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POPULATION STATUS AND HABITAT REQUIREMENTS OF THE AMERICAN BROOK LAMPREY IN SOUTHEASTERN MINNESOTA

Report to the
Minnesota Department of Natural Resources
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ABSTRACT

American brook lamprey ammocoetes, adults, and/or their spawning redds were observed at 23 stream locations in Olmsted, Winona, Fillmore, and Houston counties in southeastern Minnesota. During 1995 and 1996, adult lamprey (147 in 1995, 54 in 1996) were observed in spawning areas between 25 April and 9 May at 13 stream locations. Spawning occurred at water temperatures ranging from 12.615.5°C, and was concentrated at the head of riffles in water < 50 cm deep with bottom current velocity < 0.2 m/sec and substrates of cobble, gravel, and coarse sand. Spawning redds averaged approximately 200 cm^2 in area, were dug out to an average depth of 5 cm below the surrounding sediment level, and generally were spaced 40-70 cm apart. Typical spawning group size was 4-6 lamprey per redd. Only 42 ammocoetes were collected from 13 stream sites, preferring water depths < 50 cm, water column velocities < 0.1 m/sec, and sediment organic contents < 12%. The size range of ammocoetes collected suggests the presence of possibly three size/age classes. At 150-m-long sites where ammocoetes were collected by single-pass electrofishing, the median number of ammocoetes collected was three. Three-pass removal sampling of ammocoetes in Pine Creek produced density estimates ranging from 0-1.68 ammocoetes/100 m^2 (mean = 0.63/m^2). Spawning populations of American brook lampreys in most streams surveyed were small, and ammocoete abundance was low. These apparently small populations should be given greater protection and their susceptibility to decline or disappearance should be examined.

INTRODUCTION

Until recently, the American brook lamprey, *Lampetra appendix* (DeKay), was listed as a Special Concern species within Minnesota. Minnesota is on the extreme northwestern periphery of the species' distribution, which covers the northeast quarter of the continental united States, ranging from Minnesota south to Arkansas, east to Virginia, and north to the St. Lawrence River basin (Rohde 1980). Within Minnesota, its distribution is restricted to the southeastern portion of the state, specifically the tributaries of the Mississippi, Minnesota, and St. Croix rivers (Eddy and Underhill 1974). The American brook lamprey is one of six lamprey species found in Minnesota, and one of the three nonparasitic members of its class within the state (Eddy and Underhill 1974, Lee et al. 1980, Cochran and Pettinelli 1988). Although American brook lampreys are generally uncommon in Minnesota, they apparently are much more abundant in Wisconsin. This species is the most widespread lamprey species in Wisconsin, and was collected at 6% of all stream and river sites sampled throughout the state during the period 1974-1986 (Fago 1992).

American brook lampreys are most common in the Buffalo, Black, and Trempealeau River basins (across the Mississippi River from southeastern Minnesota), where they were collected at 18% of all sites sampled, averaging 10 lampreys per site (Fago 1983).

The American brook lamprey typically inhabits clear, high-gradient streams (Pflieger 1975, Trautman 1981). These may be medium-sized streams and rivers (>5 m average width; Pflieger 1975, Trautman 1981), or the headwater tributaries of larger streams (Eddy and Underhill 1974, Fago 1983). Successful completion of the life history of the American brook lamprey requires two distinctly different stream habitats: clear, high-gradient riffles with bottoms of clean gravel and sand for spawning adults, and clear, low-gradient waters with bottoms of mixed sand and organic debris for ammocoete (larval lamprey) development and growth (Eddy and Underhill 1974, Trautman 1981). Both habitats are critical, and human activities within a stream watershed may reduce or destroy both types of habitat. For example, populations of the American brook lamprey have been reduced or eliminated by increased turbidity that can compromise ammocoete feeding efficiency, increased sedimentation of fine silt and clay particles that can smother spawning and ammocoete habitats, pollutants that sicken or injure ammocoetes during their 5-year life span, and insurmountable dams that prevent adults from migrating into spawning areas (Eddy and Underhill 1974, Trautman 1981).

This study was undertaken to assess the current status of populations of the American brook lamprey within different watersheds in its range in Minnesota. It also was designed to assess the physical nature of the habitat occupied by the species.

MATERIALS AND METHODS

Background Information

Collection records of the American brook lamprey in Minnesota were obtained from the Minnesota Department of Natural Resources Natural Heritage database. This database included over 100 records of American brook lamprey collections spanning 10 counties in southeastern Minnesota over a 20-year period. These records, along with numbers of lamprey collected if available, were plotted on a stream map of the region to assess general distribution and abundance patterns for the species. Based upon this map, as well as personal collection data and conversations with various fisheries biologists, fishermen, landowners, and other resource managers, stream sites were selected for observation during the 1995-1996 study period.

Population Assessments

Lamprey populations were assessed in two different ways. During the spring spawning period (late April - early May), visual counts of adults within the spawning habitat were made. Long (up to 2 km) sections of the streams were walked until spawning groups were located. Repeated scans were then made from various vantage points along and/or within the stream to tally the individuals actively involved in spawning activity (redd construction and/or spawning), as well as the number of redds present within the spawning area. If water surface disturbances or submerged vegetation or woody debris obscured spawning groups, they were temporarily displaced from the spawning redd by hand into a large dip net held immediately downstream from the redd in order to count them. After counting, they were returned to the point of capture. This procedure easily captured all lamprey within a given redd, and, judging from their immediate return to spawning activities when released, had no observable effect on spawning behavior. Detailed observations of these spawning events also were recorded, and photographs were taken of stream sites and spawning redds. In particular, detailed close-up photographs were made of spawning redds and spawning lamprey on redds with a camera equipped with a 50-mm lens coupled with a 2X converter.

