CLEAR LAKE PRICKLY SCULPIN
***Cottus asper* ssp. (Richardson)**

Status: Moderate Concern. The Clear Lake prickly sculpin cannot be regarded as secure because of continual changes in water quality and high abundance of alien species in its lake habitats.

Description: Prickly sculpins can be distinguished from other sculpins by their long dorsal and anal fins (Moyle 2002). For Clear Lake prickly sculpin, fin spine and ray counts are 8-9 soft spines in the first dorsal fin, 20-21 rays in the second dorsal fin, and 17-19 rays in the anal fin (Hopkirk 1973). The dorsal fins join at the base. Pelvic fins have one spine fused with the first ray and 3 additional rays. The pectoral fins have 17-18 rays. Prickling, which gives the body a rough feel, is well developed on the body (Hopkirk 1973). Prickly sculpin, in general, have 5-6 gill rakers, 6 branchiostegal rays on each side, and 2-3 pre-opercular spines, of which only one is usually observable. The lateral line has 28-43 pores and is complete. Palatine teeth are easily observable. They normally have one but, occasionally, two pore(s) on the chin. The caudal peduncle is rounded and narrow in relation to body depth. Coloration varies but is usually mottled reddish brown to dark brown with 4-5 dark saddles on the dorsal surface and light yellow to white on the belly. During breeding, males turn very dark and both sexes develop orange edges on the first dorsal fin. Non-breeding males can be distinguished from females by their long, V-shaped genital papilla. Clear Lake prickly sculpin tend to have smaller adult body size (usually <60 mm TL) than most other California prickly sculpins.

Taxonomic Relationships: Prickly sculpin are highly variable morphologically, widely distributed, and have poorly studied systematics (Kresja 1965, 1970). Although pelagic larvae allow for wide dispersal, it is likely that genetic differences exist between subgroups. Three distinct forms of prickly sculpin exist in California: the coastal form, Central Valley form, and Clear Lake form (Hopkirk 1973). Hopkirk (1973,1988) indicated that the Clear Lake form merited subspecies status based on the number of anal (ca. 18) and pectoral (17-18) fin rays, the partial prickling on adults and trophic adaptations for feeding on small benthic invertebrates. Recent genetic studies support the distinctiveness of the Clear Lake sculpin, perhaps at the species level, with the most closely related populations occurring in Cache Creek downstream of the lake (Baumsteiger et al. 2012).

Life History: Clear Lake prickly sculpin are most commonly found near shore, associated with beds of tules and gravel substrates (Week 1982). Assuming they have similar life history to other forms, they spend most of their time lying on the bottom during the day and become more active at night. Prickly sculpin are not especially gregarious, although aggregations of prickly sculpin have been observed near lake shores in British Columbia (Northcote and Hartman 1959). They are not territorial outside of the breeding season.

Clear Lake prickly sculpin complete their entire life cycle within the lake (Broadway and Moyle 1978). Spawning takes place in March and April, as indicated by presence of larvae in the water column. Presumably, like other prickly sculpins, they spawn under rocks and logs. Males build nests by excavating a small area beneath rocks and then clean the underside of the rock to which eggs are attached. Males lure females into the nest and courtship occurs mostly at night (Kresja 1965, 1970). Once spawning is complete, males chase females from the nest and guard embryos until they hatch. Males move in the nest to facilitate water circulation over the eggs and ensure hatching (Moyle 2002). Fecundity ranges from 280 to 11,000 eggs per female, depending on size and age (Patten 1971); presumably fecundities of Clear Lake sculpins are on the low side of this range because of their relatively small size. In lakes, such as Clear Lake, larvae swim up into the water column upon hatching (5-7 mm TL), live as plankton for 3-5 weeks, and eventually settle as juveniles (15-20 mm) on the bottom. Juveniles in lakes move into shallow water upon settling (McLarney 1968). Clear Lake sculpins move offshore during the day and move inshore to feed at night, although some are found in shallow water at all times of day (T. Ford, UC Davis, unpubl. report 1977, Broadway and Moyle 1978).

