PRELIMINARY STUDIES ON THE BIOLOGY OF NATIVE MICHIGAN LAMPREYS - JAMES D. HALL 1960

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By

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ABSTRACT

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The parasitic chestnut lamprey is uniquely abundant in the Manistee River system of the Lower Peninsula of Michigan. Its abundance and parasitic habits have prompted this investigation, which is designed to (1) identify the factors related to its high population level, (2) appraise the relationship of the chestnut lamprey to the trout population, with consideration of lamprey control, and (3) supply data on the basic life history and ecology of the three native lampreys of the watershed: chestnut, northern brook, and American brook.

The chestnut lamprey is present in all the major river systems in the western Lower Peninsula, but seems most abundant in the forty miles of the upper Manistee between Deward and Sharon. Larval chestnut lampreys were most common in the main stream about in the middle of this area; they were seldom found in the tributaries. Data from electric shocking and quadrat sampling indicate that both population density and size distribution of larval lampreys may be correlated with particle size of the substrate.

Few adult chestnut lampreys could be collected with the shocker, but about 20 percent of the legal-sized trout collected bore lamprey scars. The use of baited traps is planned to develop more accurate information on population density, movement, and rate of feeding of the adults in the stream.

Adult lampreys were allowed to feed on trout in an aquarium. Of 8 trout (6.8 to 9.4 inches long) used in the experiment, 5 were killed as a result of from 1 to 7 separate attacks by 6 lampreys (5.0 to 8.6 inches long). One trout was not fed upon and 2 died from other causes.

No decision is yet possible on the desirability and feasibility of attempting to control the chestnut lamprey in the Manistee River. The extensive ground water contribution to the stream would complicate the operation, and the cost would be high.

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A THESIS

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Dr. Gerald P. Cooper

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INTRODUCTION

The abundance of the parasitic chestnut lamprey in the upper Manistee River of Michigan presents a problem which is both unique and challenging. This lamprey occurs throughout a wide geographical range in the United States and Canada, yet nowhere is reported to attain the population densities observed in Michigan. Within this state, however, there are substantial local differences in its abundance. The chestnut lamprey occurs in all the major drainages in the western half of the Lower Peninsula, but is most abundant in the upper Manistee River, where trout bearing either lampreys or fresh scars are often taken by anglers.

What factors allow the species to attain its unusual population level in the Manistee River? What effect has the lamprey on the resident game fish population? What is the role of native lampreys in the economy of a stream? What will be the effect of the removal of the native species by the extensive sea lamprey control program of the U. S. Fish and Wildlife Service? Is lamprey control in the Manistee desirable and feasible? These and other questions have prompted the current investigation.

With the exception of the excellent taxonomic revision of the genus by Hubbs and Trautman (1937) and the investigations of Crowe (1939, Institute for Fisheries Research MS. Report No. 548; 1959, I. F. R. MS. Report No. 1558), very little has been recorded on the chestnut lamprey. My study, begun in 1959, is designed to identify the factors related to the high chestnut lamprey population level; appraise the relationship of the lamprey to the trout population in the Manistee, with consideration of lamprey control; and supply data on the basic life history and ecology of the three native lampreys of the watershed--chestnut, northern brook, and American brook. The investigation is organized into three major divisions: (1) distribution and abundance, (2) food and feeding, and (3) growth and survival. The first two of these divisions are reported on in the present progress report, which summarizes information obtained in the summer of 1959 and presents an outline of further work.

Taxonomy of the Lampreys

Hubbs and Trautman (1937) treated six species of *Ichthyomyzon*, three parasitic and three non-parasitic. Subsequently an additional species was described by Raney (1952). The adults of these seven species can be distinctly separated by external characters. Identification of their larvae is presently uncertain, however.

The pattern of external and internal pigmentation is used to distinguish the larvae of eastern American lampreys with two dorsal fins, *Lampetra* and *Petromyzon* (Vladykov, 1950 and 1960). Likewise, about one-half of the large larvae (longer than 70 mm) of *I. castaneus* and *I. fossor* from the Manistee River appear to be separable on the basis of pigmentation of the lateral line organs and tail (Crowe, 1959 MS., supported by my later work).

In January 1960 I sent a series of 116 *Ichthyomyzon* larvae from the Manistee River to Dr. Vadim D. Vladykov. He found some typical forms of both *I. castaneus* and *I. fossor*, but noted (personal communication) that "there are apparently present some 'intermediate' specimens." He felt that they could be satisfactorily separated after internal examination of pigmentation of the peritoneum and precursor of the tongue. The results of that examination have not yet been received (July 1960).