Lamprey populations also were assessed during the summer and autumn months by collecting ammocoetes from their burrows in the softer sediments with the aid of a backpack electrofishing unit (Smith Root Type VII). At some stream sites, a 50m section of stream was blocked off with nets at upstream and downstream ends, and lamprey populations and capture efficiencies were estimated by three-pass removal sampling (Armour et al. 1983). Most sites were sampled with a single electrofishing pass through a measured stream section, whereas at a few sites only likely ammocoete habitats were spot sampled.

Habitat Assessments

American brook lamprey habitats were assessed during both spring and summer/autumn population surveys. For each location where spawning adult lampreys or their spawning redds were located, a variety of physical habitat measurements were made. Such measurements included stream width, depth, current velocity (bottom velocity and average water column velocity based on measurements at 0.6-depth, Marsh-McBirney Flowmate current meter), and water temperature. In addition, the total area of spawning habitat, distances between adjacent redds, redd dimensions (width, length, depth below substrate), and substrate particle sizes were measured.

During summer/autumn surveys, lamprey habitat assessments were made at stream sites at the point of collection of each individual ammocoete. Water depth and current velocity at 0.6-depth were measured, and a sample of the substrate from which the ammocoete emerged was collected and returned to the laboratory for particle size (serial sieving of dried sediments through U.S. Standard # 20, 40, and 80 sieves) and organic matter (weight loss on ignition of dried sediments at 550°C for 3 h) analyses.

RESULTS

Spring Field Work

During late-April through early-May 1995, 23 stream sites in Fillmore, Houston, Olmsted, and Winona counties were examined for the presence of spawning American brook lamprey (Table 1). Adult American brook lamprey and/or their spawning redds were observed at nine of these sites (Table 1). The number of lamprey observed at these sites ranged from 1 to 69, and totaled 147 individuals for all sites combined. Active redd construction and/or spawning were observed at five of the stream sites (Badger Creek, Pine Creek, Rupprecht Creek, South Branch Whitewater River, North Branch Whitewater River). More than 86% of all lampreys observed were part of a spawning group rather than lone individuals (Table 2). Spawning groups for all sites combined averaged approximately 6 individuals (Table 2). However, mean spawning group size differed significantly among streams (ANOVA $F_{3,15} = 9.58$, $p = 0.001$), with spawning groups at Rupprecht Creek being two to three times larger than those observed at other sites (Table 2). Spawning redds were observed at seven sites, with the number of redds per site ranging from 3 to 21 (Table 1). Four of the 70 total redds examined (5.7%) were at least partially concealed beneath submerged beneath branches, or other types of vegetation.

During the 1996 spawning season, 27 stream sites were examined in the same four counties (Table 1). Twenty of these sites were visited for the first during 1996, whereas seven of the sites had been examined in 1995. Four of the sites were visited more than once during the 1996 spawning season. Adult lamprey and/or their spawning redds were observed at 17 locations (Table 1). At those sites where lamprey were observed, numbers ranged from 1 to 23, with a total of 54 individuals observed during the spawning season. Ongoing redd construction and/or spawning were observed in six streams (Badger Creek, North Branch Whitewater River, Etna Creek, South Branch Root River, North Branch Creek, and South Branch Creek). As in 1995, more lamprey were observed as part of a spawning group than as loners (Table 2). However, loners were proportionately more common in 1996 than in 1995 ($X^2 = 13.63$, df = 1, p

< 0.001). Mean spawning group size did not differ (ANOVA $F_{4,4}$ = 0.92, p = 0.533) between streams in 1996, nor did mean group size for all streams combined differ (t = 1.63, df = 26, p = 0.115) between 1995 and 1996 (Table 2). Spawning redds were detected at 14 sites during 1996 (Table 1), with 5 of the 173 redds (2.9%) examined constructed partially beneath submerged vegetative cover.

Different water temperatures apparently were associated with various spawning -related behaviors of American brook lamprey. Prior to the onset of spawning, lamprey were collected at cold water temperatures (Table 3) within riffle habitats immediately adjacent to spawning areas. Lamprey appeared to use the shelter of large rocks (2050 cm in diameter) or other large objects (such as discarded appliance parts!) within these riffles (15-30 cm deep, >0.5 m/sec current velocity) as staging areas prior to entering the spawning habitat. At similar or slightly warmer temperatures, spawning redds were observed being dug or already completed, although spawning was not witnessed (Table 3). All 10 instances of actual spawning that were observed occurred at warmer temperatures, ranging between 12.6 and 15.5°C (Table 3).

In general, lamprey spawning redds were located at the head of riffles in areas containing various mixtures of coarse substrata (coarse sand, gravel, and cobble up to 7 cm in diameter), immediately upstream from the beginnings of surface water turbulence associated with the riffles. Mean water depth over spawning redds ranged from 16 to 59 cm in the different streams (Table 4). Mean bottom current velocities measured within spawning redds in the various streams ranged from 5 to 26 cm/sec, whereas mean water column velocities above redds ranged from 20 to 57 cm/sec (Table 4). Stream widths at spawning sites ranged from 2.6 to 12.3 m (Table 5). Redds generally were oval in outline and bowl-shaped, dug out to average depths of 4 to 6 cm below that of the surrounding stream bottom (Table 5). They were constructed by lamprey first carrying or dragging larger materials (up to 5 cm in diameter) out of an area with the aid of the oral disk, and then clearing out smaller particles by violent thrashings of the body while attached by the oral disk to a larger rock at the upstream edge of the redd. The area of individual spawning redds differed considerably among the streams, with average redd area ranging from a low of 94 cm2 in Pine Creek to a high of 463 cm^2 in Rupprecht Creek (Table 5). However, the majority of redds generally occupied areas between 150 and 250 cm2. When more than one spawning redd was present within a riffle, redds usually were spaced 40 to 70 cm apart (Table 6). Although redds within the North Branch Whitewater River averaged nearly 2X further apart than those in other streams, mean spacing did not differ significantly among streams (ANOVA $F_{5,25}$ = 2.43, p = 0.063). Mean redd densities were highly variable (range from <0.4 to >5.4 redds/m^2), but not significantly different (ANOVA $F_{5,7}$ = 0.48, p =

