NATURAL HISTORY OF THE SEA LAMPREY (Petromyzon marinus) IN MICHIGAN

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 55

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

NATURAL HISTORY OF THE SEA LAMPREY (*Petromyzon marinus*) IN MICHIGAN

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 55

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Explanatory Note

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for the official use of Federal, State or cooperating agencies and in processed form for economy and to avoid delay in publication.

Washington, D. C.
December 1950

United States Department of the Interior
Oscar L. Chapman, Secretary
Fish and Wildlife Service
Albert M. Day, Director

Special Scientific Report - Fisheries

No. 55

NATURAL HISTORY OF THE SEA LAMPREY, *Petromyzon marinus*, IN MICHIGAN 1/

By

Vernon C. Applegate
Fishery Research Biologist

CONTENTS

1/ Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation.

LIST OF FIGURES

LIST OF TABLES IN TEXT

LIST OF APPENDICES

ACKNOWLEDGMENTS

All investigations reported herein were conducted by the writer while employed as a Fisheries Biologist by the Institute for Fisheries Research of the Michigan Department of Conservation. Funds covering all aspects of the studies were provided by special allotment from the aforementioned agency. Permission to publish these investigations was granted by the Michigan Conservation Department to implement the expanded program of sea lamprey research currently being undertaken by the Fish and Wildlife Service. Both Mr. Fred A. Westerman, Chief, Fish Division, and Dr. Albert S. Hazzard, Director, Institute for Fisheries Research, were most helpful in offering suggestions and in aiding the work program. Dr. Hazzard likewise contributed guidance in the technical aspects of the studies.

The success of the inventory of sea lamprey spawning streams was entirely dependent upon the cooperation of many agencies. The assistance and cooperation of the Conservation officers and their district and regional supervisors of the Division of Field Administration is herewith acknowledged. Members of the Parks and Forestry divisions contributed assistance as did many members of the Fish Division. Messrs. Leland R. Anderson, Dexter B. Reynolds, W. R. Crowe, L. N. Allison, Stanley Lievense, H. E. Predmore, Jr., and Howard Loeb, as district biologists or members of the Institute staff accomplished much of the field work in connection with this study.

Criticism and assistance in organizing units of biological study and in the preparation of this report was given by Dr. Karl F. Lagler, Department of Zoology, University of Michigan. All figures, drawings, reproductions, and some pictures were prepared by Mr. William Cristanelli of the Institute staff. Among the several assistants who worked with me in the laboratory and in the field, I am particularly indebted to Mrs. Eda S. Applegate, to Mr. Albert N. Gabrielson of Carp Lake, Michigan, and Mr. Earl Schaedig of Rogers City, Michigan.

Supplementary financial aid for certain phases of the work was supplied by the Trust Fund for Fishery Research of the Associated Fishing Tackle Manufacturers.

Frontispiece.--Close-up of the oral sucking disc of an adult sea lamprey.

I. Introduction

The appearance of the sea lamprey, Petromyzon marinus, in the upper Great Lakes and its spread and multiplication in these waters during the past two decades has become a matter of increasing concern to those engaged in the fishing industry and to conservation agencies in those states bordering on the lakes. As early as 1937, Hubbs and Pope (1937) suggested that this predatory parasite might become an increasingly damaging factor in an already depleted fishery. The gravity of the problem today is all too apparent in the large spawning runs of this species observed in Michigan streams and in the reports of lamprey-scarred fish submitted by commercial fishermen.

In June of 1946, the Michigan Conservation Commission ordered a comprehensive investigation and study on the sea lamprey in Great Lakes waters, with the object of attempting to discover and develop effective control methods. Immediately following this directive, information was solicited from commercial fishermen by the conservation officers concerning known spawning streams, percentage of total fish taken that were scarred, and the effect of scars on the marketability of the fish. These data were summarized by Shetter (1949) and are discussed, in part, elsewhere in this report.

The problem received further consideration in September and November, 1946, at conferences called by Dr. John Van Oosten, In Charge, Great Lakes Fishery Investigations, U. S. Fish and Wildlife Service, with representatives from the states bordering on the Great Lakes and from the Province of Ontario attending. A Great Lakes Sea Lamprey Committee was formed and a coordinated program of investigation and study was evolved. A summary of the activities of this Committee and the implementing legislation has been presented by Applegate (1947).

The present report will discuss the results of various phases of an intensive study of the distribution and life history of the sea lamprey in Michigan waters, begun early in 1947 by the Michigan Institute for Fisheries Research. These investigations represent this State's part of the cooperative program of research outlined at the previously cited conferences. The initial step in the investigations was an inventory of the size and distribution of sea lamprey spawning runs entering Michigan streams in the spring. This information is vitally important for it provides a measure of the population to be considered for reduction and a basis for cost estimation for certain proposed controls. The results of this inventory conducted in 1947 and 1948 follow, preceded by a summary of the records which illustrate the spread and increase of the sea lamprey in the upper Great Lakes.

