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Diatoms as Food of Larval Sea Lamprey Petromyzon marinus

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DIATOMS AS FOOD OF LARVAL SEA LAMPREY *Petromyzon marinus*

by

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DIATOMS AS FOOD OF LARVAL SEA LAMPREY (PETROMYZON MARINUS)

Introduction

The food and food preference of larval sea lamprey, Petromyzon marinus (Linnaeus), have not been investigated. This report presents data on the use of diatoms by young-of-the-year[1/] sea lamprey and the availability and utilization of diatoms by sea lamprey ammocetes of varying sizes.

Gage (1893) stated that the food of larvae consisted of microscopic organisms. Okkelberg (1922) found that the brook lamprey, Entosphenus wilderi (Gage), uses diatoms as a food source right after it absorbs the yolk plug. The food of the larval American brook lamprey, Lampetra lamottei (Le Sueur), in the Great Lakes region consisted mainly of diatoms and desmids with mixtures of protozoa, algae, sand, and pollen, according to Creaser and Hann (1929). Wigley (1959) found his data on ammocetes (unidentified) corresponded with that of Creaser and Hann and stated, "Thus it appears that the only selection of 'food' by ammocetes is on the basis of particle size." Schroll (1959) discussed the biology of feeding of ammocetes of Lampetra planeri (Bloch) and Eudontomyzon danfordi (Regan) in Europe. He found the food of the larvae to be chiefly diatoms in the spring, summer, and fall, and detritus in the winter. He also

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1/ Young-of-the-year larvae (age-group 0) hatch in June and July and are considered age-group 0 until January of the succeeding year when they become age-group I.

attempted to show larvae were selective in their feeding due to the selectivity of the mucous band. Larvae showed some selectivity for flour and diatoms over artificial fish food, chopped nematodes, rotifers, and tubificids. Sterba (1962) states, "A selective uptake of food in the sense of Schroll's theory does not take place in the light of my own experience. The possibility exists, however, that the fineness of the oral filter decreases with age (a purely mechanical property) and the size of the particles are pre-sorted changes." All studies show a predominance of diatoms and detritus in the diet of larval lampreys.

Feeding Behavior of Ammocetes

Sea lampreys spend their larval life in crescent-shaped or U-shaped burrows in the mud bottom of streams and are known as ammocetes. I held 20 ammocetes ranging in length from 111 to 132 millimeters in a 15-gallon aquarium from November 19, 1963 to June 15, 1964, and observed several larvae feeding. The opening of the burrow was very evident in the mud and the size and shape of the burrow could be seen when an ammocete burrowed along the glass wall of the aquarium. The following description is based upon Applegate's (1950) description and my own observations.

When ready to feed, the ammocete comes to the top of its burrow until its oral hood is at the surface of the mud. Microorganisms, detritus, and water are taken inside the branchial basket by the pulsating velum, and a sieve apparatus blocks the larger matter and lets microorganisms

and smaller particles through. These particles agglutinate on a mucous band secreted by the branchial glands and are pushed by cilia to the intestine. Ammocetes expel all larger foreign matter by expanding the branchial region and closing the gill opening. They then reverse the water flow and blow the particles out through the oral hood. The unusable detritus which gets past the sieve apparatus is expelled through the gill slits by constriction of the branchial basket.

I. Use of Diatoms by Young-of-the-year Sea Lamprey

Studies by previous authors have been only on large ammocetes (40 millimeters and over). I initiated a study on larvae from 7 to 24 millimeters long to determine the approximate size that larvae begin to use diatoms as a food and the genera, numbers, and average size of diatoms and fragments found in their intestines.

Materials and Methods

Ammocetes were collected in October 1960 from the Big Garlic River, Marquette County, Michigan, and preserved in 5-percent formalin. The ammocetes ranged from 7 to 24 millimeters and were subdivided into three groups (7 to 8 millimeters, 12 to 15 millimeters, and 20 to 24 millimeters). There were 20 ammocetes in each group. Preliminary studies showed individual ammocetes contain comparable numbers and species of diatoms. Therefore, ammocetes in each size range were grouped and considered a unit.

Several ammocetes (20 millimeters) were dissected with the aid of a binocular microscope (30 X) and their intestines and intestinal contents removed with dissecting probes. Removal of the intestines by this method was difficult and time consuming. The simple process of placing the whole ammocete in an acid-potassium dichromate bath solved the difficult step of manually removing the intestine. The acid dissolved all tissue and left the cleaned diatoms for study. This process worked well and was used to prepare ammocetes for the study.

