# LAHONTAN CUTTHROAT TROUT
***Oncorhynchus clarkii henshawi***

**High Concern. Status Score = 2.0 out of 5.0.** Despite significant efforts in recent years, wild, self-sustaining Lahontan cutthroat trout in California face a large and increasing risk of extinction over the next 50 years.

**Description:** Lahontan cutthroat trout (LCT) are the largest subspecies of cutthroat trout (USFWS 2013). They are variable in coloration; lake-dwelling Lahontan cutthroats are pale gold with pink or purple hues along their flanks and gill plates and a back that ranges from a greenish-bronze to dark olive color. In streams, LCT attain smaller sizes than those in lakes, and may exhibit purple or bluish hues along their flanks. LCT have large rounded black spots distributed over the back and caudal peduncle, but most spots are found above the lateral line. They possess characteristic yellow to red streaks of color along the underside of the mandible that give them their name. These marks are often absent or extremely faint in fish smaller than 8 cm TL. They have 21-28 gill rakers, and there are 40-70 pyloric cecae present. They have teeth on the upper and lower jaws, head and shaft of the vomer, palatines, tongue, and basibranchial bones. Their scales are generally smaller than those of rainbow trout, with 150-180 along the lateral line. Parr possess 8-10 narrow parr marks along the lateral line, which they often retain to adulthood in streams (Behnke 1992, 2002, Moyle 2002).

**Taxonomic Relationships:** Lahontan cutthroat trout are one of the most genetically distinct cutthroat trout subspecies, reflecting their long history of isolation from other salmonids. Lahontan cutthroat trout (LCT) are close relatives of the Paiute cutthroat trout, and are divided into three distinct population segments based on geographic distribution, ecology, behavior and genetics (USFWS 2010). However, recent genetics work (Peacock et al. 2010) suggests that a fourth segment should be designated for fish in the Steen Mountains, known as the Willow-Whitehorse basin in southeastern Oregon. The Western Lahontan basin segment is comprised of fish in the Truckee, Carson and Walker river basins (California and Nevada, Trotter 2008). Pritchard and colleagues (2012) found evidence to support the theory that Paiute cutthroat trout evolved from Lahontan cutthroat trout in the Carson River basin nearly 12,000 years ago. They also found 34 distinct segments of DNA that distinguish LCT from Paiute cutthroat trout, adding further weight to the subspecies status of Paiute cutthroats. LCT, like most other cutthroat trout, readily hybridize with rainbow trout, and can also spawn with Paiute cutthroat trout to create fertile offspring, resulting in loss of phenotypic expression and genetic diversity over time (California Trout 2015). This vulnerability has been a driver of their decline across their range.

**Life History:** Through their range of diverse habitats, LCT exhibit riverine resident, migratory, and lacustrine life histories, making them very adaptable to a range of conditions (Behnke 2002). Despite this habitat adaptability, LCT are very intolerant of other salmonids and rarely coexist with them (USFWS 2013). While LCT can thrive in lake environments, they are obligate stream spawners. Lacustrine trout are capable of making extensive migrations to find suitable spawning areas. Trotter (2008) indicates that some trout from Pyramid Lake in Nevada historically ascended the Truckee River to spawn in tributaries to Lake Tahoe.

They feed primarily on terrestrial and aquatic invertebrates in both larval and adult phases, as well as oligochaetes and other non-insect macroinvertebrates such as zooplankton

(USFWS 1995). Large LCT will feed on juvenile fish of other species when such food is abundant, and can attain great sizes of over 9 kg; they historically attained even larger sizes in Pyramid Lake, Nevada, and supported a major commercial fishery there for decades (USFWS 2013). LCT generally can live from 4 to 9 years, with stream-dwelling fish having shorter life spans than lake-dwellers. However, there is anecdotal evidence that LCT in Independence Lake, CA may live as long as 13 years (W. Somer, CDFW, pers. comm. 2016).

Spawning takes place in streams from April to July depending on stream flow, water temperature and elevation (Peacock and Dochtermann 2012). However, autumn spawning runs have been reported from some populations (USFWS 2013), and spawning migrations occur at observed water temperatures between 5 and 16° C (USFWS 1995). LCT reach reproductive maturity at age 3 to 4 in stream habitats (Peacock and Dochtermann 2012). Consecutive-year spawning is unusual, and there is approximately 60-70% post-spawning mortality for females and 85-90% for males (USFWS 1995). Only 50% of surviving females spawn again as compared to 25% of males (USFWS 2013). Lacustrine females have higher fecundity rates than do riverine females based on their greater size and age. Lacustrine LCT females can produce 600 to 8,000 eggs each, while smaller stream-dwelling female LCT produce only 100 to 300 eggs. Gravel from 6 to 50 mm is optimum for redd construction and embryo incubation (Coffin 1981). Preferred water depths for redds average 13 cm, and velocities average 56 cm/s (Schmetterling 2000). Water must be saturated with oxygen and have minimal siltation to prevent eggs from suffocating. Spawning LCT develop bright red coloration on the underside of the mandible, operculum and along their flanks; coloration is more intense in males, which also display a hooked lower jaw during spawning.