II. History of the sea lamprey in the Great Lakes

A recapitulation of the distribution of the sea lamprey as embodied in published reports and summaries of reports (Hubbs and Pope, 1937; Shetter, 1949) is necessary to provide a background for this paper. Additional unpublished records have been added to augment the present known data.

Prior to November 8, 1921, when an adult specimen was recovered in Lake Erie, the sea lamprey had been known in the Great Lakes basin only from Lake Ontario and its tributaries. In these waters it is apparently native and occurs abundantly in a dwarfed form. Locally it is known as the "lake lamprey" and is about one half the size of the large sea lamprey of marine habit. These adult "lake lampreys" probably do not exceed 15 inches in total length. Their destructive attacks upon native food and game fishes were noted at an early date (Gage, 1893, 1928; Surface, 1898, 1899; Huntsman, 1917; Dymond, Hart, and Pritchard, 1929).

Until recent times, the spread of the sea lamprey into the upper Great Lakes was blocked by the Niagara Falls.[1] It is believed that access was granted the species to the waters above the Falls by the construction of the Welland Canal between Lakes Ontario and Erie. This canal was first opened to shipping in 1829 and was reconstructed into its present system of seven locks in 1932 (Zimmermann and Bright, 1942). It is interesting to note that there is a lapse of 92 years between the opening of the canal and the identification of the first sea lamprey in Lake Erie. The present locks of the Welland Canal are considered inadequate and are the object of current agitation for improvement of the St. Lawrence Waterway. It is a consideration, that further enlargement and improvement of these structures will implement further ingress of sea lampreys from Lake Ontario into the western Great Lakes.

---

[1] Bensley (1915) included *Petromyzon marinus* provisionally in "Fishes of Georgian Bay" based on reports of fishermen that lampreys 15 inches long were sometimes taken on whitefish and trout from deep water. Radforth (1944) suggested that these specimens may have found their way into Lake Huron via the Trent Waterway but did not think it likely. We must therefore concur with the opinion of Hubbs and Pope (1937) that this hearsay report was based on a native lamprey (*Ichthyomyzon sp.*).

The completion of the Trent Waterway connecting Lake Ontario and Georgian Bay (Lake Huron) in 1918 opened another possible, but somewhat improbable, means of introduction into the upper lakes. This system consists of approximately 235 miles of circuitous waterway extending from Trenton, Ontario, on Lake Ontario to Port Severn on Georgian Bay of Lake Huron. It embraces 46 boat locks, 32 1/4 miles of constructed canal, and numerous power and water level maintenance dams creating heads as great as 58 feet. Boat traffic in the system is not heavy. The sea lamprey might have distributed itself into Lake Huron by this route, but the weight of evidence indicates that they gained entrance to the upper lakes via the Welland Canal.

In the two and one half decades following the capture in 1921 of the first adult specimen in Lake Erie, the sea lamprey has dispersed rapidly throughout the upper lakes establishing itself in Lakes Erie, Huron, and Michigan in that order. Recent reports indicate that it had become established in Lake Superior at least by 1945. Although its spread and multiplication has not approached the spectacular quality of another exotic introduction, the smelt (*Osmerus mordax*), it is nonetheless firmly established and present in large numbers.

The history of the spread of the sea lamprey in the Great Lakes is written in the chronology of all available records, published and unpublished. A summary is presented herewith, by drainages, which documents its spread. The period covered is 1921 through 1948. This is the interval during which the establishment of the sea lamprey was recognized throughout the Great Lakes. In the following summary, notations concerning the nature of the record and the source are included wherever possible.

1921

Lake Erie and tributaries.—One specimen, 21 inches long, taken off shore from Merlin, Ontario, in central Lake Erie on November 8, 1921 (Dymond, 1922).

1927

Lake Erie and tributaries.— One specimen caught near West Sister Island, Ohio, on November 14, 1927 (Osburn, Wickliff and Trautman, 1930). One specimen caught near Sandusky, Ohio; identified by Dr. John Van Oosten (Hubbs and Brown, 1929).

1928

Lake Erie and tributaries.--One specimen, 22 inches long, taken at Pointe Aux Pins, opposite Rondeau Harbor, Ontario (date not given). W. C. Bates who captured this specimen reported to Dr. Van Oosten that he occasionally took large lampreys in his nets (Hubbs and Brown, 1929). One specimen collected near Sandusky, Ohio, in the spring by a Mr. W. M. Tidd (Hubbs and Brown, 1929).

1930

Lake Erie and tributaries.--One specimen, 13.75 inches long, taken by a fisherman in the St. Clair River in second week of May, 1930; attached to a 4.5-pound "pikeperch" (Hubbs and Pope, 1937).

1932

Lake Erie and tributaries.--Adult specimen collected in the Huron River at Flat Rock, Wayne County, Michigan, on May 8, 1932 (Creaser, 1932); this was the first record of a spawning migrant and verified establishment of the species in Lake Erie. Penetration into Lakes St. Clair and Huron was probably well begun on, or before, this date.

1934

Lake Erie and tributaries.--A mature sea lamprey, 455 millimeters long, collected in Swan Creek, tributary of the Maumee River in Toledo, Ohio, on May 8, 1934; spawning migrant (Hubbs and Pope, 1937).

