Philip A. Cochran, Martin E. Sneen,
and Alan P. Gripentrog

Notes on the biology of the American brook lamprey (Lampetra appendix) *in Wisconsin*

Abstract *American brook lampreys* (Lampetra appendix) *were collected from Taylor Creek in Rock County and were documented for the first time from Jambo Creek in Manitowoc County. Spawning at both sites occurred in early May at lower water temperatures (12–14°C) than previously recorded in Wisconsin. Although most spawning groups occurred in the open on gravel substrate, as is typically reported of spawning by lampreys, some spawning groups were found beneath cover. The sample of adult lampreys from Taylor Creek included a statistically significant excess of males. Adult male lampreys had relatively larger oral discs than females, whereas females displayed swelling along the leading edge of the second dorsal fin. A review of previous studies indicated that mean total lengths of adult males tend to be greater than those for females, although differences between means are rarely statistically significant at individual sites. Where the two species of nonparasitic lampreys have been collected from the same stream systems in Wisconsin, American brook lampreys occur upstream from northern brook lampreys* (Ichthyomyzon fossor) *significantly more often than vice versa.*

The American brook lamprey (*Lampetra appendix*) is widely distributed in eastern North America (Rohde 1980). Although it has been studied in other parts of its range (e.g., Hoff 1988; Lanteigne et al. 1981; Rohde et al. 1976; Seagle and Nagel 1982), little information on this species has been collected in Wisconsin (Becker 1983). Since the time that Becker's (1983) account was prepared, additional references to American brook lampreys in Wisconsin have been confined primarily to locality records (Cochran 1984; Fago 1982, 1983, 1984a, 1984b, 1985a, 1985b, 1986, 1992). The purpose of this note is to report new data on the biology of the American brook lamprey in Wisconsin, including several topics absent from or incompletely considered in Becker's (1983) account.

Methods

We collected adult lampreys in breeding condition at two sites. Taylor Creek is located in the Rock River basin (Mississippi River drainage) in Rock County (T2N, R10E, Sec. 30/31). At the site of capture, the West Church Road crossing, stream width was 4–5 m, the water was clear and up to 1 m deep, and the bottom was primarily sand, except for a concentration of rock slabs, cobble, and gravel beneath the bridge. Jambo Creek is a tributary to the East Twin River (Lake Michigan drainage) in Manitowoc County (T21N, R23E, Sec. 26). Stream width was 4–5 m, depth was 15–100 cm, and the water was clear with a slight reddish stain. Several gravel-bottomed riffles were present. American brook lampreys have been reported previously from Taylor Creek (Fago 1982) and from the East Twin River (Fago 1985b) but not from Jambo Creek (Fago 1985b).

Samples of lampreys were taken to the laboratory, where they were anesthetized with tricaine methanesulfonate (MS-222), measured for total length to the nearest mm, and weighed to the nearest 0.01 g. Oral disc lengths of lampreys from Jambo Creek were measured by pressing them flat against a transparent rule. Voucher specimens were placed in the University of Wisconsin-Madison Zoology Museum (Taylor Creek: UWZM 8432, Accession No. 84–77; Jambo Creek: UWZM 9951, Accession No. 91–176). Statistical analyses of morphological data were conducted with MINITAB (Schaefer and Anderson 1989).

It has been stated that American brook lampreys tend to be found upstream from northern brook lampreys *(Ichthyomyzon fossor)* when the two species occur in the same stream system (Morman 1979). We tested the applicability of this conclusion to Wisconsin waters with distribution maps provided by Fago (1983, 1984a, 1984b, 1985a). By overlaying transparencies of the maps for the two species, it was possible to tally cases in which one species occurred upstream of the other or vice versa. Deviations from random were tested through use of the binomial expansion (Sokal and Rohlf 1981).

Results

At Taylor Creek, 11 American brook lampreys were collected on May 4, 1984, at a water temperature of 14°C. All were captured beneath the bridge; 8 of the 11 were captured after a single individual was observed next to a rock slab and that slab was overturned. Ten of 11 lampreys were male, a result significantly different from expected under the null hypothesis that both sexes are equally abundant and equally vulnerable to capture (binomial test, $p = 0.012$). The males were readily made to express a rather transparent fluid from their urogenital papillae; the milt of spawning male American brook lampreys was described by Dean and Sumner (1897) as nearly colorless. Many individuals displayed the sorts of abrasions and other minor wounds that result from spawning activity.

