KLAMATH RIVER LAMPREY
Entosphenus similis (Vladykov and Kott)

Status: Moderate Concern. Very little is known about this species; thus, the conservative course of action is to consider its numbers to be in decline until new information becomes available to indicate otherwise. However, Klamath River lamprey do not appear to be at immediate risk of extinction.

Description: The Klamath River lamprey is a small (14-27 cm TL, mean 21 cm), predatory lamprey that can be identified by strong, sharply hooked cusps on their oral plates. Three strong cusps on the supraoral plate ('tongue') are easily noticeable. The anterior field above the mouth has 10-15 teeth, 4 inner lateral plates on each side, resulting in the typical cusp formula of 2-3-3-2, 20- 29 cusps in line on the transverse lingual lamina (tongue plate), and 7-9 velar tentacles. The trunk usually has 60-63 myomeres (range of 58-65). The disc length is about 9 percent of the total body length, and is at least as wide as the head. The horizontal eye diameter is about 2 percent of the total body length. Although similar to Pacific lampreys, Klamath River lampreys tend to be more heavily pigmented. Ammocoete larvae have not been described.

Taxonomic Relationships: The Klamath River lamprey was described by Vladykov and Kott (1979), from specimens caught in the Klamath River, California. Four other lamprey species have also been described from the upper Klamath River basin: dwarf Pacific lamprey (*E. tridentata*), Pit-Klamath brook lamprey *(E. lethophaga)*, Miller Lake lamprey (*E. minimus)* and Modoc brook lamprey *(E. folletti).* The Pit-Klamath brook lamprey is the common nonpredatory lamprey of the upper Klamath and Pit river drainages, while the Miller Lake lamprey is an unusually small predatory form that is confined to the upper basin in Oregon (Lorion et al. 2000). The Modoc brook lamprey was also described by Vladykov and Kott (1976), from specimens collected from Willow Creek (Modoc County), a tributary to Clear Lake Reservoir on the Lost River. Although described as nonpredatory, it was later found to be predatory, providing little reason to separate it from Pacific lamprey (C. Bond, pers. comm. 1995). Consequently, Modoc brook lamprey has not been accepted as a separate species (Nelson et al. 2004). In contrast, the Klamath River lamprey is morphologically and biochemically distinct (Docker et al. 1999, Lorion et al. 2000, Lang et al. 2009).

Life History: No specific life history information is currently available, although Klamath River lamprey appear to be non-migratory and are resident in both rivers and lakes of the Klamath basin. Adults prey on adult coho and Chinook salmon and other large fishes in the basin. Wales (1951) thought that lamprey predation on migratory salmon was a major factor limiting salmon abundance in the Shasta River, because he observed such a high frequency of salmon with lamprey wounds (41%) and because "lampreys are abundant in the Shasta (p. 33)." However, salmon mortalities have not been attributed to lamprey predation in recent spawning ground (carcass) surveys or at weir operations (B. Chesney, CDFW, pers. comm. 2011).

Habitat Requirements: Little is known about the habitat requirements of Klamath River lamprey. Presumably, ammocoete larvae have the same basic requirements as those of Pacific lamprey, living in backwaters with soft substrates. The environmental tolerances of Klamath River lamprey have not been documented but they are likely similar to those of Pacific lamprey. If this is the case, then Klamath River lamprey need cold, clear water (Moyle 2002) for spawning and incubation. They also require a diverse range of habitats to complete their life cycle. Adults typically use spawning gravel to build nests, while ammocoetes burrow in soft sediments for rearing (Kostow 2002). Ammocoetes also need larger substrates as they grow (Stone and Barndt 2005) and algae for food (Kostow 2002) in habitats with slow or moderately slow water velocities (0-10 cm/s; Stone and Barndt 2005).

Distribution: Klamath River lamprey are found throughout the Klamath River basin in mainstem rivers, including the Trinity River in northern California and the Klamath River in southern Oregon (Boyce 2002). Their distribution in the lower Klamath and Trinity basins likely coincides with those of spawning Chinook and coho salmon, their main prey in the lower river, and with large suckers and cyprinids in the upper basin. However, detailed distribution of this species is not known.

Trends in Abundance: As with other upper Klamath basin lampreys, abundance estimates for Klamath River lamprey do not exist. However, they appear to be common throughout their range (S. Reid, pers. comm. 2008).

