A NEW NONPARASITIC SPECIES OF LAMPREY OF THE GENUS *ENTOSPHENUS* GILL, 1862, (PETROMYZONIDAE) FROM SOUTH CENTRAL CALIFORNIA

VADIM D. VLADYKOV[1] AND EDWARD KOTT[2]

ABSTRACT: A new nonparasitic lamprey from the Friant-Kern Canal, east of Delano, California, is described and illustrated. The holotype (number CAS 35987) is deposited in the California Academy of Sciences, San Francisco, California. The species is distinguishable from all species of the genus *Entosphenus* by: 1) low number of trunk myomeres—53 in the ammocoete and between 54 and 57 (average 55.5) in transformed specimens, whereas in other species the range is 58–73; 2) reduced dentition with typical numbers of teeth—2 supraoral cusps, 1-1-1-1 inner lateral teeth on each side of the disc, 9–12 (average 10.3) posterial teeth; 3) only 3 velar tentacles, whereas in other species the number of tentacles varies from 5 to 18; 4) small size of transformed specimens, 117–142; and 5) restricted distribution. The description is based on the study of eleven newly transformed individuals and one ammocoete.

Lampreys from California of the family Petromyzonidae are represented by two genera, *Lampetra* Gray, 1851, and *Entosphenus* Gill, 1862. The first genus belongs to the subfamily Lampetrinae, whereas, the other belongs to the subfamily Entospheninae (Vladykov, 1972).

The genus *Lampetra*, as defined by Gray (1851) and accepted by several subsequent authors (Regan, 1911; Holly, 1933; Hubbs, 1967; and Vladykov and Follett, 1967), is represented in western North America by at least three species. *Lampetra ayresii* (Günther, 1870), a parasitic species recently redescribed by Vladykov and Follett (1958), and *L. pacifica* Vladykov, 1973, a nonparasitic species are found in California. Another nonparasitic species, *L. richardsoni* Vladykov and Follett, 1965, has a known distribution from Oregon to British Columbia and the possibility exists that it may be found in northern California.

The genus *Entosphenus* was established by Gill (1862) on the basis of the type species *Petromyzon tridentatus* Gairdner as described in Richardson (1836). Several authors (Berg, 1931; Holly, 1933; Vladykov and Follett, 1967; Hubbs, 1967; and McPhail and Lindsey, 1970) accepted this as a valid genus. On the other hand, some recent authors (Hubbs, 1971; Hubbs and Potter, 1971; Bond and Kan, 1973; and Kan, 1975) consider *Entosphenus* as a subgenus of *Lampetra*. The most important differences between these two genera, as pointed out by Vladykov and Follett (1967), and Vladykov and Kott (1976), are indicated in table 1.

Heretofore, in California and Oregon, three species of *Entosphenus* were known: *E. tridentatus* (Gairdner in Richardson, 1836), a large parasitic species; *E. minimus* (Bond and Kan, 1973), parasitic but small in size; and a nonparasitic species, *E. lethophagus* (Hubbs, 1971). Hubbs correctly stated that supplementary study is required for the untangling of the *Entosphenus* complex. The present description of a new nonparasitic species supports Hubbs' idea.

METHODS

In the description of the new species of *Entosphenus*, the definitions of the different body proportions follow Vladykov and Follett (1965) and the terminology of teeth is that of Vladykov and Follett (1967). The trunk myomeres were counted between the last (7th) gill-opening and the anterior tip of the cloacal slit (Hubbs and Trautman, 1937; Vladykov, 1949).

The present study is based on the examination of 11 newly transformed individuals, including the holotype, and one ammocoete received on loan from the California Academy of Sciences. Unfortunately, they are not well-preserved. All measurements are reported in millimeters unless noted otherwise.

Entosphenus hubbsi, new species
Figure 1–3

Holotype.—W336 (1 ♂, 131 mm); canal east of Delano, Kern Co., California; about 15 February

[1] Dept. Biology, University of Ottawa, Ottawa, Canada.

[2] Dept. Biology, Wilfrid Laurier University, Waterloo, Ontario, Canada.

1972; collected by D. P. Christenson; deposited in California Academy of Sciences CAS 35987.

