LAHONTAN LAKE TUI CHUB
Siphateles bicolor pectinifer (Snyder)

Status: High Concern. The only verified population in California occurs in Lake Tahoe. This population is declining due to lake changes associated with intense human use of the Lake Tahoe Basin. If tui chub in nearby Prosser, Boca and Stampede reservoirs are confirmed to be *S. b. pectinifer,* then the threats facing this taxa are significantly diminished.

Description: Lahontan Lake tui chubs can reach lengths of 35 to 41 cm FL. The mouth is small, terminal, and oblique. Pharyngeal teeth occur in a single row (5-5, 5-4, or 4-4) and are hooked, with narrow grinding surfaces. This subspecies is characterized by numerous (29-40) long, slender gill rakers; this is the primary characteristic that serves to differentiate it from sympatric *S. b. obesa* (Miller 1951, Vigg 1985, Moyle 2002). The inter-gill raker distances are usually less than the width of the gill rakers themselves. Other morphological characteristics that differentiate *pectinifer* from *obesa* are the more oblique mouth, the slightly concave profile of the head, and uniform blackish or silvery body coloration (Miller 1951). Dorsal and anal fin rays usually number 8, but may range from 7-9; fins are short and rounded. Scales are large, with 44-60 along the lateral line. Spawning males have reddish fins and develop small, white breeding tubercles on their body surfaces; females have reddish fins, slightly enlarged anal regions, protruding genital papilla, and deeper bodies.

Taxonomic Relationships: The systematics of tui chubs are confounded by the fact that many populations appear morphologically similar but are genetically divergent. Distinctive populations occur in the many isolated drainages of the Great Basin, while large lake populations have two sympatric morphs – a pelagic form with many fine gill rakers and a benthic form with fewer, coarser gill rakers. Incomplete meristic and genetic studies add to the taxonomic confusion.

Prominent ichthyologists who have studied the native fishes of the Great Basin have had differing opinions about *S. b. pectinifer*'s taxonomy. Widely varying opinions range from "no valid standing as a taxonomic unit" (La Rivers 1962, p. 420) to assignment of its own genus by J. O. Snyder (1917). Consequently, La Rivers (1962) considered *S. b. pectinifer* to have the most complex taxonomic history of any member of the Great Basin fish fauna. It was first described as *Leucidius pectinifer* by Snyder (1917) who simultaneously described the sympatric 'stream' form as *Siphateles obesus;* the morphological differences between these two forms were great enough for Snyder to place *obesa* and *pectinifer* in different genera. Hubbs and Miller (1943) considered *L. pectinifer* to be a subspecies of *Siphateles obesus* and, thus, called it *Siphateles obesus pectinifer*. Shapovalov and Dill (1950) recognized that both forms were part of the *Siphateles bicolor* complex and renamed them *S. b. pectinifer* and *S. b. obesus*, respectively. Bailey and Uyeno (1964) designated *Siphateles* as a subgenus of *Gila* and designated the fine gill raker tui chub as *Gila bicolor pectinifer*. However, biochemical evidence suggests that tui chubs are more closely related to other Californian minnows than they are to other species of *Gila* (Simons and Mayden 1998). In light of this evidence, Moyle (2002) resurrected the generic name *Siphateles,* first used by Cope (1883) and then by Snyder (1918).

Presently, there are ten *Siphateles* taxa recognized in California (Moyle 2002), although three lack formal taxonomic descriptions: Lahontan Lake tui chub (*Siphateles bicolor pectinifer*), Eagle Lake tui chub, (*S. b. ssp*.), Goose Lake tui chub (*S. t. thalassinus*), Cow Head tui chub (*S. thalassinus vaccaceps*), High Rock Springs tui chub (*S. b. ssp*.), Owens tui chub (*S. b. snyderi*), Mohave tui chub (*S. mohavensis*), Lahontan Creek tui chub (*S. b. obesa*), Klamath tui chub (*S. b. bicolor*), and Pit River tui chub (S. *b. ssp.*). The first four subspecies are included in this report, while the Owens and Mohave tui chubs are already listed as endangered species by both state and federal governments. The Pit River tui chub was listed by Hubbs et al. (1979) as an undescribed subspecies. The tui chubs of the upper Pit River are now considered to be part of the Goose Lake population (Chen et al. 2009) but questions remain about taxonomic affinities of tui chubs distributed in the lower Pit River basin. The High Rock Springs tui chub is extinct.