0.783), among the streams examined. Substrata and bottom current velocity together appeared to be the most important factors affecting redd location. Lamprey did not construct redds at the head of riffles where bottom substrata appeared favorable but bottom current velocities exceeded 40 cm/sec, nor were they located in riffles with the "preferred" bottom current velocities but too fine (fine sand and silt) of a substratum. At some locations, some redds were constructed beneath submerged objects that at least partially concealed spawners (see above).

Summer Field Work

During June to September 1995 and June 1996, 41 surveys for lamprey ammocoetes were conducted at 23 sites on 14 streams in Winona, Olmsted, and Wabasha counties (Table 7). Thirteen of these sites were locations where American brook lampreys previously had been collected. Lamprey (42 total) were collected at only six sites, five of which were known lamprey habitats. Surveys were unsuccessful at locating lamprey at eight sites where they had been collected before, including Rupprecht Creek, which two months earlier had the highest number of spawning lampreys observed during this study. Nearly 70% (29 of 42 individuals) of all lamprey collected were found at two locations, Pine Creek and North Branch Whitewater River (Table 7). The majority of surveys produced three or fewer lamprey.

Three-pass removal sampling was conducted for lamprey ammocoetes in three Pine Creek locations during both June and September. These six sampling efforts produced 13 lamprey, with each 50-m stream section yielding 0 to 5 lampreys. Based on these collections, densities of American brook lamprey ammocoetes in Pine Creek averaged 0.63 ammocoetes/100 m2 of stream area, ranging from 0 to 1.68 individuals/100 m^2. Extrapolating from these density estimates, a typical 150-m-long section of Pine Creek should contain approximately seven ammocoetes. Because of the low numbers of ammocoetes collected during removal sampling, only a single, per-pass capture efficiency estimate of 58% was determined. If this efficiency estimate is realistic, then the numbers of ammocoetes collected in single-pass electrofishing efforts should be nearly doubled to estimate the actual numbers of ammocoetes present. More work remains to be done to more confidently assign an electrofishing capture efficiency estimate to American brook lamprey ammocoetes in southeastern Minnesota streams.

Wet weight and total length measurements were obtained from 17 American brook lamprey ammocoetes collected from Pine Creek, North Branch Whitewater River, Ferguson Creek, Beaver Creek, and Bear Creek and preserved in 10% formalin. Specimen total lengths and wet weights ranged from 14 to 24 cm and from 4 to 24 g, respectively. The length-weight data show a strong exponential relationship (Figure 1), but information is lacking for individuals <15 cm long. Also, distinct size (= age?) classes were not obvious, indicating that either most individuals were of similar age or that age classes cannot be separated easily based on length or wet weight.

Stream habitat data were collected at the points of capture of 34 of the 42 lamprey at the six stream sites during summer and autumn (Table 8). Lamprey generally were found living in burrows in soft sediments in shallow water. There was no significant difference (ANOVA $F_{5,28} = 1.67$, $p = 0.174$) among the streams in the water depths where lamprey were collected, with 27 of the 34 individuals being found in water < 50 cm in depth. There were significant differences (ANOVA $F_{4,26} = 6.26$, $p = 0.001$) among streams for average current velocity (at 0.6 depth) at lamprey collection sites, with Pine Creek lamprey found in the fastest water (Table 8). However, the vast majority (26 of 31) of individuals were collected at locations with velocities < 0.10 m/sec. Many of the ammocoetes were collected in close proximity to submerged woody debris such as logs and branches along stream margins, often sound in sediments within the slow, swirling eddies produced where the woody debris disrupted the normal stream flow. All 16 ammocoetes collected in the North Branch Whitewater River were found occupying the same accumulation of submerged woody debris. In Pine Creek, four of the 13 lamprey also were found in association with woody debris, but the majority were living in fine sediment accumulations within sparse beds of aquatic macrophytes. These sparse beds also were located near the stream banks, but often had higher current velocities than habitats near woody debris, resulting in the higher current velocities reported for lamprey sites in this stream (Table 8).

Stream sediments in which lamprey ammocoetes were living were analyzed for organic content and particle size distribution. Sediment organic content was usually low (Table 8) and did not differ (ANOVA $F_{4,25} = 1.70$, $p = 0.182$) among streams. Laboratory analysis of sediment particle sizes showed significant differences ($X^2 = 437.8$, df = 12, $p < 0.001$) in the mixtures of different size classes among the stream sites (Figure 2). Pine Creek and Bear Creek ammocoetes were collected from sediments dominated by very fine particles, whereas Whitewater and Ferguson Creek specimens occupied slightly coarser sediments. The single Beaver Creek sediment sample analyzed was dominated by the largest particles of any sample examined. When statistical comparisons were limited to those streams where multiple sediment samples were analyzed, the mixture of particle size classes still differed significantly ($X^2 = 238.9$, df = 6, $p < 0.001$).

