KERN BROOK LAMPREY
***Lampetra hubbsi* (Vladykov and Kott)**

Status: High Concern. Only six populations of Kern brook lamprey exist and they are isolated from one another; five are in short reaches below dams, so their persistence depends on dam operations and maintenance of suitable habitats for ammocoetes. The possible discovery of a 7th population in the Sacramento River watershed, however, suggests the species may be more widely distributed than is currently known.

Description: The Kern brook lamprey is a non-predatory lamprey, so the teeth in its oral disk are small and blunt (Brown and Moyle 1992). Its morphology is like that of other lampreys: eel-like body, no paired fins, and a sucking disc instead of jaws. Larvae, known as ammocoetes, are similar to adults in shape but lack eyes and a well-developed oral disc. The Kern brook lamprey is much smaller than predatory anadromous lampreys; adults range from 81 to 139 mm TL and ammocoetes from 117 to 142 mm TL. Ammocoetes are typically larger than adults because non-predatory lampreys shrink following metamorphosis (Vladykov and Kott 1976). The number of trunk myomeres (i.e. the "blocks" of muscle mass along the body) ranges from 51 to 57 in ammocoetes (Tables 1, 2). In adults, the supra-oral lamina (tooth) typically has two cusps, with four inner lateral teeth on each side of the disc. The typical cusp formula is 1-1-1-1 (Vladykov and Kott 1976). The sides and dorsum are a grey-brown and the ventral area is white. Dorsal fins are unpigmented, but there is some black pigmentation restricted to the area around the notochord in the caudal fin (Vladykov and Kott 1976).

Taxonomic Relationships: The Kern brook lamprey was first described by Vladykov and Kott (1976) as a dwarf, non-predatory species in the genus *Entosphenus*. Based on dentition, the describers indicated the Kern brook lamprey was derived from the predatory Pacific lamprey, *E. tridentatus*, as are some other brook lampreys (Docker 2009). However, molecular analysis demonstrated it was derived from the predatory river lamprey, *Lampetra ayersi*, as is the western brook lamprey, *L. richardsoni* (Docker et al. 1999, Lang et al. 2009). Boguski et al. (2012) examined the genetics of lampreys from many populations in Pacific coast drainages; a single ammocoete from Paynes Creek (Tehama County) proved to be closely related to *L. hubbsi*. There are three potential scenarios to explain this: (1) it is a single, highly isolated population of *L. hubbsi*; (2) it is a separate undescribed species, and (3) other *L. hubbsi* populations exist in watersheds in the Sacramento Valley but have been overlooked. Clearly, more work on lamprey distribution and systematics in California is needed. The Pacific brook lamprey is differentiated from Kern brook lamprey on the basis of anatomical features (Tables 1, 2), as well as by mitochondrial DNA. The two species do not appear to be sympatric.

Table 1. Comparative counts and measurements of lamprey ammocoetes. *L ayersi* is from Vladykov (1973), *L. tridentata* and *L. hubbsi A*, from Vladykov and Kott (1976, 1979), *L. ayersi* from Richards et al. (1982) and *L. hubbsi B* from Brown and Moyle (unpubl. data). Data from Brown and Moyle are given as mean ± S.D. (above) and range (below). Data from other studies are mean (above) and range (below).

	Lampetra ayresi	*L. richardsoni*	*L. tridentata*	*L. hubbsi* A	*L. hubbsi B*
Total length (mm)	-	117	128	130	106 ± 19
	69 - 119	75 - 143	117 - 144	66 - 140	
Trunk myomeres	65	54	68	55	54 ± 2
	63 - 67	52 - 57	66 - 70	53 - 57	51 – 5

Table 2. Diagnostic characteristics of recently transformed adult lampreys of four *Lampetra* species. Data are from Vladykov and Follett (1958, 1965), Vladykov (1973) and Vladykov and Kott (1976).

	L. ayresi	*L. richardsoni*	*L. tridentata*	*L. hubbsi*
Trunk myomeres	68	56	66	56
	(60 - 71)	(53 - 58)	(63 - 70)	(54 - 57)
Cusps on supraoral lamina	2	2	3	2 - 3
Inner lateral "teeth"	3	3	4	4
Cusps on infraoral lamina	8.9	7.7	5.1	5.0
	(7 - 10)	(7 - 10)	(5 - 6)	5
Row of posterial "teeth"	absent	absent	present	present[1]
Predatory?	yes	no	yes	no

[1]Absent from two of eleven specimens examined by Brown and Moyle (unpublished data)

Life History: No documentation of the life history of Kern brook lamprey exists. However, if their life history is comparable to that of other non-predatory brook lampreys, they should live for approximately 4-5 years as ammocoetes before metamorphosing into adults (Moyle 2002). Based on collections (P. Moyle and L. Brown, unpublished data), metamorphosis occurs during fall. The adults presumably over-winter and spawn the following spring after undergoing metamorphosis.

