CLEAR LAKE TULE PERCH
***Hysterocarpus traskii lagunae* (Hopkirk)**

Status: High Concern. The Clear Lake tule perch is endemic to three highly altered lakes which have already lost the majority of their native fishes. Tule perch populations seem to have dropped to very low levels in Clear Lake; they are probably absent from Lower Blue Lake, but still common in Upper Blue Lake.

Description: Tule perch are small (up to 150 mm SL), deep-bodied fish, bluish to purple dorsally, and white to yellow ventrally. Three color variants have been described, based on their lateral barring patterns: wide-barred, narrow-barred, and bars absent but, in Clear Lake, the unbarred form is absent, and most (73%) are narrow-barred. Adults have a pronounced hump (nuchal concavity) immediately anterior to the dorsal fin, which is deeper on Clear Lake fish than other subspecies. The dorsal fin has 15-18 spines and 9-15 rays; the anal fin, 3 spines and 20-26 rays; the pectoral fins, 17-19 rays. There are 38-43 scales along the lateral line (Baltz and Moyle 1981). Clear Lake tule perch are deeper bodied than other subspecies (Hopkirk 1973, Baltz and Moyle1981).

Taxonomic Relationships: The tule perch is the only freshwater species in the marine family Embiotocidae. *Hysterocarpus traskii lagunae* was described by Hopkirk (1968) as one of three subspecies. Morphometric analyses by Baltz and Moyle (1981) confirmed that the Clear Lake tule perch is different from Russian River tule perch (*H. t. pomo*) and Sacramento tule perch (*H. t. traskii*). The three subspecies also show genetic divergence (Baltz and Loudenslager 1984), as well as striking differences in life-history patterns (Baltz and Moyle 1982).

Life History: Tule perch are deep-bodied livebearers. Females produce young that are large, considering the size of the mother. As a result, females have reduced swimming abilities while pregnant. These attributes drive the life history adaptations of this unusual fish. See the Russian River tule perch account in this report for an overview of tule perch life history in a riverine environment. Tule perch have inhabited Clear Lake, one of the oldest lakes in North America, for a long period of time. Their scales have been found in sediment cores from the lake bottom that cover 25,000 years, but they have presumably been in the lake much longer (Hopkirk 1988).

From an evolutionary perspective, Clear Lake represents a remarkably stable environment which is reflected in the life history strategy of Clear Lake tule perch, compared to those of the other two subspecies (Baltz and Moyle 1982). Clear Lake tule perch are relatively long-lived (6-7 years). Females delay reproduction until their second or third year at lengths of 110 to 120 mm; they give birth to 25-35 free swimming young of relatively large size, presumably because both adults and young have high survival rates at larger sizes. Curiously, the populations in Upper Blue Lake show signs of being stunted (all fish < 100 mm SL) but they maintain the same basic life history strategy, although brood sizes are small, with 10-12 young (Baltz and Moyle 1982).

Clear Lake tule perch are gregarious and are usually found in aggregations, especially during the day, that may include several hundred fish (Moyle unpublished observations). The Clear Lake tule perch, with its terminal mouth, protrusible jaw, and long gill rakers is adapted for selective feeding on larger zooplankton species. Cook (1964) found that tule perch fed mostly on zooplankton but switched to feeding on midge (Chironomidae) larvae when midges were abundant.