DISCUSSION

The population status of American brook lampreys was very difficult to assess in southeastern Minnesota streams. Although the species was located successfully in several systems, determining population sizes was problematic. Populations of brook lampreys are most readily detected and surveyed during their spring spawning period (Cochran and Pettinelli 1988). At those stream sites where spawning was observed during both 1995 and 1996, most displayed dramatic declines in the numbers of spawners present. However, these counts may not correlate with true changes in the spawning population, as spawning periods can be short-lived and may be missed without daily visits to spawning habitats (Cochran et al. 1993). Lamprey spawning redds are easy to locate and are more long-lived, so it may be possible to use the number of redds within a stream as an estimator of relative population size. However, the variable number of spawners that may use a single redd (Hoff 1988, Cochran et al. 1993, present study) probably limits the usefulness of this approach.

The status of lamprey populations also can be assessed by using electrofishing techniques to collect ammocoetes (Pajos and Weise 1994, Bergstedt and Genovese 1994). American brook lamprey ammocoetes have been collected successfully with the aid of backpack electrofishers in several different localities (Lanteigne et al. 1981, Seagle and Nagel 1982, Pajos and Weise 1994), and were successful at collecting ammocoetes for this study. Ammocoete densities determined for Pine Creek in this study (mean = 0.63 ammocoetes/100 m2) are significantly lower than those (31-118 ammocoetes/100 m^2) determined for American brook lamprey ammocoetes in a Lake Superior tributary (Pajos and Weise 1994). (Pajos and Weise [1994] found that electrofishing underestimated ammocoete densities when compared to densities determined by lampricide treatment. However, at very low densities such as those determined for Pine Creek, differences between electrofishing and lampricide density estimates were not significant. Therefore, the density estimates determined by electrofishing in Pine Creek probably are fairly realistic.) A small, spring-fed tributary of Lake Michigan was estimated to contain over 100,000 American brook lamprey ammocoetes (Smith and McLain 1962). No other density estimates of American brook lamprey ammocoetes could be located in the scientific literature, but based on the number of ammocoetes collected from a variety of streams in other studies (Lanteigne et al. 1981, Seagle and Nagel 1982), densities in these areas likely also are considerably higher than those determined for Pine Creek. Since Pine Creek appeared to have one of the larger populations of lampreys based on this study, it is likely that southeastern

Minnesota streams, in general, tend to have relatively small populations of the American brook lamprey.

Although the sizes of spawning American brook lamprey were not measured in this study, the sizes of the few ammocoetes measured were similar to those of spawning adults reported by other investigators (Kott 1971, 1974, Seagle and Nagle 1982, Cochran et al. 1993). This might suggest that electrofishing for ammocoetes samples only the larger, older ammocoetes, and may therefore underestimate lamprey populations. However, the sizes of ammocoetes collected in this study correspond to those of at least three of the four age groups likely present during the summer months (Seagle and Nagel 1982). Only the youngest and smallest ammocoetes were missing from collections from southeastern Minnesota streams. The inability to distinguish size/age classes in the present study likely resulted from combining too few individuals from too many sample sites and too many sampling dates. Greater sampling effort in extremely good ammocoete habitat in late autumn probably will be needed to collect large numbers of all possible age groups of lamprey from southeastern Minnesota. Based on recent collections of suspected southern brook lamprey *(Icthyomyzon gage)* ammocoetes from St. Croix State Park streams, the electrofishing unit used in this study is capable of collecting large numbers of ammocoetes of all sizes down to 29 mm total length and 0.06 g wet weight (N. Mundahl, unpublished data).

Most of the variables associated with spawning American brook lampreys measured in this study agree with previously published accounts on this species. Water temperatures, water depths, redd dimensions, and number of spawners per redd agree with earlier observations (Seagle and Nagel 1982, Hoff 1988, Cochran et al. 1993). Distances between redds (most < 1 m) were considerably less than the 3 m spacings reported by Hoff (1988), but similar to those described long ago by Young and Cole (1900) for *Lampetra wilderi.* Spawning redds constructed beneath submerged cover have been reported for American brook lamprey and several other species of brook lampreys in Wisconsin (Cochran and Gripentrog 1992, Cochran et al. 1993). American brook lamprey ammocoetes were collected from southeastern Minnesota streams in areas of typical ammocoete habitat. Ammocoetes of most species of North American lampreys occupy similar areas of soft sediments in areas of reduced current, especially in the vicinity of submerged woody debris (Anderson and White 1988, Stephen Bowen, Michigan Technological University, personal communication, Konrad Schmidt, personal communication, N. Mundahl, personal observation). These areas are most suitable for the burrowing and feeding habits of this lamprey life stage (e.g., Moore and Beamish 1973, Moore and Mallat 1980, Mallat 1982). American brook lamprey ammocoetes have been reported from mostly sandy substrates among emergent vegetation in water depths < 30 cm (Lanteigne et al. 1981), as well as from finer sediments in deeper water around rootwads and submerged timber (Konrad Schmidt, personal communication). Median particle size and heterogeneity of sediments is important in habitat selection by American brook lamprey ammocoetes, with ammocoetes only tolerating sediments with < 50% silt content and < 21 % organic content (Anderson and White 1988). With a few exceptions (e.g., Bear Creek and some Pine Creek and Whitewater River samples), sediments occupied by ammocoetes in this study generally agreed with these reported values. American brook lamprey ammocoetes apparently are less tolerant of silt or organic content than are other species of brook lamprey (Anderson and White 1988). The tendency for American brook lampreys to be found upstream from other species of brook lampreys occupying the same stream system has been attributed to their preference for cooler water temperatures (Cochran et al. 1993). However, these upstream, higher-gradient stream sections may also have reduced concentrations of silt and organic matter relative to downstream sections, making them more favorable for American brook lamprey ammocoete burrowing and feeding.

Management Implications

During this study, American brook lamprey ammocoetes, adults, and/or their spawning redds were observed at 23 stream locations in Olmsted, Winona, Fillmore, and Houston counties in southeastern Minnesota. The Minnesota Department of Natural Resources Natural Heritage database contains many additional collection records for these as well as six additional counties, with most records spanning the past 20 years. These records indicate that the American brook lamprey occurs in many streams throughout its range in Minnesota.