Lake St. Clair and tributaries.--Reportedly observed in Clinton River at Rochester, Oakland County, Michigan, in spring by Harry Yates of that city; spawning run? (Shetter, 1949).

1935

Lake Erie and tributaries.--Two mature sea lampreys, 459 and 528 millimeters, respectively, collected in Swan Creek, Toledo, Ohio, on April 26, 1935; spawning run (Hubbs and Pope, 1937).

1936

Lake Michigan and tributaries.--One 15.5-inch male, presumably on spawning run, taken in outlet of Elk Lake at Elk Rapids, Antrim County, Michigan, on June 13, 1936 (Hubbs and Pope, 1937). One immature adult, not quite 9 inches long, captured 5 miles south of Sturgeon Bay Canal, Door County, Wisconsin, on August 1, 1936 (Hubbs and Pope, 1937). One immature adult, 17 inches long, taken just off St. James on Beaver Island on October 19, 1936 (Hubbs and Pope, 1937). One 16-inch specimen taken 15 miles east of Milwaukee, Wisconsin, on March 22, 1936; attached to a 4.5-pound lake trout (Hubbs and Pope, 1937).

1937

Lake Huron and tributaries.--Spawning run reported in Ocqueoc River, Presque Isle County, Michigan (Conservation Officer Marvin Horton's semi-monthly report).

Lake Michigan and tributaries.--One specimen, 19 inches long, taken 27 miles east of Port Washington, Wisconsin, on February 4, 1937; attached to a 3.5-pound lake trout (Hubbs and Pope, 1937). One 20-inch specimen taken NW by W St. Joseph, Michigan, on March 2, 1937 (Hubbs and Pope, 1937).

1938

Lake St. Clair and tributaries.--Spawning observed on May 27, 1938, in the Clinton River in Oakland County, Michigan (T3N, R11E, S.13) and in Macomb County, Michigan (T3N, R12E, S.19) by M. B. Trautman and Dr. H. J. Deason (Trautman and Deason, 1938; Unpubl. report).

Lake Huron and tributaries.--Dead specimen picked up in Laperell Creek (T37N, R2W, S.24), tributary to Cheboygan River, Cheboygan County, Michigan, on July 12, 1938. Identified by Dr. C. W. Creaser (verbal communication).

1939

Lake St. Clair and tributaries.--Nests and spawning migrants observed by Dr. H. J. Deason on May 23 and 27, 1939, in the Clinton River, Oakland and Macomb counties, Michigan, at locations observed in 1938. Fewer lampreys seen than in 1938 and Deason suggests no increase in size of spawning run in this river (Deason, 1939; Unpubl. report).

1941

Lake Huron and tributaries.--Spawning run observed in the Au Gres River, Iosco County, Michigan, by Dr. D. S. Shetter (Shetter, 1949).

1943

Lake Huron and tributaries.--A "young" sea lamprey was taken from a lake trout caught off Kettle Point, Ontario, on May 22, 1943 (Radforth, 1944).

Lake Michigan and tributaries.--Spawning run observed in the Platte River, Benzie County, Michigan, by Dr. D. S. Shetter (Shetter, 1949).

1944

Lake Huron and tributaries.--Spawning runs observed in the Rifle River (Ogemaw County?), Michigan and the Ocqueoc River, Presque Isle County, Michigan, by Dr. D. S. Shetter (Shetter, 1949).

1945

Lake Huron and tributaries.--Spawning run observed in the Ocqueoc River, Presque Isle County, Michigan, by Dr. D. S. Shetter (Shetter, 1949). An adult sea lamprey, attached to a sucker, was taken near Topinabee, Michigan, in Mullet Lake, Cheboygan County (Cheboygan River drainage); identified by Dr. C. W. Creaser (verbal communication).

1946

Lake Superior and tributaries.--An immature adult, 9.5 inches long, was taken off Rock Harbor, Isle Royale, in early August, 1946; identified by Dr. John Van Oosten. A large female, 490 milimeters long, was taken off Whitefish Point in eastern Lake Superior in December, 1946 (Creaser, 1947).

Tributaries of all basins.--A survey primarily based on interviews with commercial fishermen was made by Michigan conservation officers in the late spring and early summer. Spawning runs were reportedly present in 68 Michigan streams (Shetter, 1949). These latter records are discussed elsewhere in this report.

1947

Lake Superior and tributaries.--An immature adult, 19.3 inches long, was taken in May, 4 miles offshore in Grand Traverse Bay, east side of Keweenaw Peninsula; attached to lake trout caught trolling; identified by V. C. Applegate.

Tributaries of all basins.--Sea lamprey spawning runs were verified in 74 Michigan streams and reliably reported in 9 additional streams; see subsequent discussion.