Recent genetic studies have shown that considerable variation exists among populations of tui chubs, all of which were formerly classified as subspecies of *S. bicolor* (Harris 2000, Chen et al. 2007, Chen et al. 2009). Hence, the subspecific status of *S. b. pectinifer* remains controversial. Not only is the zoogeographic range of *S. b. pectinifer* contained within that of *S. b. obesa,* but Harris (2000) suggested that *S. b. obesa* should be elevated to species status and that *S. b. pectinifer* be submerged within it.

Conversely, studies in both Lake Tahoe and Pyramid Lake, Nevada, indicate that the two forms segregate ecologically (Miller 1951, Galat and Vucinich 1983) and do not interbreed. The existence of sympatric, morphologically distinct tui chub morphs has been repeatedly and consistently observed in large lakes throughout the range of *Siphateles*, most famously in Pyramid Lake and Lake Tahoe but also in Walker Lake, Goose Lake, Eagle Lake and Honey Lake, among others. The main character distinguishing the morphs is number and morphology of gill rakers, although only in Pyramid Lake and Lake Tahoe are the two morphs clearly separated.

It is possible that the distinctive fine gill raker form of tui chub has arisen multiple times in each of these large lake systems, although it may be just a single lineage in the Truckee basin. Similar situations of parallel evolution in California fish taxa may exist, such as the run timing of summer steelhead populations and bony plate development and migratory behavior of threespine stickleback in coastal California streams. A sizeable literature base has developed on trophic polymorphism; of particular relevance to lake dwelling tui chub are trophic polymorphisms among other fishes in lacustrine environments. Examples include char in arctic lakes, whitefish in Canadian and Idaho lakes, cichlids in African Rift lakes, threespine stickleback in British Columbia lakes and sunfishes in the eastern United States. References can be found compiled in reviews on the subject by Smith and Skülason (1996) and, more recently, by Dayan and Simberloff (2005). Until taxonomic studies are completed, all distinctive populations of tui chubs should be managed as separate taxa.

Life History: Lahontan Lake tui chub feed mostly on zooplankton, especially cladocerans and copepods, but also consume benthic insects such as chironomid larvae, annelid worms and winged insects such as ants and beetles (Miller 1951, Marrin and

Erman 1982). They are primarily mid-water feeders, with gill-raker structure adapted to feeding on plankton. In contrast, the co-occurring *obesus* form is primarily a benthic feeder (Miller 1951). A comparison of stomach contents of both subspecies captured together in bottom-set gill nets indicated *obesa* had fed on benthic insects such as chironomids and trichopterans, while *pectinifer* had fed on planktonic microcrustacea (Miller 1951). There is no significant ontogenetic niche shift in diet for *pectinifer*; it feeds on plankton throughout its life (Miller 1951). In Pyramid Lake, both types of tui chubs feed primarily on zooplankton (mostly microcrustaceans) when less than 25 mm FL, but the *obesa* subspecies feed increasingly on benthic and terrestrial macroinvertebrates as they become larger (Galat and Vucinich 1983). There is an ontogenetic change in gill-raker numbers in the two forms that accompanies the differentiation of diets. When less than 25 mm FL, the two morphs are indistinguishable, even based on gill-raker counts, but the gill-raker number increases in *pectinifer* with size until the two forms are readily distinguishable at ≥50 mm FL.

Tui chubs are preyed upon by large trout and, to a lesser extent, by birds and snakes. Examination of stomachs of rainbow trout and lake trout in Lake Tahoe revealed that 10% and 7%, respectively, of their stomach contents consisted of tui chubs (Miller 1951).

In Lake Tahoe, spawning apparently occurs at night during May and June and possibly later (Miller 1951). By early August, females do not have mature ova. Lahontan Lake tui chubs spawn by 11 cm SL (Miller 1951). They are probably serial spawners, capable of reproducing several times during a season (Moyle 2002). Snyder (1917) documented that reproductive adults spawned in near-shore shallow areas over beds of aquatic vegetation and found fertilized eggs adhering to the aquatic vegetation. He noted that young remained in the near-shore environment until winter when they were 1-2 cm in length and then migrated into deeper water offshore.

Growth (length increments) of tui chubs is linear until about age 4, when weight increases more rapidly and length increments decrease. The largest Lahontan Lake tui chub caught in Lake Tahoe was 13.7 cm SL (Miller 1951). These fish are considerably smaller than the tui chubs in Walker Lake, Nevada, where they grow to 21 cm SL (Miller 1951). It is likely that the largest Lahontan Lake tui chubs are in excess of 30 years old (Scoppetone 1988, Crain and Corcoran 2000).