The beaker containing the acid, potassium dichromate, and diatoms from the dissolved intestine was filled with distilled water, allowed to set for 4 hours, and then decanted. The procedure was continued until the dichromate color was gone and the solution was no longer acidic. The total solution of each sample was reduced by decantation and evaporation to a 3-milliliter stock solution. Three drops (0.3 milliliter) of the stock solution were used in the preparation of each slide, and two slides were made for each of the three size groups of ammocetes (7 to 8, 12 to 15, and 20 to 24 millimeters). Prior to removal of the 0.3 milliliter samples, the bottle containing the stock solution was agitated to insure even distribution of the diatoms. A calibrated pipette was used to remove the sample from the bottle and the sample was placed on the cover slip.

Botanical textbooks (Johansen, 1940; Smith, 1950) recommend an acid bath to clean diatoms in preparation of slides. Ruth Holland (personal

communication), a diatomist at the Bureau of Commercial Fisheries Limnological Laboratory, Ann Arbor, Michigan, used a slightly modified method for cleaning diatoms. The method is presented verbatim in Table 1 and was used throughout the study. In this method, nitric acid was used rather than sulfuric acid, as sulfuric acid destroys some of the more fragile diatoms.

Turtox CNC 10, synthetic diathane, balsam, and Hyrax[2/] mounting media were tested for mounting diatoms on slides. Turtox CNC 10 and synthetic diathane could not be used, as diatom frustules were only blurred images at 440 X. Balsam, while it allowed for viewing under dry power (440 X), did not have a high enough refractive index to allow diatoms to be viewed under oil immersion at 970 X with sufficient clarity for identification. Hyrax, with a refractive index of 1.65, was excellent and permitted extreme clearness of detail under oil immersion at 970 X.

Diatoms were counted with a single eyepiece Spencer microscope at a magnification of 970 X. Counts of diatoms were started at the bottom of the slide and read left to right across the slide. Diatoms were counted across a field 1 millimeter wide and 18 millimeters long. After one field was counted, the slide was moved up 2 millimeters and another count made. Seven fields were counted for a total of 126 millimeters^2 of each slide.

Diatoms were identified to genera, counted, and measured with an ocular micrometer to the nearest micron. Any diatom frustule that was broken was counted as a fragment.

2/ Hyrax obtained from Braun-Knecnt-Heimann Company, Denver, Colorado.

Table 1.--Procedures for cleaning diatom cultures (steps 1-8) and preparation of permanent slides (steps 9-16)

1. If the diatoms are preserved in anything other than formalin, get rid of preservative by decantation.

2. Add two or three times as much acid as liquid left in the beaker after decantation. Use concentrated nitric acid, as hydrochloric and sulfuric acids destroy some of the diatoms.

3. Add potassium dichromate gradually. Wait until activity dies down before adding more. Add approximately 1/4 teaspoon. Any excess can be gotten rid of by decantation because it is soluble in water. If after boiling undissolved dichromate remains in the bottom, you have added too much and must cut down next time.

4. After adding dichromate let the solution set overnight.

5. Heat the acid and dichromate solution to a slow boil until back to the original volume of solution.

6. Let the solution cool and fill beaker with distilled water.

7. Let the solution set 4 hours and decant carefully; do not lose any material. Repeat decanting four times. If any color remains in the beaker, decant until color is gone. Check for any acid remaining with litmus paper.

8. Transfer to vial - be sure to rinse beaker into vial. (Set up repeatable standard.)

9. Use clean coverslips - number "0" only.

10. Add the cleaned material to the coverslip by drop method. Keep track of the number of drops for each coverslip.

11. Let the material dry very slowly - placing the slide on a warming plate is preferred. Do not change thermostat on plate once it is set. The coverslip will dry in 2 hours. (Theoretically, material is considered to be evenly distributed on the coverslip.)

12. Transfer the coverslip to a high heat hot plate and heat for approximately 20 minutes (this removes the water from the diatoms).

(continued)

Table 1.--Continued

13. Put a drop of Hyrax (liquid mounting medium, refractive index 1.65) on a slide. Diamond mark the slide with the number of the collection.

14. Transfer coverslip to the Hyrax (be sure diatoms on the coverslip are facing down). Heat evenly to evaporate any benzene from the Hyrax.

