BLUE CHUB
Gila coerulea (Girard)

Status: Moderate Concern. Blue chubs are still common within their limited range in California but they are affected by changing conditions, especially water quality, in the upper Klamath Basin.

Description: Blue chubs resemble Klamath tui chubs, with which they are usually associated, except that they have finer scales (58-71 in the lateral line), are not as deep bodied, have longer fins, and have pointed heads with larger mouths, with the maxillary reaching the eye. There are 9 dorsal rays, 8-9 anal rays, and 14-17 rays in each pectoral fin. The pharyngeal teeth (2, 5-5, 2) are sharp, slightly hooked and located in two rows. The lateral line is curved ventrally. Blue chubs seldom exceed 40 cm SL and often have dark backs and silvery blue sides. Spawning males have blue snouts and bright orange tinges on their sides and fins.

Taxonomic Relationships: This species has been taxonomically stable since Charles Girard described it in 1856. The confusion that once existed over its scientific name was cleared up by Bailey and Uyeno (1964). Biochemical studies have determined blue chub to be distinct from other *Gila* species (Simons and Mayden 1998) and Smith et al. (2002) place it in the monotypic genus *Klamathella*. Schönhuth et al. (2012), however, recommend refraining from using *Klamathella* until the full systematics of the genus *Gila* have been completed (a work in progress).

Life History: Blue chubs grow rapidly in their first four years of life and mature at about 12-15 cm SL. Growth slows upon maturity but can continue to reach 38 cm FL (Scoppettone 1988). Blue chubs are long-lived. One individual at 34 cm FL was aged at 17 years (Buettner and Scoppettone 1991). Little has been published on the growth or early life history of blue chubs. Blue chubs are omnivorous, as indicated by their generalized body shape and tooth structure. Blue chubs collected from Willow Creek, Modoc County, in August, 1972 (all one year of age, 29-59 mm SL) fed mostly (66% by volume) on aquatic insect larvae and flying insects, including chironomid midge larvae and pupae, water boatmen, and water fleas. In comparison, two-year-old chubs (61-109 mm SL) fed heavily on filamentous algae (68%) and larger aquatic and terrestrial insects (Moyle 2002). Blue chubs from Oregon were found to have a similar diet (Lee et al. 1980).

Spawning occurs in May through August over shallow, rocky areas at temperatures of 15-18°C (Lee et al. 1980). In 1966, C.R. Hazel documented their spawning behavior in Upper Klamath Lake, Oregon: "On the afternoon of May 4, 1966, I observed an estimated 200-300 blue chubs spawning at the shoreline on the northern end of Eagle Ridge. Spawning was taking place from near the surface to a depth of 0.3 to 0.5 m. The bottom was composed of large gravel and rubble of volcanic origin. The water was clear with a low concentration of blue-green algae . . . the water temperature was 17° C. Two to several males would approach a female and exhibit rapid and violent agitations of the water, making it impossible to see exactly what was taking place. In some instances the female was pushed from the water onto dry land and in a few situations, eggs were spawned outside the water. After these activities, egg masses were found attached to [submerged] rocks either on the sides or near the bottom edge. Many of the depositions were found along rocky edges at depths to 0.5 m." Blue chubs gather to broadcast spawn in large schools in the summer months (ODFW 1996). As many as 30,000 eggs may be released in one spawning event. Spawning usually occurs adjacent to shorelines over gravel substrates in shallow (< 3 inches) water. Embryos hatch in approximately 7-9 days and larvae are pelagic, with an ability to concentrate in favorable areas (e.g., to avoid being exported from a lake) (Markle et al. 2009). Juveniles rear in shallow water until they reach sexual maturity around 3 years of age. Blue chubs may be an important food source for waterfowl, such as red-necked grebe (*Podiceps grisegena*; Watkins 1988) and mammals, such as mink (ODFW 1996).

