GOOSE LAKE LAMPREY
Entosphenus sp.

Status: High Concern. The Goose Lake lamprey does not face immediate extinction risk but its restricted distribution makes it vulnerable to land and water use practices, climate change, and other factors which could compromise its status.

Description: This predatory lamprey is similar to the widespread Pacific lamprey, *E. tridentatus*, except that it is much smaller (adult TL 19-25 cm vs. 30-40 cm for Pacific lamprey) and not as dark in color. Both forms can be recognized by the sharp, horny plates in the sucking disc, the most distinctive being the crescent-shaped supraoral plate, which has three distinct cusps. The middle cusp is smaller than the two lateral cusps. Adult Goose Lake lampreys are shiny bronze in color. Ammocoetes can be distinguished from those of the sympatric Pit-Klamath brook lamprey (*E. lethophaga*) by the larger number of myomere segments (64-70 between the last gill opening and anus).

Taxonomic Relationships: The Goose Lake lamprey was first recognized as distinct by Carl Hubbs (1925) but he did not formally describe it as a species. It is presumably derived from Pacific lamprey or its derivatives from the Klamath River drainage. However, Goose Lake and the Pit River drainage, to which it connects, have been separated from the Klamath drainage since the early Pleistocene (1-3 million years). Some insights into evolution of the Goose Lake lamprey are provided by Lang et al. (2009); they used mitochondrial DNA (cytochrome B) to examine relationships among all lamprey species. While Goose Lake lamprey *per se* were not used in the analysis, the non-predatory Pit-Klamath brook lamprey was included, which is most likely the closest relative of the Goose Lake lamprey. Lang et al. (2009) found that it was part of the *Entosphenus* clade, which includes the various non-anadromous lampreys from the upper Klamath River as well as the Pacific lamprey. The relationship of Pit-Klamath brook lamprey to others within the clade is largely unresolved. Genetic differences, at least those based on mitochondrial DNA, indicate that the genome of lampreys is very conservative so that population structure, even in the widespread Pacific lamprey, has not been detected (Goodman et al. 2008). Regardless, the lampreys of the Goose Lake basin are likely a distinct evolutionary lineage, perhaps representing more than one.

Within the basin, there are two basic hypotheses about the relationship between the predatory Goose Lake lamprey and the non-predatory Pit-Klamath brook lamprey: (1) they represent different life history forms of the same species, or (2) they are separate species. These same hypotheses, often unresolved, exist for the pairs of predatory and non-predatory lampreys found throughout the world (Docker 2009). It is generally assumed that the non-predatory forms evolved from predatory forms. In the case of the Goose Lake basin, the issue is complicated by the fact the Pit-Klamath brook lamprey has been described as occurring in both the Goose Lake and Klamath River basins, despite their long separation (Hubbs 1971).

Nevertheless, because of its distinctive morphology and ecology and long isolation from other populations, it is most likely that the Goose Lake lamprey is a distinct species, separate from the Pit-Klamath brook lamprey (Kostow 2002) and from other lamprey species in the Klamath River (Docker et al. 1999). As a separate species,

the Goose Lake lamprey may include both predatory and non-predatory life histories, assuming that the predatory form is only expressed when migrations to Goose Lake are feasible (Kostow 2002). Limited data on adult distribution, presented in Scheerer et al. (2010), suggest that the two lamprey species are at least partly segregated by elevation, with the Goose Lake lamprey found in stream reaches closest to the lake.

Life History: The life history of this taxon is largely unknown, but presumably the adults live for a year or two in Goose Lake, preying on Goose Lake tui chubs, suckers, and redband trout. In 1989, adult lampreys were observed attached to gill-netted tui chubs and lamprey wounds were common in larger chubs (P. Moyle and R. White, unpublished observations). They migrate up suitable tributary streams in spring for spawning, with a peak in May (Kostow 2002). They require clean gravels for spawning, combined with soft-bottomed habitat downstream of the spawning areas for rearing of ammocoetes. Thus, spawning areas may be as much as 20-30 km upstream from the lake. Ammocoetes probably spend 4-6 years in tributary streams before metamorphosing into adults (at about 8-13 cm TL) in the fall and moving into the lake in spring (Kostow 2002). During periods of drought, when access to the lake is not available, adult lampreys will feed on stream fishes although survival appears to be low (Kostow 2002).

Habitat Requirements: Adults live in shallow, alkaline Goose Lake where they prey on larger fishes. Like other lampreys, Goose Lake lampreys require gravel riffles in streams for spawning and ammocoetes require muddy backwater habitats downstream of spawning areas. Kostow (2002) characterizes the habitat of ammocoetes as "fine silt lenses along low gradient stream meanders, most often through meadows…(p. 18)." However, the habitat requirements of Goose Lake lamprey have not been well studied or distinguished from those required by Pit-Klamath brook lamprey. For further description of stream and lake habitats, see the Goose Lake redband trout account in this report.