15. Place the hot slide on asbestos board and proceed to position the coverslip on the slide at the same time pressing the coverslip down evenly with dissecting probes.

    NOTE: If the whole process is properly done, the coverslip should be colorless when held up to the light.

16. Label and proceed with count.

Results

The sea lamprey uses the diatom as a food source right after it absorbs the yolk plug (Table 2). The diatom becomes a major part of the food when the ammocete reaches a length of 12 to 15 millimeters. A total of 14 genera was identified in the ammocetes' intestines.

As the ammocetes increase in length, they use an increasing proportion of diatoms (Table 2).

There is also an increase in the average size of the diatoms and fragments used by the larger ammocetes. The construction and growth of the sieve apparatus of the ammocete explain the increase in the size of the diatoms. The spacing between the oral tentacles in the sieve apparatus possibly increases as the ammocetes increase in length, thereby allowing larger particles to go through the apparatus.

The young larvae used Navicula more than any other genera of diatom.

II. Availability and Utilization of Diatoms

Preliminary investigation on the use of diatoms by ammocetes (7 to 24 millimeters) indicated a possible selection of diatoms by the sea lamprey ammocete. A study designed to determine the availability of diatoms with selection of diatoms by the ammocete was initiated in 1964.

Table 2.--Percentage composition of various genera of diatoms in sea lamprey ammocetes (7 to 24 millimeters) from the Big Garlic River, Marquette County, Michigan

[Number of individuals in parentheses.]

Genus	Size range of ammocetes		
	7-8 mm	12-15 mm	20-24 mm
Navicula	31.3 (5)	25.0 (8)	58.9 (86)
Cyclotella	31.3 (5)	0.0	0.0
Eunotia	18.8 (3)	6.3 (2)	0.0
Synedra	6.2 (1)	6.3 (2)	13.7 (20)
Cocconeis	6.2 (1)	12.5 (4)	1.4 (2)
Fragilaria	6.2 (1)	3.1 (1)	0.0
Pinnularia	0.0	21.8 (7)	6.8 (10)
Cymbella	0.0	6.3 (2)	8.2 (12)
Diploneis	0.0	6.3 (2)	1.4 (2)
Stauroneis	0.0	3.1 (1)	8.2 (12)
Diatoma	0.0	3.1 (1)	0.0
Gomphonema	0.0	3.1 (1)	0.0
Nitzschia	0.0	3.1 (1)	0.0
Amphora	0.0	0.0	1.4 (2)
Total	100.0 (16)	100.0 (32)	100.0 (146)
Number of fragments	5	15	32
Average size of diatoms and fragments (microns)	10	41	66

Materials and Methods

Samples of ammocetes and diatoms were collected on May 19, 1964, from a pool in Snyder Creek, Schoolcraft County, Michigan. The width of the stream is 2 to 15 feet and the average depth 10 inches. Normal stream flow is approximately 8 cfs.

Larvae were collected with an electric shocker (Braem and Ebel, 1961) from an area 1 square yard and preserved in 5-percent formalin. The samples consisted of 10 small specimens (33 to 35 millimeters long and about 2 years old) and 10 large larvae (70 to 72 millimeters long and about 3 to 4 years old).

The age of the ammocetes was estimated from a length-frequency graph (Figure 1). It is difficult to interpret ages from length-frequency graphs due to overlap of year classes. However, Snyder Creek has been under study since May 22, 1960, when it was chemically treated with a selective larvicide by the Bureau of Commercial Fisheries, Marquette, Michigan. The selective larvicide, 3-trifluoromethyl-4-nitrophenol, has been proven to be an effective chemical for eradicating lamprey populations from a river (Applegate, et al., 1961). The first year class following chemical treatment was established in July 1960. This year class and succeeding year classes were monitored by semiannual collections until the time larvae were collected for this study on May 19, 1964. Peaks in the length-frequency graph probably represent modes of year classes and have been interpreted as such.

