seen again. Bull trout were apparently in decline throughout most of the 20th century, although in the 1930s they still supported a small fishery in the McCloud River (Wales 1939). By the 1950s, after the construction of Shasta Dam, they were scarce (Rode 1990). They became increasingly rare in the 1960s and were likely extirpated by the late 1970s.

Nature and Degree of Threats: Habitat degradation and fragmentation associated with the construction of Shasta and McCloud reservoirs, coupled with non-native trout introductions, were the principal causes of bull trout decline in California. According to Moyle (2002, p. 299-300) the factors that resulted in their extirpation from California are:

Depletion of salmon. In the 19th century, the McCloud River supported at least two runs of Chinook salmon, (probably) a small run of coho salmon, and a steelhead run. Salmon carcasses and juveniles likely supported fairly large bull trout populations at that time. The 19th-century Sacramento River commercial fishery, combined with sediments from hydraulic mining, severely depleted salmon runs in the McCloud River. The Baird Hatchery, established on the lower McCloud River in 1874 to take eggs from Chinook

salmon in order to help restore depleted runs, may ironically have contributed to the decline of McCloud River salmon because the weir at the hatchery blocked much of the run at times. In the early 20th century, Chinook salmon recovered somewhat, but not to former levels. In 1942, Shasta Dam blocked access for all salmon upstream and passage of bull trout downstream. Salmon were a major driving force in the McCloud River ecosystem, so their depletion and loss undoubtedly had a major impact on the piscivores in the river, including bull trout.

Introduction of brook trout. Brook trout were established in the McCloud River watershed by about 1910. They are now present in small tributaries that juvenile bull trout may once have used for rearing. Brook trout will hybridize with bull trout, and this is a major cause of the decline of resident populations in Oregon and elsewhere. There is no evidence that hybridization took place in the McCloud River.

Introduction of brown trout. Brown trout probably entered the McCloud River in the 1920s, although they may not have been abundant until after Shasta Reservoir was created in the 1940s. The reservoir allowed a substantial migratory population of large brown trout to develop. Large brown trout are ecologically similar to bull trout, hanging out in large pools and preying on other fish. They may have contributed to bull trout decline through a combination of competition and predation. A recent study suggests that under increasing warming associated with climate change, brown trout are replacing bull trout in waters with temperatures greater than 12°C across Montana; perhaps under warmer temperature regimes, brown trout were better able to outcompete and displace the native bull trout in the McCloud River (Al-Chokhachy et al. 2016).

Shasta Dam and Reservoir. Construction of Shasta Dam in 1942 and the creation of Shasta Reservoir blocked access of major salmon runs, provided better habitat for migratory brown trout, and flooded about 26 km of the lower McCloud River (nearly a quarter of the bull trout's habitat). Although fluvial bull trout elsewhere have become adfluvial following construction of reservoirs, this did not happen with Shasta Reservoir. Small numbers of bull trout were documented in the reservoir fishery, but runs from the reservoir back into the McCloud River never developed. Presumably, the reservoir was too warm for growth and survival (Rode 1990).

McCloud Dam and Reservoir. McCloud Dam was completed in 1965 and blocked the river about 45 km upstream from Shasta Reservoir. This was the final blow to bull trout in California. The McCloud Reservoir flooded 8 km of prime habitat for bull trout, severed the connection between juvenile and adult habitats by blocking adult migrations to upstream areas, and altered conditions downstream of the dam, reducing flows, reducing recruitment of spawning gravel, reducing the frequency of flushing flows, increasing turbidity in the fall, and, most importantly, raising water temperatures in the river by 5-10°C (Rode 1990). After completion of the dam, long-lived bull trout survived for 10-12 years before becoming extirpated.

Status Score = 0.0 out of 5.0. Extinct in California. Bull trout are extinct in California and are listed by the USFWS (1999) as threatened throughout the rest of their range in the United States.

Effects of Climate Change: The persistence of bull trout in California despite warm summer temperatures was likely due to the springs that maintain cool flows in the

McCloud River, even during severe drought. Increases in air temperature or reductions in snowpack during prolonged drought may reduce available wetted habitat, as was seen in during the 2012-16 drought in the McCloud/Mount Shasta region. Under a changing climate in California, shifts in precipitation patterns that favor more frequent and prolonged drought and more intense, if infrequent storms, are likely to be exacerbated in the future, to the detriment of coldwater fish species such as bull trout that rely on snowmelt and springs during warm and dry summer months. In a recent study, Kovach et al. (2015) found negative correlations between maximum summer temperatures and decreased allelic richness and diversity in bull trout across their range in the Columbia River basin, suggesting that those populations most at risk are the least able to deal with a changing climate due to low diversity and ability to shift their range. Therefore, remaining bull trout populations in North America are likely very susceptible to negative impacts of climate change, such as displacement by invasive brown trout and further restriction by thermal barriers (Al-Chokhachy et al. 2016).

Management Recommendations: CDFW had a plan for restoring bull trout through establishing resident populations in some tributaries upstream of McCloud Reservoir and in the lower river (Rode 1990). These populations would be supplemented by hatchery fish if they could not sustain themselves, which is likely. Attempts at introducing fish from the Klamath River Basin in Oregon to the McCloud River have failed, and additional attempts are unlikely unless the best source populations recover their former abundance (Rode 1990).

Presumably if McCloud Dam was removed or re-operated to produce colder water downstream through increased flows, a plan could be re-implemented for reintroduction of adfluvial bull trout. However, because Shasta Dam blocks access to spawning salmon, the abundance of prey is much lower than it was historically, so the river is likely not able to support a self-sustaining population of bull trout, especially in the face of competition and predation from brown trout. The Bureau of Reclamation and National Marine Fisheries Service (NMFS) are considering trapping and trucking adult and juvenile salmon around Shasta Dam to re-populate the McCloud River, though serious questions over the costs and effectiveness of such programs remain (Lusardi and Moyle *In review*). If this were to happen, perhaps talk of re-introducing bull trout to the McCloud River would resume.

New References:

Al-Chokhachy, R. et al. 2016. "Are brown trout replacing or displacing bull trout populations in a changing climate?" *Canadian Journal of Fisheries and Aquatic Sciences* 73(9): 1395-1404.

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Kovach, R. et al. 2015. "Genetic diversity is related to climatic variation and vulnerability in threatened bull trout." *Global Change Biology* 21(7): 2510–2524.