Distribution: The Goose Lake lamprey is endemic to Goose Lake and its tributaries in Oregon and northeastern California. However, a comprehensive assessment of the distribution and habitat utilization of California tributary streams by lampreys has not been performed. Within California, they have been collected only from Lassen and Willow creeks, Modoc County, (G. Sato, BLM, pers. comm. 1994), both above and below potential migration barriers (Hendricks 1995). Ammocoetes were found to be common in Cold Creek, a tributary to Lassen Creek. No ammocoetes were found in Davis, Pine or Willow creeks. It is likely that dams and diversions now restrict distribution of lampreys by blocking adult migration and by drying up suitable habitats downstream. In Lake County, Oregon, they are common in Thomas Creek and a population apparently exists in Cottonwood Reservoir, on Cottonwood Creek (Oregon Dept. of Fish and Wildlife, unpubl. data, 1995). Scheerer et al. (2010) found lamprey ammocoetes to be widely distributed and often abundant in Oregon streams, but did not distinguish species.

Trends in Abundance: There are no trend data for Goose Lake lamprey but their populations likely decline during extended periods of drought and then increase rapidly when wet periods return and the lake fills again. Thus, Goose Lake lampreys were fairly

common in Goose Lake, where they were readily collected from large tui chubs caught in gillnets, until the lake dried up in the summer of 1992 (R. White, USFWS, pers. comm. 1995). The Goose Lake lamprey has the potential of becoming extirpated, especially in California, if the lake and lower tributaries are dry for several years in a row. However, adults may survive by preying on stream fishes and the ammocoetes may persist for 3-4 years if there are adequate flows in the habitats they occupy. The Cottonwood Reservoir population is of unknown size but the reservoir may serve as a refuge, provided a minimum pool is maintained throughout extended drought periods. In Lassen and Willow creeks, ammocoetes were common at densities of 11-50 individuals per 150 ft of stream (Hendricks 1994). Abundance of spawners is not known but 50-100 spawners in most years in each stream may be a reasonable estimate, based on accessible habitat, number of ammocoetes, and abundance in the lake. The importance of Lassen and Willow creeks to persistence of the entire population in the Goose Lake basin is unknown but it is assumed that most spawning and rearing habitat occurs in Oregon streams (Scheerer et al. 2010).

Nature and Degree of Threats: The principal threat to the Goose Lake lamprey is desiccation of its habitats, Goose Lake and its tributaries, which is exacerbated by human activities, including diversions for agriculture and grazing. The combination of severe, extended drought, along with human demands for scarce water resources in the basin, may have resulted in accelerated desiccation of the lake during the 1986-1992 drought and, again, in 2010, resulting in a dry lakebed.

Agriculture. Farming occurs primarily on lands close to the lake, often adjacent to tributary streams, with the result that some streams reaches are channelized, down-cut, and silted from erosion. The diversion of water from streams for agriculture and other uses may reduce or completely dewater habitats required by ammocoetes and adults for survival during droughts, as well as accelerating desiccation of the lake itself. Diversions and dams may prevent adults from reaching spawning areas in tributary streams, although small reservoirs may also serve as refuges for adults. The loss of suitable habitat for ammocoetes is likely to be particularly severe in the lower reaches of streams near agricultural areas.

Grazing. Livestock grazing is one of the greater land uses in the Goose Lake basin. In-stream and riparian habitats can be degraded or eliminated through stream erosion and bank destabilization caused by livestock grazing in riparian areas, especially through the removal of woody riparian plants. In the past, many areas in the California portion of the Goose Lake basin were degraded by grazing, although restoration actions, especially on Lassen Creek, have reversed some of these impacts. While improved management of most grazed lands has reduced the threat of grazing in the short term, as the climate becomes warmer and more variable (see Effects of Climate Change section), there is considerable potential for negative impacts from grazing to increase without expanding the use of riparian protection measures such as exclusionary fencing.

Fire. The Goose Lake basin is semi-desert and wildfires are common. Impacts of fires on lampreys (and other fishes) are not known but are likely to be minimal, unless a major fire causes direct mortality through increased stream temperatures or indirect mortality associated with loss of canopy cover (in-stream shading), accelerated erosion, or landslides in upstream areas.

Alien species. Scheerer et al. (2010) found six species of alien fishes in Oregon streams tributary to Goose Lake, mostly in low elevation areas or areas associated with reservoirs and other altered habitats. Alien species appear to be scarce in Lassen and Willow creeks although predatory brown trout are common in Pine and Davis creeks. Illegal introductions of possible predators (catfish, bass) remain a concern.