1948

Lake Superior and tributaries.--A sexually maturing adult, 16.0 inches long, was taken on May 31, 1948, by Rino Merila, fisherman at Portage Entry, on a reef 10 miles north of Pt. Abbay (Baraga County); specimen attached to a 6-pound lake trout taken by hook in 12 fathoms of water; identified by V. C. Applegate. Dr. Raymond E. Johnson of the Minnesota Department of Conservation reported the taking of the first sea lamprey in the Minnesota waters of Lake Superior. The spread may now be termed completed.

Tributaries of all basins.--Additional field investigations brought the total spawning runs verified in Michigan streams to 92 with sea lampreys reliably reported in 16 additional streams; see subsequent discussion.

III. The inventory of sea lamprey spawning streams

As mentioned previously, a survey of sea lamprey spawning streams was conducted in 1946 by Michigan Conservation Officers, primarily by means of inquiry from commercial fishermen. In all, 68 streams in Michigan were reported to have sea lamprey spawning runs (Shetter, 1949).

With the advent of an intensive program of research on the sea lamprey, the need was felt for more precise information on the size and location of the spawning runs in Michigan waters. Furthermore, it was deemed advisable to have trained fishery biologists verify the presence of sea lampreys since four native species of lampreys occur in the same region. These could lead to numerous false reports.

The mechanics of the inventory in the year 1947 required the cooperation of the Field Administration Division of the Department of Conservation and the public at large, particularly organized groups such as sportsmen's clubs, Boy Scouts, 4-H clubs, etc. Considerable publicity of the program preceded the known spawning season. Posters requesting cooperation from the public in reporting sea lamprey runs were put up by local conservation officers along stream banks, in public buildings, and public meeting places (Figure 1). These posters requested that the local conservation officer be notified when sea lampreys were observed in streams. The conservation officers were instructed to forward all reports immediately to the district fishery biologist within whose zone they were located. Each officer received a memorandum along with the supply of posters. The memo described the mechanics and requirements of the program.

All reports were investigated by the district fishery biologists or other members of the Fish Division. Special report forms (Figure 2) were provided each biologist to insure uniformity of the data to be taken at each site of observations. Required were: location; size of sea lamprey run; and characteristics of spawning grounds.

The inventory was repeated in 1948. Its conduct was the same as that of 1947 with the exception that, in general, only those reports that constituted new records of distribution were personally investigated by the biologists. Furthermore, in this year, the district fishery biologists were instructed to investigate as thoroughly as possible the largest runs occurring in their areas.

Results of the inventory

The presence of migrating sea lampreys or sea lamprey spawning activity was verified in 92 Michigan streams in the drainages of Lakes Erie, Huron, Michigan, and Superior. (Table 1 and Figure 3; Appendix A, Table 1.) Their presence in sixteen additional streams is considered relatively certain, but they were not positively identified in these locations. Records for these latter streams are classified as "reliable reports" (Table 1 and Figure 3; Appendix A, Table 1).

To facilitate grouping the distributional records and comments in both tables and text, I have utilized the administrative regions established by the Department of Conservation. Region 1 is the entire Upper Peninsula. Region 2 is the northern half of the Lower Peninsula with its southern boundary an imaginary line extending from the City of Muskegon to the City of Bay City. Region 3 is the southern half of the Lower Peninsula south of this imaginary line.

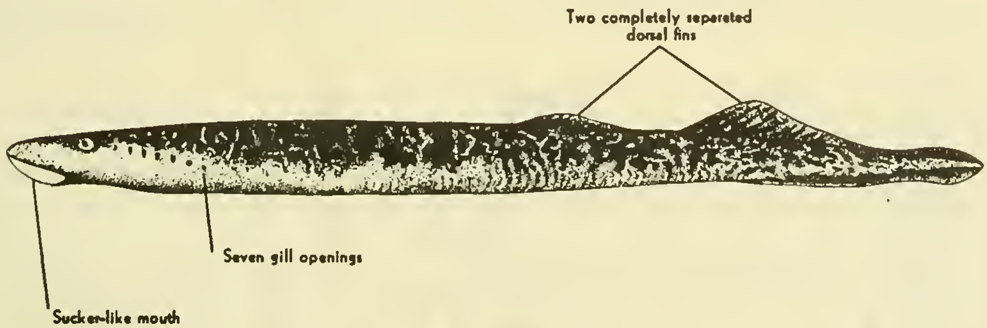
FISHERMEN!

YOUR COOPERATION IS REQUESTED

THE SEA LAMPREY IS SPREADING RAPIDLY THROUGH MICHIGAN WATERS AND IS BELIEVED TO BE A MENACE TO THE COMMERCIAL FISHERIES OF OUR STATE. THE DEPARTMENT OF CONSERVATION IS ENGAGED IN A PROGRAM TO LEARN METHODS OF CONTROL OF THIS FISH PARASITE.

SEA LAMPREYS MIGRATE INTO MANY OF OUR STREAMS AND RIVERS EACH SPRING TO SPAWN.

IF YOU SEE ONE OR MANY OF THESE PARASITES IN A STREAM OR RIVER, PLEASE NOTIFY THE LOCAL CONSERVATION OFFICER OR THE NEAREST STATE FISH HATCHERY. OR, IF THIS IS NOT PRACTICABLE, WRITE CONSERVATION DEPARTMENT, LANSING.