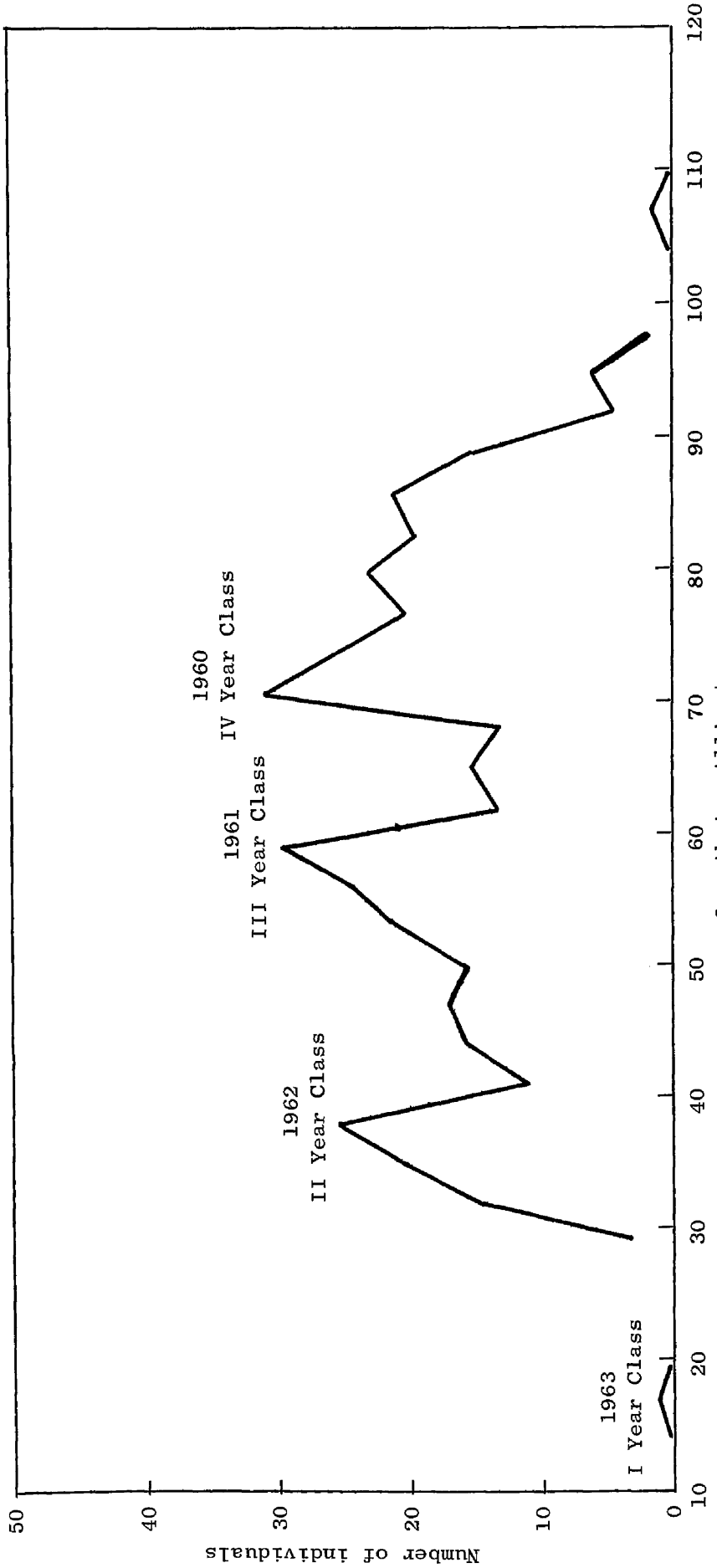

Figure 1.--Lengths of sea lamprey ammocetes collected in Snyder Creek, Schoolcraft County, Michigan, May 19, 1964.

The habitat where the sample of ammocetes was taken contained ammocetes of all sizes and appeared to be preferred by the ammocetes over other areas in the stream. Habitat 100 feet below the sample area was not preferred as few ammocetes were found in it.

A mechanical analyses of a 1-pint sample of the soil of these two habitats showed the following particle size distribution and percentages in habitat:

Soil type	Particle size (mm)	Percentage in habitat	
		Preferred	Non-preferred
Very coarse sand	> 1.0	1	1/0
Coarse sand	1.0 - 0.5	7	63
Medium sand	0.5 - 0.25	30	15
Fine sand	0.25 - 0.10	43	18
Very fine sand	0.10 - 0.05	15	2
Silt and clay	< 0.05	4	2

1/ Less than 0.5.

The particle size appears to be one factor in determining whether the habitat is acceptable to the ammocete. In the non-preferred habitat 63 percent of the sample was coarse sand and in the preferred habitat it was mostly fine sand (58 percent). The number of diatoms in the preferred habitat was also thought to be greater, but this was not verified.