Despite the widespread occurrence of American brook lampreys in southeastern Minnesota, their abundance at most stream locations appears to be very low. Most collections during this study and most records from the Natural Heritage database included far fewer than 10 lamprey per site. Personal collection records indicate that American brook lampreys comprise < 1 % of total fish numbers at most locations (N. Mundahl, unpublished data). Although historical records are few, these indicate that American brook lampreys were previously much more abundant in Minnesota streams. For example, the Credit River near Savage and the South Fork Zumbro River in Rochester previously held large populations of lamprey, but they have declined drastically or disappeared as a result of development in the drainage basins and flood-control projects (Eddy and Underhill 1974, Natural Heritage database). Similar declines have been reported in Ohio (Trautman 1981), as well as other areas throughout the Great Lakes region (Vladykov 1973). Comparative historical information on most populations of brook lamprey throughout southeastern Minnesota is lacking, so definitive statements on population change cannot be made. However, based on personal observations, most populations of American brook lampreys in southeastern Minnesota are much smaller than those of suspected southern brook lamprey in the St. Croix river drainage. Although it is the limited range of suspected southern brook lampreys in Minnesota that has been most important in listing it as a Special Concern species, I feel that the low numbers of American brook lampreys at most locations also warrant some degree of protection for this species. I suggest that this species be returned to Special Concern status within the state pending a more comprehensive analysis of these apparently small populations and their susceptibility to decline or disappearance.

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Table 1. Stream sites examined for spawning American brook lamprey during April and May, 1995 and 1996, and the numbers of lamprey and spawning redds observed. Values in parentheses indicate numbers of redds partially concealed by submerged logs, branches, or other types of vegetation

Stream	County	Location	Date	Number of lamprey	Number of redds
1995 Sample Sites					
Pine Creek	Winona	T105N R9W SE35	4/25/95	6	0
Coolridge Creek	Winona	T105N R9W NW26	4/25/95	0	0
Badger Creek	Houston	T103N R6W NW17	4/30/95	17	4
East Beaver Creek	Houston	T102N R6W NE17	4/30/95	0	0
Beaver Creek	Houston	T102N R6W NW5	4/30/95	0	0
Pine Creek	Winona	T105N R9W SE26	5/2/95	21	13 (1)
Hemmingway Creek	Winona	T105N R9W SW26	5/2/95	0	0
Salem Creek	Olmsted	T106N R15W NW24	5/2/95	0	0
S. Fork Zumbro River	Olmsted	T106N R15W SE25	5/2/95	0	0
Rupprecht Creek	Winona	T107N R9W NE24	5/4/95	69	21 (3)
S. Branch Whitewater River	Winona	T107N R10W SE14	5/5/95	18	13
S. Branch Whitewater River	Winona	T107N R10W NE10	5/5/95	0	0
N. Branch Whitewater River	Winona	T107N R10W NE9	5/5/95	14	9
Rush Creek	Fillmore	T104N R8W NE4	5/6/95	0	0
Rush Creek	Winona	T105N R8W NW29	5/6/95	0	0
Trout Run	Winona	T107N R10W NW29	5/7/95	0	0
M. Branch Whitewater River	Winona	T107N R10W NW16	5/7/95	0	0
M. Branch Whitewater River	Winona	T107N R10W SE9	5/7/95	1	0
Trout Valley Creek	Winona	T108N R9W NW5	5/8/95	0	0
Trout Valley Creek	Winona	T108N R9W NW17	5/8/95	0	7

Table 1. - continued

Stream	County	Location	Date	Number of lamprey	Number of redds
Thompson Creek	Houston	T104N R4W SE32	5/10/95	0	0
Crystal Creek	Houston	T104N R5W NE31	5/10/95	0	0
Beaver Creek	Winona	T108N R10W SW15	5/11/95	1	3
1996 Sample Sites					
Rupprecht Creek	Winona	T107N R9W NE24	4/23/96	0	11 (2)
			4/30/96	1	10 (1)
			5/4/96	1	0
			5/8/96	2 (dead)	0
Rollingstone Creek	Winona	T107N R8W SW5	4/23/96	0	0
Trout Valley Creek	Winona	T108N R9W NW17	4/23/96	0	0
			5/8/96	0	0
Badger Creek	Houston	T103N R6W NW17	4/28/96	2	1
			5/5/96	0	0
Beaver Creek	Houston	T102N R6W NW5	4/30/95	1	0
Trout Run Creek	Fillmore	T104N R10W NE20	4/27/96	0	0
Trout Run Creek	Fillmore	T104N R10W NE17	4/27/96	0	0
S. Branch Whitewater River	Winona	T107N R10W SE14	4/30/96	0	11
N. Branch Whitewater River	Winona	T107N R10W NE9	4/30/96	1	25 (1)
			5/4/96	6	29 (1)
S. Branch Whitewater River	Winona	T107N R10W NW14	5/4/96	0	0
Diamond Creek	Fillmore	T103N R9W SW11	5/5/96	0	3
Crystal Creek	Houston	T104N R5W NE31	5/5/96	0	0
Etna Creek	Fillmore	T102N R13W NW36	5/7/96	1	1