Nature and Degree of Threats: The declining quality of aquatic habitats throughout much of the Klamath-Trinity drainage, as well as the declining number of salmon (NRC 2004), make it likely that Klamath River lampreys are less abundant than they once were (Table 1). Generally, any factor that reduces abundance of large prey species is likely to also reduce Klamath River lamprey abundance (Moyle 2002).

Dams. Seven major dams are present in the Klamath-Trinity River basin. These dams change the physical and biological characteristics of the streams where they occur (Knighton 1998). In particular, they may limit or inhibit the longitudinal (upstream-downstream and vice-versa) movements of fishes, including both Klamath River lamprey and their prey, thereby limiting access to suitable spawning and rearing habitats. Dams have also degraded the quality of preferred habitat in the main stem Klamath River (Hamilton et al. 2011).

Agriculture. Alfalfa production and pasture in the Shasta and Scott basins may diminish flows, particularly in dry water years (NRC 2004). Diminished flows can reduce suitable habitats in streams, as well as create conditions (e.g., high water temperatures, low dissolved oxygen levels) that increase salmonid mortality, thereby reducing adult Klamath River lamprey prey availability. Diversion of water, warm polluted return water, and similar by-products of agriculture are also presumably limiting lamprey populations.

Grazing. Livestock grazing is pervasive in Klamath River watersheds, with disproportionate effects on smaller tributaries, reducing water and habitat quality (USFWS 1991). Grazing practices in some subbasins (e.g., Shasta River) have altered stream morphology and degraded habitat quality to the detriment of native fishes

(USFWS 1991, Gosnell and Kelly 2010). Grazing can lead to localized increases in water temperature when riparian vegetation is removed, as well as low oxygen concentrations from excess fecal nutrient loading.

	Rating	Explanation
Major dams	Medium	Seven major dams exist in the system and likely disrupt instream movement, gene flow, and opportunities for recolonization
Agriculture	Medium	Major influence on Scott and Shasta rivers by reducing salmon prey abundance (NRC 2004)
Grazing	Medium	Pervasive in Klamath River watersheds with disproportionate effects on smaller tributaries
Rural residential	Low	Widespread rural development throughout range but housing densities very low
Urbanization	n/a	
Instream mining	Low	Legacy effects have likely reduced the amount and quality of suitable habitats
Mining	Low	Impacts are unknown but assumed to be minor
Transportation	Medium	Roads are a source of sediment that may affect spawning and rearing
Logging	Medium	Widespread changes to watersheds; greater impact in past than today
Fire	Low	While wildfires are common throughout the Klamath basin, direct impacts to Klamath River lamprey are likely minimal
Estuary alteration	n/a	
Recreation	n/a	
Harvest	n/a	
Hatcheries	n/a	
Alien species	Low	No known impacts

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Klamath River 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 to the taxon under consideration. Certainty of these judgments is low. See methods section for descriptions of the factors and explanation of the rating protocol.

Instream mining. Instream mining may alter larval rearing habitats through scour and deposition and through direct displacement of ammocoetes. When the Scott River and other areas were dredged for gold in the 19th and 20th centuries, large areas of potential habitat were destroyed; when combined with dewatering from diversions (often relicts of mining), past dredging may have had considerable legacy effects upon lamprey populations and their habitats.

Transportation. Roads, both paved and unsurfaced, have been built within the riparian corridor of many Klamath streams (USFWS 1991). Many miles of dirt roads have also been built in most of the Klamath-Trinity watersheds. Road building can decrease the quality of nearby aquatic environments to the extent of altering animal behavior and overall species composition (Trombulak and Frissell 2000). Road building can decrease the amount of canopy cover over streams and potentially increase water temperatures, limit the ability of streams to meander, impair the creation of slow water habitats, and increase sediment and pollutant input from surface run off. Increased fine sediment input into streams can decrease the quality of spawning gravels for adult lamprey and other fishes. However, it is possible that increased sedimentation may provide additional habitat for lamprey larvae.