Paratypes.—W333–335, 337–343 (7 ♂, 117–142 mm; 3 ♀, 140–141 mm), W344 (ammocoete, 160 mm): collected with the holotype; CAS 35988.

Diagnosis.—Low number of trunk myomeres, 53 in the ammocoete and between 54 and 57 in transformed specimens (average 55.5); reduced dentition; only three velar tentacles; and reduced pigmentation on its caudal fin. Other diagnostic features are summarized in tables 3–5.

Description of the holotype.—The holotype, a male 131 mm in total length, is referable to maturity stage three (early maturity: sexual products rather small; dorsal fins separated). Intestine is reduced to a threadlike thickness (0.9). Measurements (in percent of total length) are: disc length, 4.2; prebranchial length 9.2; eye length, 1.5; branchial length, 10.7; trunk length, 54.2; tail length, 28.2. Disc length, as a percentage of branchial length, is 39.3. There are 55 trunk myomeres (Fig. 2).

Since the holotype is a recently transformed individual, its disc is not fully developed and the teeth are not well-cornified. There are four inner lateral teeth on each side of the disc; the second tooth, on both sides, is bicuspid, the rest are unicuspid. There is a single row of nine unicuspid posterials. The supraoral lamina is provided with a cusp at each end, but the median cusp, as is typical for parasitic species of *Entosphenus,* is absent. The infraoral lamina has five cusps. The three lingual laminae were so poorly developed that the cusps could not be counted (Fig. 1); no enlarged median cusp was observed on the transverse lingual lamina.

The holotype is a newly transformed individual and its two dorsal fins are far apart (8) and the genital papilla is not visible. The color of the specimen, preserved in 4–5 percent formalin, is brown on the sides and back and whitish on the ventral surface. The dorsal fins are unpigmented. Pigmentation on the caudal fin is reduced to an area about the notochord and its shape is rather rounded posteriorly.

Transformed Specimens.—Total length (Table 2)—Lengths of eight males range from 117 to 142 (average 129.1) and of three females from 140 to 141 (average 140.3). Proportional measurements of different body regions and number of trunk myomeres are given in tables 2 and 3, respectively.

Figure 1. Enlarged disc of the holotype of *Entosphenus hubbsi*, new species, (tag W336), male, 131 mm, Friant-Kern Canal, east of Delano, California.

Dentition (Table 5)—The teeth are not fully cornified, hence, counts of some cusps are uncertain. A single row of posterials is present, which is typical for all species of the genus *Entosphenus.* The number of posterials ranges from 9 to 12 (average 10.[illegible]). These were small, weakly developed and difficult to count, all were unicuspid. The supraoral lamina has only two cusps, one at each end, except in one specimen (W338), which has a third cusp. The infraoral lamina has five cusps, blunt and weakly cornified. All specimens of *E. hubbsi* have eight inner laterals, four on each side of the disc as is characteristic of the genus *Entosphenus.* The number of cusps varies from one to three on the inner laterals; however a single cusp was most frequently observed (Table 5). The cusps on the lingual laminae were weakly developed and hence could not be counted. No enlarged median cusp was observed on the transverse lingual lamina.

TABLE 1. Principal differences between the genera *Entosphenus* and *Lampetra.*

Character	*Entosphenus*	*Lampetra*
Posterials	in one row	completely absent
Infraoral Cusps	typically 5	typically 7–8
Transverse Lingual Lamina	median cusp barely distinguishable from lateral cusps	median cusp greatly enlarged in comparison with lateral cusps
Inner Laterals	4 on each side of the disc	3 on each side of the disc
Supraoral Lamina	typically with 3 cusps	typically with 2 cusps