Table 1. - continued

Stream	County	Location	Date	Number of lamprey	Number of redds
S. Branch Root River	Fillmore	T102N R12W NW22	5/7/96	5	7
North Branch Creek	Fillmore	T102N R12W NW13	5/7/96	23	11
S. Branch Root River	Fillmore	T102N R12W NW24	5/7/96	0	7
South Branch Creek	Fillmore	T102N R12W NW24	5/7/96	10	8
Beaver Creek	Winona	T108N R10W SW15	5/8/96	0	?
S. Fork Zumbro River	Olmsted	T105N R15W NE1	5/9/96	0	15
S. Fork Zumbro River	Olmsted	T105N R14W NW6	5/9/96	1	12
S. Fork Zumbro River	Olmsted	T105N R15W SE3	5/9/96	0	0
S. Fork Zumbro River	Olmsted	T105N R15W SE5	5/9/96	0	0
S. Fork Zumbro River trib.	Olmsted	T105N R15W SW4	5/9/96	0	0
Salem Creek	Olmsted	T106N R15W SW16	5/9/96	0	10
Salem Creek	Olmsted	T106N R15W SE19	5/9/96	0	12
Salem Creek	Olmsted	T106N R15W NW24	5/9/96	0	0

Table 2. Numbers of American brook lamprey observed as lone individuals and group sizes of active spawners during 1995 and 1996 spawning seasons.

Stream	Number of loners	Numbers in spawning groups	Mean ± SD spawning group size
1995			
Pine Creek	6		
Badger Creek	?	?	
Pine Creek	6	3-2-5-5	3.75 ± 1.50
Rupprecht Creek	0	12-9-12-11-14-4-7	9.86 ± 3.44
S. Branch Whitewater R.	1	4-3-5-3-2	3.40 ± 1.14
N. Branch Whitewater R.	2	5-5-2	4.00 ± 1.73
M. Branch Whitewater R.	1		
Beaver Creek-Win. Co.	1		
1995 Totals	**17 (13.1%)**	**113 (86.9%)**	**5.95 ± 3.79**
1996			
Badger Creek	0	2	2.00
Beaver Creek-Hou. Co.	1		
Rupprecht Creek	4		
N. Branch Whitewater R.	5	2	2.00
Etna Creek	1		
S. Branch Root R.	1	4	4.00
North Branch Creek	4	7-4-4-4	4.75 ± 1.50
South Branch Creek	3	2-5	3.50 ± 2.12
S. Fork Zumbro R.	1		
1996 Totals	**20 (37.0%)**	**34 (63.0%)**	**3.78 ± 1.64**

Table 3. Water temperatures (°C) associated with various spawning-related behaviors of American brook lamprey in southeastern Minnesota streams, April-May 1995 and 1996.

Behavior/stream	**Water temperature**	**Date**
Adults hiding in riffles		
Pine Creek	7.9-8.6	4/25/95
Rupprecht Creek	6.9	4/30/96
S. Fork Zumbro River	10.6	5/9/96
Redds present,no spawners		
Trout Valley Creek	9.8	5/8/95
Rupprecht Creek	8.3	4/23/96
Diamond Creek	10.4-10.5	5/5/96
Salem Creek	10.8	5/9/96
Active redd building, no spawning		
Etna Creek	10.5	5/7/96
Active spawning		
Badger Creek	13.8	4/30/95
	12.6	4/28/96
Pine Creek	13.3	5/2/95
Rupprecht Creek	13.0	5/4/95
S. Branch Whitewater R.	15.5	5/5/95
N. Branch Whitewater R.	15.1	5/5/95
	13.2-13.4	5/4/96
S. Branch Root River	14.3	5/7/96
North Branch Creek	13.9	5/7/96
South Branch Creek	14.2	5/7/96

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Table 4. Mean (± SD;sample size) water depths (cm) and current velocities (m/sec) at American brook lamprey spawning redds in southeastern Minnesota streams, April-May 1995 and 1996. Values in parentheses are sample sizes.

		Current velocity	
Stream	**Depth**	**Bottom**	**0 6-depth**
1995			
Badger Creek	30 (6;12)		0.44 (0.07;6)
Pine Creek	25 (7;13)	0.26 (0.08;11)	
Rupprecht Creek	59 (15;19)	0.15 (0.07;13)	0.32 (0.10;13)
S. Br. Whitewater R.	43 (9;13)	0.13 (0.05;13)	0.41 (0.06;13)
N. Br. Whitewater R.	36 (4;7)	0.23 (0.05;9)	0.57 (0.07;9)
Trout Valley Creek	28 (12;7)	0.05 (0.02;7)	0.20 (0.08;7)
Beaver Creek-Win.	16 (1;3)	0.08 (0.06;3)	0.29 (0.02;3)
1996			
Badger Creek	33 (-; 1)	0.17 (-; 1)	
Rupprecht Creek	47 (14;10)	0.10 (0.02;10)	
S. Br. Whitewater R.	25 (7;11)	0.12 (0.05;11)	
N. Br. Whitewater R.	33 (5;25)	0.15 (0.05;25)	
Etna Creek	18 (-;10)	0.18 (-;l)	
S. Br. Root River	17 (4;7)	0.15 (0.07;7)	
North Branch Creek	23 (8;11)	0.16 (0.09;11)	
South Branch Creek	24 (8;8)	0.11 (0.05;8)	
S. Fork Zumbro R.	26 (8;15)	0.13 (0.08;15)	
Salem Creek	24 (8;12)	0.15 (0.09;12)	

Table 5. Spawning redd dimensions (area: cm^2, maximum depth below surrounding substrate level: cm) for American brook lamprey in southeastern Minnesota streams, April-May 1995. Values are means with SD in parentheses. Sample sizes are labeled n.

Stream (width)	Area	n	Depth	n
Pine Creek (2.6-2.8 m)	94 (37)	10	6 (-)	1
Rupprecht Creek (3.4 m)	463 (320)	14	4 (-)	1
S. Br. Whitewater R (12.3 m)	162 (84)	13	4 (1)	13
N. Br. Whitewater R (11.4 m)	186 (49)	7	4 (1)	7
Trout Valley Creek (3.6 m)	250 (144)	7	5 (1)	7
Beaver Creek-Win (6.2 m)	174 (58)	3	5 (1)	3

Table 6. Mean (±SD) spacing (distance to nearest redd, cm) and density (number of redds per m^2) of American brook lamprey spawning redds in six streams in southeastern Minnesota, April and May 1995. Samples sizes are labeled as n.