At Jambo Creek, we observed spawning lampreys in 1988, 1989, and 1992. Several spawning groups were detected on May 2, 1988, but only one lamprey was found on May 4 at the same site. Water temperature was not measured on May 2, but was 16°C on May 4. In 1989, spawning groups were not observed on April 22, April 26, or April 30, but were present on May 3 at a water temperature of 13°C. All spawning groups were located just above riffles. Five groups were on open gravel substrate; individual group sizes were 6, 6, 7–10, 10–15, and 20–30. In addition, a group of ten lampreys was

building a spawning depression beneath an overhanging stump, and a group of unknown size was building a pit beneath a large rock slab. Ten lampreys, five of each sex, were collected from among the spawning groups. On May 4, the lampreys had for the most part dispersed from the area occupied on the previous day; a single lamprey was observed beneath the stump that had sheltered a spawning group. Two spawning groups were located much further downstream. Water temperature remained at 13°C. In 1992, approximately 15 lampreys were observed over approximately 150 m of stream. All were in the open, and most were isolated individuals, but two pairs and one group of three were found in flat water just above riffles. Six females and three males were collected. Water temperature was 12°C.

The mean total length of the 30 American brook lampreys collected during this study was 160 mm (range: 139–187 mm). Mean body mass was 6.61 g (range: 3.83–11.27 g). Use of student's t-tests revealed significant differences between lampreys collected at Jambo Creek in 1989 and 1992 in mean total length ($t = 4.43$, $p < 0.001$) and mean body mass ($t = 4.52$, $p < 0.001$) (Table 1). Differences in mean total length and body mass between lampreys from Taylor Creek and Jambo Creek (1989 and 1992 data pooled) were not significant. For each of the three samples from Taylor and Jambo creeks, mean total length and body mass of male lampreys were greater than corresponding values for females (Table 1). When data for the three samples were pooled, the sexes were significantly different in both mean total length ($t = 2.81$, $p < 0.01$) and mean body mass ($t = 2.77$, $p = 0.01$).

The simple linear regression of the natural logarithm of body mass in grams (lnW) on the natural logarithm of total length in mm (lnL) was:

$$(1) \quad \ln W = -16.9 + 3.70 \ln L$$

($r^2 = 0.921$, $n = 30$). Analysis of covariance failed to reveal significant differences between regression lines calculated separately for the two sexes or for the two collection sites.

We measured the oral disc length of each lamprey from Jambo Creek and calculated relative disc length as the ratio of disc length to total length (expressed as a percentage). Total length was positively correlated with disc length ($r = 0.617$, d.f. = 17, $p < 0.01$). Analysis of covariance, with total length as the covariate, revealed a significant difference in disc length between the two sexes ($F_{1,16} = 12.53$, $p < 0.005$). This reflected a difference in mean relative disc length of males (5.83%, S.E. = 0.21%) and females (5.12%, S.E. = 0.13%). In addition to having relatively smaller oral discs, the Jambo Creek females displayed swelling along the leading edge of the second dorsal fin.

At Taylor Creek, American brook lampreys were collected with spotfin shiners (*Cyprinella spiloptera*), bluntnose minnows (*Pimephales notatus*), white suckers (*Catostomus commersoni*), banded darters (*Etheostoma zonale*), johnny darters (*Etheostoma nigrum*), and fantail darters (*Etheostoma flabellare*). At Jambo Creek, a designated trout stream, electrofishing on October 21, 1991, yielded the following species: brown trout (*Salmo trutta*), creek chub (*Semotilus atromaculatus*), common shiner (*Luxilus cornutus*), white sucker, black bullhead (*Ictalurus melas*), smallmouth bass (*Micropterus dolomieui*), green sunfish (*Lepomis cyanellus*), and mottled sculpin (*Cottus bairdi*). Only sculpins and young-of-the-year suckers were observed in large numbers.

We found 12 cases in which American brook lampreys and northern brook lampreys occurred together in the same stream

Table 1. Mean total length in millimeters and mean body mass in grams of American brook lampreys (*Lampetra appendix*) collected at Taylor and Jambo creeks, Wisconsin. Standard errors are in parentheses. All measurements were of living, anesthetized animals.