Life History and Ecology

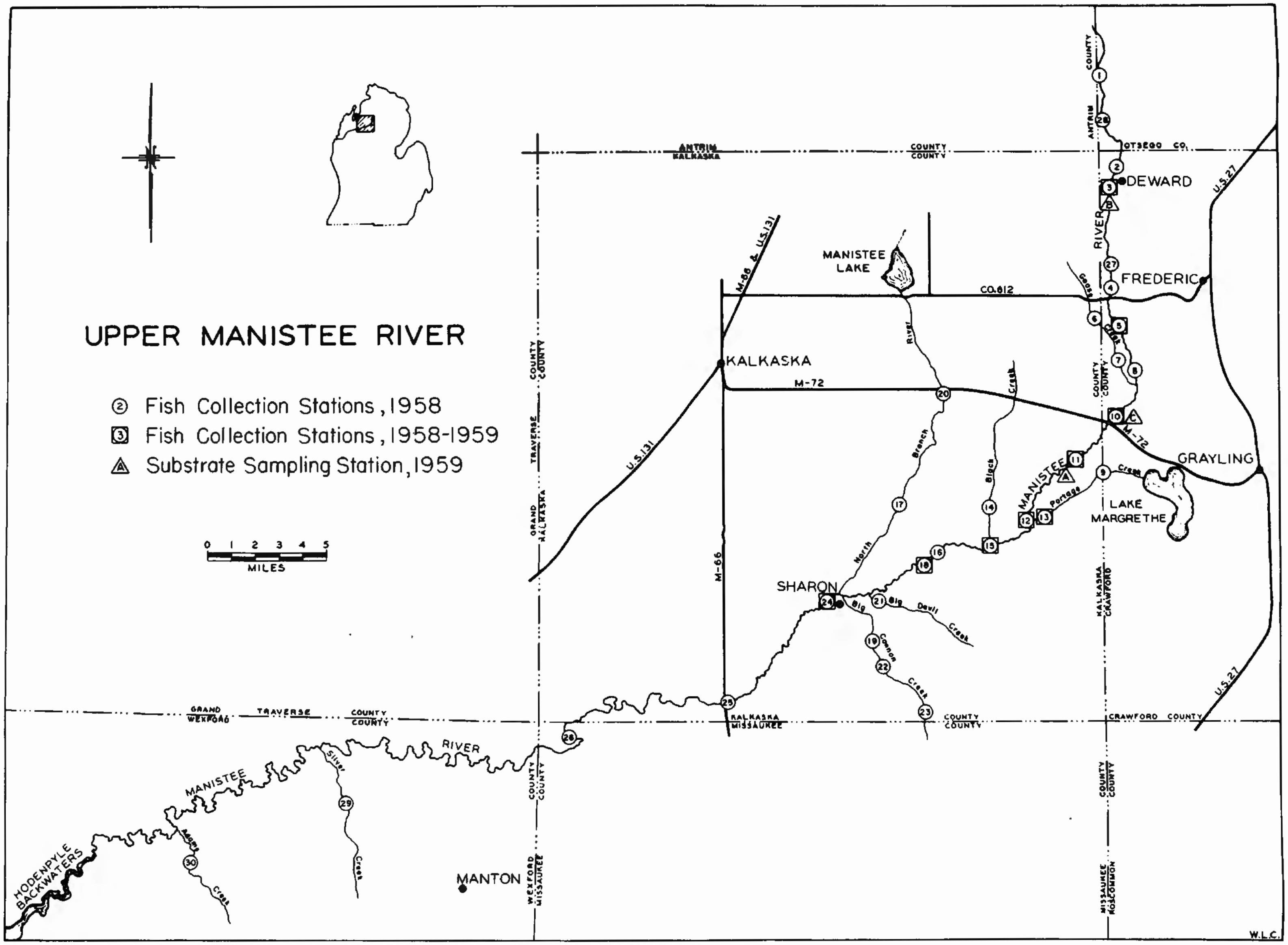
The life history and ecology of the chestnut lamprey have received brief mention in taxonomic and distributional studies by Gudger (1930), Hubbs and Trautman (1937), Knapp (1951), Hall and Moore (1954), and Bailey (1959). The life history of the northern brook lamprey has been more extensively investigated (Reighard and Cummins, 1916; Okkelberg, 1922; Leach, 1940; Churchill, 1947; and Vladykov, 1949). Brief studies on other native species have concerned *Ichthyomyzon greeleyi* (Raney, 1939), *I. gagei* (Dendy and Scott, 1953), *Lampetra planeri* (Schultz, 1930), and *L. aepyptera* (Seversmith, 1953).

Lamprey life history investigations in North America date to the pioneering studies of Gage (1893, 1928) on *Petromyzon marinus* and *Lampetra lamottei*. Work on lamprey biology has received considerable emphasis in recent years due to invasion of the Great Lakes region by the sea lamprey and the consequent decline in the lake trout population there (e.g., Applegate, 1950; Wigley, 1959).

Description of the Study Area

The Manistee River is the northernmost of five large rivers which drain the western half of the Lower Peninsula of Michigan. Its drainage basin, slightly over 100 miles long, covers an area of some 1,780 square miles. The river originates in several small lakes in a glacial outwash plain near the Otsego-Antrim county lines, about twenty miles northwest of Grayling (Fig. 1). It flows southwesterly through this plain and empties into Lake Michigan near the city of Manistee. (U. S. House of Representatives, 1931.)

Figure 1.--Map of the upper Manistee River system, showing location of sampling stations. (Modified from Crowe, 1959 MS.)


UPPER MANISTEE RIVER
Fish Collection Stations, 1958
Fish Collection Stations, 1958-1959
Substrate Sampling Station, 1959
0 1 2 3 4 5
MILES
MANISTEE LAKE
KALKASKA
M-72
CO. 612
DEWARD
FREDERIC
GRAYLING
LAKE MARGRETHE
SHARON
MANTON
U.S. 131
M-88 & U.S. 131
M-66
U.S. 27
ANTRIM COUNTY
KALKASKA COUNTY
OTSEGO CO.
GRAND TRAVERSE COUNTY
WEXFORD COUNTY
MISSAUKEE COUNTY
CRAWFORD COUNTY
ROSCOMMON
MANISTEE RIVER
North Branch
Black Creek
Portage Creek
Big Devil Creek
Cannon Creek
Silver Creek
HODENPYLE BACKWATERS
W.L.C.

The Manistee River has the most stable flow of any major stream in Michigan and is among the most stable in the United States (Pettingill, Brater; personal communications). The U. S. Geological Survey operates a stream gauging station on the river near the bridge at highway M-72 (approximately midway in the length of my sampling area). According to records which date from 1942 to 1957, the maximum flow at this station has been 354 cfs (cubic feet per second); the minimum, 122 cfs; and the mean, 184 cfs (U. S. Geological Survey, 1959). Approximate base-flow measurements, taken on August 25, 1954, were: upper end of sampling area, near Deward, 66 cfs; bridge at M-72, 173 cfs; lower end of the sampling area, just downstream from the mouth of the North Branch of the Manistee, 343 cfs (U. S. Geological Survey, 1957).

The Manistee watershed was once forested with a stand of high grade white and red pine. Most of these trees were harvested between 1870 and 1905, and the logs were floated downriver. The skidding of logs over the steep sand banks apparently resulted in accelerated erosion of sand into the river. Along with bank erosion, extensive fires denuded the land. Although it is difficult to reconstruct the fire history in detail, it appears that large fires burned nearly every year in at least some areas of the drainage basin until about 1920. The fires caused increased erosion into the river and allowed establishment of the present stands of jack pine and aspen. (U. S. House of Representatives, 1931; U. S. Forest Service, 1951.)

