GOOSE LAKE TUI CHUB
Siphateles thalassinus thalassinus (Cope)

Status: Moderate Concern. Goose Lake tui chub remain numerous in Goose Lake and in the lower reaches of most large tributaries to the lake. However, Goose Lake dries out completely during periods of drought and the tui chub is particularly susceptible to periodic elimination of lake habitat, followed by great reductions in population size.

Description: The Goose Lake tui chub is differentiated from other *Siphateles* taxa by their longer fins, more posterior dorsal fin, longer head, and larger number of dorsal rays, usually nine (Snyder 1908b). Coloration is similar to Lahontan Lake tui chub, although larger specimens from Goose Lake (up to 30 cm FL) are uniformly silver except for a white belly. For a general description of tui chub see the Lahontan Lake tui chub account in this report.

Taxonomic Relationships: The Goose Lake tui chub was first described by E. D. Cope (1883) as *Myloleucus thalassinus*. He simultaneously described a second species of tui chub from the lake as well. Snyder (1908b) noted that Cope collected numerous dried chubs that had been dropped by fish-eating birds along the shoreline and hypothesized that the second species described by Cope was based on these poorly preserved specimens. However, there are apparently two morphological types of tui chub in Goose Lake: a "standard" heavy-bodied tui chub and another form with a less robust body and more pointed head (R. White and P. Moyle, unpubl. obs.). Snyder (1908b) placed *thalassinus* in the genus *Rutilus* because Jordan and Evermann (1896) synonymized *Myloleucus* with *Rutilus*. North American cyprinids placed in the European genus *Rutilus* eventually were referred to generic names of New World minnows, including *Gila*. Snyder (1908b) considered *thalassinus* to be native to Goose Lake and the upper Pit River from Big Valley upstream to Goose Lake. Hubbs et al. (1979), however, considered the form in the Pit River to be distinct from the Goose Lake form, although no evidence was provided. For reasons that are now obscure, Hubbs et al. (1979) used the specific name *thalassina* which was subsequently adopted by other workers; however, *thalassinus* (Cope 1883) has precedence and is used here.

In 2001, a genetic study using mitochondrial DNA found that tui chub in the Cow Head, Warner, and Goose Lake basins are closely related and are sufficiently genetically distinct from other tui chubs as to be recognized as a single species under the name *Siphateles thalassinus* (Harris 2000). Harris recognized two lineages within *S. thalassinus*, one in Goose Lake and the other in the Pluvial Lake Warner Basin, which includes both the Cow Head and Warner basins. Harris's findings supported Hubbs and Miller's (1948) postulation of a possible relationship between Cow Head tui chub and chubs from the lakes in Warner Valley, Oregon, because of the stream connection that existed between the Cow Head Basin and the Warner Valley drainage.

Chen et al. (2009) used microsatellite DNA to further resolve the taxonomy of tui chubs of the northwestern Great Basin. Chen's results supported Harris's systematics regarding the species status of *S. thalassinus.* Chen (2009) also found that tui chub populations of the upper Pit River drainage were genetically indistinguishable from those

in Goose Lake and that these two populations, taken together, were sufficiently distinct to warrant subspecies status as *S. t. thalassinus.*

Rutter conducted the only known comparison of tui chub from above and below Pit River Falls and noted substantial differences in lateral line scale counts between the populations (Rutter 1908). However, both he and Snyder (1908b) considered tui chub populations in Goose Lake and the upper Pit River to be similar. Then, in 1979, without providing a rationale, Hubbs et al. listed Pit River and Hat Creek (tributary to the lower Pit River, below Pit River Falls) tui chub populations as discrete undescribed subspecies. No systematic work has been conducted on the lower Pit River tui chub populations since then, which means that, over a hundred years after Rutter published his findings, the relationship between upper and lower Pit River populations of tui chub remains unresolved.

For a general discussion of tui chub taxonomy, see the Lahontan Lake tui chub account in this report.

Life History: The life history of this subspecies has been little studied. Chubs commonly reach 250 mm FL in the lake and fish as large as 316 mm FL have been collected, indicating that this form may be very long-lived in lake habitats. In streams, however, they rarely exceed 120 mm FL. The size distribution of tui chubs sampled from Goose Lake in 1989 showed two modes. The great majority (>90%) of fish were less than 120 mm SL, while the remainder were 200-300 mm SL (R. White, USFWS, unpubl. data 1989). Most tui chubs are opportunistic omnivores and consume a wide variety of aquatic invertebrates (Moyle 2002). Tui chubs are a major prey base of Goose Lake lamprey; depending on the length class, 20-70% of the tui chubs >200 mm SL sampled in 1989 had lamprey scars (R. White, unpubl. data 1989).