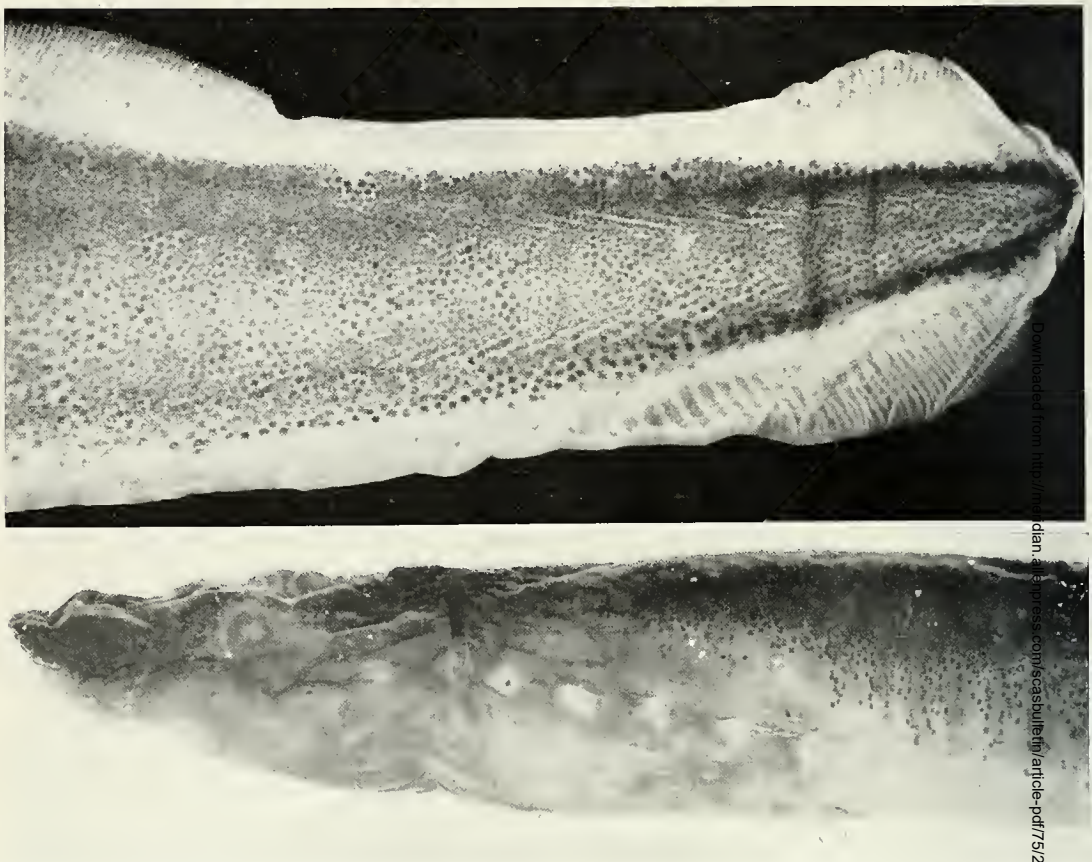

Figure 2. Enlargements of the head and tail regions of the holotype of *Entosphenus hubbsi*, new specie

Velar tentacles (Table 5)—Velar tentacles were counted in three specimens. In each only three tentacles are present, a single median, the shortest, and one lateral on each side. Length of longest tentacles was about 0.5 in all specimens.

Coloration.—The sides and back are brown and the lower surface is whitish. The dorsal fins are unpigmented. On the caudal fin black pigmentation is restricted to a narrow zone about the notochord.

Sexual dimorphism.—Secondary sexual characteristics have not yet fully developed, as the specimens had just recently transformed.

Ammocoetes.—Only one ammocoete was available for study (Table 4). It had 53 myomeres. The body proportions are shown in table 4. There is a broad nonpigmented zone above the branchial pores, and dark pigment was absent from the prebranchial region. Pigmentation of the caudal fin is similar to that of adult (Fig. 3).

This new species is dedicated to Carl Leavitt Hubbs, a distinguished friend and a keen student of lamprey taxonomy.

Comparisons.—The principal differences between *E. hubbsi* and the other three described species are as follows: 1) number of myomeres; 2) number o velar tentacles; 3) certain of the body proportions; 4 number and degree of development of different type of teeth; and 5) pigmentation of the caudal fin. Thes differences (other than pigmentation) are presente in tables 3–5.

Number of myomeres.—In 11 transformed spec mens of *E. hubbsi* there are 54–57 (mean 55.5 myomeres. This number is lower than that found i any of the other three species. For the nonparasiti species, *E. lethophagus*, Hubbs (1971) reported 63–6 (mean 65.6) for specimens from California, and 58–7 (mean 66.6) for those from Oregon. In the case o *E. minimus*, a very small, but parasitic form fron Oregon, Bond and Kan (1973) counted 60–65 (mea 62.8). In the much larger *E. tridentatus*, we counte 66 transformed individuals with 63–70 (mean 66.3 myomeres.