Much available evidence indicates that the grayling was the sole species of game fish in the river prior to 1850 (Smedley, 1938; Hubbs and Lagler, 1958). If so, here the brook, brown, and rainbow trouts have "invaded" the habitat of the native lamprey, an interesting contrast to the sea lamprey invasion of the Great Lakes. It is possible that the relationship between the chestnut lamprey and the trout in the Manistee River has not yet reached the dynamic equilibrium which might be expected eventually (Odum, 1959).

DISTRIBUTION AND ABUNDANCE

Earlier studies indicate that the relative abundance of the chestnut lamprey varies considerably from year to year and place to place in the upper Manistee River (Crowe, 1959 MS.). One objective of the present study is to determine why this is so. Both field and laboratory observations are planned, but so far only field data have been gathered. Emphasis to date has been on distribution of larvae.

Larval Stage

General distribution

Crowe (op. cit.) made fish collections with a 220-volt D. C. electric shocker at thirty stations in the Manistee River system from September 19-26, 1958. Sampling was repeated at nine of these stations from August 5-12, 1959 by the writer and a crew headed by E. E. Schults. The repeat stations were selected to include the area where the chestnut lamprey was commonly found in the earlier sampling.

The ratio of Ichthyomyzon to Lampetra in the collections at each station was generally the same for the two years, although consistently more lampreys were taken in 1959 (Table 1). More were collected in 1959 probably because emphasis was placed on intensive collection of larval lampreys in that year.

Previous work (Cooper, Shetter, and Hayne, 1959, I. F. R. MS. Rept. No. 1577) has shown that the catch per hour of fish taken by a shocker is not a good index of population density. Shocker

Table 1.--Number of lamprey ammocoetes (older than young of the year) collected per hour[1] with an electric shocker from the Manistee River system, September 19-26, 1958 and August 5-12, 1959. (1958 data from Crowe, 1959 MS.)

Station	Total larvae		Lampetra lamottei		Ichthyomyzon (both species) Number		Ichthyomyzon (both species) Percentage of total larvae		I. castaneus[2]	I. fossor[2]
	1958	1959	1958	1959	1958	1959	1958	1959	1958	1958
3	48	121	48	121	0	0	...	...	0	0
5	133	225	128	217	5	8	3.8	3.6	5	0
10	146	418	128	325	18	93	12.3	22.2	11	7
11	265	317	165	198	100	119	37.7	37.5	65	35
12	96	420	58	305	38	115	39.6	27.4	17	21
13[3]	28	68	24	62	4	6	14.3	8.8	2	2
15	126	253	90	173	36	80	28.6	31.6	17	19
18	288	178	216	119	72	59	25.0	33.1	25	11
24	132	117	120	104	12	13	9.1	11.1	3	5
Totals	1,262	2,117	977	1,624	285	493	22.6	23.3	145	100

[1] All stations except three in 1958 were shocked for 60 minutes. These were: No. 13 (30 minutes), No. 18 (30 minutes), and No. 24 (40 minutes).

[2] Tentative identifications of Ichthyomyzon (by Crowe) are given for 1958 to show the approximate number of each species.

[3] Portage Creek.

efficiency is affected by water conditions and experience of personnel. I believe the problem is accentuated in shocking for lampreys. Larvae continue to emerge from the substrate throughout several minutes of shocking over a very small area. Thus the percentage of larvae recovered will vary according to the rate of travel of the individual with the electrode. Also, lamprey larvae are less paralyzed by the electricity and are more difficult to retrieve, being smaller than most other stream fishes.

The data from the two years are hardly comparable because of the different emphasis on species being collected. Even within the single year of my study (1959) different collectors were involved at various stations, introducing some variability. Until it is possible to isolate small areas and shock them completely, the present data are the best available for analysis of general distribution.

The statistic which I believe potentially least in bias is the ratio of Ichthyomyzon to Lampetra. As stated above, although abundance of lampreys (all species combined) in the river may have changed between 1958 and 1959, this ratio remained fairly constant at each station.

There is clearly a concentration of Ichthyomyzon, both in percentage and total numbers, in the area of Stations 11 and 12, where the gradient is low. A possible explanation for this concentration could be that the most suitable spawning areas lie just above. Downstream movement of larvae (Stauffer and Hansen, 1958, I. F. R. Ms. Rept. No. 1535) would carry them into this area. Assuming downstream migration and the location of major spawning areas upstream from

Stations 11 and 12, the average length of larvae should increase progressively downstream. The average length of larvae collected at Station 10 was less than at any other station. These assumptions could be misleading, however, if there is a relationship between larval length and substrate preference. The abundance of small larvae at Station 10 could be due to a prevalence of preferred habitat. Spawning of I. castaneus has not been observed in the Manistee River.

In Crowe's survey of 1958, extensive collecting effort was made on the tributaries of the main river, but very few larval Ichthyomyzon were taken. At 11 stations on 6 tributaries, the flow of which varies from 1.9 to 30 cfs, 145 larvae were collected. Only 18 of these were Ichthyomyzon (15 from one station). Two were tentatively identified as I. castaneus. There are very few Ichthyomyzon larvae in Portage Creek (Fig. 1), which appears to be suitable lamprey habitat in all physical respects. There have been local reports of Ichthyomyzon spawning in Goose Creek (Fig. 1), but these are unsubstantiated.

Possible reasons why Ichthyomyzon is rare in small streams are: (1) water temperature at spawning time may be unfavorable, (2) spawners may prefer large streams, or (3) hatchlings may migrate from the tributaries very rapidly. Evidence that a rather narrow range of temperature is required for survival to hatching of sea lamprey eggs (Piavis, in press) may support the first explanation.