Eggs hatch after incubating from 4 to 6 weeks, depending on water temperature, and fry emerge from gravel after 13 to 23 days (USFWS 1995). Fry can spend up to two years in their natal stream before migrating to available lake habitat, but most migrating fish move after their first summer (Trotter 2008). Growth rates vary with water temperature and food availability. Faster growth occurs in larger, warmer waters, particularly where forage fish are available. Summit Lake-strain fish at the Lahontan National Fish Hatchery Complex have recorded sustained growth rates up to 150 mm each year (USFWS 2016). In smaller, colder water bodies, growth is slower and longevity is reduced. Gerstung (1986) found mean fork lengths of LCT from 6 streams in the Sierra Nevada to average 89, 114, 203, and 267 mm at ages 1-4, respectively.

**Habitat Requirements:** LCT are noteworthy for being very adaptable and tolerate a variety of habitats and temperatures - from deserts to high alpine tributary streams - in California. The species can persist in streams where temperatures may exceed 27°C for short periods and can fluctuate 14-20°C in a day. They can also survive prolonged exposure to temperatures of 23-25°C, but cease to grow when temperatures exceed 22-23°C (Dickerson and Vinyard 1999, Moyle 2002) and show sublethal impacts such as reduced feeding, growth rates, and movement at temperatures above 24°C (Robison et al. 2008). Ideal summer temperatures for growth and development average 13°C ± 4° C (Hickman and Raleigh 1982), and recent studies (Peacock and Dochtermann 2012) suggest that upper thermal tolerances are heritable traits to some degree. Lacustrine LCT also have a considerably higher tolerance for alkalinity, total dissolved solids, and lower dissolved oxygen than most freshwater fish (Koch et al. 1979).

In streams, LCT prefer reaches with well-vegetated and stable stream banks, greater than 50 percent stream cover, and pools with close proximity to cover as well as riffle-run complexes for spawning and feeding (USFWS 2013). Stream substrate composition, cover, geomorphology, and water quality constrain LCT distribution; recent mark-recapture studies (Alexaides et al. 2012) indicate that LCT, like most other cutthroat trout, utilize pool habitat more than any other habitat type. Lack of such habitat caused increased migration distances and range sizes in individual tagged fish, and was associated with higher mortality in tagged fish in the Truckee River. Habitat diversity is important for survival of young-of-year fish, especially during winter months when LCT survival is lowest. Nick points, or transition areas between more and less confined valley stream reaches tend to concentrate LCT, indicating that hyporheic subsurface flows provide refuge from warm temperatures in summer and anchor ice in winter and create relatively deeper pools in shallow stream reaches (Boxall et al. 2008).

**Distribution:** Lahontan cutthroat trout are native to the greater Lahontan basin in eastern California, southern Oregon, and northern Nevada (Trotter 2008, Figure 1). In California, LCT were historically found in large, low-gradient rivers such as the Truckee River, moderate gradient streams such as the Carson and Walker rivers, and small, headwater streams at high elevations such as the many tributaries to Lake Tahoe. They were also present in the Susan River drainage in the Eastern Sierra, but have been extirpated from that drainage for some time (Trotter 2008). LCT remaining in California represent the western and southernmost extent of the species in their native range, making these periphery populations susceptible to habitat degradation and disturbance (Haak et al. 2010).