Preliminary examination indicated that ammocetes within each of the two size groups contained comparable numbers and species of diatoms. Schroll (1959) also found that ammocetes of comparable ages in several rivers of Europe consumed similar numbers of various diatoms. Therefore, the 10 ammocetes in each size group were treated as a unit.

Diatoms were recovered from the intestine of 10 small ammocetes by dissolving the whole larvae in a concentrated nitric acid-potassium dichromate bath leaving the diatoms in solution. The intestines of the 10 large ammocetes were removed from the ammocete and digested in the acid bath; this eliminated excessive fat droplets that result from solution of the whole animal, hinder the preparation of slides, and interfere with diatom counts.

It was not difficult to remove the intestine from the large ammocetes (70 to 72 millimeters). A transverse cut was made just anterior to the anus and behind the last gill slit. The intestine was then removed with a forcep by pulling it from the body cavity.

Diatoms in the stream were sampled by collecting 1-liter water samples at the middle of the 1 square yard area where the ammocetes were taken. Water depth was 18 inches; one sample each was taken at the surface, middepth, and bottom. The bottom sample was taken approximately 2 inches from the sand-silt bottom. After the water was filtered through millipore paper (pore size 0.45 $\pm$ 0.02 micron), the diatoms were removed by dissolving the paper in a nitric acid-potassium dichromate solution.

Two other methods of sampling water were considered, the "black jar" and "plexiglass plate" methods. The "black jar" method employs a 4-liter glass jar with its sides painted black. The jar is filled with water from the stream, placed in direct sunlight or under a fluorescent lamp, and allowed to stand for 24 hours. The living diatoms congregate on the top and around the edge of the water. After the allotted time, the top liter of water containing the living diatoms is siphoned off. The liter of water is then run through a millipore filter and the filter paper preserved in 5-percent formalin. By this method, live diatoms are counted and used as an index of population. The "black jar" method was not used in this study because I was interested in total diatom counts and the reproduction of diatoms over the 24-hour period when the jar stood may have introduced an uncontrolled variable.

The other method was the "plexiglass plate" method (Grzenda and Brehmer, 1960). This method involves the use of plexiglass plates to collect plankton. The plates are installed in the stream for predetermined amounts of time to allow accumulation of periphyton on the plates and then removed. The periphyton growth is scraped from the plexiglass plates and allowed to stand in 95-percent ethanol for a minimum of 48 hours in total darkness. Samples can be stored in this manner for as long as 30 days without the loss of phytopigments due to decomposition. The samples are filtered through glass wool and the volume of the filtrate adjusted to 50 milliliters by either dilution or evaporation. The density of the phytopigment solution was read on a Klett-Summerson colorimeter (4-centimeter

solution depth) using a red filter 640 - 700 millimicrons. The measured pigment absorbency can be used for comparative purposes and also quantitative estimates. The plexiglass plates had to be in the stream I studied 3 to 4 days to get a reliable reading on the colorimeter and possibly different genera of diatoms adhere to the plexiglass plates more readily than others. Therefore, this method was not used.

The removal of 1 liter of water from the three strata of the stream was thought to be the best method of sampling and is the standard method used frequently by other authors (Kutkuhn, 1958; Holland, 1965). There could be some question as to whether the water sample actually represents the diatoms available to the ammocetes for the ammocetes could have fed a number of days before I took the water sample. A review of the literature revealed no studies on the intake of food by ammocetes or the time it takes the food coming in to go through the ammocete and be expelled. It seems unlikely that the composition of the diatom genera in a stream would change drastically over a period of a few days, and it is reasonable to assume that a few days is the appropriate time interval that food is retained by the ammocete.

Each sample of diatom from the ammocetes and the water was deacidified and concentrated to a 3-milliliter stock solution by repeated washing, decantation, and evaporation. Slides were prepared for each sample by the method previously described with the following modifications: 0.1 milliliter of the stock solution was spread evenly on a coverslip

(No. 0, 18 millimeters square), allowed to dry, then heated at 200° C. for 1/2 hour to remove all water; the coverslip was then inverted and placed on a drop of Hyrax mounting medium (refractive index 1.65) on a slide; and the slide was heated at 200° C. until all the gases were released from the Hyrax. Three slides were prepared for each sample, of which two were used for the counts. The third slide was made in case a slide was broken.

Identification and counts were made at a magnification of 970X. Counts with an ocular micrometer included 126 millimeters^2 of each slide. Numbers of diatoms on the two slides from each sample were similar (Table 3). The percentage of error ranged from 2.3 to 12.3 percent, with an average error of 7.0 percent.