Habitat Requirements: The main population of Clear Lake tule perch spends it entire life cycle in Clear Lake, which is warm (summer temperatures 25-28°C) and shallow (average depth 6.5 m), with primarily sandy or soft bottom substrates. Clear Lake is eutrophic, alkaline (pH of ca. 8) and fairly turbid (Secchi depth, <2m) (Suchanek et al. 2008). Historically, smaller populations occured in Lower Blue Lake, which is similar to Clear Lake in its environmental attributes, and in Upper Blue Lake, which is clearer and cooler. Clear Lake and the Blue Lakes are quite different from habitats occupied by other tule perch subspecies which live in rivers, usually with clear, cool water, or in the turbid brackish water of the San Francisco Estuary. Their presence in this wide range of habitats suggests that tule perch are very tolerant of environmental variables. However, their absence from the San Joaquin Valley floor (Brown 2000) suggests that poor water quality limits their distribution in this part of their historic range (Moyle 2002). Laboratory studies indicate that Sacramento tule perch can withstand temperatures up to 30°C but they are rarely found in the wild at temperatures greater than 25-27°C (Cech et al. 1990). Clear Lake tule perch presumably have slightly higher temperature tolerances, although this has not been tested.

A key habitat requirement of Clear Lake tule perch is cover, especially for pregnant females and small juveniles. They are usually found in small shoals in deep (3+m) tule beds, among rocks (especially along steep rocky shores), or among the branches of fallen trees. Piers may also provide some cover but, in Clear Lake, such cover is usually occupied by alien sunfishes.

Distribution: This subspecies is confined to Clear Lake and to Upper and Lower Blue lakes, in Lake County (Hopkirk 1973, Moyle 2002). Presence in Lower Blue Lake has not been confirmed in recent years.

Trends in Abundance: Early accounts indicated that tule perch were one of the more common fishes in Clear Lake (e.g., Stone 1873). In sampling performed with three kinds of gear from 1961-1963, Cook et al. (1964) found tule perch to be the 5th most abundant fish in their catches. In his review of the status of native fishes in the lake, Cook (1966) found tule perch to be "reasonably abundant" throughout the lake. In July, 1977, Broadway and Moyle (1978) likewise found tule perch to be the fifth most abundant fish captured in 78 seine hauls. Abundance of tule perch in Clear Lake in recent years is not known but they were found to be uncommon or absent in more recent sampling. Tule perch favor habitat around heavy structure and vegetation, such as tule beds, and these habitat types are difficult to sample using conventional methods such as seine nets. The Clear Lake Vector Control Agency samples a number of areas by beach seine around the lake each year. In 2005, eight perch were caught, in 2007, seven perch, in 2010, six perch, and in 2012, seven perch (J. Scott, pers. comm. 2013). Because tule perch are not common in near-shore habitats along beaches, it is possible that they may have been underrepresented in seine catch reports (e.g., Broadway and Moyle 1978). However, boat electrofishing surveys should provide good indications of at least presence/absence.

Electrofishing surveys by CDFW collected 37 perch in 1999, 25 in 2000, four in 2001, three in 2002, one in 2008, six in 2010, and one in 2012 (J. Rowan, CDFW, pers. comm. 2013). In short, tule perch appear to have become very scarce in Clear Lake in the past 10-20 years. Both sampling methods used in recent years, however, have biases that select again capturing tule perch, although past sampling suggests they were common regardless of technique used.

Clear Lake has rarely been 'clear' in the past so visual surveys are not employed, although tule perch are readily visible in Upper Blue Lake, where they still appear to be common (J. Rowan, CDFW, pers. comm. 2011). Their status in Lower Blue Lake is not known but conditions there are similar to Clear Lake (shallow, turbid, dominated by non-native species).

Nature and Degree of Threats: The threats to this subspecies reflect large-scale anthropogenic changes to the Clear Lake basin. Osleger et al. (2008) examined sediment cores from the lake and found an abrupt change in sediment characteristics starting around 1927, when the Sulphur Bank Mercury Mine opened up on the edges of the lake. Core analyses revealed that the cultural eutrophication of Clear Lake "began with the advent of large-scale open-pit Hg mining in 1927 and subsequent human-induced landscape modification involving heavy earthmoving equipment. These activities resulted in increased erosion/sedimentation rates and associated nutrient input into the lake, culminating in algae blooms and reduced surface water quality through the rest of the 20^{th} century (Osleger et al. 2008, p. A255)."