SEA LAMPREY

Adult sea lampreys usually will be more than a foot long. They usually appear mottled with brown and black on the backs and they may have a somewhat golden tint.

MICHIGAN DEPARTMENT OF CONSERVATION

Figure 1.--Poster utilized in 1947 and 1948 to request the aid of the public in reporting sea lamprey spawning runs.

INSTITUTE FOR FISHERIES RESEARCH
Division of Fisheries
MICHIGAN DEPARTMENT OF CONSERVATION

REPORT OF SEA LAMPREY SPAWNING RUN

County__________ Main Drainage__________
Name of stream__________ Trib. to__________
Point of examination__________
(Locate to section or fraction if possible)

(Check appropriate answers unless otherwise indicated)

VERY IMPORTANT!

1. How many sea lampreys were observed by you:
   One or several? ______ A large number?______

2. Under what conditions were they observed:
   During passage upstream?______
   On or using their spawning beds?______
   Attached to some species of fish?______
   Below a dam?______
   At a weir?______
   (Other?)______

3. What is your estimate of the size of the run:
   Scattered migrants only? ______
   A small number of migrants? ______
   A moderate number of migrants? ______
   A large number of migrants? ______

4. If sea lampreys were observed on their spawning grounds, you may be able to estimate the number present and the extent of the spawning grounds:

   What is your estimate of the number of spawners? ______

   What is your estimate of the spawning area being used (use convenient linear measure)? ______

5. Where you made your observations, what was the:

   Water temperature?______ Air temperature?______ Time?______

   Color and turbidity of the water:
   White?______ Light brown?______ Brown?______
   Clear?______ Turbid?______ Heavily silted?______

   Stream bottom type: mud?______ sand?______ gravel?______
   rubble?______ rocky?______

   Current: Sluggish?______ Moderate?______ Rapid?______

   Width of stream?______ Depth______
   (feet or yards)

6. Were other species of lampreys observed:
   Michigan brook lamprey?______ American brook lamprey?______
   Chestnut lamprey?______ Silver (lake) lamprey?______

7. Are you forwarding a sample specimen for final verification:
   Yes?______ No?______

\-\-\-\-\-\-\-\-\-\-\-\-

Date that observations were made______

Time______ Observer______
(Please sign)

Source of original report of run______

\-\-\-\-\-\-\-\-\-\-\-\-

This report is to be prepared after verifying the presence of migrating sea lampreys in a stream or river and may be used to record either the results of personal surveys made or the verification of reports received by you from other persons or agencies.

Please answer all questions, sign the form, and forward as soon as possible to Vernon C. Applegate, P.O. Box #72, Rogers City, Michigan.

Any notes or comments will be helpful and may be entered in the following space:

Figure 2.--Questionnaire utilized during the inventory by field personnel for reporting sea lamprey runs.

Table 1. Summary of reports of migrating or spawning sea lampreys in Michigan streams in 1947 and 1948.

Drainage	Total reports in 1947[1]	Total reports in 1948[1]	New records in 1948[1]	Grand total of distributional records for 1947 and 1948[1]
Upper Peninsula (Region 1)				
Lake Superior	2 (1)	2	2	4
Lake Michigan	12	8 (2)	5 (2)	17 (2)
Lake Huron and Munuscong Lake	2	2	1	3
Subtotals	16	12	8	24
Lower Peninsula (Region 2)				
Lake Michigan	24	15 (2)	6 (1)	30 (1)
Lake Huron	27 (3)	16 (2)	3 (1)	30 (4)
Subtotals	51	31	9	60
Lower Peninsula (Region 3)				
Lake Michigan	16 (5)	15 (7)	5 (3)	21 (8)
Lake Huron	0	1	1	1
Lake Erie	0	0	0	0
Lake St. Clair	0	2 (1)	2 (1)	2 (1)
Subtotals	16	18	8	24
Totals	83[1]	61[1]	25[1]	108[1]

[1] Both verified and reliable reports are combined in totals. Numbers in parentheses are numbers of reliable reports included in figure preceding them.

Present distributional records convey the impression that most sea lamprey spawning activity occurs in the northern half of the Lower Peninsula of Michigan (Table 1 and Figure 3). This impression is probably correct although I do not believe that the true extent of the sea lamprey spawning populations in the southern half of the Lower Peninsula has been fully determined. The spring of 1947 was an extremely wet season, and in 1947 and 1948 more or less sustained flood conditions existed in southern Michigan (Region 3) streams during the migratory and spawning period. Turbid, flood waters interfered materially with stream observations in these years with the probable result that many runs were not discovered. These conditions were particularly evident in southeastern Michigan where very few runs were reported in either year. For example, in the Huron and Clinton rivers no runs were identified in these years. These same streams were utilized by sea lampreys as early as 1932 and 1938 respectively. There is no reason to assume that these waters would no longer be in use. However, I do not believe that extensive sea lamprey spawning activity will ever be found in this region. Sluggish currents, and particularly the predominantly sandy and/or silted character of many stream beds in this area, preclude spawning by the sea lamprey. The lampreys require at least some small gravel with which to build their nests and spawning was only observed in those streams of Region 3 in which there were at least small patches of gravel.