Results

A total of 21 genera was identified including 17 genera in the water and 20 in the ammocete sample (Table 4). Synedra, Fragilaria, Navicula, Gomphonema, Meridion, and Cocconeis constituted approximately 98 percent of the diatoms in the water and 97 percent of the diatoms eaten by the ammocetes. The percentage composition for various genera was similar for the three strata of water, but the number of diatoms was greatest near the bottom and least at the surface. The counting technique did not distinguish between live and dead diatoms; I do not know whether shells of dead diatoms contributed to the larger number on the bottom.

Table 3.--A comparison of diatom counts on two slides prepared from samples of water and sea lamprey ammocetes from Snyder Creek, Schoolcraft County, Michigan

Sample	Number of diatoms		Percentage difference
	Slide number 1	Slide number 2	
Water			
Top	350	307	12.3
Middle	464	503	8.4
Bottom	1,068	1,135	6.3
Ammocete			
33-35 mm.	589	554	5.9
70-72 mm.	1,324	1,355	2.3

Table 4.--Percentage composition of various genera of diatoms in samples of water and in sea lamprey ammocetes from Snyder Creek, Schoolcraft County, Michigan

[Number of individuals in parentheses. T is trace < 0.05%.]

Genus	Water[1/]			Ammocetes	
	Surface	Middepth	Bottom	33-35 mm	70-72 mm
Synedra	42.2 (277)	45.4 (439)	40.3 (888)	46.6 (533)	22.2 (595)
Fragilaria	26.0 (171)	24.3 (235)	31.7 (699)	8.7 (99)	14.4 (385)
Navicula	10.8 (71)	11.5 (111)	7.7 (170)	19.1 (218)	32.9 (881)
Gomphonema	6.1 (40)	6.1 (59)	7.7 (170)	11.9 (136)	13.0 (347)
Meridion	9.4 (62)	7.7 (74)	6.5 (142)	7.1 (81)	8.2 (220)
Cocconeis	3.7 (24)	3.7 (36)	4.2 (92)	3.7 (42)	6.0 (160)
Cymbella	0.9 (6)	0.6 (6)	0.3 (6)	1.1 (13)	1.3 (35)
Amphora	0.2 (1)	0.3 (3)	0.7 (16)	0.3 (3)	0.2 (4)
Achnanthes	0.0	0.0	0.3 (7)	0.0	0.4 (11)
Tabellaria	0.0	0.0	0.2 (4)	0.2 (2)	T (1)
Surirella	0.2 (1)	0.2 (2)	T (1)	0.3 (3)	0.1 (3)

(continued)

Table 4.--Continued

Genus	Water[1/]			Ammocetes	
	Surface	Middepth	Bottom	33-35 mm	70-72 mm
Eunotia	0.3 (2)	0.0	0.1 (2)	0.1 (1)	0.1 (3)
Diploneis	0.0	0.1 (1)	0.1 (2)	0.3 (3)	0.3 (7)
Diatoma	0.0	0.0	T (1)	0.0	0.0
Pinnularia	0.0	0.1 (1)	T (1)	0.1 (1)	0.5 (12)
Amphipleura	0.3 (2)	0.0	T (1)	0.0	T (1)
Stauroneis	0.0	0.0	T (1)	0.2 (2)	0.1 (3)
Cyclotella	0.0	0.0	0.0	0.3 (3)	T (1)
Neidium	0.0	0.0	0.0	0.3 (3)	T (1)
Hantzschia	0.0	0.0	0.0	0.0	0.2 (4)
Rhopalodia	0.0	0.0	0.0	0.0	0.2 (5)
Total	100.0 (657)	100.0 (967)	100.0 (2,203)	100.0 (1,143)	100.0 (2,679)

1/ Stream depth at the sampling location was 18 inches.

The six abundant genera occurred at frequencies that were significantly different (as determined by a chi-square test: $P < 0.001$, df = 6) in the water and two size groups of ammocetes (Table 4). Synedra was most abundant in the water samples (40.3-45.4 percent) and in small ammocetes (46.6 percent), but accounted for only 22.2 percent of the diatoms consumed by large ammocetes. Fragilaria was less well represented in both groups of larvae than in the water. It constituted only 8.7 percent of the diatoms in the small ammocetes and 14.4 percent in the large ammocetes, as compared with 24.3-31.7 percent in the stream.

