EAGLE LAKE TUI CHUB
***Siphateles bicolor* ssp.**

Status: Moderate Concern. Although abundant, the Eagle Lake tui chub is endemic to a single, highly alkaline, terminal lake.

Description: No robust description of the Eagle Lake tui chub exists but they resemble other chubs in the *Siphateles pectinifer/obesa* complex. Eagle Lake tui chubs have a range of 12-28 gill-rakers on the first arch. Gill rakers are bimodally distributed, with peaks at 17-18 and 23-25, respectively (Kimsey 1954). Two body forms are present in the lake, one obese with a pronounced nuchal hump and the other slender. However, all other meristic characters are smoothly distributed across the entire population and Kimsey (1954) found no correlation between body form and gill raker number. Spawning individuals of both sexes develop reddish coloration on the fins. Males also develop small, white breeding tubercles on their body surfaces, while females develop slightly enlarged anal regions, protruding genital papilla, and deeper bodies (Kimsey 1954). Maximum size appears to be around 45 cm TL.

Taxonomic Relationships: This form was once regarded as a hybrid between *S. b. pectinifer* and *S. b. obesa* (Kimsey 1954, Hubbs and Miller 1943, Hubbs et al. 1974), based on gill raker counts. However, lack of other hybrid characters and the isolation of this lake from other parts of the Lahontan Basin indicate a long, separate evolutionary history. For a detailed discussion of tui chub taxonomy, see the Lahontan lake tui chub, *S. b. pectinifer,* account in this report.

Life History: Kimsey (1954) conducted the most comprehensive study of the natural history of this chub. Eagle Lake tui chub shoal in open waters of the lake, forming schools of fish of similar sizes. During the spawning season, schools break up and mature adults congregate in near-shore, shallow areas with dense beds of aquatic plants. At this time immature fish remain scattered throughout the lake.

Spawning occurs from mid-May through the beginning of July. Adults in spawning aggregations mill around dense macrophyte beds at about 1m depth and deposit adhesive eggs that stick to aquatic plants (*Myriophyllum spicatum, Ceratophyllum demersum, Potamogeton* sp.). The newly laid eggs are a pale orange-yellow, but color fades to a lighter straw-yellow after some time. Kimsey (1954) estimated the fecundity of a 27-cm female tui chub at 11,200 mature eggs, but he considered this a conservative estimate because not all eggs mature simultaneously. Thus, tui chubs are probably serial spawners, capable of reproducing several times during a season (Moyle 2002).

Newly hatched larvae are well developed and immediately begin to feed on rotifers, diatoms, desmids, and other microscopic material. Larval body plans of western cyprinids are extremely similar; however, larval tui chub develop a nuchal hump at just 5.5 mm (Remple and Markle 2005). Juveniles aggregate along the lakeshore in huge schools until about December, at which time they move into deeper waters. The young-of-year feed on zooplankton and on terrestrial insects blown into the lake from the surrounding forest (G. Grant, unpublished report; Eagles-Smith 2006). Adult Eagle Lake tui chubs appear to be opportunistic omnivores, although their diet shifts towards benthic

organisms as they grow larger (Eagles-Smith 2006). Larger fish also show a shift into feeding at higher trophic levels, presumably because of their consumption of benthic invertebrates (Eagles-Smith 2006). The bulk of their stomach contents usually consist of detritus, with small quantities of algae, benthic and planktonic invertebrates, and aquatic macrophytes (Kimsey 1954). P. Moyle and students (unpublished data) found gut-contents of adult tui chub in Eagle Lake to consist of 83% detritus, 2% algae and 15% invertebrates. Eagle Lake tui chubs are also a key part of the lake ecosystem, as a major intermediary link between lower trophic levels (detritus, algae, invertebrates) and higher levels such as Eagle Lake rainbow trout and piscivorous birds (Eagles-Smith 2006). The lake supports exceptionally large breeding populations of osprey (*Pandion haliaetus*), western grebes (*Aechmorphorus occidentalis*), Clark's grebes (*A. clarkii*), eared grebes (*Podiceps nigricollis*) and other fish-eating birds; these abundant birds can be observed diving for and consuming large quantities of tui chub in most months of the year (J. Weaver, CDFW, unpublished observations).