The greatest activity in the Upper Peninsula (Region 1) was confined to the Lake Michigan drainages. A survey of streams entering Lake Superior in the western third of the Upper Peninsula was conducted in 1947 and 1948 by Mr. Leland Anderson, District Fishery Biologist at Watersmeet. Fifty-six streams were examined by him in each year between the last week of May and July 11. No evidence of runs was found although the habitats examined in this area were generally suitable for lamprey use. In streams entering Lake Superior from the eastern part of the Upper Peninsula, only a few sea lamprey runs have been verified and these are located at the most eastern extension of the lake. The paucity of data relative to runs in this area may be due to the interaction of several factors: (1) the area is quite inaccessible to observation and the human population for spotting runs is sparse; (2) the species is in its initial stages of penetration in Lake Superior; and, (3) there may be a general ecological unsuitability for the species in this basin. A moderate spawning run was observed in the Tahquamenon River by Dr. Frank Jobes of the U. S. Fish and Wildlife Service in June, 1948, but not in any other Lake Superior drainage which he examined in the eastern two-thirds of the peninsula. Field personnel of the Conservation Department captured specimens to verify the presence of the species in two additional eastern Lake Superior tributaries.

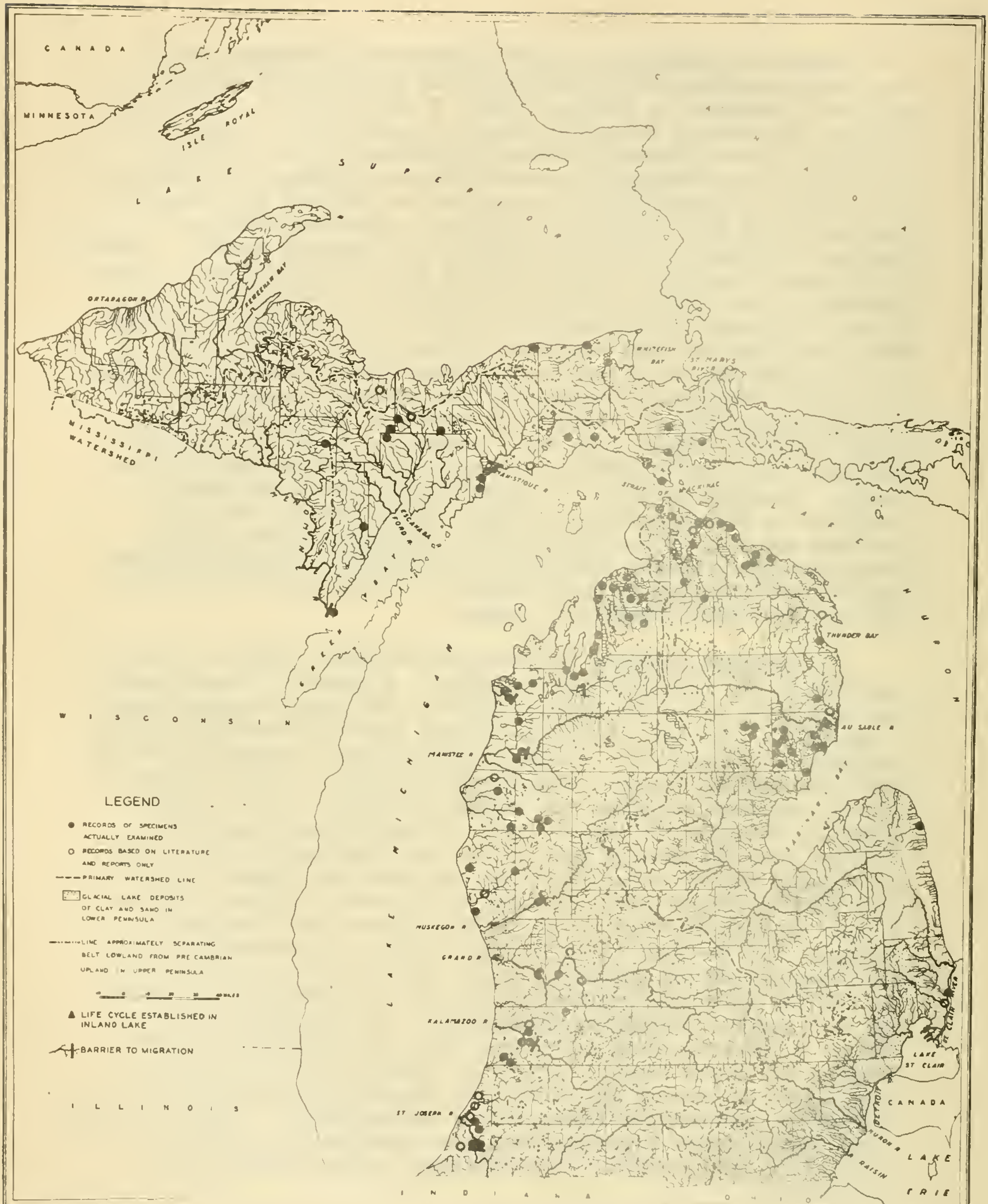


Figure 3.--Distribution of migrating and spawning sea lampreys observed or reliably reported in Michigan streams in 1947 and 1948.