Navicula made up only 7.7-11.5 percent of the diatoms in the stream (the lowest concentration was at the bottom where the larvae were feeding), but constituted 32.9 percent of the diatoms taken by large ammocetes and 19.1 percent of those eaten by small larvae. Gomphonema occurred in the same concentrations on the bottom (7.7 percent) as Navicula; it was less well represented in larvae of both size groups (11.9-13.0 percent) than Navicula, but like Navicula was better represented in the larvae than in the stream. Meridion was represented similarly in the stream (6.5-9.4 percent) and ammocetes (7.1-8.2 percent). The percentage occurrence of Cocconeis was similar in the water (3.6-4.2 percent) and in small ammocetes (3.7 percent), but was slightly greater in the large ammocetes (6.0 percent).

Feeding Selectivity

Schroll (1959) has demonstrated that the use of diatoms by larval lampreys is influenced by availability of the diatoms, and by preference of the ammocetes and the selectivity of their feeding apparatus.

In Snyder Creek ammocetes favored Navicula and Gomphonema, which were present in about equal numbers in the water near the bottom, but were approximately two to four times more frequent in the food of large ammocetes, and about twice as frequent in small larvae. Gomphonema is attached to the bottom by branched gelatinous stalks, which may make frustules that break free more available to ammocetes which feed by straining the water at or very close to the bottom. Navicula is a solitary, free-floating diatom; the reason for the much higher percentages in the larvae than in the water is unknown.

As age or size of the larvae increased, the frequency of occurrence of Synedra decreased and that of Fragilaria and Navicula increased. Since the water and larvae were collected from the same area, these diatoms were presumably equally available to ammocetes of both size groups.

The characteristics of the sieve apparatus of the ammocete and the morphology of the different diatom genera may influence the selection of diatoms. The oral sieve, just anterior to the pharynx, blocks larger particles and lets microorganisms and small particles pass. Food particles agglutinate on a mucous band secreted by the branchial glands posterior to

the sieve and are passed by cilia toward the intestine. The sieve may block the ribbon-like colonies of Fragilaria, which was much less common in the food than in the environment, but apparently did not block the broad, wedge-shaped colonies of Meridion. Meridion colonies, however, break up more easily than Fragilaria colonies and therefore would not form as large masses as Fragilaria.

Summary

Larvae of the sea lamprey use diatoms as a food source shortly after absorbing the yolk plug (7 to 8 millimeters). The average number and size of the diatoms increased as the size of the ammocete increased. Navicula was the most predominant genus found in young-of-the-year ammocetes from the Big Garlic River, Marquette County, Michigan.

Synedra, Fragilaria, Navicula, Gomphonema, Meridion, and Cocconeis were the most abundant of 21 genera of diatoms identified in Snyder Creek or in food eaten by resident ammocetes of the sea lamprey (Petromyzon marinus). These genera constituted approximately 98 percent of the diatoms in the water and 97 percent of the diatoms eaten by larvae. The most important genus, Synedra, accounted for about 47 percent of the diatoms consumed by small ammocetes (33 to 35 millimeters), 22 percent of the diatoms taken by the large larvae (70 to 72 millimeters), and 40 to 45 percent of the diatoms in the water. Fragilaria was much less common in the food of ammocetes than in the water; Navicula and Gomphonema

were more common in the food than in the water; and Meridion and Cocconeis occurred in roughly similar numbers in the food and water.

III. List of Diatom Genera and Species

The following is a list of the diatoms found in the Big Garlic River, Marquette County, Michigan. Ruth Holland, Bureau of Commercial Fisheries, Ann Arbor, Michigan, and I identified the diatoms. Dr. Matthew Hohn, a diatom specialist at Central Michigan University, verified the identifications.

The list of diatom genera is accurate; however, the list of diatom species is preliminary work and identifications are tentative.