Habitat Requirements: Lahontan Lake tui chub are schooling fish that inhabit large, deep lakes (Moyle 2002). They seem to be able to tolerate a wide range of physicochemical water conditions based on the fact that they are found in oligotrophic Lake Tahoe as well as in Pyramid Lake, a mesotrophic and highly alkaline lake. In Lake Tahoe, the larger fish (>16 cm TL) exhibit a diel horizontal migration by moving into deeper water (>50 m) during the day and back into shallower habitat at night (Miller 1951). However, they always remain high in the water column. Smaller individuals occupy shallower water. Additionally, there is a seasonal vertical migration, with fishes located deeper in the water column during winter and moving back into the upper water column during summer (Snyder 1917, Miller 1951). Algal beds in shallow, inshore, areas appear to be necessary for successful spawning, embryo hatching and larval survival.

Distribution: Lahontan Lake tui chubs are found in Lake Tahoe and Pyramid Lake, Nevada, which are connected to each other by the Truckee River, and in nearby Walker Lake, Nevada. Plankton-feeding populations of chubs in Stampede, Boca, and Prosser reservoirs on the Truckee and Little Truckee rivers may also be Lahontan Lake tui chubs because they have a superior oblique mouth and fine gill rakers and are never found in tributary streams (Marrin and Erman 1982, D. Erman, pers. comm.). Other tui chub populations in the Lahontan basin of uncertain taxonomic affinity also occur in Topaz Lake on the California-Nevada border and in Honey Lake, Lassen County.

Trends in Abundance: Actual abundance is not known, but is likely quite small compared to historic numbers. The Lake Tahoe population is the only confirmed population in California, but the chubs in Stampede, Boca, and Prosser reservoirs may also belong to this subspecies, although no sampling or analysis has been carried out to verify this assertion. Only small numbers have been collected from Lake Tahoe in recent years (P. Budry, Utah State University, unpubl. data) and the Lahontan Lake tui chub has not been studied in Lake Tahoe since the late 1940s (Miller 1951). In the intervening years, the zooplankton community in the lake has changed dramatically. *Daphnia*, which are an important prey of adult chubs, have been nearly eliminated (Richards et al. 1975) by introduced kokanee salmon (*Oncorhynchus nerka*) and opossum shrimp (*Mysis relicta*), both of which feed on zooplankton.

Putative *S. b. pectinifer* populations in the three California reservoirs mentioned above and verified *S. b. pectinifer* populations in Pyramid and Walker lakes in Nevada are large but abundance estimates are lacking.

Nature and Degree of Threats: Until the taxonomy of peripheral populations has been decided, the future of Lahontan Lake tui chubs in California essentially depends on their ability to persist in Lake Tahoe (Table 1).

Major dams. Dams on California tributaries to the Truckee River are apparently a mixed blessing for lake tui chubs. They allow for diversion of water, lowering the level of Pyramid Lake, Nevada and potentially negatively affecting tui chubs there, while creating potential habitat in their reservoirs (additional habitats within California). The reservoir populations are unstudied, however, and may not be *S. b. pectinifer*.

Urbanization and rural development. Water diversion, waste water treatment, wetlands destruction and increased sedimentation from ever increasing development in the Lake Tahoe Basin have altered the lake's physical environment; however, it is unknown how these stressors affect tui chubs. Lake Tahoe has been undergoing physical and chemical change as the result of nutrients, sediments and pollutants entering the lake from surrounding development, as well as more distant sources. Shoreline development has presumably also negatively affected tui chubs because they spawn in shallow water and larvae may require warm habitats with adequate cover for the first few weeks of life (although this is not known). There is some indication that the marsh that is now the development called Tahoe Keys (a major source of alien species in the lake) was once an important rearing area for tui chubs (Miller 1951).

Logging. The Tahoe Basin has been heavily logged in the past and some logging continues, contributing to sediment delivery. Effects on tui chubs are likely minimal, especially when compared to other factors changing the lake.

Fire. The entire Tahoe Basin is increasingly prone to catastrophic fire which may, in turn, deliver huge sediment loads to the lake. This may affect tui chub spawning and feeding and generally change the nature of Lake Tahoe, especially as climate change effects are predicted to increase the frequency and intensity of fire in this region.

Recreation. The Lake Tahoe region is a year-round recreation destination and the increasing influx of permanent residents and visitors drives most of the changes that affect fishes and other organisms in the lake, from water chemistry (e.g. via air pollution) to sedimentation and increasing eutrophication (e.g., surface run off of nutrients and pollutants from ski resorts, casinos, golf courses, recreational parks and trail development).