The microhabitat of larval lampreys

Field collections made by electric shocking on the Manistee River during 1959 gave data for tentative conclusions on the microdistribution of larval lampreys. Occurrence of larvae was not random and seemed to be importantly affected by the nature of the substrate (as shown for aquatic insects by Lauff and Cummins, unpublished data). In general, areas of moderate current (about one to two feet per second) with a stable bottom held largest numbers of ammocoetes. Specifically, slight hummock areas of reasonably firm sand and silt, supporting a light growth of Chara and lying on the inside of a bend in the river, seemed most suitable. Areas with much black muck and silt produced good numbers of larvae only when this soil type was consolidated and supported a rather dense stand of Chara or other vegetation. Apparently there is a difference between the habitat preference of larvae of the sea lamprey and native lampreys. Applegate (1950) noted that the sea lamprey prefers unconsolidated black muck material in backwaters. Lampreys were seldom found in the Manistee in areas of slack water, either in the extensive quiet side channels or in eddies.

Size of larvae also appeared to be correlated with type of substrate. Most small larvae were collected from firm sand, and many of the large ones from muck or silt in weed beds. Small larvae seemed more restricted in this regard than large ones. This apparent difference in substrate preference by larvae of different sizes may be related to the inability to construct and maintain a burrow. Possibly only the larger larvae can produce enough mucus to maintain a burrow in the soft sediments (Newth, 1930).

A quadrat sampling program was employed for quantitative precision in analysing patterns of local distribution and microhabitat. In the summer of 1959 several methods of sampling were tried in an effort to develop a suitable one.

Methods.--On the basis of Crowe's 1958 survey data, a section of the river from Deward to Sharon was chosen as the sampling area. A map was traced from aerial photographs (scale: 8 inches = 1 mile). Miles were marked off with a map measurer beginning at the confluence of the North Branch of the Manistee River just below Sharon and proceeding upstream to a point just above Deward, a distance of 44 miles by river. Eleven stations, each 110 yards long, were selected in the following manner. Each 4-mile section was divided into 64 sixteenth-mile areas and random numbers were chosen (Dixon and Massey, 1951) to select one sampling area within each section. The order in time of sampling these eleven areas during the summer was also chosen randomly (although sampling was completed at only three areas). With the aid of the large-scale photographs and because of the generally accessible nature of the stream, I could easily locate these sampling areas from the ground.

Three methods were used to select sampling sites within the areas. At the first area (A) sampling sites were placed in a simple random arrangement. The stream bed of the area was mapped roughly with a chain and hand compass, horizontal and vertical coordinates were assigned on the map, and numbers chosen from a table of random numbers were used to determine the coordinates of each sampling site.

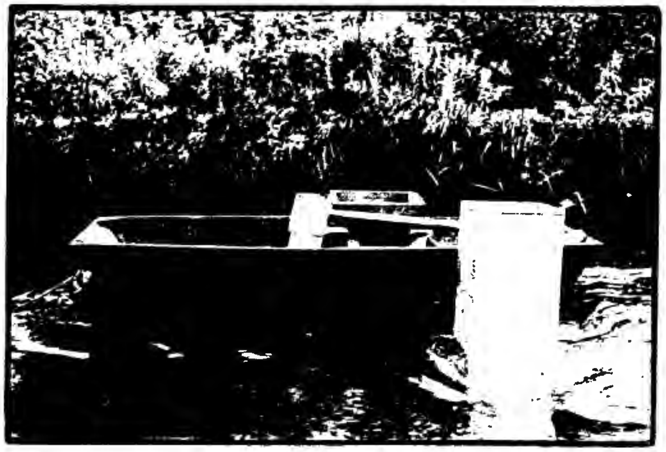
The next method, attempted at area B, was location by random transect. Random numbers were used to locate end points of the transect line on either bank of the stream and to position sampling sites along the line from the west bank. Sampling sites closer together than four feet were rejected due to disturbance of the adjacent sampling area.

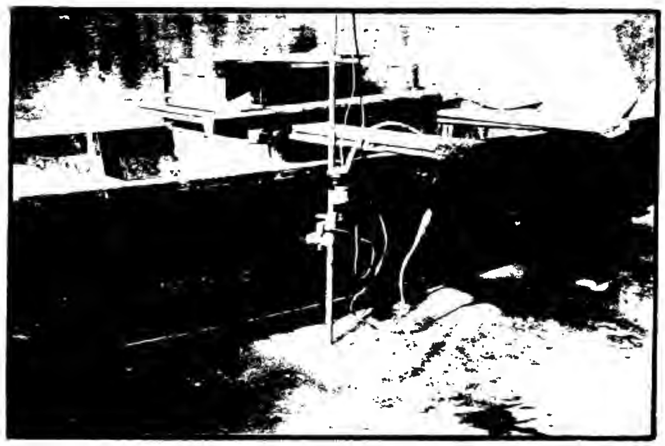
A third method was tested at an additional area selected arbitrarily and designated C. Here, sampling sites were subjectively selected for apparent ease and effectiveness of sampling.

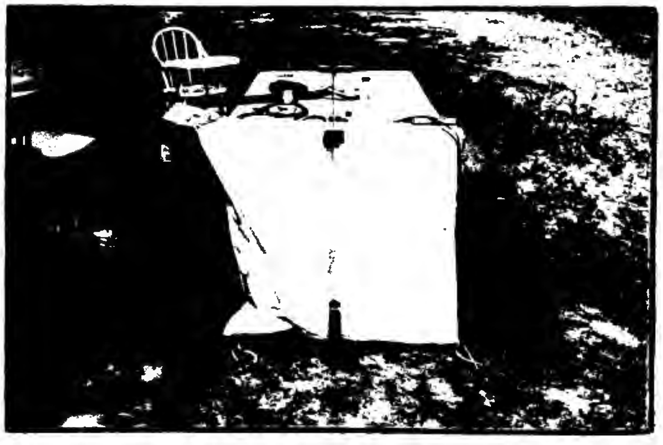
The sampling device used throughout was an open-ended square-foot box of galvanized steel, 3 feet high (Fig. 2) and similar to that described by Needham (1928). The box was driven into the substrate to a sufficient depth (usually not less than 12 inches) to produce a tight seal which would hold when the water within the sampler was removed. A sample of the substrate 6 inches deep and 1 1/2 inches in diameter was taken from the center of the quadrat with a piston core sampler (Fig. 2). The sample was preserved in 10 percent formalin for later analysis. The substrate was then scooped out of the sampler to a depth of 6 inches with a small scap net. The material was transferred to a 16-mesh screen and washed. All organisms were preserved in 10 percent formalin. Prior to sampling, current velocity was measured with a Pygmy current meter loaned by the U. S. Geological Survey (Fig. 2). This meter is calibrated from 0.079 to 4.86 feet per second and is small enough to provide sensitive measurement of current velocity within one inch of the stream bottom.