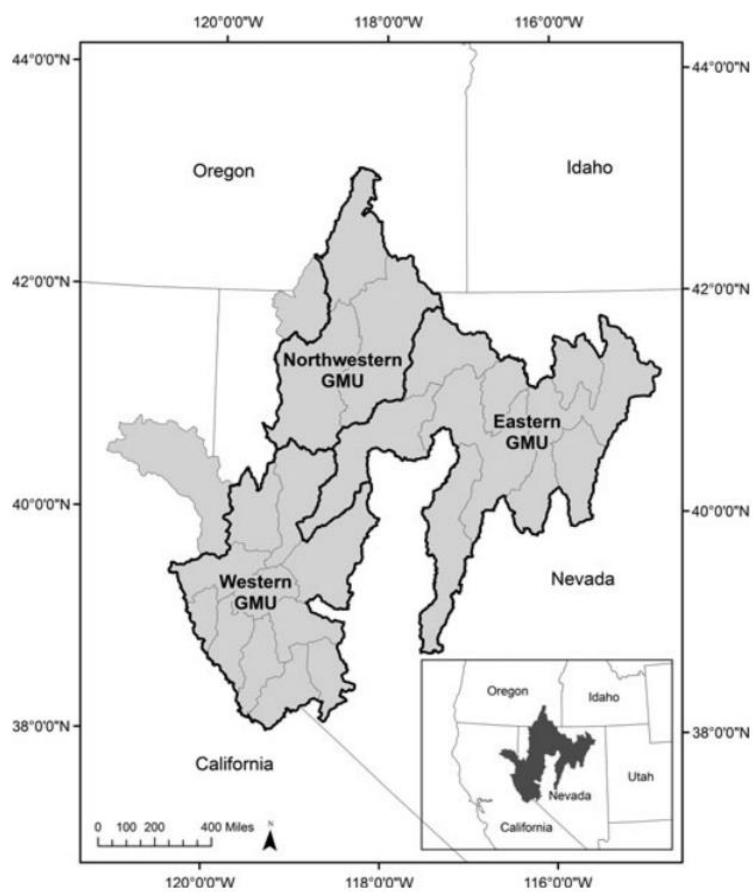


**Figure 1**. LCT Geographic Management Units. From: Pritchard et al. 2013. Fig 2, pg. 278.

The species first occupied Lake Lahontan during the Pleistocene about 25,000 years ago, which receded over time, leaving remaining populations at the former lake edges. Gerstung (1986) reported that LCT distribution in 1844 included some 11 lacustrine populations occupying approximately 334,000 acres of lakes, and between 400 and 600 fluvial populations over 3,600 miles of streams in the Lahontan Basin. They now occur in a wide variety of cold-water river and lake habitats, ranging from terminal alkaline lakes such as Pyramid and Walker Lakes to the alpine oligotrophic waters of Lake Tahoe and Independence Lake. In the Truckee Basin, LCT from Pyramid Lake migrated upstream to spawn in tributaries to Lake Tahoe, as well as in the main river. In the Carson, Walker, and Truckee basins, only a few scattered streams continue to maintain LCT populations (Trotter 2008, Table 1). In total, there are only 16 lakes and streams that are known to still contain LCT within their historical range in California. LCT have also been planted and become established in several creeks outside their historical range, including west slope drainages near the Truckee basin such as Austin Meadow Creek (Nevada County), Pole Creek (Placer County), and others.

| Carson River Drainage | Truckee River Drainage | Walker River Drainage |
|---|---|---|
| East Fork Carson River*<br>Murray Canyon Creek*<br>Raymond Meadows Creek**<br>Poison Flat Creek*<br>Golden Canyon Creek*<br>Heenan Lake* | Independence Lake*<br>Upper Independence Creek*<br>Pole Creek**<br>Upper Truckee River**<br>Fallen Leaf Lake** | Murphy Creek**<br>Slinkard Creek**<br>Mill Creek**<br>Wolf Creek**<br>Silver Creek**<br>By-Day Creek*<br>Bodie Creek*** |
| *Reintroduced populations of Independence Lake strain, actively managed by CDFW<br>**Population may have been lost in drought due to desiccation | *Population in historical range<br>**Historical populations once extirpated but reintroduced | *Historical population maintained above a barrier<br>**Historical populations once extirpated but reintroduced<br>***Population may have been lost in drought due to desiccation |

**Table 1**. List of known populations of Lahontan cutthroat trout in their native California range.

| Yuba River Drainage | Stanislaus River Drainage | Mokelumne River Drainage | San Joaquin River Drainage | Owens River Drainage |
|---|---|---|---|---|
| Macklin Creek<br>Austin Meadows Creek<br>East Fork Creek<br>Unnamed tributary to East Fork Creek | Disaster Creek | Marshall Canyon Creek<br>Pacific Valley Creek<br>Milk Ranch Creek | West Fork Portuguese Creek<br>Cow Creek | O'Harrel Canyon Creek |

**Table 2**. Known populations of LCT outside their historical native range (W. Somer, CDFW, and C. Mellison, USFWS, pers. comms. 2016).

**Trends in Abundance:** As a species, LCT have lost over 30 remote, isolated populations between 1980 and 1995, and more local extirpations are likely to continue due to impacts stemming from interactions with nonnative species, habitat fragmentation and degradation, and climate change (Peacock et al. 2010). CDFW's (2016) estimate that LCT persist in less than 5% of their original stream habitat and in a mere 0.4% of their original lake habitat in California indicates that remaining LCT populations are a fraction of what they once were. Wild, self-sustaining populations in headwater streams in California likely total only a few hundred fish age 1+ and older (CDFW 2009). The small Bodie Creek and Raymond Meadows Creek populations that were opportunistically established by biologists in California may have been lost due to impacts associated with the ongoing drought (C. Mellison, USFWS, W. Somer, CDFW, pers. comms. 2016). To help combat this ongoing loss of populations, LCT have been established in nine creeks outside of their native range in California through stocking, nonnative species removal, barrier creation, and active management (Table 2). While abundance estimates are lacking, all stream populations most likely contain less than a few hundred adult fish, perhaps with the exception of the Upper Truckee River. Independence, Fallen Leaf, and Heenan Lakes contain more mature adults as a result of active management, hatchery stocking, or both, but reliable population estimates for lake habitats are not available for these habitats.