Habitat Requirements: Goose Lake is a massive, natural alkaline lake covering approximately 39,000 surface hectares straddling the Oregon-California border. The lake is shallow, averaging 2.5 m deep, hyper-eutrophic and very turbid (Johnson et al. 1985). A thermocline (and hence temperature stratification and dissolved O_2) appear to be affected by wind conditions, as indicated by data from September, 2009 (R. White, unpubl. data 1989). On a calm September day, water temperature at one sampling locality was 17°C from the surface to 40 cm depth, with a sharp drop at 40-50 cm, and 14-15°C at 50-200 cm depths. At a second locality, temperature decreased from 23°C at the surface to 15°C at 35 cm, remaining at about 15°C between 35cm and 2.5 meter depths. At those two localities, dissolved oxygen concentration held at about 8-10 mg O_2 l^{-1} from the surface down through the water column, but dropped abruptly to <1 mg O_2 l^{-1} in deeper water, depending on locality. The drop in O_2 occurred at about 150 cm depth at one locality, and between 260-270 cm depths at the second locality. On a windy September day, the water temperature was 15˚C throughout the water column (surface to 185 cm depth) measured at one locality. Dissolved O_2 was constant (slightly <10 mg O_2 l^{-1}) from the surface to 170 cm depth, but dropped abruptly to <4 mg O_2 l^{-1} at about 175-180 cm.

The surface elevation of Goose Lake fluctuates seasonally, but averages 1,433 m. In California, no tui chubs have been found in streams above 1441 m in elevation, although tui chubs have been found above 1550 m in Oregon streams (J. Williams,

unpubl. data). In streams, Goose Lake tui chub prefer pools and are generally not found in swift water, although they have been collected from runs in Battle Creek on the west shore of Goose Lake (J. Williams, unpubl. data). Goose Lake tui chubs have been collected in habitats with temperatures ranging from 9-29°C. In July, 1992, large numbers of chubs were observed in the lower reaches of Willow and Lassen creeks (G. Sato, pers. comm. 1993), where they may have been attempting to escape from the increasing alkalinity of the drying lake.

In Oregon streams, Scheerer et al. (2010) found tui chubs mainly in the lowermost reaches in low gradient, unforested stream channels and irrigation ditches, although a few tui chubs were also collected at higher elevation sites. The wide, silt-bottomed habitats were mainly associated with agricultural fields. The principal co-existing species in these agricultural reaches were alien species such as brown bullhead (*Ameiurus nebulosus*) and fathead minnow (*Pimephales promelas*).

Distribution: In addition to Goose Lake itself, *S. t. thalassinus* also occurs in low-elevation sections of streams tributary to the lake and in Everly Reservoir, Modoc County California, as well as in Cottonwood, Dog and Drews reservoirs in Oregon (Sato 1992a). In 2007, the Oregon Department of Fish and Wildlife collected relatively large numbers of tui chub from Dry, Drews, Dent, Thomas and Cox creeks on the Oregon side of the basin (Heck et al. 2008, Scheerer et al. 2010).

The Goose Lake basin is a disjunct subbasin of the upper Pit River. At extreme high water, Goose Lake spills into the North Fork Pit River as it did in 1868 and 1881. Since the late 19th century, storage and diversion for irrigation have substantially reduced the inflow to Goose Lake and future overflow of the lake into the Pit River is deemed unlikely (Phillips et al. 1971). However, because of this historical hydrologic connection, the fish faunas of Goose Lake and the upper Pit River share most taxa and tui chub populations from the two basins are genetically indistinguishable (Chen et al. 2009).

Reid et al. (2003) found tui chub in 7 of 12 sampling sites in the upper Pit River watershed, including the mainstem Pit River near Canby, the North Fork Pit River from the vicinity of Parker Creek down to the confluence with the South Fork Pit River, just below Alturas, and in the headwaters of the South Fork Pit River in Jess Valley.