Alien species. The greatest impacts to the aquatic ecosystem of Lake Tahoe have been the result of introductions of non-native fishes and invertebrates. Mysid shrimp and kokanee salmon have largely eliminated *Daphnia*, which were the major food source of tui chubs, while introduced lake trout (*Salvelinus namaycush*), rainbow trout (*O. mykiss*), and brown trout (*Salmo trutta*) prey on them. . In recent years, the invasions of predatory smallmouth bass (*Microterus dolomieui*) and largemouth bass (*M. salmoides*) into the lake constitute an additional threat to the tui chub population, especially since these predatory centrarchids occupy chub spawning and rearing habitats. As the lake becomes more eutrophic, it may actually be able to support more fish, including tui chubs, but the number and abundance of alien species will also likely increase. In contrast, the alkalinity of Pyramid Lake, Nevada, has largely prevented the establishment of non-native species, with the exception of Sacramento perch (*Archoplites interruptus*). Adult perch (<300 mm) feed largely on tui chubs (Galat et al. 1981).

	Rating	Explanation
Major dams	Medium	Reservoirs may have created habitat but they also reduce freshwater flow into Pyramid Lake
Agriculture	n/a	
Grazing	Low	Grazing occurs in the Tahoe Basin which may contribute to changes in water quality
Rural residential	Medium	Water diversion, waste water treatment, wetlands destruction and increased sedimentation in the Tahoe Basin have changed the lake's physical environment; direct impacts to tui chubs are unknown
Urbanization	Medium	Same as above
Instream mining	Low	No known effect
Mining	Low	Legacy effects are largely unstudied
Transportation	Low	A large portion of the suspended sediment in Lake Tahoe has its origins in sand applied to de-ice roads
Logging	Low	Logging contributes sediment delivery to the lake, with much greater impacts in the past
Fire	Low	The entire Tahoe basin is increasingly prone to catastrophic fire; direct impacts to tui chubs are likely to be minimal
Estuary alteration	n/a	
Recreation	Medium	Recreational use of the Tahoe Basin is the primary force driving the area's rapid development
Harvest	n/a	
Hatcheries	n/a	
Alien species	High	Long-term impacts from introduced predators and competitors may be reducing populations

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Lahontan 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 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.

Effects of Climate Change: The following list includes the predicted impacts and potential consequences of climate change to Lake Tahoe and the northern Sierra Nevada:

- A shift in winter precipitation from snow to rain. This shift in annual hydrologic timing could increase the transport of fine sediment and nutrients to the lake.
- A shift toward earlier snowmelt (Dettinger and Cayan, 1995; Cayan et al, 2001; Stewart et al., 2005). A change to the volume, temperature and timing of streamflow into the lake could increase the lake's thermal stability and could

possibly prolong the residence time of fine sediment near the lake surface, further decreasing water transparency.

- An increase in the average temperature of Lake Tahoe (Coats et al. 2006). An increase in temperature is likely to increase Lake Tahoe's resistance to mixing which could have profound effects on the lakes aquatic community. Thermally driven disruption to historic mixing conditions in Lake Tahoe would favor introduced species over native species.

The combination of these effects could change the water chemistry and temperatures in Tahoe and Pyramid lakes. These effects could also result in reservoirs becoming too low to support tui chub populations. While the Lahontan Lake tui chub is presumably quite physiologically tolerant, changes to its food supply may result in population declines. These predicted impacts are speculative; however, studies should be conducted to document changes and develop trend data in order to inform conservation strategies to address climate change. Moyle et al. (2013) rated this form as "less vulnerable" to extinction from the effects of climate change than most other native fish species because of its refuge in Lake Tahoe.

Status Determination Score = 2.4 - High Concern (see Methods section, Table 2**).** The Lahontan Lake tui chub does not appear to be at risk of extinction; however, the status of the endemic population in California (Lake Tahoe) is largely unknown (Table 2). The Lake Tahoe population may have declined from its historic abundance, while the population in Pyramid Lake, Nevada continues to be large. The taxonomic identity and status of reservoir populations is not known.

Metric	Score	Justification
Area occupied	1	Found only in Lake Tahoe in CA
Estimated adult abundance	2	Population size in Lake Tahoe uncertain; no surveys conducted in over 60 years
Intervention dependence	5	No intervention required at this time
Tolerance	4	Relatively tolerant
Genetic risk	1	Genetics not well understood but the single confirmed population in California is isolated in one (albeit large and deep) lake
Climate change	2	Effects expected to be severe in the Lake Tahoe area
Anthropogenic threats	2	See Table 1
Average	2.4	17/7
Certainty (1-4)	2	Questions about taxonomy and lack of recent population surveys influence status evaluation

Table 2. Metrics for determining the status of Lahontan Lake tui 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 Lake Tahoe and other Lahontan basin waters (Honey Lake, Topaz Lake, Stampede, Boca, and Prosser reservoirs) are needed to determine the distribution and abundance of Lahontan Lake tui chub in California. Equally important, a taxonomic study is needed of all potential populations of this subspecies in California and Nevada. A study comparing genetics to morphology, especially of sympatric morphs found in large lake systems, would be of particular interest. These studies are needed in order to develop a management plan to protect tui chub diversity. Currently, persistence of this form depends on the management of the water quality and biota of Lake Tahoe, including control of non-native, predatory fishes.