To bolster LCT populations in California, CDFW and USFWS are working with US Forest Service and other partners to continue to monitor reintroduction efforts on the Upper Truckee River. From 2007 to 2009, the number of LCT captured rose each year (1,700, 1,900, and 2,400, respectively) across repeat surveys in the same reaches, indicating the population is increasing and multiple year classes continue to survive and reproduce (CDFW 2009). Recent recovery efforts to remove invasive brook and brown trout in Upper Independence Creek, spawning tributary to Independence Lake and stronghold of natural spawning of LCT in their historical California range, has also shown some promise. Following several years of brook trout removals through strategic stream de-watering and electrofishing, management partners have begun de-watering the main lake in the fall to desiccate kokanee eggs spawned in the lake (C. Mellison, USFWS, pers. comm. 2016). Over several years, LCT juveniles emigrating from the creek jumped from about 14,000 to 40,000 individuals (Scoppettone et al. 2012). In 2010, 237 adult LCT passed the weir en route to spawning grounds in Upper Independence Creek, representing the largest number of potential spawners recorded in recent memory, perhaps due to increased survival of fry and juveniles after removal of brook trout (C. Mellison, USFWS, pers. comm. 2016). In follow-up surveys in lower Independence Creek, multiple size and age classes of LCT were observed, indicating that juvenile LCT are exhibiting a shift to a more resident life history by rearing in the creek for longer timeframes. This change in habitat utilization is perhaps increasing their fitness and survival to spawning age (CDFW 2012), but no LCT population studies have been conducted at Independence Lake recently.

**Factors Affecting Status:** Major factors affecting LCT habitat and abundance, especially alien species, are discussed below.

*Alien species.* Non-native trout introductions and invasions pose the single greatest threat to the continued persistence of LCT in California. Lahontan cutthroat trout were the only salmonid historically found in the Eastern Sierras, with the exception of the closely-related Paiute cutthroat trout and Eagle Lake rainbow trout and. They do not persist in habitats with non-native trout, except in Independence Lake, though recent studies suggest that active removal and management of nonnative salmonids are essential for LCT persistence in this remaining stronghold for the species in California (Rissler et al. 2006, W. Somer, CDFW, pers. comm. 2016). Brown trout are voracious predators on juvenile LCT and they are fall spawners, which gives juvenile brown trout a competitive advantage over LCT, which emerge from gravel in spring. Brook trout occur in much higher densities than other trout and effectively outcompete LCT for habitat and resources. Rainbow trout life history strategies and spawn timing overlap with LCT, causing frequent hybridization between the two species, resulting in dominance of rainbow trout-type phenotypes (Al-Chokhachy et al. 2009). Lake trout have also contributed to the demise of LCT from Lake Tahoe and Fallen Leaf Lake through predation, competition, and perhaps disease. Vander Zanden et al. (2003) indicate that the food webs of Lake Tahoe are now so altered from interactions with introduced species such as lake trout that re-establishing cutthroat trout in the lake may not be possible, though the US Fish and Wildlife Service has been actively stocking Fallen Leaf Lake for LCT reintroduction since 2002 (USFWS 2013). More recent introductions of centrarchids and other non-native fish and invertebrates will hamper restoration efforts even further in the future (W. Somer, CDFW, pers. comm. 2016).

The Lahontan Basin has changed dramatically as a result of human uses, such as dams and diversions for power generation and agriculture, that such interchanges are no longer possible. This makes it very challenging to maintain genetic diversity in isolated populations without genetic drift, founder's effects and possible inbreeding depression. The lack of interconnected habitat and large populations of non-native trout together effectively eliminate the possibility for recovering historical self-sustaining natural meta-populations throughout most of their range. Only limited LCT populations survive in isolated streams, leading to a dearth of genetic diversity that likely does not represent the entire historical genome of the species. Because LCT historically inhabited many isolated subbasins, there were presumably many genetically distinct populations with local adaptations that have been lost. USFWS (2010) recommended that remaining populations should be maintained in their basins of origin to the extent practicable and translocated where appropriate to reduce introgression and competition with nonnative trout and to safeguard genetic stocks. Lacustrine LCT are most at risk of losing their genetic integrity because there are only two small, naturally-reproducing populations left within their native range in California (Independence and Fallen Leaf lakes) (USFWS 2013).

*Major dams.* Dams are present on most major Lahontan cutthroat streams, fragmenting habitats, creating barriers to migration, and removing large areas in reservoirs and rivers that were once suitable LCT habitat. Agricultural water diversions (mainly from Derby Dam effectively disconnected Pyramid Lake from the Truckee River for most of the 20th century, lowering lake levels nearly 24 m and greatly increasing the lake's alkalinity. As the result of federal listing of LCT and Lahontan sucker, or "cui-ui," (*Chasmistes cujus*) as threatened species, flows have been somewhat restored to the river and lake levels have risen, but habitat is still reduced compared to historical levels. The Truckee Meadows Water Authority manages water withdrawals for downstream users, and stands committed with partners from The Nature Conservancy, California Department of Fish and Wildlife, US Forest Service, US Fish & Wildlife Service, Tahoe National Forest, and local conservation groups to helping restore and protect LCT populations in the basin. In the Walker River basin, the LCT population persisted until Bridgeport Dam was built in 1924, followed by Weber Dam in 1933, effectively cutting the population off from its spawning habitat.