Kimsey (1954) aged Eagle Lake tui chubs at 6-7 years using scales; however, Crain and Corcoran (2000) found that if opercular bones were used instead, the ages of adult tui chubs (30-35 cm SL) ranged from 12-33 years. Growth is rapid until age of 4 years, slows until age 7 and is very limited after 8 years (Crain and Corcoran 2000). Such ages and growth rates appear to be typical of tui chubs and suckers (Catostomidae) of the terminal lakes of the Great Basin (Scoppettone 1988).

Habitat Requirements: Eagle Lake is a large (22,000 ha) lake at an elevation of 1,557 m. It is estimated that 14% of the annual water budget for Eagle Lake is provided from stream flow, 38% from direct precipitation and 48% from sub-surface flow (Bureau of Land Management, Eagle Lake Water Budget 2010). Surface water enters the lake from Pine Creek and a number of smaller creeks, all of which are ephemeral, flowing only during winter and drying out by late spring. There is no outflow from Eagle Lake. Bly Tunnel (constructed in the 1920s), which was used to release small amounts of water into Willow Creek, a tributary to Honey Lake, is now closed off (P. Divine, CDFW, pers. comm. 2012). Most water loss is through evaporation.

Eagle Lake is highly alkaline (pH about 9 in most years), clear (secchi depth typically 4-6 m), and cool (summer temperatures rarely >20˚C at the surface). Average depth is 5-7 m, with a maximum depth of 30 m (in the southern basin). Eagle Lake tui chubs are found throughout the lake, but mature fish exhibit a seasonal migration from the deep southern basin of the lake in winter to the more shallow middle and northern basins, where spawning occurs, in spring. They require beds of aquatic vegetation in shallow, inshore areas for successful spawning, egg hatching, and larval survival (Kimsey 1954).

Distribution: This form is confined to Eagle Lake, Lassen County, California. Kimsey (1954) found no stream populations. However, tui chubs have been consistently found in three decades of fish surveys of upper Willow Creek (P. Moyle, unpublished data), which historically connected to Eagle Lake (outflow) via the Bly tunnel (BLM 2007).

Trends in Abundance: At present, tui chubs are the most abundant fish in Eagle Lake and support large populations of fish-eating birds and the piscivorous Eagle Lake

rainbow trout. There is no indication that they are less abundant than they were formerly, but the population may suffer if lake levels continue to drop and alkalinity increases. Eagle Lake is currently (2011-13) at near-record low levels, so tui chub populations may decline with changing water chemistry and reduced habitat, particularly dense stands of tule beds they utilize for cover, many of which are now stranded on the dry shoreline.

Nature and Degree of Threats: Eagle Lake tui chubs and the entire unique Eagle Lake ecosystem face two major threats: alien fishes and extremely depressed lake levels. The greatest threat to Eagle Lake tui chub is reduced lake levels due to extended drought. Eagle Lake is a terminal lake, from which water leaves naturally by evaporation (90%) and subsurface flow (10%), resulting in its very alkaline waters (BLM 2010). Lesser threats include recreational development of the lakeshore and surrounding watershed as well as the continued effects of livestock grazing (Table 1). For a thorough discussion of all factors affecting the watershed, see the Eagle Lake rainbow trout account in this report.

Agriculture. The water diversion through Bly Tunnel has been completely closed. Other agriculture using ground water may influence lake levels; however, there are insufficient ground water data to assess potential impacts from ground water use outside the basin.

Alien species. With the complete closure of the Bly Tunnel, in combination with the unlikely event of a long wet period, lake levels could actually rise. Under such conditions, the lake would become considerably less alkaline and be able to support introduced fishes, as it did in the early 1900s, when largemouth bass and brown bullheads were common. These introduced fishes died out when lake levels dropped during the drought of the 1930s. The impact these fishes had on chub populations is not known. However, the effects of introduced diseases, predators, parasites, or competitors from future fish introductions could be disastrous to the lake ecosystem, including introductions of more alkalinity-tolerant species. Although illegal, introduction of bait or sport fishes by the public remains a possibility.