Prickly sculpin feed primarily on benthic invertebrates and small fish. In Clear Lake, 74% of their summer diet was historically chironomid midge larvae and pupae (Cook 1964). Amphipods became an abundant prey item after invasion of Mississippi silverside, *Menidia audens* , which greatly reduced midge abundance (Broadway and Moyle 1978, L. Decker and M. LeClaire, UC Davis, unpubl. report 1978). However, amphipods were more commonly eaten by sculpins captured inshore, while chironomid larvae were more common in fish captured offshore. Clear Lake prickly sculpin feed at all times of the day and night but more intensely at sunrise and sunset. The rate for complete digestion of one chironomid larva is about 7 hours (T. Ford, UC Davis, unpubl. report 1977). Diets of fish collected from sandy substrates are less varied than in those collected from rocky substrates. Diets vary little with size with the exception of pelagic larvae, which feed on planktonic copepods and cladocerans (Broadway and Moyle 1978, Eagles-Smith et al. 2008b). However, ontogenetic shifts in diet, from small invertebrates to larger invertebrates and fish, have been noted for prickly sculpin in Lake Washington (Tabor et al. 2007). Prickly sculpin are prey to other species but are not common in diets even where they are abundant, as in Clear Lake.

Clear Lake prickly sculpin growth is highly variable. One study found young-of-year, on average, measured 26 mm SL, while 1+, 2+, 3+, and 4+ age fish measured 34 mm, 44 mm, 48 mm, and 55 mm, respectively (L. Decker and M. LeClaire, UC Davis, unpubl. report 1978). Another study determined Clear Lake prickly sculpin to measure 28 mm SL at 1+ and 35-45 mm at 2 to 5+ (T. Ford, UC Davis, unpubl. report 1977). One individual was aged at 5+ at 95 mm SL, yet lengths for 3+ fish ranged from 30-90 mm. The length-weight relationship for Clear Lake prickly sculpin was determined by Ford (1977) to be $W = 1.02 \times 10^{-5} SL^{3.19}$, where SL is standard length.

Habitat Requirements: The Clear Lake prickly sculpin is adapted to life in a warm (summer temperatures 25-28°C), shallow (average depth 6.5 m), lake with mostly sandy or soft bottom substrates. The lake has been highly productive for thousands of years as a result of shallow, warm, well-mixed waters. Clear Lake and lower Blue Lake are thus eutrophic, alkaline (pH of ca. 8), and fairly turbid (Secchi depth, <2m) (Suchanek et al. 2008). Upper Blue Lake, in contrast, is clear and cool. Sculpins show no apparent preference for substrates within the lake and are abundant on soft and sandy bottoms; they have been found at depths up to 10 m (Broadway and Moyle 1978). While spawning has not been directly observed, it is likely they require logs, rocks and similar substrates for their nests. Clear Lake prickly sculpin do not inhabit streams of the Clear Lake basin, although prickly sculpin are found in Cache Creek and its tributary, Bear Creek, a tributary downstream from the lake (Hopkirk 1973; J. Baumsteiger, UC Merced, unpublished data, 2013).

Distribution: Clear Lake prickly sculpin are found in Clear Lake, Lake County, a large, natural lake, and in Upper and Lower (presumed) Blue lakes, in the Clear Lake basin (Hopkirk 1973). They may also occur in small numbers in Cache Creek, the outlet of the lake, although this population appears to be genetically and ecologically distinct from the Clear Lake population (J. Baumsteiger, UC Merced, unpublished data, 2013). Clear Lake is the largest freshwater lake in California (not counting Lake Tahoe, which is partly in Nevada). It is located in the Coast Ranges at 402 m elevation and has a surface area of about 17,670 ha (Moyle 2002).

Trends in Abundance: Prickly sculpin are apparently abundant in Clear Lake (Broadway and Moyle 1978). However, survey data indicate that, while the population experiences wide fluctuations, the general trend is declining (Figure 1). Eagles-Smith et al. (2008) found sculpin to be one of the most common fish in the lake, with no significant changes in density (based on area seined) from 1986 through 2004.