Natural barriers also helped shape LCT distribution and life history over time. While native beavers create barriers, they may provide important benefits to LCT across the Eastern Sierra through dam creation that maintains water in streams throughout summer months and drought, as seen in the Upper Truckee meadow habitat over the last several years (C. Mellison, USFWS, pers. comm. 2016). Beaver dams can create habitat complexity, slow and store water, create deeper pool habitat, and disrupt solid-freezing of small headwater streams in winter. Conversely, their dams may negatively impact LCT by creating barriers to migration, increasing water temperatures in pools directly upstream, downstream siltation in the event of a washout during high flow events, and potentially reducing water quality downstream through blooms of iron-fixing bacteria (C. Mellison, USFWS, pers. comm. 2016).

*Harvest.* Heavy commercial fishing in lacustrine populations in the 19th and early 20th contributed to the collapse of commercial fisheries for Lahontan cutthroat trout in the 1940s and their eventual extirpation from Pyramid Lake and Lake Tahoe (Trotter 2008, Al-Chokhachy et al. 2009). Townley (1980) estimates that between 1873 and 1922, approximately 100,000-200,000 pounds of LCT were annually harvested from Pyramid Lake and the Truckee River system alone. By the 1940s, LCT were extinct in Pyramid Lake, and hatcheries were required to support the popular sport fishery there. Those populations continue to this day thanks to complete hatchery support from the Lahontan National Fish Hatchery Complex in Gardnerville, NV. In California, mandates for barbless hooks and catch-and-release angling for LCT have helped reduce impacts of harvest on this species, though the impacts of poaching on refuge populations are unknown (Alexaides et al. 2012).

*Logging.* Watersheds containing LCT were heavily logged in the 19th century to provide timber for mines in Nevada and railroad ties, removing vegetation and increasing silt loads in the rivers (Trotter 2008). In many LCT streams, water was either diverted down flumes to carry logs, or was impounded behind splash dams and then abruptly released to wash logs to downstream sawmills; the alternating drying and flooding destroyed habitat and depleted fish populations in the mainstem Truckee River (USFWS 1995). Historical logging in the species' native range discharged large amounts of industrial and sewage wastes directly into streams until the 1930s, further degrading habitat and water quality (USFWS 1995).

*Grazing.* Heavy livestock grazing throughout the LCT range, especially of cattle in riparian zones, has degraded habitat through trampling of banks and riparian vegetation leading to erosion, channel incision and siltation of streams. Resulting loss of riparian vegetation and cover has resulted in higher water temperatures and reduced cover, leaving fish more vulnerable to reduced water quality and predators. As much as 70% of LCT habitat occurs on Bureau of Land Management and National Forest lands, where grazing has historically been permitted. Public lands are far less heavily grazed today, which allows beaver to thrive, but active grazing still occurs throughout LCT range (C. Mellison, USFWS, pers. comm. 2016). In areas where grazing still occurs, canyon areas should be prioritized for cattle exclusion to protect areas of hyporheic flow that provide refuge (Boxall et al. 2008). For a more complete account of grazing on high elevation trout populations, see the California Golden Trout species account.

*Mining.* The historical effects of mining on fish populations is not well understood in California, in part because the most impacts occurred during the Gold Rush of the mid-19th century. Placer mining removed instream habitat and diverted water, while hardrock mining released debris, sediment, and toxic effluent into streams from mines. These activities took place across Lahontan cutthroat streams, but their impacts are largely unrecorded (Trotter 2008).

*Disease.* A number of parasites and pathogens have potentially adverse effects on LCT and their recovery. Heenan Lake and Lahontan National Hatchery Complex have been sites of significant disease outbreaks in the past, increasing the potential for negative population-scale impacts on wild populations. Hatcheries often present the biggest risk of exposure because they often recycle their water and have fish in close proximity. The release of infected hatchery fish could result in transmission of pathogens to wild fish populations. There have been widespread reports of *Renibacterium salmoninarium*, the causative agent of bacterial kidney disease, in both hatchery LCT and wild trout within the historical range of LCT as well as whirling disease and bacterial gill disease (J. Stead, URS, pers. comm. 2007). In the past, such diseases have infected LCT in hatcheries and have reduced the ability of CDFW to plant these fish (W. Somer, CDFW, pers. comm. 2007). Any hatchery operations carry the risk of disease spread to wild populations, but evolving hatchery management practices ameliorate these risks to the extent practicable.