Locality	*Sex*	*Sample size*	*Total length (mm)*		*Body mass (g)*	
Taylor Creek	Male	10	161.5	(3.0)	6.80	(0.46)
	Female	1	158.0	—	5.48	—
	Both sexes pooled	11	161.2	(2.7)	6.68	(0.44)
Jambo Creek	Male	5	174.8	(4.9)	9.20	(0.84)
	Female	5	160.0	(2.1)	6.71	(0.47)
1989	Both sexes pooled	10	167.4	(3.5)	7.95	(0.61)
	Male	3	153.3	(1.3)	5.48	(0.17)
	Female	6	148.3	(2.3)	4.80	(0.25)
1992	Both sexes pooled	9	149.9	(1.7)	5.02	(0.21)
Both sites pooled	Male	18	163.8	(2.7)	7.25	(0.46)
	Female	12	154.0	(2.2)	5.65	(0.35)
	Both sexes pooled	30	159.9	(2.1)	6.60	(0.34)

(Fago 1983, 1984a, 1984b, 1985a). The American brook lamprey was reported further upstream in 10 of 12 streams. This result is significantly different from expected under the null hypothesis that the two species are equally likely to be found further upstream (binomial test, $p = 0.039$).

Discussion

Some generalizations about the temperature at which American brook lampreys spawn in the spring appear to be inaccurate. Becker (1983) stated that spawning in Wisconsin may begin at water temperatures of "about 17.2°C (63°F)." Robison and Buchanan (1988) cited Becker (1983) but inexplicably raised the temperature to "about 65°F (18°C) . . . ." In contrast, we observed spawning groups at temperatures of 12–14°C, and spawning at one site was apparently completed by the time water temperature had reached 16°C. Moreover, Cochran (1984) reported the occurrence of several spawning groups in Waukesha County at a water temperature of 15.4°C. While it is true that spawning by American brook lampreys in other parts of North America has been reported at temperatures as high as 20.6°C, most published accounts place the onset of spawning well below 15°C (Table 2).

Lampreys typically are reported to spawn in open, shallow, gravel-bottomed habitats. Cochran and Gripentrog (1992), however, reported that several species in the genus *Ichthyomyzon* aggregate beneath cover objects and sometimes spawn beneath cover. Our observations at both Taylor and Jambo

Table 2. Water temperatures at which American brook lampreys (*Lampetra appendix*) have been observed spawning.

Locality	*Temperature*	*Authority*
Wisconsin	12°C, 13°C, 14°C	This study
Wisconsin	15.4°C	Cochran (1984)
Michigan	17°C	Young & Cole (1900)
Michigan	First appear at 13–14.5°C	Okkelberg (1921)
Michigan	Mean of 14.1°C with a range of 6.7–20.6°C and a peak in one stream from 9.5–13.5°C	Morman (1979)
Quebec	8.3°–20.5°C with a peak at 17°C	Vladykov (1949)
Massachusetts	10–11°C	Hoff (1988)
New Hampshire	10–15.5°C	Sawyer (1960)
New York	10–18°C, but usually 15–18°C	Gage (1893, 1928)
New York	18.9°C	Dean & Sumner (1897)
Delaware	6.8–12.0°C	Rohde et al. (1976)
Tennessee	<15.5°C	Seagle & Nagel (1982)

creeks show that American brook lampreys also occasionally aggregate and spawn beneath cover objects. Young and Cole (1900) reported that nests may be situated beneath overhanging banks or logs.

In one of our samples of spawning-phase adults, males outnumbered females by a significant margin. Care must be taken when interpreting the literature on this topic. For example, Schuldt et al. (1987) cited Seagle and Nagel (1982) among authors who reported an excess of males, but Seagle and Nagel (1982) stated that the sex ratio was not statistically different from 1:1. Hoff (1988) and Scott and Crossman (1973) cited Young and Cole (1900) as reporting that males outnumbered females by a ratio of 5:1, but it was Dean and Sumner (1897) who reported that figure. Hoff (1988) reported that females outnumbered males 5:2, but with a sample size of 7, that result is not significantly different from 1:1 (binomial test, $p = 0.453$). Generally, however, adult male American brook lampreys outnumber females in collections made during or just prior to the spawning season (Dean and Sumner 1897; Young and Cole 1900; Kott 1971; Schuldt et al. 1987). Presumably, the sex ratio varies over time, since males are reported to precede females to the spawning site (Young and Cole 1900; Okkelberg 1921; but see Kott 1971).