The following additional measurements were taken: water depth and direction of flow, distance to nearest shore, bottom contour and type, estimated percentage of shade, and abundance of aquatic vegetation and organic debris.

Figure 2.--Devices used in quadrat sampling: Upper--The square-foot sampler in place; Middle--The Pygmy current meter; Lower--The substrate core sampler.







Results.--The performance of the sampling device (and perhaps the method of locating sampling sites) left much to be desired (Table 2). The presence of stones and debris beneath the substrate surface made it difficult to get a water-tight seal around the bottom of the sampler in water deeper than 2.0 feet, or in fast current. As a result, material from outside the sampling area was frequently drawn into the sampler. In shallow areas of sand and silt, however, the sampler performed very well.

Since much of the stream is fast and deep, often several sampling sites had to be located before one sample could be taken. The area was considerably trampled in the process. In the simple random sampling at area A, approximately 45 man-hours were required to plan and execute 13 samples which yielded only 3 ammocoetes.

The random transect method used at area B proved somewhat more satisfactory than that used at area A. Little time was involved in laying out the area and locating the samples, yet the bias inherent in subjectively selecting sampling areas was avoided. Compared with the procedure at area A, however, the difficulty with the sampler was as great here. The water at B was deeper and faster, and only seven of nineteen measured samples could be successfully completed.

In the limited test given it, the non-random selection method of sample location did not show any advantage over the random transect method in the yield of lamprey larvae. The percentage of samples which could be carried to successful completion was significantly greater here than in the other two areas, but hidden sticks and stones still prevented effective sampling.

Table 2.--Number of lamprey ammocoetes collected in square-foot quadrats from the Manistee River, July 25 to September 2, 1959

Sample number	Number of ammocoetes[1]	Bottom type	Current velocity Surface	Current velocity Bottom	Remarks
Site A					
1	0	Sand-gravel	1.29	1.20	Tight seal
2	0	Sand	0.84	0.68	"
3	0	Sand	0.98	0.62	"
4	0	Sand-silt	0.13	0.10	"
5	0	Sand	1.46	0.94	"
6	0	Sand	1.52	0.87	"
7	2	Sand	1.10	0.55	Leak
8	0	Sand	1.63	1.23	Leak
9	0	Sand	1.22	0.84	Leak
10	0	Sand-silt-debris	0.85	0.52	Leak
11	0	Sand	1.67	0.68	Tight seal
12	1	Sand	1.12	0.22	Leak
13	0	Silt	0.08	0.16	Tight seal
Site B					
1	0	Sand-gravel	1.79	1.03	Leak
2	0	Sand-silt	0.98	0.46	Leak
3	2	Sand-silt	1.58	0.95	Leak
4	0	Sand-gravel	0.98	0.70	Tight seal
5	0	Sand-gravel	1.27	0.62	"
6	0	Sand-gravel	1.03	0.36	"
7	0	Sand-gravel	1.10	0.83	"
Site C					
1	0	Sand-silt	1.56	0.94	Tight seal
2	0	Sand-silt	2.43	0.98	Leak
3	0	Sand-silt	0.33	0.50	Tight seal
4	0	Sand-silt	0.74	0.47	"
5	0	Sand-silt	1.00	0.45	"
6	2	Sand-silt	0.65	0.46	"

[1] All ammocoetes collected were *Lampetra lamottei*, except for one *Ichthyomyzon* spp. at C-6.

<u>Experimental analysis of factors affecting habitat selection</u>

Field data suggest that several environmental factors may be important in determining distribution of larval lampreys in the stream substrate. Experimental analysis of some of these factors is proposed, including current velocity, substrate particle size, and substrate compaction.

Adult Lampreys

<u>General distribution in the river system</u>

The general distribution of adult chestnut lampreys in the river system corresponds roughly with that of <u>Ichthyomyzon</u> larvae (Table 3). In the extensive collecting of 1958, adults were found only in the main stream from Deward to Sharon (however, fish were difficult to collect below Sharon). Adults were not collected from any of the six tributaries sampled, although four scarred trout were found in Portage Creek. Wicklund (personal communication) reported fish carrying lampreys in several areas in Goose Creek, another tributary.

The presence of adults at Station 3, apparently above the upper limit of larval distribution, contradicts the report (Trautman, 1957) that parasitic adults move downstream to feed after metamorphosis. Other evidence suggesting at least some upstream feeding movement are the records (I. F. R. files) of adult chestnut lampreys in Manistee Lake and Lake Margarethe (Fig. 1), coupled with the apparent absence of their larvae in the tributaries of these lakes. These tributaries have not been sampled extensively enough to permit a final conclusion, however.

Table 3.--Electric shocker collections of adult lampreys from the Manistee River system, September 19-26, 1958 and August 5-12, 1959

Station			*Lampetra lamottei*		*Ichthyomyzon fossor*		*Ichthyomyzon castaneus*	
	1958	1959	1958	1959	1958	1959	1958	1959
3	3	2	1	1	0	0	2	1
5	0	4	0	0	0	0	0	4
10	8	0	2	0	0	0	6	0
11	3	2	1	0	1	0	1	2
12	6	0	0	0	1	0	5	0
13	2	0	2	0	0	0	0	0
15	3	1	1	0	0	0	2	1
18	16	0	5	0	2	0	9	0
24	3	0	3	0	0	0	0	0
Totals	44	9	15	1	4	0	25	8

Downstream movement may also occur. For example, adults might move down as far as the first impoundment, about 80 miles downstream, feed there, and return upstream to spawn. If possible, some newly transformed individuals will be marked to trace their movements.