A survey of the streams of the eastern tip of the Upper Peninsula from the Sault Ste. Marie to St. Ignace was made by me in June, 1948. Reports had previously been sparse or lacking for this area. Twenty watersheds and/or small streams were examined including five on Drummond Island. With one exception, no sea lampreys or evidence of sea lampreys were found. Generally, in all of the watersheds examined in this area, the streams had a low gradient and the current was sluggish in both tributaries and main channel. Bottom types were almost exclusively silt, sand, or clay in varying combinations. Silt loads were heavy in the larger watersheds. Stream characteristics in this area (eastern Chippewa and Mackinac counties) are quite unsuitable for sea lamprey spawning.

On this survey, sea lampreys were found in Taylor Creek, a tributary of the Munuscong River. Unlike the balance of this watershed which was examined, Taylor Creek had a moderate gradient, clear water, and areas of rock, rubble, and gravel riffle. Spawning activity observed was limited.

Easier access, moderate flood conditions, and extensive areas suitable for sea lamprey spawning facilitated the inventory of streams in the northern half of the southern peninsula (Region 2). I believe that we have definitely located the sites of the major spawning runs in this area. Unfortunately we have very little accurate data as to the actual magnitude of most of these. The records on magnitude are largely crude estimates (Appendix A, Table 1).

Generally speaking, sea lamprey spawning runs occur in every major Michigan river system in the Lake Michigan basin: The St. Joseph, Kalamazoo, Grand, Muskegon, Pere Marquette, Manistee, Platte, Boardman, Manistique, and Menominee. These rivers support the largest runs observed in this basin. In northern Lake Huron (north of Saginaw Bay) all major drainages attracted spawning migrants: the Rifle, Au Gres, Au Sable, Thunder Bay, Ocqueoc, and Cheboygan. Again, these were the largest runs observed in this area.

Establishment in inland lakes

Until this inventory, there was some conjecture as to whether the sea lamprey could, or would, become established in some of our large and rather deep inland lakes although the species is known from certain of the Finger Lakes in New York. Proof follows that small populations of this fish are passing their adult, parasitic period in Burt and Mullet lakes, Cheboygan County. Furthermore, these small populations are apparently creating limited spawning runs of their own in tributaries of the Cheboygan River drainage of which the lakes are a part. The Cheboygan River itself is blocked at its mouth by a power dam which in itself constitutes a virtual barrier to further migration of the large run entering that river each year from Lake Huron. Unfortunately this barrier is accidentally by-passed in two ways: first, a boat lock, adjacent to the dam, is occasionally operated during the spring season and undoubtedly acts as an efficient "fish elevator"; secondly, some are known to escape upstream from youngsters who consider it fine sport to dip sea lampreys at the base of the spillway of the dam and occasionally throw the lampreys over the causeway atop the dam into the upper river channel.

The evidence supporting establishment of the sea lamprey in Burt and Mullet lakes is itemized as follows:

(1) A sexually immature adult sea lamprey, 15.1 inches long (weight: 135 grams), was taken in Burt Lake on August 1, 1947. This specimen was attached to a rainbow trout.

(2) A sexually immature adult sea lamprey, 12.2 inches long (weight: 68 grams), was taken in Mullet Lake off the mouth of Nigger Creek on August 1, 1947. This specimen was attached to a sucker.

(3) An adult sea lamprey, attached to a sucker, was taken in Mullet Lake near Topinabee on August 16, 1945 (Specimen identified by Dr. C. W. Creaser.)

(4) A spawning migrant was observed in the Sturgeon River (tributary to Burt Lake) at Wolverine on June 24, 1947.

(5) An adult, female sea lamprey was captured by fishermen in the Pigeon River (Otsego County, T32N, R1W, S.10) on June 11, 1948 (identified by W. R. Crowe). Sea lamprey redds were observed by W. R. Crowe in the Pigeon River (Cheboygan County, T34N, R2W, S.10) on or about June 9, 1948. The Pigeon River is a tributary of Mullet Lake.

(6) The report of a spawning run in Laparell Creek, tributary to the Cheboygan River below Mullet Lake, is considered reliable.

Items one to three alone are considered adequate evidence of establishment of the species in these lakes. Data collected elsewhere seem to indicate that transforming and newly-transformed sea lampreys generally do not become established in smaller and/or less suitable lakes in a watershed, but pass directly downstream to the Great Lakes.