Habitat Requirements: Principal habitats of Kern brook lamprey are silty backwaters of large rivers in foothill regions (mean elevation= 135 m; range= 30-327 m). In summer, ammocoetes are usually found in shallow pools along edges of run areas with minimal flow (L.R. Brown, US Geological Survey, pers. comm.), at depths of 30-110 cm where water temperatures rarely exceed 25 degrees C. Common substrates occupied are sand, gravel, and rubble (average compositions are 40%, 22%, 23%, respectively). Ammocoetes seem to favor sand/mud substrate, where they remain buried with the head protruding above the substrate and feed by filtering diatoms and other microorganisms from the water. This type of habitat is apparently present in the siphons of the Friant-Kern Canal. Adults require coarser gravel-rubble substrate for spawning. Temperature requirements for Kern brook lamprey are not known but the fact they are present almost entirely in reaches where summer temperatures rarely exceed 24 degrees C suggests a cool-water requirement.

Distribution: The Kern brook lamprey was first discovered in the Friant-Kern Canal (hence the inaccurate name; it is not found in the Kern basin). It has since been found in six locales which, presumably, represent isolated populations: the lower reaches of the Merced River, Kaweah River, Kings River, and San Joaquin River, as well as in the Kings River above Pine Flat Reservoir and the San Joaquin River above Millerton Reservoir, but below Redinger Dam (Brown and Moyle 1987, 1992, 1993; Fig. 1). In 1988, ammocoetes and adult lampreys were found in several siphons of the Friant-Kern Canal, when they were poisoned during an effort to rid the canals of white bass (*Morone chrysops*). The "low-count" lampreys (i.e., low numbers of trunk myomeres) reported from the upper San Joaquin River between Millerton Reservoir and Kerckhoff Dam by Wang (1986) are also most likely *L. hubbsi*, as are similar ammocoetes from the Kings River above Pine Flat Reservoir. As indicated in the taxonomy section, presumed Kern brook lampreys have been identified from Paynes Creek, Tehama County, which may indicate other populations exist as well.

Trends in Abundance: Since this species was first discovered in 1976, attempts to fully document its range have been only partially successful. Little is known about its past or present abundance. However, data collected to date suggest that this species is a San Joaquin basin (including the Kings River) endemic (Brown and Moyle 1992, 1993). Isolated populations of Kern brook lamprey seem spottily distributed throughout the San Joaquin drainage in regulated rivers, so their distribution and abundance are probably much reduced from pre-dam times. Ammocoetes thrive in the dark siphons of the Friant-Kern Canal, but it is unlikely that there is suitable spawning habitat in the canal, so those individuals probably do not contribute to the persistence of the species.

Nature and Degree of Threats: Populations of this species are scattered throughout the middle San Joaquin-Kings drainage and are isolated from one another. Such a limited and fragmented distribution makes local extirpations increasingly probable, along with a high degree of genetic risks from small population sizes and isolation; without interconnected populations and the possibility of recolonizing degraded habitats, eventual extinction may occur.

Major dams. It is likely that the river reaches flooded by Millerton and Pine Flat reservoirs were once important habitats for Kern brook lamprey. Today, the probability of local extirpation is increased by the fact that all known populations, with one exception, are located below dams, where stream flows are regulated without regard to the habitat requirements or life history needs of lampreys. Fluctuations or sudden drops in flow may isolate ammocoetes or result in the drying of habitats. Gravels required for spawning may be eliminated (trapped by dams) or compacted so they cannot be used by adults, while silt required by ammocoetes may be flushed out of the cool-water reaches that appear to be preferred by larvae. Dams also isolate populations, eliminating gene flow and preventing recolonization from nearby populations. Management of flows in the lower reaches of the San Joaquin and Kings rivers, including the new restoration flows below Friant Dam, as well as flows to reduce impacts from agricultural return waters, will need to account for the needs of this species in order for populations to persist.

Agriculture. Channelization, road building, irrigation withdrawls, and other activities associated with farming eliminate backwater areas required by ammocoetes. Ammocoetes may also be carried by water being delivered to farms via the Kings River to "dead-end" habitats such as the Friant-Kern siphons. In addition, pollutants are of concern (including elevated temperatures) in agricultural return waters, which may reduce lamprey survival.