Abundance

Some estimate of the population level of adult chestnut lampreys in the stream would be extremely useful in assessing the impact of the lamprey on the trout population. For several reasons electric shocking does not provide data suitable for this purpose, but a specially-designed lamprey trap baited with fish, might be useful. Marking the adults individually (Wigley, 1952) and releasing them for recapture in traps might provide data on population levels, movement, territoriality, and feeding habits. An attempt might also be made to remove as many as possible of the adults from a section of the stream.

FOOD AND FEEDING

"Who eats whom" has been characterized by Bates (1960) as the central question pertinent to the description of ecological communities. Another objective of the present study is determination of the food habits and method of feeding of larval and adult lampreys.

Larval Stage

Since no specific investigations of the food habits of *Ichthyomyzon* larvae have yet been reported, most of the general information presented here is from the literature on *Petromyzon* (Gage, Applegate) or *Lampetra* (Creaser and Hann, Newth).

General description of food

Desmids, diatoms, and protozoans have been identified as the principal gut contents of larval lampreys. From examination of only fifteen specimens it was concluded that such foods were obtained from the flowing water and materials being moved along the surface of the bottom, but not from materials in the substrate. Sand grains were found in all specimens. (Creaser and Hann, 1929.)

Method of feeding

Larval lampreys feed with their anterior end near an opening in a burrow constructed in the substrate; in this position water is pumped in through the oral hood and out of the gill openings in a combined feeding and breathing process (Gage, 1928; Applegate, 1950). Large detritus is kept out of the pharynx by a sieve apparatus (oral cirri) which is periodically cleaned by a reverse current of water.

A mucus thread, secreted by the endostyle, is formed into a cone at the anterior end of the pharynx by the action of two ciliated grooves. Food particles passing the oral cirri are trapped in this cone of mucus, which is carried posteriorly to the gullet as a single strand by a water current produced by the joint muscular pumping of the pharynx and extension and retraction of the two velar folds. (Newth, 1930.)

Adult Lampreys

Food of the chestnut lamprey

The adult chestnut lamprey is known to feed on the following species of fish: the largemouth bass and the channel catfish (Gudger, 1930); trout, the carp, the white sucker, and the northern pike (Hubbs and Trautman, 1937); the chain pickerel (Knapp, 1951); and the golden, river, and northern redhorses, the smallmouth buffalo, the green sunfish, and the smallmouth bass (Hall and Moore, 1954). In the Manistee I found lamprey scars on brook, brown, and rainbow trouts, the white sucker, and the burbot. The creek chub is also attacked there (Crowe, personal communication). Although the samples are small, a substantial percentage of the legal-sized trout (over 7 inches) captured at the nine stations in the Manistee River were scarred by lampreys: 6 of 31 (19.4 percent) in 1958, and 8 of 43 (18.6 percent) in 1959. The rate of scarring of other fish was somewhat lower (Table 4).

There is evidence for a size selectivity by the lampreys, as the smallest scarred fish taken in 1959 was a 6.2-inch brook trout.

Table 4.--Fish of all species (over 3 inches long) collected with an electric shocker from the Manistee River system, 1959, showing numbers scarred at each station

Station	Number collected	Number scarred	Percentage scarred
3	40	2	5.0
5	60	6	10.0
10	0	..	....
11	10	4	40.0
12	2	0	....
13	13	5	38.5
15	8	1	12.5
18	4	0	....
24	13	0	....
Total	150	18	12.0

This apparent selectivity, however, could be the result of rapid mortality of small fish attacked by lampreys. This same source of error could obscure any real species preference shown by the lampreys, as the preferred fish might be quite susceptible and not turn up in shocker collections. For still another reason data from shocking are inadequate to assess the rate of feeding in the stream. Many of the legal-sized trout in the stream are hatchery fish, and there is no means of distinguishing separate plantings of them. A high percentage of scars could indicate a large lamprey population, a small fish population, or planted fish which had been in the stream for a long time.

The use of caged trout in the stream, planned for 1960, should avoid much of the difficulty inherent in shocking. Because of the many uncertainties in the data collected by shocking, aquarium tests were set up to gather more accurate information.