	Rating	Explanation
Major dams	Low	Reservoirs may act as refuge during drought; diversion dams may block spawning and in-stream movement
Agriculture	Medium	Alfalfa fields along lower reaches of streams may negatively affect water quality
Grazing	Medium	Grazing is pervasive and is likely to have strong interactions during periods of reduced flow
Rural residential	Low	Few residences
Urbanization	n/a	
Instream mining	n/a	
Mining	Low	Uranium mines exist in the area but their impacts are unknown
Transportation	Medium	Roads and culverts can block migration; potential increased siltation
Logging	Low	Widespread in watersheds but impacts reduced from the past
Fire	Low	A continuous threat in this part of the state; impacts to lampreys unknown
Estuary alteration	n/a	
Recreation	n/a	
Harvest	n/a	
Hatcheries	n/a	
Alien species	Medium	Aliens present in certain portions of the basin; impacts to lampreys are unknown

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Goose Lake lamprey 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: The Goose Lake basin is located in an arid portion of California and this area has, in the recent past, suffered extended periods of drought. Climate change is likely to decrease summer stream flows in key streams, increasing competition for water and riparian habitats between humans (livestock, agriculture) and

fishes. Goose Lake may dry more frequently and for longer periods of time due to increased frequency of drought. Increased stream temperatures of 2-4°C may affect lampreys, although similar species can tolerate fairly warm water. These conditions may also favor alien competitors and predators (Scheerer et al. 2010). An increase in fire frequency or intensity in this dry landscape may decrease riparian shading, add sediment, or otherwise make streams less suitable for lampreys and other fishes. Moyle et al. (2013) consider the Goose Lake lamprey to be "critically vulnerable" to extinction as the result of climate change because predicted reduction in snow pack will result in decreased flow in tributary streams with corresponding reduced lake levels.

Status Determination Score = 2.9 – High Concern (see Methods section Table 2). Goose Lake lamprey do not face immediate extinction risk but their California populations are small and isolated, making them vulnerable to climate change and other factors which could compromise their status. The American Fisheries Society regards Goose Lake lamprey as a threatened species, with declining populations (Jelks et al. 2008), while NatureServe ranks it as Critically Imperiled (T1) and the Forest Service regards it as Sensitive.

Metric	Score	Justification
Area occupied	2	Only known from Willow, Lassen, and Cold creeks in CA
Estimated adult abundance	1	California abundance not known but numbers of adult spawners is likely small in most years and zero in dry years
Intervention dependence	4	Persistence requires habitat improvement and maintenance
Tolerance	4	Not known but presumably fairly broad
Genetic risk	3	Potential for impacts from small population size and isolation
Climate change	2	Stream habitat likely to be reduced as is frequency of lake drying
Anthropogenic threats	4	See Table 1
Average	2.9	20/7
Certainty (1-4)	2	Very little is published on this lamprey

Table 2. Metrics for determining the status of Goose Lake lamprey 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 lamprey and other Goose Lake fishes were little studied and largely unmanaged until 1991, which contributed to their increased likelihood of extinction. The Goose Lake Fishes Working Group was formed in 1991, with representatives from private landowners, federal and state agencies, and environmental groups to explore management measures for all fishes native to Goose Lake and its tributaries (Sato 1992a, see Goose Lake redband trout account in this report). As a result of this program, stream restoration projects have improved reaches of Lassen Creek, presumably providing better habitat for lamprey spawning and rearing. The biology and status of the population in Cottonwood Reservoir needs to be investigated, as well as the possibility of establishing similar refuge populations of the species elsewhere. An investigation of this unusual lamprey's life history and habitat requirements should be conducted in order to develop management and conservation strategies in both California and Oregon. In particular, stream flow models need to be developed under various climate scenarios in order to determine predicted base flows. At a minimum, flows in key tributary streams should provide adequate rearing and holding habitat during extended drought (>5 years) in order for the species to persist and recolonize the lake during wetter periods. Enhancing spawning access, as well as restoring rearing and holding habitats, in streams in California and Oregon (especially in Lassen, Willow, and Thomas creeks) would benefit all native Goose Lake fishes. In addition, studies should be developed to determine both the evolutionary and ecological relationships between the Goose Lake lamprey and the Pit-Klamath brook lamprey. See the Goose Lake sucker account in this report for further discussion of management actions that would encompass the entire Goose Lake basin and likely benefit Goose Lake lamprey.

Figure 1. Distribution of Goose Lake lamprey, *Entosphenus sp.*, in Goose Lake, California and Oregon. The extent to which they are distributed upstream in the Thomas Creek drainage in Oregon is unknown.