Number of velar tentacles.—In the genus *Entos phenus*, these tentacles have been counted only in *E tridentatus* (Mather, 1926; McPhail and Lindsey 1970; and Vladykov and Pharand, 1972). Th reported number varied from 11 to 18; however i the present study we found that in 10 specimens th

TABLE 2. Body proportions (in percent of total length) and disc length (in percent of branchial length) of recently transformed specimens of *Entosphenus hubbsi*, new species, from Friant-Kern Canal east of Delano, Kern Co., California

Tag No.	Total Length (mm)	(TL)	d – B_1 / TL	B_1 – B_7 / TL	B_7 – a / TL	a – C / TL	O / TL	d / TL	d / B_1 – B_7
					Males				
W334	117		9.0	9.4	51.3	30.8	1.7	4.3	45.5
W333	118		9.3	10.2	53.4	28.0	1.7	4.7	45.8
W335	121		10.7	10.7	53.7	27.3	2.1	4.5	42.3
W338	130		10.0	11.2	56.9	28.5	1.9	4.2	42.3
W336*	131		9.2	10.7	54.2	28.2	1.5	4.2	39.3
W337	135		8.8	11.1	54.1	28.9	1.9	3.7	41.7
W341	139		9.0	10.8	54.0	27.7	1.4	4.3	40.0
W342	142		9.2	9.5	54.6	28.2	1.4	4.2	44.4
Mean	129.1		9.4	10.5	54.0	28.5	1.7	4.3	42.7
Range	117–142		8.8–10.7	9.4–11.2	51.3–56.9	27.3–30.8	1.4–2.1	3.7–4.7	39.3–45.8
					Females				
W339	140		9.6	8.6	55.0	28.2	1.8	4.6	54.2
W340	140		8.9	10.7	55.0	27.5	2.1	3.9	36.2
W343	141		8.5	8.5	53.5	30.1	1.4	4.6	54.2
Mean	140.3		9.0	9.3	54.5	28.6	1.8	4.4	48.3
Range	140–141		8.5–9.6	8.5–10.7	53.5–55.0	27.5–30.1	1.4–2.1	3.9–4.6	36.6–54.2

* Holotype.

TABLE 3. Comparison between number of trunk myomeres and proportional measurements (in percent of total length) of transformed specimens of *Entosphenus hubbsi*, new species, with those of three other species of the same genus. Data refer to means and ranges for each character.

	Entosphenus hubbsi		*Entosphenus minimus*		*Entosphenus lethophagus*	*Entosphenus tridentatus*		
	Males	Females	Males	Females	Sexes combined	Males	Sexes combined	Females
Authority	Present Study		Bond and Kan (1973)		Bond and Kan (1973)	Present Study		
Number of Specimens	8	3	33	12	18	8	66	11
Myomeres	55.5	55.7	62.3	63.8	66.3[1]		66.3	
	54–57	55–57	60–64	62–65	64–70		63–70	
Total Length (mm)	129.1	140.3	86.4	79.8	140.8	303.1		315.3
	117–142	140–141	76–129	72–87	110–170	263–476		208–480
Prebranchial Length	9.4	9.0	15.0	14.2	12.1	14.3		13.8
	8.8–10.7	8.5–9.6	13.7–16.4	13.4–14.8	10.4–13.5	13.4–15.8		12.5–15.4
Branchial Length	10.5	9.3	9.2	9.1	10.3	10.9		10.8
	9.4–11.2	8.5–10.7	7.9–10.8	8.3–10.0	8.9–11.5	10.0–12.2		9.6–11.6
Trunk Length	54.0	54.5	44.1	48.3	46.5	45.5		46.9
	51.3–56.9	53.5–55.0	42.6–47.3	45.9–51.3	43.5–52.6	43.5–47.0		43.8–50.8
Tail Length	28.5	28.6	31.5	28.5	30.9	29.0		27.8
	27.3–30.8	27.5–30.1	29.0–32.9	25.9–31.0	27.1–33.5	27.8–30.5		25.2–31.3
Eye Length	1.7	1.8	2.4	2.5	1.6	2.4		2.4
	1.4–2.1	1.4–2.1	2.1–3.1	2.3–2.8	1.1–2.1	2.1–2.9		2.1–2.9
Disc Length	4.3	4.4	6.3	5.8	5.0	7.7		7.5
	3.7–4.7	3.9–4.6	5.7–7.4	5.0–7.3	3.6–6.1	7.1–9.1		6.5–9.1