Logging. The entire Klamath-Trinity basin has been heavily logged with attendant impacts on streams, especially increases in sedimentation from logging roads. Certain logging practices can alter the hydrology of streams (Wright et al. 1990), such that habitats become unsuitable for some fishes (Reeves et al. 1993). As with road building, logging can increase the amount of solar radiation reaching streams, decrease the amount of nutrients entering food webs, impair recruitment of large woody debris (habitat complexity, cover) and increase the amount of fine sediment eroding from hillslopes into streams. However, with current California timber harvesting rules, logging had a much more pronounced impact on stream habitats in the past than it does today (NRC 2004).

Effects of Climate Change: The potential impacts of predicted climate change to Klamath River lamprey are poorly understood because so little is known about their biology, life history, or environmental tolerances. Nevertheless, increased water temperatures (> 22 °C) brought about by climate change may increase incidence of deformities and mortalities of incubating eggs and larvae, as has been observed in Pacific lamprey populations (Meeuwig et al. 2005). Summer water temperatures already frequently exceed 20°C in many streams in the Klamath River basin and temperatures are expected to increase under all climate change scenarios (Hayhoe et al. 2004, Cayan et al. 2008). Increased summer temperatures may affect the growth and metabolic costs of juvenile and adult Klamath River lamprey that hold and rear in rivers throughout the summer. Climate change is also predicted to change the flow regimes in rivers. Klamath River flows may peak earlier in the spring and continue tapering through the summer before pulsing again later in the fall. The resulting changes in river flow and temperature may change the timing of adults and juveniles entering and exiting streams. High flows can disrupt incubation and rearing habitat due to increased bed mobility (Fahey 2006). However, flow alterations associated with climate change may be attenuated by dam operations. Shifts in distribution are expected to be upward in elevation and northward in latitude but may be impeded by passage through dams and culverts, along with increased metabolic costs associated with increased water temperatures. Moyle et al. (2013) rated Klamath river lamprey as “highly vulnerable” to extinction as the result of climate change in the next century, based on the largely speculative evidence presented above.

Status Determination Score = 3.9 - Moderate Concern (See Methods section, Table 2). The Klamath River lamprey does not appear to be at much risk, given its wide distribution within the Klamath and Trinity basins, although it may be negatively affected by climate change in the future (Table 2). The paucity of information available on this species, including present and past abundance and distribution, makes a conservation status determination difficult. Additional information is needed in order to better understand its status.

Metric	Score	Justification
Area occupied	5	Widely distributed in Klamath basin (Moyle 2002)
Estimated adult abundance	4	Unknown, but appears to be common throughout range (S. Reid, pers. comm. 2010)
Intervention dependence	5	Populations appear to be resilient and persistent
Tolerance	3	Environmental tolerances have not been identified, but are presumed similar to other lamprey species in the Klamath River basin
Genetic risk	5	No known genetic risk
Climate change	2	Potentially threatened by changes in hydrology and temperature
Anthropogenic threats	3	Five threats rated as intermediate (Table 1)
Average	3.9	27/7
Certainty (1-4)	1	Population size, distribution, and environmental tolerances largely unknown

Table 2. Metrics for determining the status of Klamath River lamprey, where 1 is a major negative factor contributing to status, 5 is factor with no or positive effects on status, and 2-4 are intermediate values. See methods section for further explanation.

Management Recommendations: The principal impediment toward improved Klamath River lamprey management and conservation is the lack of empirical data and general knowledge of their abundance, distribution, environmental tolerances, and key aspects of life history. As such, the following management actions are recommended:

1. Establish a Klamath River lamprey research and monitoring program. Program goals should include: 1) a status assessment of all lampreys in the basin; 2) identification of key conservation opportunities; and 3) development of life history and habitat requirement studies, to inform a limiting factors analysis. Additionally, an identification key needs to be developed to distinguish ammocoetes of Klamath basin lamprey species.
2. Establish a lamprey data center, as part of the research and monitoring program, which would collect and integrate *all* lamprey information collected in California. The many rotary screw traps used to monitor outmigration of juvenile salmonids, in particular, are a largely untapped source of data, especially in the Klamath River system. Many trap operators record captures of lamprey ‘smolts’ and ammocoetes. The lampreys are rarely identified to species but most are likely Pacific lampreys in the lower river; however, Klamath River lampreys may also be represented in the catch.