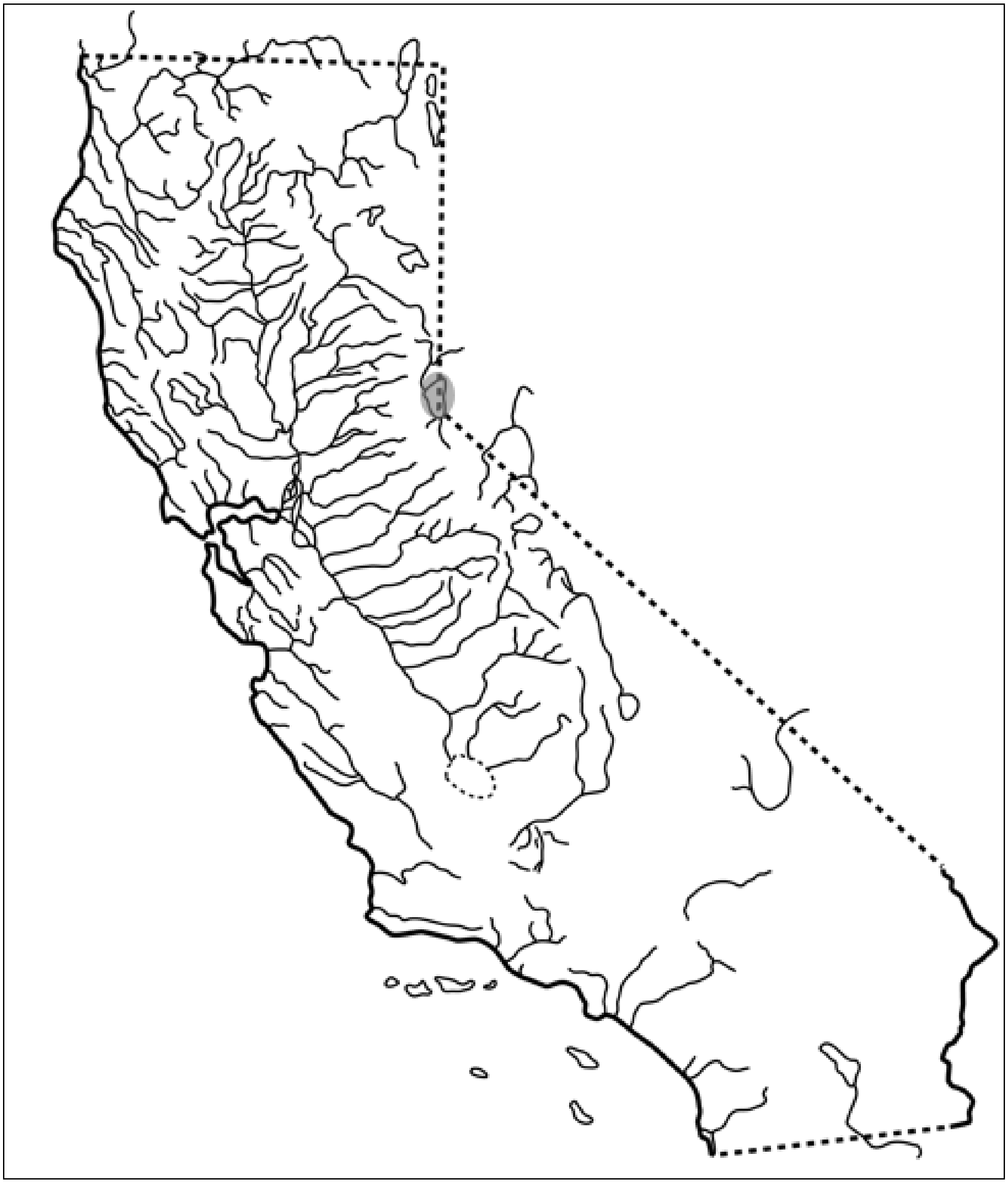

Figure 1. Distribution of verified Lahontan Lake tui chub, *Siphateles bicolor pectinifer* (Snyder), in Lake Tahoe, California.