[1] According to Hubbs (1971), in 83 specimens from Pit River, Sprague River, and Crooked Creek, the mean number of myomeres in *E. lethophagus* is 66.3 (range: 58–73).

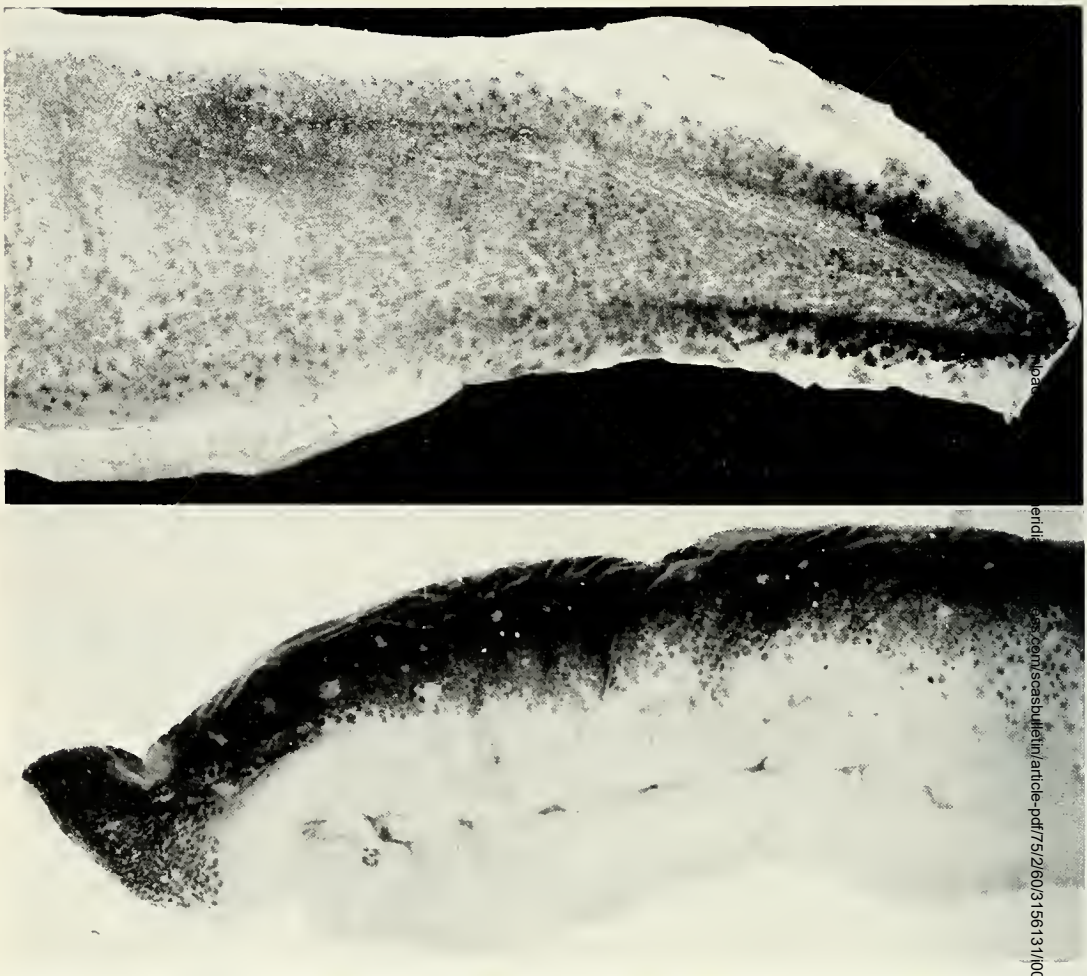

Figure 3. Enlargements of the head and tail regions of an ammocoete of *Entosphenus hubbsi*, new specie 160 mm.

number of tentacles was 9–15 (mean 12.5). In one specimen of *E. lethophagus*, and one of *E. minimus*, we counted only seven tentacles; however, in *E. minimus* the range is 5–7 according to Bond (*pers. comm.*). In three specimens of *E. hubbsi*, we found only three tentacles in each.