Aquarium feeding experiments

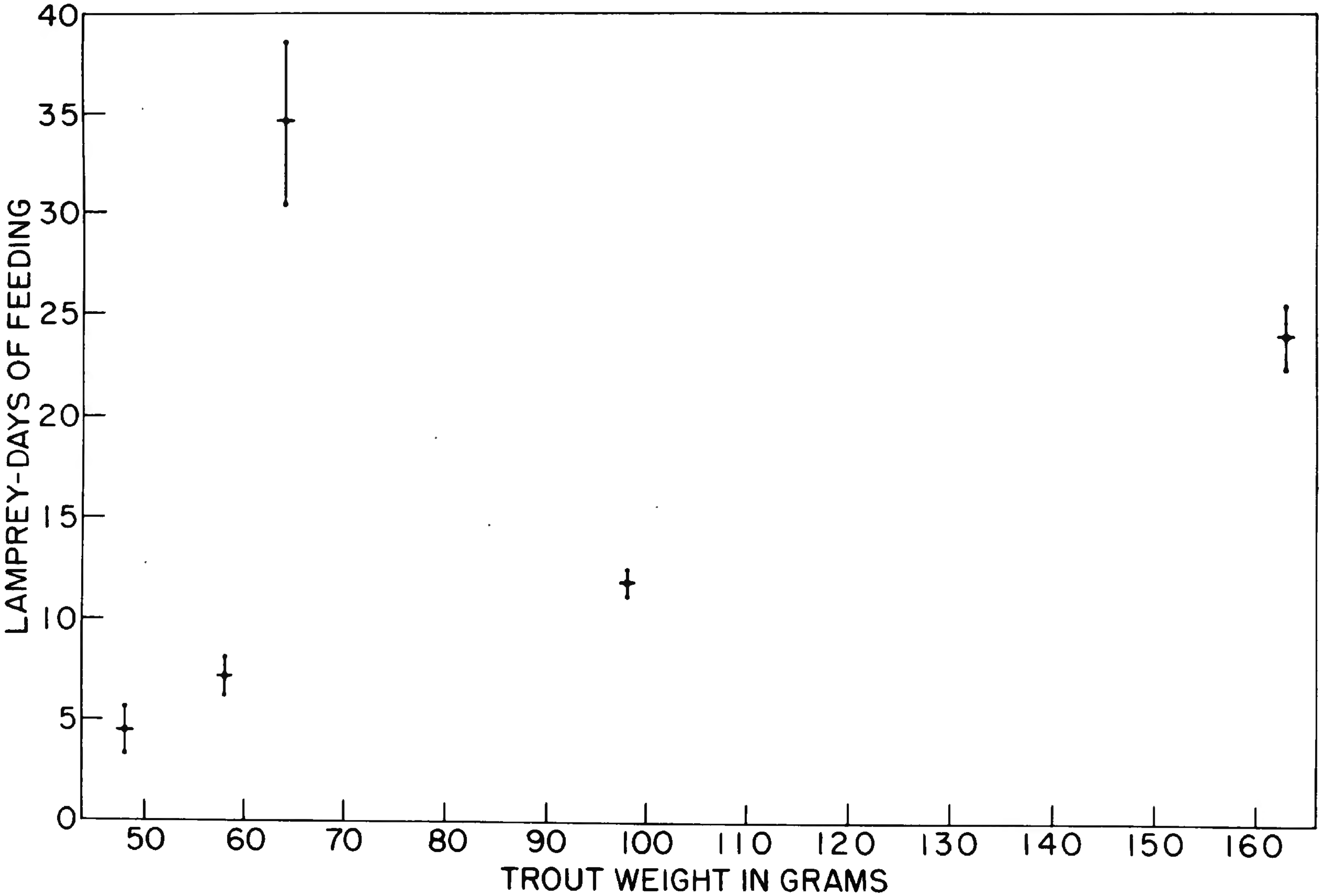
Whether the chestnut lamprey actually kills fish, or is only an esthetic problem, is one of the significant questions raised in this investigation. A pilot study, along the lines of aquarium work by Lennon (1954) and Parker and Lennon (1956) on the sea lamprey, was designed to see if feeding of the chestnut lamprey also could be studied in the laboratory.

Methods.--Six adult chestnut lampreys, from 5.0 to 8.6 inches long (all measurements are reported as total length), were placed in a 50-gallon aquarium at the Grayling State Fish Hatchery. I made observations on these lampreys from July 21 to September 11, 1959. These observations were continued intermittently to December 22, 1959 by Dr. L. N. Allison. Rainbow and brook trout from the hatchery stock were used as host fish. They ranged from 6.8 to 9.4 inches long. Observations were made at irregular intervals, therefore maximum and minimum time intervals that each lamprey could have been attached to the host were calculated, and the length of attack expressed as the mean of these two figures. The total time of attack on a fish is expressed in lamprey-days of feeding, wherein two lamprey-days is considered as one lamprey feeding for two days, or two lampreys feeding on the same fish for one day. Although both the fish and lampreys used in my study were of differing size, neither was distinctively marked, so individual observations were not always possible.

Results.--Multiple attacks were common, and the lampreys killed small trout in a rather short time (5 days in one instance). Of 8 trout used in the experiment between July 21 and September 11, 1959, 5 were killed as a result of attack by lampreys, 1 was not attacked, and 2 died after jumping from the aquarium. Although my data are not directly comparable to observations of Parker and Lennon (op. cit.) due to size differences of lampreys and host fish, it appears that the chestnut lamprey is relatively less lethal than the sea lamprey. In general, large fish were able to survive lamprey attack for a longer period than small ones (Fig. 3), although there was a considerable difference in the length of attack necessary to kill two fish of approximately the same weight. Three possible sources of this variability are: (1) individual differences in the hardiness of fish or in the feeding rate of lampreys, (2) increased severity of a multiple attack in contrast to several single attacks spread over a long period (although an opposite conclusion was reached by Parker and Lennon), and (3) non-feeding attachment, not differentiated by me but found by Parker and Lennon (op. cit.) to occur for about 20 percent of the total attachment time.

The maximum period an individual lamprey was continuously attached to a trout was 18.3 days (1 hour is recorded as 0.04 day)--

Figure 3.--Relationship between weight of trout used in aquarium feeding experiments and the lamprey-feeding time necessary to kill these fish.



LAMPREY-DAYS OF FEEDING
0
5
10
15
20
25
30
35
40
50
60
70
80
90
100
110
120
130
140
150
160
TROUT WEIGHT IN GRAMS

an attack which resulted in the death of the fish. The shortest period of an attack was 14 hours. The outcome of the 21 separate attacks recorded from July 21 to September 11 was as follows: 11 were terminated by the death of the host fish (mean length 6.2 days, range 1.6 to 18.3 days), 7 were terminated prior to death of the host (mean length 6.7 days, range 14 hours to 18.2 days), and 3 were prematurely interrupted due to disturbance by the observers.

I saw only two initial attachments; both occurred on the same day. Five trout had been introduced into the aquarium an hour earlier. The lampreys were swimming around slowly. On one pass a 6-inch lamprey moved within 2 inches of a 6.8-inch trout and then made a very sudden lunge and attached itself to the fish. Thereupon the trout began to swim very rapidly and erratically. Within 15 seconds the lamprey dropped off.

Soon afterward a 6-inch lamprey successfully attached to an 8.5-inch trout which had one lamprey already attached. The mode of attachment was similar, but the trout made no serious attempt to dislodge the lamprey. After a few short rapid movements the fish settled down to normal activity.