Urbanization. Fresno is rapidly expanding around the San Joaquin River with attendant stressors associated with urban development, including road building, bank stabilization, pollution, and recreation.

Instream mining. Large sections of the San Joaquin River have been mined for gravel, both destroying shallow-water habitats needed by ammoceotes and creating large pits that provide ideal habitats for predatory fishes. It is likely that lampreys were extirpated from gravel pit regions once mining began.

Alien species. Kern brook lamprey habitats typically support a mixture of native and non-native fishes (Moyle 2002). The impacts of alien fishes, especially predatory bass (*Micropterus* spp.), are not known, but are likely to be negative, given the vulnerability of migrating larvae and adults to predation.

	Rating	Explanation
Major dams	High	Most populations exist below dams, where habitat is degraded and flows are highly regulated
Agriculture	High	Most populations are susceptible to agricultural pollution, diversions and other factors
Grazing	Low	Present along some streams
Rural residential	Low	Effluent from waste water and bank protection to reduce flooding may affect habitats
Urbanization	Medium	Fresno and other urban areas are expanding; potential for increased impacts from pollution, habitat degradation and fragmentation
Instream mining	Medium	Gravel pits present in some areas; associated impacts may have eliminated lampreys from reaches of the San Joaquin River
Mining	n/a	
Transportation	Low	Roads and railroads along rivers may alter habitats and increase both sediment and pollutant input
Logging	n/a	
Fire	Low	
Estuary alteration	n/a	
Recreation	Low	Areas accessible to off-road vehicles and other uses may reduce ammocoetes habitats or disrupt spawning
Harvest	n/a	
Hatcheries	n/a	
Alien species	High	Alien predators present; effects unknown but potentially significant

Table 3. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Kern 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 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.

Effects of Climate Change: The southern Central Valley of California is predicted to experience reduced stream flows and increased water temperatures, as a result of longer, more frequent, droughts and warmer air temperatures. Kern brook lampreys live in regulated rivers, so climate change effects are most likely to manifest from changes in dam and reservoir operations, including reduced dam releases (drying up rearing areas) or warmer temperatures of released water. Without consideration for lamprey needs, such operational changes can greatly increase extinction risk. Moyle et al. (2013) indicated the Kern brook lamprey is "critically vulnerable" to climate change, facing extinction because of changed dam operations, including reduced flows during droughts, and alteration/degradation of habitats to favor expansion of alien species.

Status Determination Score = 2.3 - High Concern (see Methods section, Table 2). The Kern brook lamprey does not appear to be at immediate risk of extinction but its status could change rapidly, given the limited number of isolated populations and their existing distribution either below or just above dams. Jelks et al. (2008) considered the species as threatened and declining, while NatureServe considers its status to be somewhere between Imperiled (G2) and Critically Imperiled (G1). The species was petitioned for federal listing in 2003 as threatened, but the petition was denied on Dec. 27, 2004 because "the petition did not provide sufficient information to warrant initiating a status review (USFWS 2004)."

Metric	Score	Justification
Area occupied	2	Six known populations occur in two watersheds but all are isolated from one another by dams and diversions; possible 7th population needs further investigation
Estimated adult abundance	3	Not known but probably <1000 adults in each population
Intervention dependence	3	Long-term persistence requires habitat improvements and flow regulation
Tolerance	3	Unstudied but probably moderate
Genetic risk	2	Populations fragmented; potential for bottlenecks or inbreeding depression
Climate change	1	Populations below dams could be threatened by changes in river management
Anthropogenic threats	2	See Table 3
Average	2.3	16/7
Certainty (1-4)	2	Little published information on abundance, distribution, or status, especially in the recent past

Table 4. Metrics for determining the status of Kern brook 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. This score does not take into account the apparent population in the Sacramento River watershed. See methods section for further explanation.

Management Recommendations: The Kern brook lamprey would most benefit from proactive management strategies and actions treating it as if it were already a listed species, in order to reduce the probability of actual listing. A thorough survey of the known habitats and populations of this species needs to be conducted to determine status and possible trends. Extensive surveys are needed to determine present distribution and to provide more exact information on habitat requirements within its known range, as well to determine if populations exist outsides the known range (e.g., in the Kaweah River, Sacramento Valley). A study needs to be conducted to determine if ammocoetes still use the silty bottoms of siphons in the Friant-Kern Canal and if rescue and

transplantation of these larvae would be beneficial. Specialized surveys should focus on adults to determine population sizes and spawning habitat requirements. Known or probable populations should be monitored every two to five years, with trends determined by catch per effort or estimated densities of ammocoetes.