Stream	Spacing	n	Density	n
Pine Creek	47 (24)	2	1.641 (1.450)	2
Rupprecht Creek	56 (19)	6	3.481 (5.004)	4
S. Br. Whitewater R.	63 (33)	12	1.317 (0.549)	2
N. Br. Whitewater R.	107 (49)	6	0.360	1
Trout Valley Creek	63 (23)	3	4.336 (1.759)	3
Beaver Creek-Win.	37 (5)	2	5.455	1

Table 7. Stream sites in southeastern Minnesota surveyed for American brook lamprey during June to September 1995 and June 1996. Asterisks indicate stream sites where American brook lamprey have been observed or captured previously.

Stream	County	Location	Date	Number of lamprey
Pine Creek	Winona	T105N R9W SE25*	6/13/95	2
			6/15/95	3
			9/14/95	1
			9/21/95	2
			9/26/95	5
		T105N R9W SE26*	8/3/95	0
Bear Creek	Winona	T107N R9W NE13*	6/23/95	2
Beaver Creek	Winona	T108N R10W SE16*	6/29/95	2
			6/18/96	5
Coolridge Creek	Winona	T105N R9W NW26	6/15/95	0
S. Br. Whitewater R.	Winona	T107N R10W SE14*	6/26/95	0
			6/14/96	1
		T107N R10W NE14*	6/29/95	0
		T107N R10W NW11*	6/23/95	0
			6/14/96	0
Ferguson Creek	Winona	T105N R8W NW18	8/7/95	3
Hemmingway Creek	Winona	T105N R9W SW26*	8/3/95	0
East Indian Creek	Wabasha	T109N R10W NW28	8/1/95	0
			6/25/96	0
		T109N R10W NE27	8/1/95	0
			6/25/96	0
M. Br. Whitewater R.	Olmsted	T107N R11W SE26	7/28/95	0
			6/27/96	0
		T107N R11W NE35	7/31/95	0
			6/19/96	0
N. Br. Whitewater R.	Winona	T107N R10W NW9*	6/30/95	11
			7/31/95	1
			9/27/95	4
			6/20/96	0
	Olmsted	T107N R11W SE1	8/2/95	0
			6/26/96	0
Rush Creek	Winona	T106N R9W NW35*	8/3/95	0
		T105N R8W NW29*	8/4/95	0
		T105N R8W SW18*	8/7/95	0
Trout Run	Winona	T107N R10W NE29	6/20/95	0
			6/13/96	0
		T107N R10W NE29	7/21/95	0
			6/13/96	0
Trout Run Trib. #9	Winona	T107N R10W NE29	6/20/95	0
			6/13/96	0
Rupprecht Creek	Winona	T107N R9W NE24*	6/27/95	0

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Table 8. Physical characteristics of the stream habitat at specific locations where American brook lamprey ammocoetes were collected by electrofishing from six southeastern Minnesota streams during June to September 1995 and June 1996. Values are means ± standard deviations, with sample sizes in parentheses.

Stream	Water depth (cm)	Current velocity (m/sec)	Sediment organic content (%)
Pine Creek	44 ± 22 (13)	0.12 ± 0.07 (13)	7.18 ± 2.67 (13)
N. Br. Whitewater R.	31 ± 9 (12)	0.02 ± 0.01 (12)	10.97 ± 5.56 (12)
Ferguson Creek	50 ± 14 (3)	0.09 ± 0.05 (3)	6.84 ± 2.31 (3)
Beaver Creek	49 ± 16 (4)	0.04 ± 0.00 (2)	11.72 (1)
Bear Creek	20 (1)	0.00 (1)	6.01 (1)
S. Br. Whitewater R.	35 (1)	-	-

Figure 1. Length-weight relationship of American brook lamprey ammocoetes collected from several southeastern Minnesota streams during 1995.

