PIT-KLAMATH BROOK LAMPREY
***Entosphenus lethophagus* Hubbs**

Status: Moderate Concern. While Pit-Klamath brook lamprey do not currently appear to be at risk of extinction, aquatic habitats within their range are heavily altered by agriculture and grazing and their actual abundance is unknown.

Description: Pit-Klamath brook lamprey are small and non-predatory (Hubbs 1971, Renaud 2011). Their oral disc resembles that of Pacific lamprey but have fewer and smaller teeth (plates). Lateral circumoral plates number 2-3-3-2 or 1-2-2-1, with cusps often missing. They have 9-15 posterior circumoral plates, often with just one cusp. The supraoral plate has 3 cusps, although the middle one may be smaller or absent. They usually have 5 infraoral teeth. Cusps on the transverse lingual lamina are difficult to see and are file-like. The small, puckered, mouth has a disc length less than 5 percent of body length. The disc is narrower than the head when stretched (Page and Burr 1991). Myomeres along the trunk number 60-70. Mature individuals exhibit gut atrophy. Coloration in adults is dark gray on the dorsum and brassy or bronze on the ventrum. See Renaud (2011) for a description of ammocoetes and comparisons with other lampreys in the Klamath region.

Taxonomic Relationships: Pit-Klamath brook lamprey were described from specimens collected from various locations in the Pit and Klamath basins by Hubbs (1971), as *Lampetra lethophaga*. This lamprey is closely related to Pacific lamprey (Docker et al. 1999, Lang et al. 2009). Recent phylogenetic analysis indicates that the species should be placed in the genus *Entosphenus*, and removed from the genus *Lampetra* (Lang et al. 2009). Analysis of characteristics of ammocoetes confirms this relationship (Goodman et al. 2009). Non-predatory lampreys in the two drainages may have been derived independently from Pacific lamprey and may ultimately be regarded as separate taxa (Kostow, 2002, Moyle 2002).

Life History: Spawning may begin in early spring and occur through summer (Moyle 2002). Fecundities may be similar to other lampreys with equivalent sizes at about 900 to 1,100 eggs per female (Kan 1975 in Kostow 2002). In some areas, adults may not develop nuptial features such as back and belly with dark, contrasting coloration; fused dorsal fins with frills; and enlarged anal fin (Moyle 2002). Larval lampreys (ammocoetes) usually burrow among aquatic vegetation into soft substrates (Moyle and Daniels 1982), where they likely feed on algae and detritus (Moyle 2002). Based on size classes, the ammocoete stage lasts for about four years, during which time they reach about 21 cm TL. Metamorphosis likely occurs in fall. Adults presumably only move short distances to spawning areas (Close et al. 2010). They commonly co-occur with trout, marbled and rough sculpins, and speckled dace (Moyle 2002).

Habitat Requirements: Pit-Klamath brook lampreys principally occupy habitats in clear, cool (summer temperatures < 25ºC) rivers and streams in areas with fine substrates and beds of aquatic plants (Moyle and Daniels 1982, Moyle 2002). Like other lampreys, Pit-Klamath brook lampreys require gravel riffles in streams for spawning, with muddy backwater habitats downstream of spawning areas for ammocoete burrows. In the Pit River system, they seem especially common in backwaters of the spring-fed Fall River and Hat Creek (Moyle and Daniels 1982). Pit-Klamath brook lamprey in the Oregon portion of the Goose Lake basin are most commonly found in high-elevation streams in forested lands (Scheerer et al. 2010).

Distribution: Pit-Klamath brook lampreys, as currently defined, are only found in the Pit River-Goose Lake basin in California and Oregon as well as in the upper Klamath basin, upstream of Klamath lakes in Oregon (Hubbs 1971, Moyle and Daniels 1982). If this species is broken into two entities, then only *E. lethophagus* occurs in California, where it is widely distributed throughout the Pit River basin and, presumably, the Goose Lake basin in both California and Oregon (Moyle and Daniels 1982, Kostow 2002, Moyle 2002).

Trends in Abundance: Abundance and population trend information are lacking. Their populations do not seem to be in danger of extinction at this time but face multiple threats (discussed below).

Nature and Degree of Threats: Pit-Klamath brook lamprey face degradation of suitable habitats by multiple factors affecting streams in this arid region. The main stem Pit River and some of its tributaries are currently listed as impaired due to high temperatures and nutrient loading, as well as low dissolved oxygen levels (Pit RCD 2006, DEQ 2010).

Major dams. The lower Pit River supports a chain of hydropower reservoirs and some tributaries also have small dams on them. The effects of these dams on lampreys are unknown but some habitats have been inundated and populations may be fragmented as a consequence.

Agriculture. Water demands for agriculture are high along the Pit and upper Klamath rivers, resulting in decreased instream flows. Water diversions in some areas may be reducing instream flows to the extent that certain reaches go dry (Pit RCD 2006). Flood-irrigated pastures introduce nutrients into streams and raise water temperatures, via return water, and fertilizers are thought to be increasing nutrient loadings in streams (Pit RCD 2006). Pit-Klamath brook lamprey may be well adapted for some altered habitats, especially in the larval stage. Ammocoetes were common in the mud substrates of an irrigation diversion from Rush Creek, Modoc County (Moyle 2002). They are also common in silt substrates of pools below channelized sections of streams.