Habitat Requirements: Blue chubs are most abundant in habitats with warm (summer temperatures >20°C), low-velocity waters and mixed substrates (Bond et al. 1988). In the wild, they have been collected in waters as warm as 32°C (D. Markle, Oregon State University, pers. comm.). They are especially abundant in lakes but school conspicuously in a variety of habitats, including small streams, shallow reservoirs and deep lakes. Although found in perennial and intermittent sections of Boles Creek, a tributary to Clear Lake Reservoir (Modoc County), they are most common in the small, shallow, weedy reservoirs of larger perennial streams (Scoppettone et al. 1995). In Upper Klamath Lake, Oregon, they are (or were) most abundant in rocky shore and open water habitats, avoiding marshy shore areas (Vincent 1968). In the summer, they seem to be excluded from deeper parts of the lake by oxygen depletion but move back into them as oxygen levels rise (Vincent 1968).

Although wild blue chubs are often observed in warm water, laboratory studies have shown that they lose equilibrium at temperatures of 28–33°C (mean, 31.5°C) and oxygen levels of 0.6–1.5 mg/L at 20°C (Castleberry and Cech 1993). These tolerances suggest that increasingly degraded water quality can limit their distribution and cause a decline in abundance and viability (Castleberry and Cech 1993). Vincent (1968) also found that blue chub distribution was inversely related to dissolved oxygen concentrations.

Distribution: Blue chubs are widely distributed in the lower elevations of the upper Klamath and Lost rivers in Oregon and California. In California, they are also found in Clear Lake Reservoir, Lost River, Lower Klamath Lake, Tule Lake, as well as the canals and tributaries that feed them. Their distribution has expanded to include Iron Gate and Copco reservoirs on the Klamath River (CH2M Hill 2003). Their range has also expanded through introductions in Oregon (e.g., Paulina Lake; ODFW 1996).

Trends in Abundance: Blue chubs remain common in Upper Klamath and Agency lakes, Oregon (Markle and Simon 1997, Markle et al. 2009). They also are abundant in the Boles Creek watershed and Clear Lake Reservoir (Buettner and Scoppettone 1991, Scoppettone et al. 1995). Between 0.2 to 3.2% (n = 70 – 196) of the fishes collected from Iron Gate, Copco and J.C. Boyle reservoirs are blue chub (Desjardins and Markle 2000, CH2M Hill 2003). No systematic estimates of past or present abundances in California have been made. While the artificial habitats provided by reservoirs have expanded their range, pollution from agriculture, introduction and competition from alien fishes, and altered flows in the Lost River may have contributed to a reduction in overall abundance. Drought in the 1980s and 1990s further stressed the aquatic fauna of Upper Klamath basin, a system already strained by other factors, such as water diversion, pollution, introduced species, and entrainment in power plants.

Nature and Degree of Threats: Blue chubs are tolerant of a wide range of water quality conditions, but their populations in California should not be regarded as secure because the aquatic ecosystems in upper Klamath basin are heavily impacted by multiple stressors.

Major dams. The rivers and lakes of the upper Klamath Basin are largely regulated by dams which have, in some cases, created additional habitat for blue chubs (see distribution) but other factors, such as introductions of alien species, have made these habitats less secure.

Recently, focus has been placed on the impact of turbine entrainment on blue chub abundance. CH2M Hill (2003) estimated that median turbine entrainment at Copco and Iron Gate reservoirs was 115, 979 fish, while the median entrainment at J.C. Boyle was 75,655. If it is assumed that the 0.2– 3.2% of entrained fish are blue chub, as estimated by Desjardins and Markle (2002), then approximately 383 to 6,131 individuals are likely to be entrained by both dams each year and most of these are likely young-of-year (50 to 150 mm, CH2M Hill 2003). Entrainment in Klamath River dams peaks in spring and summer, between April and June, during the time that juvenile fish are moving into rearing habitats (CH2M Hill 2003). Therefore, yearly recruitment may be reduced due to disproportionate juvenile mortality associated with entrainment. In reports reviewed by CH2M Hill (2003), members of the Cyprinidae (minnows and chubs) were the third most likely group to be entrained. In Link River Dam, Oregon, blue chub made up 49% (214,204) of the entrained fish (CH2M Hill 2003). However, the high rate of entrainment at Link River Dam may reflect their relative high abundance in Upper Klamath Lake.