List of Diatom Genera

Achnanthes
Amphipleura
Amphiprora
Amphora
Caloneis
Cocconeis
Cyclotella
Cymbella
Denticula
Diatoma
Diploneis
Epithemia
Eunotia
Fragilaria
Frustulia
Gomphonema
Gyrosigma
Hantzschia
Melosira
Meridion
Navicula
Neidium
Nitzschia
Opephora
Pinnularia
Rhopalodia
Stauroneis
Stephanodiscus
Surirella
Synedra
Tabellaria

List of Diatom Species

Achnanthes lanceolata (Breb.) Grun.
Achnanthes minutissima Kutz.
Amphipleura pellucida Kutz.
Amphora perpusilla Grun.
Cocconeis pediculus Ehr.
Cocconeis thumensis A. Mayer
Cymbella laevis Naeg.
Cymbella microcephala Grun.
Cymbella tumida Breb.
Cymbella ventricosa Kutz.
Diploneis oculata (Breb.) Cl.
Eunotia flexuosa Breb. (Kutz.)
Eunotia monodon Ehr.
Fragilaria capucina Desm.
Fragilaria harrissonii (W. Sm.) Grun.
Gomphonema sphaerophorum Ehr.
Meridion circulare (Grev.) Ag.
Navicula reinhardtii (Grun.) Grun.
Neidium affine (Ehr.) Pfitz.
Neidium dubium (Ehr.) Cl.
Neidium iridis (Ehr.) Cl.
Opephora martyi Herib.
Pinnularia platycephala Sov.
Stauroneis phoenicenteron (Nitz.) Ehr.
Stauroneis pygmaea Krieg.
Synedra vaucheriae (Kutz.) Kutz.

This study is a preliminary investigation into a little-known field - the food and food preference of the sea lamprey ammocete. Information of this type could be valuable to the sea lamprey control program in the Great Lakes as it might explain why some streams cannot support a population of lampreys. It also could provide some insight into the variations in growth rates between streams and within the stream system itself. An additional contribution of the paper is a partial listing of the diatom genera and species found in the Upper Peninsula.

More information is necessary on the mechanics of the feeding apparatus of the ammocete, the size and shapes of the different diatom species, differences in feeding behavior between large and small ammocetes, and the location the larvae get most of their food.

LITERATURE CITED

Applegate, Vernon C., John H. Howell, James W. Moffett, B. G. H. Johnson, and Manning A. Smith.

1961. Use of 3-trifluormethyl-4-nitrophenol as a selective sea lamprey larvicide. Great Lakes Fishery Commission, Technical Report No. 1, 35 p.

Applegate, Vernon C.

1950. Natural history of the sea lamprey (Petromyzon marinus) in Michigan. U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 55, 237 p.

Braem, Robert A., and Wesley J. Ebel.

1961. A back-pack shocker for collecting lamprey ammocetes. Progressive Fish-Culturist, Vol. 23, No. 2, p. 87-91.

Creaser, Charles W., and Clare S. Hann

1929. The food of larval lampreys. Papers of the Michigan Academy of Science, Arts and Letters, Vol. 10 (1928), p. 433-437.

Gage, Simon H.

1893. The lake and brook lampreys of New York, especially those of Cayuga and Seneca Lakes. In Wilder Quarter-Century Book, Ithaca, 1893, p. 421-493.

Grzenda, Alfred R., and M. L. Brehmer.

1960. A quantitative method for the collection and measurement of stream periphyton. Limnology and Oceanography, Vol. 5, No. 2, p. 190-194.

Holland, Ruth

1965. The distribution and abundance of planktonic diatoms in Lake Superior. Great Lakes Research Division, The University of Michigan, No. 13, p. 96-105.

Johansen, Donald A.

1940. Plant microtechnique. McGraw-Hill Book Company, Inc., New York and London, 523 p.

Kutkuhn, Joseph H.

1958. Notes on the precision of numerical and volumetric plankton estimates from small sample concentrates. Limnology and Oceanography, Vol. 3, No. 1, p. 69-83.

Okkelberg, Peter

1922. Notes on the life-history of the brook lamprey, Ichthyomyzon unicolor. Occasional Papers Museum Zoology, University of Michigan, No. 125, 14 p.

Schroll, Fritz

1959. Zur ernahrungsbiologie der steirischen ammocoten Lampetra planeri (Bloch) und Eudontomyzon danfordi (Regan). Internationale Revue der Gesamten Hydrobiologie, Band 44, Heft 3, p. 395-429.

Smith, Gilbert M.

1950. The freshwater algae of the United States. McGraw-Hill Book Company, Inc., New York, Toronto, and Longon, 719 p.

Sterba, G.

1962. Die Neunaugen (Petromyzonidae). Handbuch der Binnenfischeriei Mitteleuropas, Vol. 3, Part 10, 263 p.

Wigley, Ronald L.

1959. Life history of the sea lamprey of Cayuga Lake, New York. Fishery Bulletin of the Fish and Wildlife Service, Vol. 59, No. 154, p. 561-617.