Once surveys are completed, several known areas of suitable habitat should be selected for special management or protection from incompatible uses, including some in the soon-to-be-restored San Joaquin River. These same areas should be the focus of life history studies and studies that determine habitat requirements.

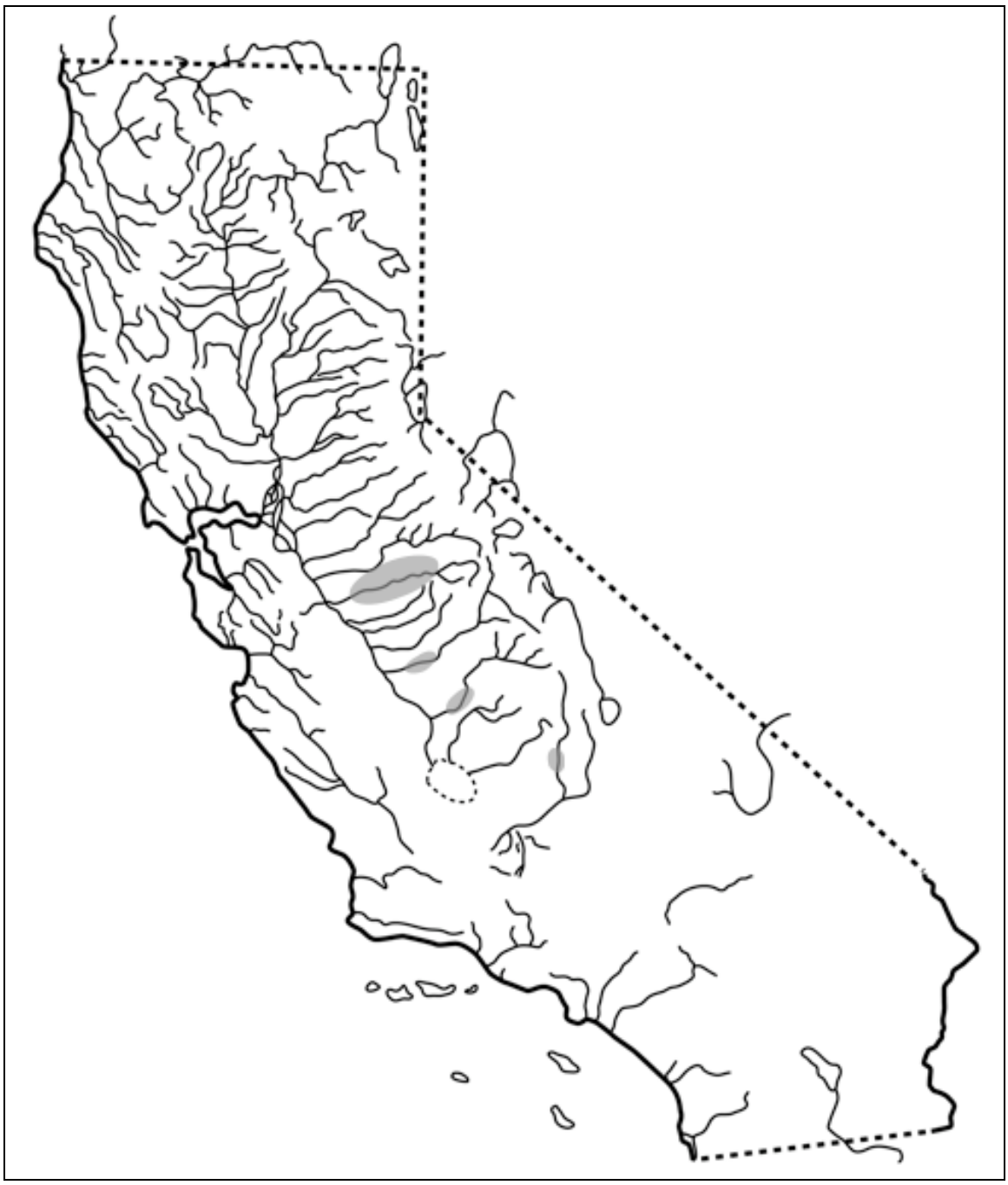

Figure 1. Known (confirmed) distribution of Kern Brook lamprey, *Lampetra hubbsi* , in California.