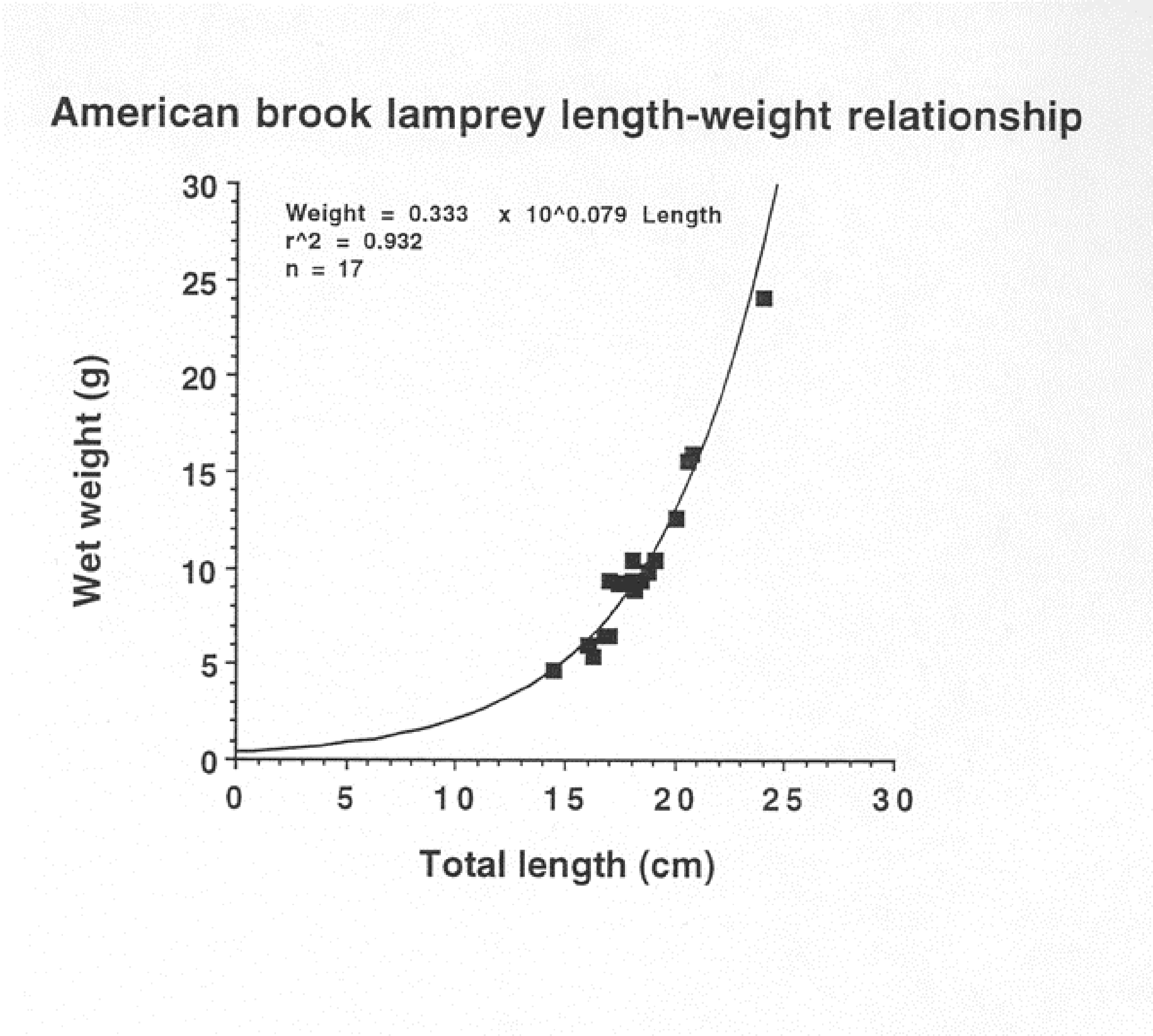
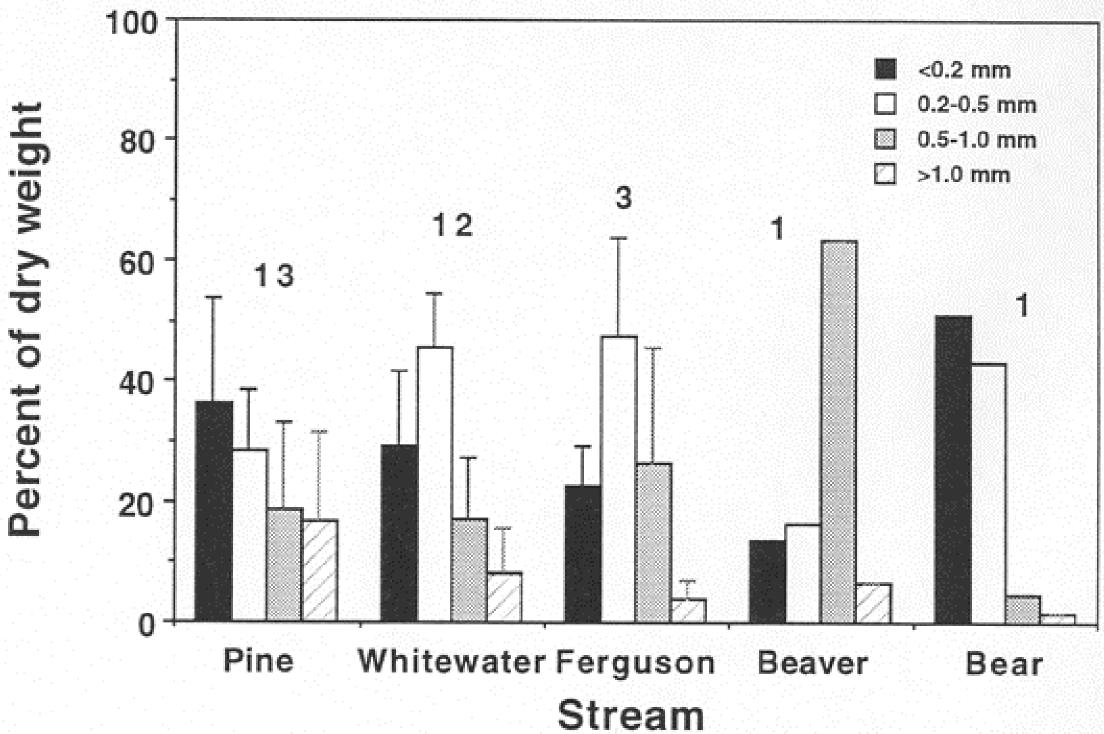

American brook lamprey length-weight relationship
Weight = 0.333 x 10^0.079 Length
r^2 = 0.932
n = 17
Wet weight (g)
30
25
20
15
10
5
0
0
5
10
15
20
25
30
Total length (cm)

Figure 2. Sediment particle size distributions at points in five streams in southeastern Minnesota where American brook lamprey ammocoetes were collected. Values are means, with vertical lines representing SD. Numbers above bars represent sample sizes.


Percent of dry weight
100
80
60
40
20
0
<0.2 mm
0.2-0.5 mm
0.5-1.0 mm
>1.0 mm
1 3
1 2
3
1
1
Pine
Whitewater
Ferguson
Beaver
Bear
Stream