3. Determine if conservation efforts for salmon and steelhead also benefit Klamath River lampreys, both in mainstem rivers and tributaries such as the Shasta and Scott rivers. Habitat restoration programs intended to benefit salmonids should be evaluated for their potential to create backwater habitat for lampreys. Studies should be performed to determine if populations of Klamath River lamprey are tied to those of salmon and steelhead (predator/prey relationships).

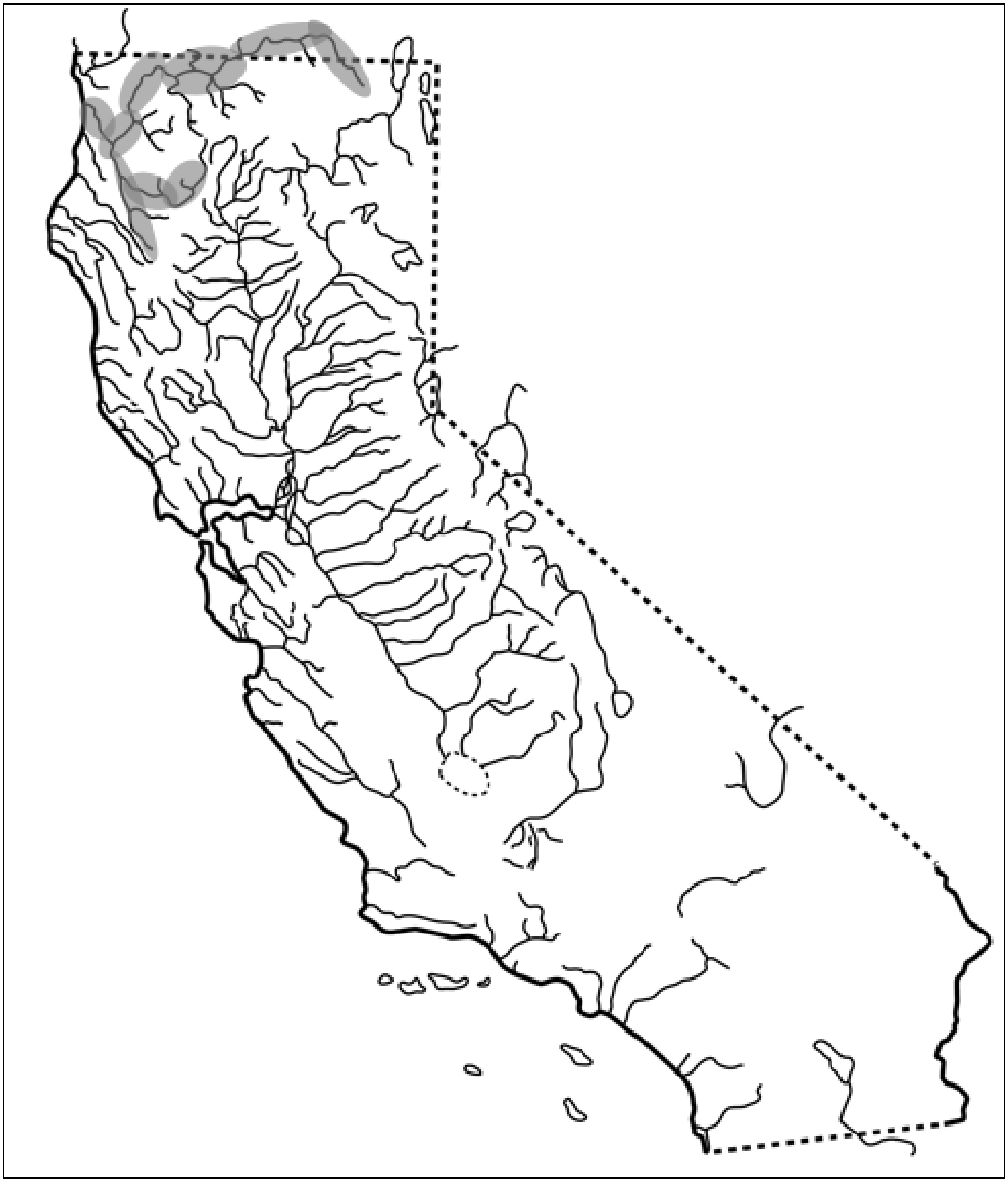

Figure 1. Distribution of Klamath River lamprey, *Entosphenus similis*, in the Klamath and Trinity rivers in California.