Body proportions in percent of total length.—In spite of the fact that our specimens of *E. hubbsi* are recently transformed individuals, they already show some specific characteristics. Their small eye length is typical for nonparasitic lampreys, in general; the average was 1.7 for males and 1.8 for females, which is very close to 1.6 for *E. lethophagus* (sexes combined). The eye length for both parasitic species, *E. minimus* and *E. tridentatus*, averages 2.4.

The disc length of *E. hubbsi* (about 4.3), as well as prebranchial length (9.4), is especially small. This can be explained partially by its nonparasitic nature and also by the fact that the specimens are only recently transformed individuals. In *E. lethophagus* (sexes combined), the disc length was 5.0; in *E. minimus*, 6.3 in males and 5.8 in females; and in *E. tridentatus*, 7.7 in males and 7.5 in females.

The prebranchial length in *E. lethophagus* was 10.3 in *E. minimus*, 9.2; and in *E. tridentatus*, almost 11.0 Other details are given in table 2.

The total length of *E. hubbsi* is from 117 to 142 which is intermediate between that of *E. minimus* (72–129) and *E. lethophagus* (110–170). The length of *E. tridentatus* is much greater, up to 690 in our material; McPhail and Lindsey (1970) give as a maximum size 760.

Dentition.—The supraoral lamina in *E. hubbsi* typically has two cusps (one specimen had three). In *E. lethophagus*, the number of cusps varied from two to four (mean 2.6). In both *E. minimus* and *E. tridentatus*, the number is three. In *E. hubbsi*, as in all species of *Entosphenus*, there are four inner lateral teeth on each side of the disc; however the number of cusps is much lower, the typical cusp formula being

TABLE 4. Comparison between number of trunk myomeres and proportional measurements (in percent of total length) of an ammocoete of *Entosphenus hubbsi*, new species, with those of ammocoetes of three other species of the same genus. Data refer to means and ranges for each character.

	Entosphenus hubbsi	*Entosphenus minimus*	*Entosphenus lethophagus*	*Entosphenus tridentatus*
Authority	Present Study	Bond and Kan (1973)	Bond and Kan (1973)	Present Study
Number of Specimens	1	102	52	25
Myomeres	53	61.8	65.5	68.7[1]
		59–66	63–68	67–70
Total Length (mm)	160	72.8	122.9	110.3
		37–111	83–190	81–132
Prebranchial Length	6.9	8.4	6.5	8.2
		6.8–11.1	5.3–8.1	7.0–9.3
Branchial Length	10.6	14.1	10.8	11.8
		11.7–17.5	9.8–12.7	9.0–14.1
Trunk Length	54.4	49.7	51.6	50.9
		47.5–53.3	48.7–53.4	48.1–53.5
Tail Length	30.6	27.9	31.0	28.9
		23.7–31.4	27.8–33.3	27.1–32.4

[1] Number of myomeres counted in 33 specimens.

TABLE 5. Comparison between number of cusps on the various types of teeth in *Entosphenus hubbsi*, new species, with those of three other species of the same genus; and the number of velar tentacles found in these species. Data refer to means and ranges for each character. Number in parentheses is number of specimens.