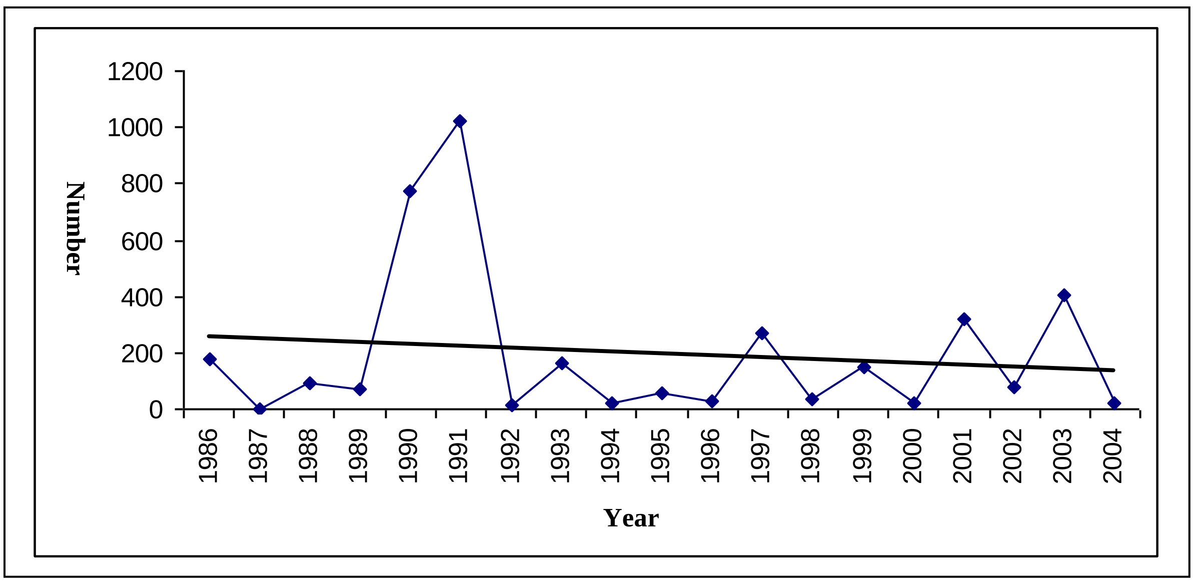

Figure 1. Number of Clear Lake prickly sculpin caught through standardized seining, Clear Lake, 1986-2004. Data from the Clear Lake Vector Control Agency.

Nature and Degree of Threats: Clear Lake is a highly altered natural lake. It is polluted with nutrients, sediment, heavy metals, and pesticides from numerous sources and has experienced invasions of many species of alien fish, invertebrates, and plants (Table 1). These changes resulted in the disappearance of five native species of fish from the lake, including the endemic Clear Lake splittail (*Pogonichthys ciscoides*). Five native species have persisted despite these stressors, including Clear Lake prickly sculpin. Whether or not prickly sculpin can continue to persist long-term in the face of rapid change and cumulative impacts, especially predation and competition from large populations of alien fishes is, however, in doubt, despite their present abundance.

Major dams. Cache Creek Dam was built in 1914 to provide water for Yolo County agriculture by storing water in Clear Lake. The effects on sculpin populations are unknown.

Agriculture. The Clear Lake basin is utilized for fairly intensive agriculture, including expanding viticulture, which sends effluents carrying fertilizers, sediments, and pesticides into the lake, although these impacts were greater historically than they are today. Fertilizers and sediments contributed to accelerated eutrophication of Clear Lake in the 20th century that resulted in major blooms of blue-green algae. While Clear Lake prickly sculpin persisted through periods of impaired water quality, die-offs of prickly sculpin elsewhere have been attributed to low dissolved oxygen concentrations associated with the senescence of algal blooms (Martin et al. 2007), including that of cyanobacteria found in Clear Lake.