| Threat | Rating | Explanation |
|---|---|---|
| Major dams | Medium | Dams are present on most major LCT lacustrine and fluvial habitats, fragmenting populations and impeding essential expression of various life histories. |
| Agriculture | Medium | Water diversions and reduced instream flows from irrigation reduce suitable habitat and increase water temperatures; these impacts are compounded in drought. |
| Fire | High | Fire suppression, coupled with increasing aridity predicted with climate change, may contribute to increased fire frequency and intensity, posing serious threats to small, isolated populations. |
| Grazing | Low | Historically pervasive in the native range of LCT, especially in meadows and along riparian corridors, but impacts have been reduced in recent decades through grazing allotment closures. |
| Rural /residential development | n/a | Majority of LCT habitat exists within National Forest boundaries. |
| Urbanization | n/a | |
| Instream mining | n/a | |
| Mining | Low | Historical mining occurred in LCT watersheds, but impacts unknown. |
| Transportation | Low | Roads are sources of erosion and sediment into streams; culverts have blocked access in the past, but impacts are likely small. |
| Estuary alteration | n/a | |
| Logging | Low | Logging and associated roads have likely contributed to stream degradation, increased water temperatures through riparian degradation, and reductions in water quality due to runoff, though much of the high-elevation habitat of LCT is sparsely wooded. |
| Recreation | Low | Little recreational use of most LCT habitats occurs. |
| Harvest | Low | Legal fishing pressure is light and limited to catch-and-release angling with barbless hooks only. |
| Hatcheries | High | Competition and hybridization with historically stocked rainbow trout represent a major threat to LCT persistence; Hatcheries will play a role in recovery of LCT. |
| Alien species | Critical | Historical and recent non-native trout introductions limit LCT recovery via competition, predation, and hybridization. |

**Table 3.** Major anthropogenic factors limiting, or potentially limiting, viability of populations of Lahontan cutthroat trout 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 high. See methods for explanation.

**Effects of Climate Change:** Despite their high thermal tolerances and adaptability, LCT in California are critically susceptible to the effects of climate change, such as shrinking available habitat due to increasing temperatures and interactions with nonnative species as their ranges shift (Wenger et al. 2011). Most populations of LCT in California persist in small, high-elevation headwater streams above barriers and devoid of other salmonids less than 8km in length; these areas represent marginal habitat at best for cutthroat trout. Fragmentation has reduced habitat availability, connectivity, and suitability, which over time diminishes gene flow and can lead to inbreeding depression. Climate change is likely to exacerbate these stressors through higher summer temperatures, decreased streamflow, desiccation, and increased frequency and magnitude of catastrophic fire (USFWS 2013).

In the past, LCT likely persisted in these harsh environments by expressing varied migratory life histories in interconnected habitats to find thermal refugia. In water over 22°C, LCT exhibit sublethal effects as well as increased mortality; the portion of their habitats above this threshold in California will continue to expand spatially and temporally in the face of a changing climate, putting the continued persistence of the species in serious jeopardy. Remaining LCT populations at the extreme edges of the species' range is crucial because these individuals have the greatest potential to adapt to increasing temperatures as climate change continues to intensify. Recent work (Warren et al. 2014) on cutthroat susceptibility to climate change impacts indicates that the Northern portions of LCT, not the southern populations in California, are the most at risk of losing potential habitat, as latitude plays an important role in shrinking habitat due to thermal tolerance thresholds butting up against topographic constraints. It is likely that the downstream elevation limits of LCT habitat will remain only in higher elevations in the California portion of their range in the future due to short growing seasons, harsh winters, and high variance in temperature extremes that will constrict their ranges. As their available downstream habitat shrinks, LCT will overlap even more with those of nonnative salmonids, changing species interactions, increasing competition and reducing survival (Wenger et al. 2011). LCT are unlikely to find refuge further upstream or in higher elevations in most areas due to natural barriers such as velocity, gradient, and flow limitations. As their distribution changes over time, LCT are likely to become even more restricted to smaller, lower-flow headwater streams, resulting in overall decreases in abundance and biomass, exacerbating their vulnerability to loss of genetic variability and local extirpations (Wenger et al. 2011).

**Status Score = 2.0 out of 5.0. High Concern.** Wild, self-sustaining populations of Lahontan cutthroat trout in California have a high likelihood of extirpation in their native range in the next 50 years, except as populations sustained by hatchery production. Wild populations of Lahontan cutthroat trout in California are small and isolated and will require continuous and enhanced management efforts over current levels to prevent extinction. Most remaining populations occupy marginal habitat in small, isolated areas outside of their native range, and are supported by intensive management of nonnative salmonids, stocking, and the coordinated recovery efforts of many partners. Local extirpations of isolated populations likely occurred during the ongoing drought, further reducing the species' remnants throughout its range. They are not formally listed under California's Endangered Species Act, but are instead specially managed as a heritage trout species by CDFW. A summary of the threats they face and their relative vulnerability is described below (Table 4).