	Entosphenus hubbsi	*Entosphenus lethophagus*	*Entosphenus minimus*	*Entosphenus tridentatus*
Authority	Present Study	Hubbs (1971)	Bond and Kan (1973)	Present Study
Supraoral	2.1 (11)	2.6 (28)	3	3.0 (18)
	2–3	2–4	–	3
Inner Laterals				
first	1.0 (21)	1.9 (52)		2.0 (37)
	1	1–3		2
second	1.3 (21)	2.4 (52)		3.0 (38)
	1–2	2–4		2–3
third	1.3 (21)	2.2 (52)		3.0 (38)
	1–3	2–3		3
fourth	1.1 (20)	1.8 (52)		2.0 (38)
	1–2	1–3		2
typical cusp formula	1-1-1-1	2[1]-2[3]-2[3]-2[1][1]	2-3-3-2	2-3-3-2
Infraoral	5.0 (9)	5.1 (28)	5	5.06 (64)
	5	4–7	–	5–6
Posterials				
total	10.3 (6)	12.1 (23)	–	17.1 (17)
	9–12	9–15	13–17	12–19
bicuspids	0	1.9 (24)	–	2.3 (17)
	–	0–12	2–6	0–5
Transverse Lingual Lamina	poorly developed	15.6 (11)	–	19.0 (17)
		12–17	17–23	16–22
		Present Study		
Velar Tentacles	3.0 (2)	7 (1)	7[2] (1)	12.5 (10)
	3			9–15

[1] Numbers in brackets are other frequently observed counts.
[2] According to Bond (*pers. comm.*) the range is 5–7 tentacles.

1-1-1-1. In *E. lethophagus*, a typical formula is 2-2-2-2 and in the two parasitic species 2-3-3-2. The number of infraoral cusps is five in *E. hubbsi*, but it is more variable (4–7) in *E. lethophagus*. In *E. minimus*, there are five and in *E. tridentatus*, typically five and rarely six. The number of posterials is the lowest in *E. hubbsi* (mean 10.3) and all are unicuspid. In *E. lethophagus*, the mean number is 12, and these also are unicuspid. In *E. minimus*, the range of posterials is 13–17 and at least two of them are bicuspid. In *E. tridentatus*, the mean number is 17 (range 0–5) typically two to four of these are bicuspid. The transverse lingual lamina is poorly developed in *E. hubbsi*; the cusps could not be counted. In other species cusps ranged as follows: *E. lethophagus* 12–17; *E. minimus* 17–23; and *E. tridentatus* 16–22.

Pigmentation of the caudal fin.—In *E. hubbsi*, the dark pigmentation of the caudal fin is restricted to a narrow band about the notochord, leaving most of the fin membrane unpigmented. In other species of *Entosphenus*, most of the fin membrane is strongly pigmented. In *E. hubbsi*, the caudal fin is more roundish; in other species of *Entosphenus* it is more pointed.

GEOGRAPHICAL DISTRIBUTION

Our specimens of *E. hubbsi* were collected in the Friant-Kern Canal east of Delano, Kern Co, California. Because the Friant-Kern Canal is about 85 percent concrete lined with a current of at least 56.6 m^3 per second, the canal cannot be considered as the normal habitat for a small nonparasitic lamprey. Therefore, it is safe to say that *E. hubbsi* originated in the Kern River system, which before the construction of this canal was an inland system. Although the Friant-Kern Canal connects through the man-made Millerton Lake with the San Joaquin River, at present no direct connection with the sea exists. Moreover, the height (97.2 m) of the Friant Dam would make it impossible for *E. hubbsi* to ascend above this dam. Further information on the Friant-Kern Canal may be obtained from Fact Sheet U.S. Dept. Interior (1974).

The only other species of lamprey known to occur in the canal near Delano is *Lampetra pacifica*. We have four transformed specimens (119–152 mm) on loan from the California Academy of Sciences which were obtained on the west side of the canal by G. Charles Mayes on 26 January 1972.

Before the construction of the canal, the Kern River basin was an inland drainage system having no connections with rivers in which other species of *Entosphenus* occur. *Entosphenus lethophagus*, according to Hubbs (1971), has been found only in the Klamath River system of Oregon and northern tributaries of the Sacramento River in California. *Entosphenus minimus*, landlocked form, is known only from Miller Lake, southern Oregon (Bond and Kan, 1973). *Entosphenus tridentatus*, typically an anadromous species, has a very broad distribution along the western seaboard of North America, extending from Alaska to Baja California (Hubbs and Potter, 1971).

In conclusion it must be stressed that because of its restricted distribution *E. hubbsi* should be considered an endangered species in California and hence should be protected as was recommended for other lamprey species by Miller (1972) and Vladykov (1973). Delay in protection could result in extinction of *E. hubbsi* in the same way that *E. minimus* has disappeared from Miller Lake (Bond and Kan, 1973).

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