Trends in Abundance: Goose Lake tui chub have been documented as extremely abundant in the lake. During 1966 gillnetting surveys of Goose Lake, tui chub comprised 88% of fishes collected (King and Hanson 1966). In 1984 it comprised nearly 96% of gillnet collections (J. Williams, unpubl. data) and, in 1989, it comprised 96% of fishes sampled by trawls, gillnets, and seines (R. White and P. Moyle, unpubl. data). Large numbers of chubs could be caught with relatively little sampling effort (e.g., 100+ in a 5-minute haul with a small trawl). In 1992, chubs were eliminated from the lake as it became progressively more shallow and alkaline and then dried. As lake levels dropped, fish crowded into the inflowing streams where they were extremely vulnerable to predation from white pelicans and other fish-eating birds. Apparently the tui chubs survived in greatly reduced numbers in stream pools and in some upstream reservoirs, but mainly in Oregon. Periodic drying of Goose Lake is a natural response to drought and the native fish assemblage evolved under these conditions. However, diversion of stream flows along with the effects of grazing, wetland reclamation and road construction have

altered streams and riparian areas, reducing the extent of stream habitat that these fish rely on during periods of drought.

Nature and Degree of Threats: The principal threat to the Goose Lake tui chub is desiccation of its principal habitat, Goose Lake, accompanied by loss of refuge habitat in tributary streams and reservoirs in the drainage. This account does not include factors affecting poorly known Pit River populations, since the two populations are effectively disjunct; however, if the two regions are considered to have just one population, the Pit River may serve as a drought refuge, unless it is completely taken over by alien species. Tui chub populations may, however, persist in the presence of alien species: Big Sage Reservoir, on Rattlesnake Creek, a Pit River tributary, once supported a successful bass fishery, with a tui chub prey base (Kimsey and Bell 1955). See the Goose Lake sucker account in this report for further details.

Agriculture. Although the lake has dried historically, diversions for irrigation and loss of natural water storage areas (e.g., wet meadows) from agriculture and grazing presumably caused it to dry up more rapidly during the recent period of prolonged drought. Even in absence of complete drying of the lake, reduction of inflows increases the likelihood that the lake will periodically become too alkaline to support freshwater fishes such as tui chub. High alkalinity may be a particular problem for early life-history stages. The key to the survival of Goose Lake tui chubs, in the past, has likely been the presence of refuges in the springs and pools of the lower reaches of tributary streams. The same factors (agricultural diversions, road building, channel alterations) which affect lake inflow also negatively impact in-stream habitat, leaving tui chub few refuges during drought. It is likely that key refuge areas are mainly in Oregon, in the 'delta' marshy areas of Thomas Creek and other tributaries. Small reservoirs created for storage of irrigation water may also serve as refuges for tui chubs.

Grazing. Livestock grazing is, perhaps, the most pervasive land use in the Goose Lake basin. Lowland refuge habitats are degraded by stream erosion and bank destabilizations caused by livestock grazing in riparian areas, especially through the removal of woody riparian plants. While improved management of most grazed lands has reduced the threat of grazing in the short-run (e.g., in the Lassen Creek drainage), as the climate becomes warmer and more variable, there is considerable potential for negative impacts of grazing (and other land uses) to increase unless there is expanded use of riparian protection measures, such as exclusionary fencing.

Transportation. Virtually all streams used by Goose Lake tui chubs are crossed by roads, which often serve as sources of siltation or barriers to fish movement.

Alien species. Goose Lake tui chubs manage to coexist with a variety of alien species, mainly in highly disturbed habitats such as irrigation ditches and reservoirs (Scheerer et al. 2010). However, predation by alien fishes should be considered in management. Education and enforcement are important tools to prevent further illegal introductions of non-native species.

	Rating	Explanation
Major dams	n/a	Impacts may exist in Oregon
Agriculture	High	Diversion of water significantly impacts stream habitat and the frequency/duration of Goose Lake desiccation
Grazing	Medium	Grazing continues to impact stream and riparian habitats
Rural Residential	Low	Relatively little residential water use in comparison to agricultural use in native range
Urbanization	n/a	
Instream mining	n/a	
Mining	n/a	
Transportation	Low	Roads cross all major Goose Lake tributaries
Logging	Low	Widespread in watershed but not intense
Fire	Low	Entire watershed prone to forest and range fires
Estuary alteration	n/a	
Recreation	n/a	
Harvest	Low	Used as bait but practice has been made illegal (article 3, Section 4.30 of CA freshwater sport fishing regulations)
Hatcheries	n/a	
Alien species	Medium	Alien species present a potential threat in drought refuges, particularly in reservoirs