Agriculture. Agriculture affects blue chubs through a combination of water diversions and pollution via return water. Diversions from rivers and reservoirs have dried up low elevation habitats once preferred by blue chubs (e.g. Lower Klamath Lake). The widespread reclamation of land in the upper Klamath basin by the U.S. Bureau of Reclamation's Klamath Project has significantly altered the landscape, reducing the amount of habitat available to aquatic species. Only about 10% of the open water and marsh habitats once available in the Upper (Oregon) and Lower Klamath lakes exist today (National Research Council 2006). The maximum surface area of Lower Klamath Lake is currently about 4,700 acres, a substantial reduction from the historical maximum surface area of 94, 000 acres. The maximum surface area of Tule Lake has also decreased significantly from 110,000 to approximately 13,000 acres. Efforts to restore wetlands began in the 1980s and continue today. Water manipulation and diking have also changed the manner in which the lakes in the upper basin behave (NRC 2006). Water management in Clear Lake causes its area and depth to vary outside of its natural range. Similarly, the surface area of Tule Lake historically varied from 55,000 to 110,000 acres; however, its surface area currently fluctuates from 9,450 to 13,000 acres. These changes likely reduce the productivity of these systems (NRC 2006).

Organic pollutants from agriculture and grazing flow into Upper and Lower Klamath lakes and Tule Lake, making them more eutrophic and less suitable for native fishes, even though blue chub are tolerant of fairly extreme environmental conditions (Castleberry and Cech 1993). Increased temperature and lower dissolved oxygen levels may negatively affect blue chub populations (Castleberry and Cech 1993). Both Lower Klamath and Tule lakes have been listed by the California State Water Resources Control Board as impaired for high pH levels (www.swrcb.ca.gov/northcoast/). Tule Lake has also been listed as impaired because of high nutrient loads. The Lost River has been listed for both high nutrients and pH concentrations. Poor water quality from agricultural drainage in the Lost River and Tule Lake has presumably reduced habitat suitability for blue chubs and other fishes.

	Rating	Explanation
Major dams	Medium	Dams change lake and river dynamics and can result in turbine entrainment
Agriculture	High	Major influence on Upper Klamath Lake (Oregon), Lower Klamath Lake and Tule Lake, through diversions and pollution
Grazing	Medium	Pervasive in much of the upper Klamath basin resulting in sedimentation and erosion of nutrient-rich soils
Rural residential	Low	Low population densities throughout area
Urbanization	Low	Minor impact of urbanization throughout its range
Instream mining	Low	Minor impact on shallow stream habitats
Mining	n/a	
Transportation	Low	Road density is relatively low in its range, but may affect water quality
Logging	Medium	Major source of sediment with roads and surface runoff associated with forest vegetation removal; greater historical impact than today
Fire	n/a	
Estuary alteration	n/a	
Recreation	n/a	
Harvest	n/a	
Hatcheries	n/a	
Alien species	Medium	Introduced fathead minnow are likely replacing blue chub in parts of their range

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of blue chub 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 moderate. See methods section for descriptions of the factors and explanation of the rating protocol.

Grazing. Grazing in the upper Lost River and lands surrounding Clear Lake Reservoir have degraded riparian habitat conditions and water quality (CRWQCBNCR 2004) with unknown impacts to blue chubs.

Rural residential. Rural communities with low population densities are common throughout the range of blue chub (NRC 2006). However, their impact on water quality is thought to be minor.

Instream mining. Past gold mining has impacted streams throughout California, leaving a legacy of degraded habitats (Moyle 2002). However, current impacts are assumed to be minor.

Transportation. Road density in the area is low but may have minor impacts to water quality when roads are located close to riparian areas.

Logging. Logging practices in the Lost River watershed and around Clear Lake Reservoir may have increased nonpoint source pollution (CRWQCBNCR 2004) and sediment input into streams and lakes.

Recreation. Translocations by anglers have increased the geographic range of blue chub in Oregon (Moyle 2002) but have had no known impact in California.