Becker (1983) listed several traits for which American brook lampreys in Wisconsin are sexually dimorphic. Breeding males each have a long, threadlike urogenital papilla and relatively high dorsal fins separated by a sharp notch. Breeding females each have a prominent anal fin fold and relatively low dorsal fins separated by a broad notch. In addition, we report here that males have relatively larger oral discs than females and that the leading edge of the second dorsal fin in females may be swollen. A difference in disc size has been previously noted for American brook lampreys in Quebec (Kott

1974) and Delaware (Rohde et al. 1976); the larger discs of male lampreys may reflect their relatively greater role in nest construction (Beamish 1982). Swelling along the anterior margin of the female's second dorsal fin was mentioned by Gage (1928) and previously reported in several other species of *Lampetra* (Pletcher 1963; Larsen 1980; Hardisty 1986a, 1986b). Perhaps the swelling provides support for the body of the male, which during the spawning act fits into the notch between the first and second dorsal fins of the female (Breder and Rosen 1966).

Adult male American brook lampreys tended to be larger than females in our samples (Table 1). In each of five previous studies (Okkelberg 1921; Hubbs 1925; Sawyer 1960; Kott 1974; Rohde et al. 1976), mean total lengths of males were slightly but not significantly greater than those for females. However, if all paired samples for the two sexes were drawn randomly from populations with identical means, the probability of obtaining such a sequence of results is very low ($p = 0.0156$, binomial test). The apparently real trend for male American brook lampreys to be on average slightly larger than females is reinforced by the results of Schuldt et al. (1987), who obtained a mean total length for males slightly but significantly greater than that for females. Such a tendency may reflect a balance of opposing selective factors. Malmqvist (1983) and Beamish and Neville (1992), respectively, found that fertilization and spawning success declined as size differences between male and female lampreys increased; fertilization was most successful when the female/male length ratio was 1.05–1.14 (Malmqvist 1983). In contrast, Malmqvist (1983) and Becker (1983) reported behavior interpreted as fighting between male brook lampreys. The former results would select against substantial sexual divergence in size; the latter phenomenon would presumably favor larger males.

The tendency for American brook lampreys to be found upstream from northern brook lampreys reflects their preference for cooler temperatures (Scott and Crossman 1973), which are often associated with spring-fed headwaters. This pattern is not inviolate, however. Classical patterns of longitudinal zonation of stream fishes may be disrupted in drainages where springs empty cold water into the mid-reaches of streams (Swaidner and Berra 1979). Morman (1979) provided examples of inverted distributions of American and northern brook lampreys that apparently were related to reversed stream temperature gradients. An example of this phenomenon in Wisconsin may occur in the Mukwonago River (Cochran 1984). Northern brook lampreys were collected not far downstream from Eagle Springs Lake, the surface of which presumably warms quickly in the spring, whereas American brook lampreys were collected further downstream, below where a trout stream and numerous springs enter the river.

Wisconsin's native lampreys are not well understood by the general public (Cochran 1984) and may suffer through association with the sea lamprey (*Petromyzon marinus*), an exotic parasitic species that has caused great destruction of valuable fish in Lake Michigan and the other Great Lakes (Smith 1971). The American brook lamprey is nonparasitic and does not harm other fishes. Nevertheless, landowners along Jambo Creek informed us that they had encouraged a Cub Scout pack to catch and kill what they mistakenly thought were sea lampreys spawning on their property. (Spawning-phase sea lampreys from Lake Michigan do ascend the East Twin River to within 4 km of its confluence with Jambo Creek, but they

are blocked by the Mishicot spillway from ascending closer.) We hope that further research on Wisconsin's native lampreys will help to dispel this sort of misunderstanding.

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***Philip A. Cochran** is an Associate Professor of Biology at St. Norbert College. He is especially interested in the ecology and geographic distribution of lampreys and other fishes.*

***Martin E. Sneen** graduated from St. Norbert College in 1990 with a B.S. degree in Environmental Science. He currently works in Madison as an environmental consultant.*

***Alan P. Gripentrog** completed his B.S. degree in Environmental Science at St. Norbert College in 1988. He now works in Washington, D.C. for the Central Intelligence Agency.*