There were several sources of error in this experiment. Trout in hatcheries, living under crowded conditions, are susceptible to disease. However, all three of the dead brook trout were autopsied by Dr. Allison, Institute Fish Pathologist, who found no sign of disease which might have been the cause of death. Rainbow trout, which are resistant to furunculosis and fin rot (Allison, personal communication), were used later to minimize the possibility of disease. Lampreys may feed more at one time of day or night than another; this would introduce a bias in the use of the mean time of attachment and release. Parker and Lennon (op. cit.) found sea lampreys to be most active during daylight hours. They recorded 1.6 times the number of attachments or detachments per hour from 8:00 A.M. to 4:30 P.M. compared with the period from 4:30 P.M. to 8:30 A.M. The death rate of the trout might have been higher had they been under the stress of a stream environment, although it is probable that wild fish, having more stamina, would survive better than hatchery fish under the same conditions (Vincent, 1960). Trout might be able to remove lampreys by scraping them across obstructions in a stream, but from observations of fish scraping lampreys across screened aquarium tops, Lennon (1954) concluded that removal of lampreys was very unlikely.

The mortality rate on lampreys was high in this experiment. Of the six placed in the aquarium between July 21 and August 6, four were killed when the fish to which they were attached jumped out of the aquarium. The two remaining lampreys died on November 23 and December 22, 1959. Parker and Lennon (1956) also reported rapid mortality of lampreys. Only 22 of 100 adults survived from the beginning of their experiments in November, 1950 until termination in June, 1952. Causes of unusual mortality in their work were fungi, parasitic protozoans, and turbidity.

Additional work.--The realization that attacks by the chestnut lamprey can be lethal to trout makes further work of particular interest and importance. The following information will be sought:

(1) number of lamprey-days of feeding necessary to kill trout and other fishes of various sizes, (2) duration of feeding and non-feeding attachment between transformation and sexual maturity, (3) location on fish of attacks, and (4) selection by lampreys of host species or host size.

GENERAL DISCUSSION AND CONCLUSIONS

The inability to distinguish larvae of the two species of *Ichthyomyzon* in the Manistee River is a major impediment to further work with ammocoetes. Dr. Vladykov is apparently nearing completion of his key to the larvae of the genus, and I will continue the work begun by Crowe (1959 MS.).

The reasons for unusually high abundance of the chestnut lamprey in the Manistee River are not yet clear, although several possibilities exist. Trout, especially the brown, will eat lampreys (Metzelaar, 1930), and one study of burbot food habits showed larval lampreys to compose the bulk of their diet (Whalls and Shetter, 1956, I. F. R. MS. Rept. No. 1476). If predation by other fishes is a significant mortality factor for the larvae, then the stability of the stream's water level could contribute to high lamprey population levels. Downstream movement of ammocoetes greatly increases during flooding conditions (Applegate and Brynildson, 1952; Stauffer and Hansen, 1958 MS.), and at this time the larvae would presumably be more vulnerable to predation. Flooding in the upper Manistee is negligible. There seems to be an inverse correlation between the population density of trout and that of lampreys. Which is cause and which effect, if indeed there is such a relationship, is not yet clear, but this deserves further consideration. There is also more habitat suitable for larval lampreys in the area studied than in many other streams of comparable size, although the two species of brook lampreys are less abundant in the Manistee than in some other Michigan streams.

From the large percentage of scarred fish collected in the river and the limited data on mortality caused in the aquarium by feeding of the adults, there is an indication that the impact of the lamprey on the trout population in the Manistee River may be more substantial than suspected. Among the main points of emphasis in further study should be determination of the population level of adult lampreys in the stream, and collection of more extensive data on the fish destroyed by an individual lamprey from metamorphosis to sexual maturity.

Knowledge of the growth rate, length of larval life, and mortality rate of ammocoetes would be extremely valuable. If known-age material were available, age assessment by weight of the eye lens might be attempted (Lord, 1959). Other methods for determining age will be explored.

At present very little can be added to the recommendations on control put forward by Crowe (1959 Ms.). Further shocking has strengthened his conclusion that ammocoetes are concentrated in areas of some current (where they would be reached by a toxicant) and are very scarce in the slack water areas. However, the extensive ground water contribution to the stream could soon dilute the toxicant to a sub-lethal level. The chemical would have to be added at several locations to achieve the correct concentration, and would not be effective in areas of upwelling.

APPENDIX

Common and Scientific Names of Fishes Mentioned in Text

(from American Fisheries Society, 1960)

Chestnut lamprey	*Ichthyomyzon castaneus* Girard
Northern brook lamprey . .	*Ichthyomyzon fossor* Reighard and Cummins
Southern brook lamprey . .	*Ichthyomyzon gagei* Hubbs and Trautman
Allegheny brook lamprey . .	*Ichthyomyzon greeleyi* Hubbs and Trautman
Least brook lamprey	*Lampetra aepyptera* (Abbott)
American brook lamprey . .	*Lampetra lamottei* (LeSueur)
Western brook lamprey . . .	*Lampetra planeri* (Bloch)
Sea lamprey	*Petromyzon marinus* Linnaeus
Rainbow trout	*Salmo gairdneri* Richardson
Brown trout	*Salmo trutta* Linnaeus
Brook trout	*Salvelinus fontinalis* (Mitchill)
Arctic grayling	*Thymallus arcticus* (Pallas)
Northern pike	*Esox lucius* Linnaeus
Chain pickerel	*Esox niger* LeSueur
Carp	*Cyprinus carpio* Linnaeus
Creek chub	*Semotilus atromaculatus* (Mitchill)
White sucker	*Catostomus commersoni* (Lacépède)
Smallmouth buffalo	*Ictiobus bubalus* (Rafinesque)
River redhorse	*Moxostoma carinatum* (Cope)
Golden redhorse	*Moxostoma erythrurum* (Rafinesque)

Northern redhorse . . . . . <u>Moxostoma macrolepidotum</u> (LeSueur)

Channel catfish . . . . . . <u>Ictalurus punctatus</u> (Rafinesque)

Burbot . . . . <u>Lota lota</u> (Linnaeus)

Green sunfish . . . . <u>Lepomis cyanellus</u> Rafinesque

Smallmouth bass . . . . . . <u>Micropterus dolomieui</u> Lacépède

Largemouth bass . . . . . . <u>Micropterus salmoides</u> (Lacépède)

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