Grazing. Extensive grazing occurs throughout the range of Pit-Klamath brook lamprey. Grazing can degrade aquatic habitats through streambank trampling, removal of riparian vegetation, or input of nutrients and other pollutants from animal wastes. Fecal matter is thought to be increasing the nutrient loading of streams in this region (Pit RCD 2006). Removal of vegetation increases erosion and entrenchment of stream channels (Pit RCD 2006) and contributes to increased solar input and corresponding water temperature increases in streams.

Rural residential. Several towns exist within the Pit-Klamath brook lamprey range (e.g. Alturas) in California. Residential areas can be sources of pollutants and increased water demands that may decrease water quantity and quality in streams.

Alien species. Many alien fish species inhabit the Klamath and Pit River basins (Close et al. 2010, Moyle and Daniels 1982). Species that can prey on lamprey include largemouth bass, brown bullhead, channel catfish, brook trout, brown trout, black crappie, and yellow perch (Close et al. 2010).

	Rating	Explanation
Major dams	Low	Dams present in range but impacts are unknown
Agriculture	Medium	Agriculture pervasive throughout range; direct effects unknown but likely contributes to substantial diversion and water quality degradation; effects may be severe at a localized level
Grazing	Medium	Grazing pervasive throughout range; direct effects unknown but likely contributes to aquatic and riparian habitat degradation, along with water quality impairment across much of range
Rural residential	Low	Small towns and residences common but widely dispersed within range; impacts likely minimal except for water withdrawls and potential pollutant inputs at a localized scale
Urbanization	n/a	
Instream mining	n/a	
Mining	n/a	
Transportation	Medium	Extensive network of unimproved roads across range; potential for increased sediment inputs and habitat fragmentation
Logging	Low	Logging occurs in forested lands; impacts unknown
Fire	Low	Wildfires occur throughout range; impacts unknown
Estuary alteration	n/a	
Recreation	n/a	
Harvest	n/a	
Hatcheries	n/a	
Alien species	Medium	Absent where alien species abundant

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Pit-Klamath brook 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 unlikely as a result; and a factor rated "no" 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.

Effects of Climate Change: Climate change is expected to increase the frequency of both drought and floods in streams. Because Pit-Klamath lamprey rear for several years in stream substrates, large flooding events may disrupt rearing habitats (Fahey 2006) and displace ammocoetes from soft sediments. On the contrary, scouring events may clean sediments from gravels that would otherwise degrade spawning habitats (Stuart 2006 in Fahey 2006). This species may not be as vulnerable as other fishes to stream flow changes associated with climate change because a few populations occur in large, spring-fed river systems (e.g. Fall River). Changes to the natural hydrograph will likely be attenuated in streams that are spring-fed, as in the upper Klamath basin at the northern end of the Pit-Klamath brook lamprey range (Quiñones 2011). Pit-Klamath brook lamprey can tolerate high turbidities and persist in seasonally intermittent streams (S. Reid, in Close et al. 2010). They also appear tolerant of higher water temperatures, which are expected to increase due to climate change. Pit-Klamath brook lamprey can tolerate summer water temperatures >25ºC in the Pit River (S. Reid, in Close et al. 2010). Moyle et al. (2013) listed the Pit-Klamath brook lamprey as "highly vulnerable" to extinction as the result of climate change by 2100; however, little is understood both about the biology of this lamprey and the potential effects of climate change on aquatic systems in the arid Pit River basin, so this rating was applied with a low degree of certainty.

Status Determination Score = 3.7 - Moderate Concern (see Methods section, Table 2). Pit-Klamath brook lamprey appear to be common throughout their range in California. However, their actual abundance is unknown. Pit-Klamath brook lamprey are subject to multiple stressors (Table 1) that can create adverse habitat conditions. NatureServe classifies Pit-Klamath brook lamprey as secure to vulnerable throughout their range.

Metric	Score	Justification
Area occupied	5	Range limited to Pit River drainage in California, but includes several tributary systems (e.g. Fall River)
Estimated adult abundance	3	Species is thought to be abundant within range but actual numbers are unknown
Intervention dependence	4	Long-term management of agriculture and grazing practices, as well as alien species, may be warranted
Tolerance	3	Pit-Klamath brook lamprey apparently tolerate warmer temperatures than other lamprey species but still require cool, clean water
Genetic risk	5	Thought to be genetically diverse, although populations in Goose Lake and Klamath basin may constitute separate species
Climate change	2	Some habitats may dry more extensively or for longer durations; ammocoetes may be displaced by unusually high flows
Anthropogenic threats	4	See Table 1
Average	3.7	26/7
Certainty (1-4)	1	Species is largely unstudied

Table 2. Metrics for determining the status of Pit-Klamath brook 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: Habitat degradation from agricultural and grazing practices poses the greatest threat to Pit-Klamath brook lamprey, effects likely to be exacerbated by increasing temperatures and more frequent flood events predicted by climate change models. Watershed management strategies exist (e.g., Pit RCD 2006, Klamath Basin Restoration Agreement) that address these and other factors that may limit fish populations in the Pit and upper Klamath basins. Beyond implementation of these strategies, basic life history studies and population monitoring should occur in order to better understand the status of this species. The following questions should be addressed as part of a status evaluation:

1) Are brook lampreys in the Pit River-Goose Lake and Klamath basins separate taxa?
2) What is the current distribution and abundance of Pit-Klamath brook lamprey in California?
3) Where are most important spawning and rearing grounds located in California?
4) What are the optimal and preferred environmental tolerances and habitat conditions for each life history stage?

Figure 1. Distribution of Pit-Klamath brook lamprey, *Entosphenus lethophagus*, in California.