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). Effects on sculpin are unknown.

Rural development. 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 filled wetlands on the lake margin, important for trapping sediment and nutrients, added septic tank effluent to the lake, and caused large-scale application of pesticides to the lake to control pestiferous gnats. Sculpin persisted despite these changes to lake characteristics.

Urbanization. Many small towns around the lake also contribute to eutrophication through sewage spills, increase in sedimentation, and removal of 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 fishes, perhaps affecting survival and reproduction (Hunt and Bischoff 1960).

Mining. The Sulphur Bank Mercury Mine dumped mining waste 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 within the 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. Mercury concentrations in Clear Lake fishes appear to be directly correlated with extent of benthic foraging, making prickly sculpin particularly susceptible to mercury bioaccumulation (Eagles-Smith et al. 2008). Indirect effects from mercury exposure include behavior disruption (prey capture, inhibition of reproduction), reduced growth rate, and disruption of physiological functions (olfaction, thyroid function, blood chemistry; Suchanek et al. 2008). However, the physical and biological attributes of the lake, including its size, alkalinity, and lack of a developed hypolimnion, appear to diminish the effects of mercury on aquatic organisms (Suchanek et al. 2008a, b).

	Rating	Explanation
Major dams	Low	Cache Creek Dam regulates lake levels, potentially exposing important near-shore habitats during draw-downs
Agriculture	Medium	Agricultural runoff contributes to eutrophication and pesticide loads
Grazing	Low	Overgrazing has occurred since the 1800s and has contributed to sedimentation and nutrient loading in the lake; greater impact in the past
Rural residential	Medium	Development has drastically altered shorelines and increased eutrophication
Urbanization	Medium	Urban runoff is a source of nutrients and pesticides; development along the lake shore has degraded habitats
Instream mining	n/a	
Mining	Medium	Mercury levels in lake fishes are highest in benthic foragers such as prickly sculpin
Transportation	Low	Roads along the lake shore can contribute pollutants and sediments
Logging	Low	Erosion from timberlands have likely increased the amount of fine sediment delivery to the lake
Fire	Low	Wild and human-induced fires are common in Clear Lake watersheds and can increase sediment delivery to the lake
Estuary alteration	n/a	
Recreation	Low	Motorized boats can contribute to pollution from oil and gas and disrupt fish habitat use
Harvest	n/a	
Hatcheries	n/a	
Alien species	High	At least three alien species likely compete with prickly sculpin; introduced piscivores may prey on sculpin

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Clear Lake prickly sculpin 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 unlikely as a result; and a factor rated "no" has no known negative impact to the taxon under consideration. Certainty of these judgments is moderate. See methods section for descriptions of the factors and explanation of the rating protocol.

Transportation. Roads follow the lake shores for long distances (e.g. highway 20), facilitating pollution from road run off and siltation by road drainage.

Logging. Clearing of forestlands around Clear Lake began in the 1840s but accelerated post-World War II, contributing to eutrophication and siltation of the lake (Suchanek et al. 2002).

Recreation. Extensive use of gas-powered watercraft in Clear Lake may negatively affect the health of prickly sculpin. Polycyclic aromatic hydrocarbons (PAH), a contaminant that enters water bodies from the combustion or oil wastes of personal watercrafts, has been implicated in causing physiological changes in prickly sculpin in Auke Lake, Alaska (Moles and Marty 2005). Prickly sculpin exposed to high concentration of PAH experienced lower condition factors and fewer lymphocytes than sculpin collected from lakes where motorized watercraft were banned. Sculpin collected from Auke Lake also had more liver lesions indicative of chronic toxicity than sculpin collected from other locations. Boats and other watercraft can also disrupt fish habitat use in shallower waters.

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 expected to increase in the future, as is the duration of ‘fire season’ under climate change models, potentially putting Clear Lake at higher risk for continued habitat degradation associated with sedimentation and eutrophication.