Major dams. Cache Creek Dam was built in 1914 to control lake outflows and levels to provide water for Yolo County agriculture. This causes lake levels to be higher, at times, than they naturally would be and fluctuate more than they did historically. The effects of lake drawdown on tule perch populations are not known but it is possible that young-of-year (YOY) perch could be forced from cover as water levels drop, making them more vulnerable to predation.

Agriculture. The Clear Lake basin supports widespread agriculture, especially orchards and vineyards, which sends effluent, including fertilizers, sediments and pesticides into the lake. These impacts were probably more severe historically than they are today. Agricultural effluents and other pollutants contributed to accelerated eutrophication in the 20^{th} century that resulted in major blooms of bluegreen cyanobacteria (Osleger et al. 2008). Although tule perch persisted in spite of significant reductions in water quality, their abundance may have been greatly reduced by these conditions.

Grazing. Heavy grazing of Clear Lake watersheds has occurred since the 1870s and has likely contributed to sedimentation and nutrient loading of the lake (Suchanek et al. 2002). Impacts were greater historically but the legacy effects of erosion, soil compaction, stream degradation, and loss of meadow and wetland habitats may still be influencing water quality and habitat suitability in Clear Lake. Effects on tule perch are unknown.

	Rating	Explanation
Major dams	Low	The level of Clear Lake is partly regulated by a dam on its outlet, Cache Creek
Agriculture	Medium	Contributes to eutrophication, sedimentation and pollution of the lake
Grazing	Low	No current lakeshore grazing but heavy historic grazing may continue to contribute to loss of habitat quantity and quality
Rural residential	High	Clear Lake and the two Blue lakes are surrounded by housing which reduces shoreline habitat and contributes pollutants
Urbanization	Medium	Towns around the lake contribute to pollution and degraded aquatic habitats, especially nearshore and shoreline habitats
Instream mining	Low	Gravel mining simplifies habitats and increases turbidity
Mining	Medium	Contamination of foodwebs from mercury may especially affect tule perch because of live-bearing life history
Transportation	Medium	Roads contribute sediment and other pollutants, as well as modify habitats along lakeshore
Logging	Low	Legacy effects of sedimentation, etc.
Fire	Low	Fire may increase sedimentation rates; fire frequency and intensity predicted to increase
Estuary alteration	n/a	
Recreation	Low	Removal of tule beds, fallen trees, etc. to improve boat access or reduce hazards reduces habitat quantity and quality
Harvest	n/a	
Hatcheries	n/a	
Alien species	High	Competition and predation from alien species are substantial

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Clear Lake tule perch. 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 section for descriptions of the factors and explanation of the rating protocol.

Rural residential. As Clear Lake became popular as a resort area in the 19th century, the lakeshore became increasingly developed with vacation and permanent homes. This development removed wetlands, which trapped sediment and nutrients, added septic tank effluent to the lake, and led to large-scale application of pesticides to the lake to control pestiferous gnats. While tule perch persisted despite changes to the shoreline and lake habitats, it is likely they declined in abundance as cover, such as tule beds and dead trees, became less abundant. Such cover is especially important to pregnant females and to their small young, immediately after birth.

Urbanization. Many small towns around the lake also contribute to eutrophication through sewage spills, increase in sedimentation, and removal of tule beds and wetlands. Local residents were leading proponents of applying pesticides to the lake. In particular, dichloro diphenyl dichloroethane (DDD) was applied (1949, 1954, 1957) to control gnat populations. DDD accumulates in the fatty tissues of fish, perhaps affecting survival and reproduction (Hunt and Bischoff 1960).