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

Effects of Climate Change: Goose Lake is located at the edge of the arid Great Basin, where relatively rare aquatic habitats are often tapped for human use. Any reduction in precipitation or increased frequency of drought is likely to further stress aquatic habitats in this basin. Snow melt and winter rains, the principle sources of water in the Goose Lake watershed, are likely to substantially decrease as the climate warms (Moyle et al. 2012). During low flow periods, lower streams reaches in the basin currently reach extreme temperatures (24-26°C). Thus an increase in air temperature, especially when combined with reductions in stream flow through diversions, could prove lethal to native fish populations. An increase in fire frequency or intensity in this dry area could also decrease riparian shading, add sediment, and otherwise alter the refuge stream habitats

that tui chub depend on during drought. See the Goose Lake sucker account in this report for a more detailed description of climate change effects in the basin. Moyle et al. (2013) consider the Goose Lake tui chub to be "highly vulnerable" to extinction in California because of climate change, but considered the chub to be confined to the Goose Lake basin. If the limited populations in the upper Pit drainage are, indeed, part of this subspecies, the chub may have greater resistance to climate change.

Status Determination Score = 3.1 – Moderate Concern (see Methods section, Table 2). The limited distribution of Goose Lake tui chub in California and its vulnerability to extended drought merit its inclusion as a species of special concern. The Goose Lake tui chub is a US Forest Service and Oregon Department of Fish and Wildlife "Sensitive Species". The American Fisheries Society considers the Goose Lake tui chub to be "threatened" (Jelks et al. 2008), while NatureServe ranks it as "imperiled" (T2). Presumably, the tui chub develops large populations when Goose Lake is full but may drop to low numbers in isolated populations when the lake dries. These same factors make it particularly susceptible to climate change.

Metric	Score	Justification
Area occupied	2	Restricted to Goose Lake and, possibly, upper Pit River basins
Estimated adult abundance	5	Robust populations when lake is full but drought can cause substantial population reductions
Intervention dependence	4	Stream refuge habitats during times of drought are impacted by agricultural water use
Tolerance	4	Tolerant of extreme DO, temperature and alkalinity levels
Genetic risk	4	Little genetic risk
Climate change	1	Goose Lake is likely to be dry more often as climate becomes more arid
Anthropogenic threats	2	See Table 1
Average	3.1	22/7
Certainty (1-4)	3	

Table 2. Metrics for determining the status of Goose 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: The Goose Lake Fishes Working Group was formed with representatives from federal and state agencies, as well as private individuals with interest in the lake, to explore management measures for all native fishes in the basin (Sato 1992a). The involvement of private landowners is particularly critical because many key refuge habitats occur on private land. The persistence of Goose Lake tui chub in the Goose Lake Basin will require active cooperation between Oregon and California because it is likely that most (if not all) natural drought refuges for tui chubs in the Goose Lake basin are in Oregon. Possible management actions include:

1. Determine the suitability of all reservoirs in the drainage as refuges for native fishes and negotiate, if necessary, for minimum pools during periods of drought. Special attention needs to be paid to potential refuges in California.
2. Identify and implement restoration projects to benefit native fishes in the lower reaches of Goose Lake tributaries in both Oregon and California.
3. Actively enforce the prohibition of use of live baitfish and introduction of nonnative fishes into Goose Lake basin, including Oregon. Where possible, eradicate existing populations of alien fishes in ponds and streams.
4. Establish instream flow protections for larger streams in the basin (Oregon: Thomas, Drews, and Dry creeks; California: Lassen and Willow creeks) to ensure adequate flows are present in lower stream reaches to maintain refuge areas and lake level during periods of drought.
5. Conduct a thorough study of the Goose Lake ecosystem, including a study of the distribution and habitat requirements of tui chubs and a systematic survey of the invertebrates present, expanding on studies in Oregon (Heck et al. 2008, Scheerer et al. 2010).
6. Investigate life history and habitat requirements of Goose Lake tui chub to determine what additional species-specific management measures are required.
7. Determine the systematic relationships among tui chubs in Goose Lake and the upper and lower Pit River.

Figure 1. Distribution of Goose Lake tui chub, *Siphateles thalassinus thalassinus* (Cope), in California. Distribution in the Pit River system is uncertain.