Alien species. Historically, 10 native fish species were found in Clear Lake (Moyle 2002). Presently, only five (hitch, blackfish, tule perch, prickly sculpin, Sacramento sucker) exist in numbers, along with at least 16 alien fish species. Sculpin persist in large numbers despite the introduction of many potential predators and competitors. They can be major prey of largemouth bass (Murphy 1949) although, so far, they have sustained populations despite potential predation impacts. It is also possible that predation on larvae by introduced planktivorous fishes, such as Mississippi silversides and threadfin shad, could reduce sculpin numbers, as could competition for benthic prey. Planktivores switch to benthic invertebrates in the lake if zooplankton is depleted by grazing, although prickly sculpin did not undergo a dietary shift when threadfin shad became extremely abundant in the lake for a short period (Eagles-Smith et al. 2008). The study of Eagles-Smith et al. (2008) suggests that Clear Lake has a highly variable community of alien fishes. An unexpected shift in this community or the invasion of a new species could impact sculpin populations.

Effects of Climate Change: Predicted increases in temperatures may increase the extent and intensity of algal blooms in Clear Lake. Coupled with reduction of tributary stream inputs in the summer, these conditions can lead to areas in the lake with very low dissolved oxygen concentrations, limiting suitable habitat for native fish species. 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 and urban or suburban runoff and effluents) into Clear Lake (Suchanek et al. 2002). In a separate analysis of 10 metrics, Moyle et al. (2013) rated the Clear Lake sculpin as ‘highly vulnerable’ to climate change, indicating that if present conditions in Clear Lake and the Blue Lakes significantly worsen as the result of climate change (e.g., water temperatures and eutrophication increase), extinction risks increase dramatically.

Status Determination Score = 3.3 - Moderate Concern (see Methods section Table 2)**.** The Clear Lake prickly sculpin have a limited distribution and face many threats that, in combination, could contribute to further population declines and potentially cause its extinction.

Metric	Score	Justification
Area occupied	2	Clear Lake prickly sculpin are only found in Clear Lake and in Upper and Lower Blue lakes
Estimated adult abundance	5	Current abundance is not known but population assumed to be large
Intervention dependence	4	Many stressors threaten the viability and health of Clear Lake prickly sculpin, although they have proven remarkably resilient
Tolerance	4	Prickly sculpin, in general, are tolerant of a wide range of natural environmental factors; however, they are likely at the limits of their tolerance in Clear Lake
Genetic risk	4	Genetic risks unknown
Climate change	2	Increased temperatures have the potential to change the base of food webs and decrease productivity
Anthropogenic threats	2	See Table 1
Average	3.3	23/7
Certainty (1-4)	3	Seine sampling provides reasonable assessment of status

Table 2. Metrics for determining the status of Clear Lake prickly sculpin, 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: The following recommendations will enhance our understanding of this form and bolster conservation efforts:

1. The Clear Lake prickly sculpin should be formally described as a subspecies (as recommended in Hopkirk 1973) and as supported by new genetic data from J. Baumsteiger, UC Merced (2013).
2. The distribution and ecology of Clear Lake prickly sculpin should be more thoroughly documented as part of a systematic sampling program for Clear Lake native fishes. In particular, its status in Upper and Lower Blue Lakes should be determined.
3. Population abundance indices should be established and determined frequently, allowing for trend monitoring.
4. Environmental tolerances specific to Clear Lake prickly sculpin should be established. Parameters studied should include: temperature, dissolved oxygen, siltation (to determine spawning success), as well as exposure to methyl mercury, pesticides, and other gas/oil derivatives.
5. A conservation plan for all fishes native to the Clear Lake basin should be developed and

implemented (see the Clear Lake tule perch account in this report).

6. Use existing laws and regulations to protect remaining shoreline habitats in order to improve spawning and rearing conditions for prickly sculpin and other native fishes, which depend on these important habitats.

Figure 2. Distribution of Clear Lake prickly sculpin, *Cottus asper* ssp. (Richardson), in Clear Lake, California.