Effects of Climate Change: Climate change predictions indicate that snow melt and winter rain, the principle sources of recharge water for Eagle Lake, are likely to substantially decrease in the future. Temperature models indicate 2-4 degree rises in average air temperature by the end of the century, or higher, which will increase evaporation rates from the lake. Thus, the lake may recede to lower levels than experienced historically with alkalinities that may inhibit tui chub reproduction. Arguably, existing record low lake levels are already the result of climate change, at least in part. Moyle et al. (2013) rated Eagle Lake tui chub as "critically vulnerable" to climate change because of the potential for Eagle Lake levels to become so low and alkaline the lake can no longer support fish life.

	Rating	Explanation
Major dams	n/a	
Agriculture	Low	Agriculture using ground water may influence lake level; closure of Bly Tunnel (2012) a significant positive development
Grazing	Medium	Grazing affects most tributary streams and meadow systems by changing the timing and quality of surface water inflow to the lake and degrading riparian and instream habitats
Rural residential	Low	Residential population of the basin is limited but increasing
Urbanization	n/a	
Instream mining	n/a	
Mining	n/a	
Transportation	Low	Paved roads surround most of the lake and an extensive network of unpaved roads exists throughout the basin; impacts are unknown
Logging	Low	Watershed has been heavily logged; effects on Eagle Lake fishes, including tui chub, are unknown
Fire	Low	Entire watershed prone to fire; predicted climate change outcomes may increase frequency and intensity of fires; effects on lake ecology unknown
Estuary alteration	n/a	
Recreation	Low	Fishing and boating on the lake present little threat
Harvest	Low	Eagle Lake sustains a small sport fishery for tui chub, but no detrimental effects are known
Hatcheries	Low	The Eagle Lake rainbow trout, the principal (albeit native) fish predator of tui chub, is sustained by a large hatchery operation; however, it is unknown if hatchery stocking has created an artificially larger population than existed historically in the lake
Alien species	Low	Introduction of alien fishes could negatively affect the native fish community, provided lake levels increase and alkalinity decreases

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Eagle Lake tui 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.

Status Determination Score = 3.3 - Moderate Concern (see Methods section, Table 2). The population of Eagle Lake tui chub is large and the presence of many age classes in the population, including very old fish, suggests that they can outlast long periods of conditions unfavorable for reproduction. Nevertheless, their isolation in one location indicates a vulnerability that justifies continuing to recognize them as a Species of Special Concern and developing a monitoring program for them (Table 2).

Metric	Score	Justification
Area occupied	1	Restricted to Eagle Lake
Estimated adult abundance	5	Robust
Intervention dependence	5	No intervention needed at present
Tolerance	4	Broad tolerances but alkalinity of lake could become extremely high during sustained drought, inhibiting reproduction
Genetic risk	3	Single population
Climate change	1	Vulnerable in entire native range
Anthropogenic threats	4	See Table 1
Average	3.3	23/7
Certainty (1-4)	3	

Table 2. Metrics for determining the status of Eagle Lake tui chub, 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: Eagle Lake should have special recognition as a one of the few lakes in the western United States that has a basically unaltered ecosystem, containing only native species and relatively low concentrations of contaminants. In particular, the lake should have recognition as habitat for its community of native fishes, including the endemic Eagle Lake rainbow trout, which feeds, in part, on tui chubs.

A management plan for the entire Eagle Lake basin (including tributary streams) should be developed, as discussed in the Eagle Lake rainbow trout account. One focus of this plan should be the establishment of a governance structure that can evaluate and regulate planned developments in the basin to ensure they are compatible with maintaining the integrity of the lake's ecosystem, including maintaining its large populations of fish-eating birds and the endemic fishes that support them.

In addition, a monitoring program for chubs should be established, as part of a broader program to monitor and manage Eagle Lake for its distinctive biota, as well as to ensure the continued absence of alien species. In particular, population age structure should be examined closely during periods when lake levels are low and alkalinities high and contingency plans should be developed in order to maintain the chub population if reproduction fails repeatedly.

Figure 1. Distribution of Eagle Lake tui chub, *Siphateles bicolor* ssp., in California.