Mining. The Sulphur Bank Mercury Mine dumped mining waste (~193,600 cubic yards) containing mercury directly into the Oaks Arm of the lake and shore from 1922-1947 and 1955-1957. These wastes contaminated the lake ecosystem with mercury and arsenic (summarized in Suchanek et al. 2002). Elevated levels of mercury have been found in fish and waterfowl in the Clear Lake basin. A current health advisory (first issued in 1986) recommends that not more than one fish from Clear Lake be consumed per week. The water column does not seem to contain high concentrations of methyl mercury, in contrast to some lake sediments. Indirect effects from mercury exposure include behavioral disruption (prey capture, inhibition of reproduction), reduced growth rate, and disruption of physiological functions (olfaction, thyroid function, blood chemistry; Suchanek et al. 2008), potentially making tule perch more vulnerable to predation. Female tule perch pass mercury and other contaminants on to their young, so this may affect survival of juveniles.

Transportation. Roads along the edge of the lake have reduced available cover (e.g. downed trees). Drainage from roads can also increase fine sediment delivery to the lake, adding to the lake's eutrophication problem, as well as various pollutants with unknown effects on tule perch.

Logging. Clearing of forest lands around Clear Lake began in the 1840s. By 1905, approximately 1.5×10^6 board feet of lumber were being processed locally (Suchanek et al. 2002). Erosion from timber harvest lands likely contributed to siltation of the lake and eutrophication and legacy effects may still be affecting aquatic habitats in the basin.

Recreation. Pollution from extensive use of gas-powered watercraft in Clear Lake may stress tule perch. Removal of tule beds, fallen trees and other obstacles to improve boat access or reduce boating hazards reduces habitat for perch, especially juveniles and pregnant females.

Fire. Natural and human-induced fires are common in the watersheds that drain into Clear Lake (Suchanek et al. 2002). Catastrophic fires can increase erosion rates and sediment delivery to the lake, contributing to eutrophication. Fire frequency and intensity are predicted to increase in the future under climate change models, potentially leading to further degradation of water quality and habitat suitability in Clear Lake.

Alien species. Historically, 10 native fish species were found in Clear Lake (Moyle 2002). Presently, only five (hitch, blackfish, tule perch, Sacramento sucker, prickly sculpin) of these species still exist in the lake, along with at least 16 alien fish species. Some native species extirpated from the lake maintain populations in tributaries streams (see the Clear Lake hitch account in this report). Until recently, tule perch seem to have persisted in at least small numbers despite the introduction of many competitors for zooplankton and benthic invertebrates. The high abundance of threadfin shad and Mississippi silverside in recent years may have seriously depleted both the zooplankton and benthic insects that tule perch depend on; when zooplankton is depleted, most planktivorous fish switch to feeding on benthic invertebrates (Eagles-Smith et al. 2008). Increased predation from alien species and decreased availability of forage base, in combination with decreased habitat quality (sedimentation, impaired water quality, removal of cover), may be working together to negatively affect tule perch populations. In recent years, largemouth bass, especially larger fish, have been abundant in Clear Lake, increasing the likelihood of predation impacts on tule perch, especially during years when alternative prey populations are low (Eagles-Smith et al. 2008). It is also possible that during periods of high threadfin shad and Mississippi silverside abundance in the lake (most years), zooplankton food resources are reduced and predator densities, especially fish-eating birds, may increase. Increased capture of tule perch as incidental prey by predators may also negatively affect their populations and pregnant females may be particularly susceptible due to their impaired swimming ability, as are newly-born young.

Effects of Climate Change: The life history, broad environmental tolerances and population resilience of Clear Lake tule perch should make them relatively resistant to the effects of climate change, especially in Upper Blue Lake. However, increasing water temperatures and more frequent lower lake levels could cause additional stress to tule perch and other fishes through decreased water quality, reduced cover availability, improved conditions for alien predators and other factors. Pregnant females and juveniles would be particularly vulnerable to these changes. Climate change predictions also state that the frequency and intensity of storm events will increase, potentially increasing sedimentation, nutrient loading and pollution (from mine wastes) into Clear Lake (Suchanek et al. 2002). In addition, indirect effects of climate change, such as increasing algal blooms or abundance of competing alien species also have potential to negatively affect tule perch. In an independent analysis using 10 metrics, Moyle et al. (2013) found that Clear Lake tule perch are “highly vulnerable” to extinction under predictions of standard climate change models.