Alien species. The upper Klamath Basin has been invaded by a number of introduced aquatic species, which are dominant in some habitats. These invasive species likely impact native fishes, including blue chub, through indirect and direct competition and predation. For instance, fathead minnow (*Pimephales promelas*), ecologically similar to blue chub (Moyle 2002), have proliferated in the lakes and canals of the region in recent years. The effect of increasing fathead minnow numbers on blue chubs and other native fishes is unknown but is thought to decrease blue chub populations (Castleberry and Cech 1993), presumably because they are better able to survive in warmer waters with lower dissolved oxygen levels than blue chubs. In Clear Lake Reservoir, Lost River and Tule Lake, introduced Sacramento perch (*Archoplites interruptus*) have become abundant (Moyle 2002). Sacramento perch are piscivorous but their impact on blue chub populations is not known. Likewise, yellow perch (*Perca flavescens*) are abundant in reservoirs also inhabited by blue chubs and may reduce populations through predation.

Effects of Climate Change: Climate change may result in increased air temperatures in this largely arid, high desert region, which may lead to reductions in habitat suitable for blue chub and other fishes (Cahill et al. 2004, Cayan et al. 2008). Expected outcomes of increased air temperatures are: increased evaporation rates (further reducing already diminished lake and reservoir levels, as well as the amount of perennial stream habitat), increased water temperatures, and decreased dissolved oxygen concentrations. Blue chub are intolerant of temperatures above a mean of 31.5°C and dissolved oxygen concentrations below 1.5 mg/L (Castleberry and Cech 1993). Elevated temperatures may also exacerbate the incidence of parasitism and resulting infection, particularly associated with the ciliate parasite *Trichodina* sp., found in blue chubs collected from Upper Klamath Lake (Foote and Harmon 1999). However, the potential effects of infection upon individual fish health and overall fitness are unclear. Because their habitats have already become fragmented by dams and portions of river and lake systems that no longer provide suitable habitat, blue chub may be particularly susceptible to the effects of climate change. Moyle et al. (2013) rate blue chub as “moderately vulnerable” to extinction as the result of the added effects of climate change.

Status Determination Score = 3.4 - Moderate Concern (see Methods section Table 2). The blue chub is clearly not in danger of extinction in Oregon (Upper Klamath Lake) but it may be more at risk in California, which contains more peripheral and fragmented populations. Overall, it is a resilient species but limited distribution in waters subject to diversion, pollution, warming, and invasive species may make them vulnerable to future declines if these stressors are not ameliorated.

Metric	Score	Justification
Area occupied	3	Present throughout limited historic range
Estimated adult abundance	2	Not known but assumed to be greatly reduced in CA
Intervention dependence	5	Populations appear self-sustaining
Tolerance	4	Tolerant but vulnerable to increased water temperatures and low oxygen
Genetic risk	5	Risk assumed to be low because blue chub are common throughout their range
Climate change	3	Vulnerable to increased temperatures and low oxygen levels, exacerbated by increases in water demand and reduction in precipitation
Anthropogenic threats	2	See Table 1
Average	3.4	24/7
Certainty (1-4)	2	Very little is published on blue chubs in CA

Table 2. Metrics for determining the status of blue chub in California, 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: Surveys of the distribution and abundance of blue chub are needed throughout its range, but especially in California. Basic life history and habitat requirement studies, particularly of early life history stages, are also needed in order to develop appropriate conservation and management strategies. CH2M Hill (2003) made several recommendations for reducing mortality due to turbine entrainment, including operating turbines at peak efficiency and elevating turbine intake depth. Presumably, the best management strategy would be to improve water quality and habitat in Clear Lake Reservoir and its outflow, Lost River, and to rewater Lower Klamath Lake, if possible, as part of renegotiations of the USBR's Klamath Project. Adherence to Total Maximum Daily Loads Action Plans should decrease nutrient loading and improve water quality (www.swrcb.ca.gov/northcoast/) for the benefit of blue chub populations.

Figure 1. Distribution of blue chub, *Gila coerulea* (Girard), in California and southern Oregon.