| Metric | Score | Justification |
|---|---|---|
| Area occupied | 2 | Occupies multiple watersheds in California, but no connectivity among them. |
| Effective adult abundance | 2 | Most wild populations have significantly less than 1,000 fish each, with lacustrine habitats and Upper Truckee River as the exceptions. |
| Intervention dependence | 1 | Hatchery program using wild brood stock required for persistence. |
| Tolerance | 5 | LCT are fairly long-lived and demonstrate broad physiological tolerance and are iteroparous. |
| Genetic risk | 1 | Hybridization risk and loss of genetic variation is well documented and the major threat to the species. |
| Climate change | 1 | LCT are extremely vulnerable to climate change in all watersheds inhabited. |
| Anthropogenic threats | 2 | 1 Critical and 2 High Factors. |
| Average | 2.0 | 14/7. |
| Certainty (1-4) | 4 | Peer reviewed literature, agency reports, grey literature, and professional judgment. |

**Table 4.** Metrics for determining the status of Lahontan cutthroat trout 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 high. See methods for explanation.

**Management Recommendations:** Since their original listing under the Endangered Species Act, Lahontan cutthroat trout were subsequently relisted as threatened in 1975 to facilitate management activities (USFWS 1995). While LCT have often persisted in isolation throughout their history, their isolation has never been as great as it is now, and extant populations are mostly maintained by stocking or managed for non-native species control. Genetic drift and stochastic events are significant challenges in current LCT management and hinder growth of effective population size growth. LCT face tremendous odds of recovery despite the combined work of agencies, landowners, non-profits, and other partners; it is unlikely that they will be delisted in the near future. According to the USFWS recovery plan, priorities include:

1. Eradicating non-native salmonids and reintroducing LCT in their native range
2. Connecting fragmented habitats so LCT can express all their life histories
3. Monitoring population genetics and maintain genetic diversity
4. Supporting water transactions and acquisitions to restore instream flows
5. Enhancing riparian and in-stream habitat and complexity through restoration
6. Restoring connectivity between and among fragmented, isolated populations

With the goal of recovering and delisting LCT in mind, there have been considerable efforts at restoring populations of LCT both inside and outside of their native range in California over the last few decades, including recent efforts to control nonnative trout and monitor and restore existing populations in Upper Truckee River near Meiss Meadows, Upper Independence Creek, Heenan Creek and Lake, nearby Slinkard, Wolf, and Silver creeks, Fallen Leaf Lake, Glen Alpine Creek, Austin Meadows Creek, By-Day Creek, and others. California's periphery populations of LCT at the western and southern extent of their range represent important sources of genetic information and ecological adaptation to harsh conditions (Haak et al. 2010). Hatchery propagation of LCT has also been ongoing since around 1939 and continues today to support LCT recovery through maintenance of genetic information and releases from the Lahontan National Fish Hatchery totaling 300,000 to 400,000 LCT a year in Nevada and Fallen Leaf Lake, and the Heenan Lake fish hatchery spawning tagged LCT for use in statewide stocking programs.

Habitat fragmentation and alien trout invasion throughout LCT range and limited resources, political will, and time required to reverse those impacts make recovery a daunting task. While nearly all current LCT habitat in California is on public (National Forest) land, almost all of the reintroduced populations exist in previously fishless waters above barriers. CDFW restoration goals are to protect and expand existing wild populations of LCT using existing populations as sources for reintroduction into historical or out-of-basin refuge habitats. Toward that end, CDFG and USFWS have spent considerable resources in maintaining genetic diversity in LCT populations, and have begun reintroducing LCT in numerous locations. Their persistence will require innovative management, habitat restoration, and elimination of competing species of trout from streams and lakes in a variety of habitats so LCT can express varied life history forms to adapt to changing conditions in the face of climate change.

Independence Lake, in the Truckee River drainage, is the only lacustrine population left in the state where LCT have continuously survived and reproduced independently. Strong partnerships and commitment allow crucial adaptive management to continue to benefit LCT in this stronghold of LCT in California. The US Geological Survey, US Forest Service, The Nature Conservancy, CDFW, USFWS, and other regional partners collaborate to provide research, expertise, and fieldwork to help conserve and recover the LCT population here. Such collaborative efforts should be supported and replicated where possible to coordinate activities that leverage limited resources and maximize potential benefits.

Efforts to protect the endangered cui-ui in Pyramid Lake have resulted in increased flows in the Truckee River, thus raising the lake level, reducing its alkalinity, and providing access to the Truckee River for spawning, which benefits LCT as well. LCT have been observed migrating through the Truckee River delta to the fish elevator at the base of Marble Bluff Dam as well as swimming up the fish ladder around the dam on spawning runs, (G. Scoppettone, pers. comm. 2007). In 2014 and 2015, increased flows allowed large LCT to enter the Truckee River and successfully spawn for the first time since 1938 (USFWS 2016), though considerable efforts will be required to connect this population to its historical access to Lake Tahoe and tributaries.