Status Determination Score = 2.3 - High Concern (see Methods section Table 2). The Clear Lake tule perch is confined to Clear Lake and the two Blue Lakes but appears to be increasingly uncommon in Clear Lake and absent from Lower Blue Lake. However, few focused abundance or distribution data exist, so its actual status remains uncertain.

Metric	Score	Justification
Area occupied	1	Restricted to the Clear Lake basin; present in Upper Blue Lake (UBL)
Estimated adult abundance	3	Abundance not known but likely small in Clear Lake; the largest population may be in UBL
Intervention dependence	3	Population in Clear Lake may need intensive management or reintroduction
Tolerance	3	Tolerant of conditions in Clear Lake although susceptible to warm temperatures and pollutants
Genetic risk	2	Genetic risks unknown; could be severe if UBL contains the principal remaining population
Climate change	2	UBL is possible refuge
Anthropogenic threats	2	See Table 1
Average	2.3	16/7
Certainty (1-4)	1	Few studies or published reports exist

Table 2. Metrics for determining the status of Clear Lake tule perch, 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: Little is known about the habitat requirements, overall abundance, or population trends of Clear Lake tule perch. Even less is known about their interspecific dynamics with introduced fishes in Clear Lake and in Upper Blue Lake. These attributes need further study in order to develop appropriate management strategies and to bolster conservation efforts. In particular, it is important to understand the requirements of YOY perch and the effects of predation and competition from alien fishes on their survival. If tule perch populations are declining in Clear Lake and have been extirpated from Lower Blue Lake in recent years, as the few available surveys suggest, then Upper Blue Lake may, ultimately, be their only refuge.

Specific recommendations include:

1. Implement comprehensive fish surveys of Clear Lake, Upper Blue Lake and Lower Blue Lake to establish baseline status of the species. Surveys should be performed using a variety of sampling gear including electrofishers, gill nets, trawls and seines and repeated at intervals (3-5 years) to develop trend information. Visual surveys should be conducted in upper Blue Lake and, when possible, in Clear Lake.
2. Using information collected in comprehensive fish surveys, establish standardized monitoring programs for the native fishes of all three lakes.
3. Establish a conservation facility for Clear Lake fishes, including tule perch, that maintains captive populations of species in decline and works closely with the

monitoring program to determine conservation strategies and priorities.

4. Determine likely causes of decline in Clear Lake and what actions, if any, can be taken to restore populations. Develop genetic and physiological studies to determine if perch from Upper Blue Lake can be used as substitutes for fish from Clear Lake in conservation strategies (e.g. reintroduction).
5. Conduct a thorough investigation of the limnology, fishes, and other aspects of Upper Blue Lake to determine what factors, if any, might threaten its value as a refuge for Clear Lake tule perch.
6. Conduct physiological studies to establish the environmental tolerances of Clear Lake tule perch in order to determine likely impacts of climate change. Parameters studied should include: temperature, dissolved oxygen, as well as exposure to methyl mercury, pesticides, and other pollutants.
7. Investigate and implement ways to improve tule perch habitat, especially for pregnant females. Use existing laws and regulations to protect remaining shoreline habitats. Habitat improvements could include: increasing cover in areas along the lakeshore, including expanding tule beds, allowing fallen trees to stay in the water, and creating artificial cover patches ('reefs') in places.
8. Develop and implement a conservation strategy for Clear Lake and Upper and Lower Blue lakes to improve water and habitat quality to benefit all native fishes.

Figure 1. Distribution of Clear Lake tule perch, *Hysterocarpus traskii lagunae* (Hopkirk). Historically, they were found only in Clear Lake, Lower Blue Lake, and Upper Blue Lake.