In the Upper Truckee River basin near Meiss Meadows, CDFG has worked to restore LCT since the 1980sthrough brook trout eradication, barrier maintenance, and habitat restoration. During 1988 through 1995, a series of labor-intensive CDFG rotenone treatments were undertaken in the headwaters to eradicate invasive brook trout and reintroduce LCT to the basin. Electrofishing has been conducted each year to keep brook trout under control and preserve the small headwater reach for LCT; CDFG has successfully eradicated brook trout from the stream in 2008, though speckled dace have been found upstream of the rock wall barrier and so annual efforts to monitor the effectiveness of the barrier will continue (CDFW 2009).

Current management is focused primarily on maintaining genetic diversity and reintroducing LCT in streams and lakes with high potential of success. The lack of interconnected watersheds to support metapopulations, however, will only persist with significant support from managers. Restoration goals should weigh actions that increase short-term viability of populations against maintaining and increasing genetic diversity for the long-term (Peacock and Dochtermann 2012). It is likely that with the continued efforts of CDFW, USFWS, the Forest Service, and USGS, there will be some improvement in LCT populations in a few watersheds, but it is unlikely that LCT will be able to persist indefinitely in self-sustaining wild populations in California.

Despite the impacts of drought and potential loss of some populations, non-introgressed, wild LCT may have actually increased in abundance since 2008. The considerable management efforts on Upper Truckee River, Independence Lake and Creek, Heenan Lake and Creek, Fallen Leaf Lake and tributary Glen Alpine Creek, Austin Meadows, By-Day, Slinkard, Wolf, and Silver creeks have likely helped maintain and even bolster populations in some cases. Small populations such as Raymond Meadows and Bodie creeks may have been lost during the drought due to increased water temperatures and desiccation, while others were saved through rescue efforts. In July and August 2015, 49 and 37 LCT, respectively, were rescued from By-Day Creek in Mono County and released in suitable habitat in small groups in restored habitat in Wolf and Slinkard Creeks (CDFW 2015). In July 2014, CDFW monitored a small out-of-basin population in 2.1km of Austin Meadow Creek in Nevada County. During visual surveys, CDFW staff located illegal pumps, and worked in cooperation with other agencies and authorities to remove the diversion and reestablish connectivity between isolated pools to provide habitat for about 50 LCT individuals to persist through the drought (CDFW 2016).

In addition, considerable hatchery production, stocking, and active nonnative trout management in Fallen Leaf and Independence Lakes has helped bolster LCT numbers. In Fallen Leaf Lake, annual stockings of fingerling and yearling LCT since 2002 from the Lahontan National Fish Hatchery Complex have allowed a small population of adults to take hold, and natural reproduction is occurring as a result in the Glen Alpine Creek tributary (Smith 2013). Active management of introduced rainbow and brook trout in the creek and installation of two weirs allow passage of native species, while excluding mature trout has helped reduce interbreeding and restore a small foothold for natural LCT spawning in California (USFWS 2013). At CDFW’s broodstock reservoir on Heenan Lake, manual rainbow trout removal is increasing prospects for natural Independence-strain LCT spawning in California in the near future. Only two rainbow trout were captured during electrofishing surveys in Heenan Creek in 2012, with no young-of-year fish seen, indicating that the spawning cycle of introduced fish has been broken. Now, after three consecutive years of capturing zero rainbow trout in the creek, CDFW can consider treatment of Heenan Lake to ensure Independence strain LCT remain so they can eventually spawn naturally in this watershed (CDFW 2012).

In the long-term, persistence of wild LCT in California will continue to require intense management, and remaining wild populations are likely to remain small and scattered even with significant allocation of resources to connect populations and allow LCT to re-colonize historical habitat void of nonnative trout. The species will continue to suffer from lack of genetic diversity, alien trout, and habitat fragmentation and alteration. Additionally, climate change will adversely impact LCT by increasing stream temperatures and reducing flows in some small streams during the summer and fall. Available habitat for LCT will likely continue to shrink based on upper thermal tolerances, shifting species distributions and resulting interactions with nonnative species, and alterations to streamflow. Hatcheries will continue to maintain sport fisheries for LCT based on changes to existing stocking practices from state legislation changes. The crucial California Fish and Game Code 1729 mandates that CDFW prioritize stocking native hatchery-produced species in place of nonnative species in state waters, and has used strategical stocking in areas known to contain LCT or where LCT could become established again. To date, the idea of utilizing a conservation hatchery for LCT in California has been tabled because the risks of genetic contamination of remaining strains of fish are too high for the perceived benefits of potential increases in genetic diversity. In the future, this may change. An aspirational goal of the Lahontan National Fish Hatchery Complex is to introduce large Pyramid Lake LCT back into the mainstem Truckee River above barriers to spawn and re-gain a foothold in their historical habitat and allow them to one day return beyond barriers in the Truckee-Tahoe basin volitionally (USFWS 2016).

In the next several years, state and federal resources that have been focused on restoring Paiute cutthroat trout will likely be freed up in the coming years and shift to LCT recovery priorities, which should further help the plight of the species (W. Somer, CDFW, pers. comm. 2016). Whether the political will, funding, and concerted effort of partners is available to continue and expand recovery efforts on a sufficient scale and timeframe remains to be seen.

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