Other inland lakes, connected more or less directly with the Great Lakes, are undoubtedly acting as additional reservoirs for adult populations. We have received several reports of adults being taken during the winter months in Lake Charlevoix (Charlevoix County) on speared whitefish, perch, and ciscoes. Dr. A. H. Stockard of the Zoology Department, University of Michigan, reported on November 6, 1947, that fishermen in Lake Charlevoix were spearing sea lampreys that had attached themselves to the bottoms of their power boats. Fishermen trolling in the same lake report sea lampreys attaching themselves to the stern of the moving boat.

We have also received several reports indicating the presence of sexually immature adults in Pentwater Lake, Oceana County. Like Lake Charlevoix, this lake is connected directly with Lake Michigan by a short channel. The most reliable of these reports concerned an 18.5-inch sea lamprey attached to a 5-pound rainbow trout that was taken on November 1, 1947. Reports of sexually immature adults in Big Platte Lake, Benzie County, and White Lake, Muskegon County are likewise considered reliable.

Lake Fenton, Genesee County; Little Traverse Lake, Leelanau County; Lake Genesarath, Beaver Island; Round Lake, Kalkaska County; Pipestone Lake, Berrien County; and Big Paw Paw Lake, Berrien County; allegedly contained sea lampreys in 1947 or 1948 but I consider these reports doubtful.

Effect of obstructions and barriers to migration

For the purposes of this discussion, a barrier to migration is differentiated from an obstruction to migration in that the former cannot be surmounted by migrating sea lampreys whereas the latter can be passed with varying degrees of difficulty, which may have some selective action among the migrants. The sea lamprey can and does negotiate many kinds of falls and low or irregularly constructed dams of moderate height. A good example of this is in the Ocqueoc River, Presque Isle County, where nearly one-half of the spawning migrants work their way over two natural falls, 4.5 and 6 feet high, and an old cement mill dam (Figures 4 and 5). In another instance, migrants are known to pass over (or through?) an irregularly constructed logging dam of some height situated in Silver Creek, Iosco County.

Figure 4.--Lower Falls, Ocqueoc River, Presque Isle County, which lampreys negotiate upstream. May 17, 1947.

Figure 5.--Upper Falls, Ocqueoc River, Presque Isle County, which lampreys negotiate upstream. May 17, 1947.

Some man-made dams, in rivers known to have sea lamprey runs, apparently are effective barriers to further upstream movement (Figure 6). In the light of present information we tentatively consider certain of these structures to be impassable for two reasons: (1) the nature and/or structure of the dam and the manner of passage of water over it, or through its power units, precludes possibility of surmounting the dam, and (2) as yet, no reports of the presence of sea lampreys have been verified above the barriers (except the Cheboygan dam). Dams at present thought to be insurmountable to lampreys are located in the following rivers: Menominee, Manistique, Cheboygan, Au Sable, Elk, Boyne, Boardman, Betsie, Manistee, Muskegon, Kalamazoo, and St. Joseph (see Appendix B for specific location and structural details).

The greater portion of some of the major watersheds of Michigan lie above these dams (Figure 3). In the St. Joseph, Kalamazoo, Muskegon, Manistee, Manistique, Menominee, and Au Sable rivers, the sea lamprey is thus denied access to tremendous potential spawning areas. This condition has doubtlessly restricted, to some degree, the rate of increase of the species and most certainly limits the total numbers which Michigan watersheds might otherwise produce.

It should be considered hereafter that any improvement of the apparently ineffectual fish ladders and chutes present on most of the aforementioned dams will materially aid the sea lampreys in reaching new spawning grounds and increasing their total numbers.

The Cheboygan, Elk River, Manistique, and Menominee dams are all located very close to the mouths of their respective rivers. Each year large spawning runs enter these rivers and are in evidence below the dams throughout the migratory period. The fate of these migrants is still unknown. It does not seem likely that they can spawn successfully in the deep estuaries prevalent below these dams. Assuming that they cannot spawn below such dams, two alternatives are afforded: (1) they make their way to other accessible streams nearly along the shore line; or (2) they remain in or near, the estuary of the river which they entered and ultimately die without spawning. The second condition might be more prevalent than the first primarily because of a possible parallel in physiology and habits between the sea lamprey and the Pacific salmons which die without spawning when blocked from their spawning grounds.

IV. Sea lamprey spawning runs

Investigations of spawning runs of sea lampreys were made in the field between April 1 and September 1, 1947, March 15 and September 1, 1948, and March 15 and September 30, 1949. I here report first on the biological characteristics of, and factors affecting, the spawning runs of sea lampreys entering Carp Creek,

Figure 6.--Foote Dam on the Au Sable River (Iosco County).
Photo by L. N. Allison.

Presque Isle County, in these years. Supplementary information of a similar nature was gained in the Ocqueoc River, also in Presque Isle County. Later discussions of spawning habits and spawning requirements of the sea lamprey are based on data collected in 1947 and 1948 only. Many other observations made during all periods, in these and other localities, are incorporated where it seems most pertinent.

These studies were undertaken in an effort to obtain more precise information than heretofore existed of that phase of the life history of the sea lamprey beginning when it enters streams to spawn. The information obtained has become of paramount importance because of the widely publicized demands for the control of this fish predator which have specified the construction of "lamprey weirs" for the capture and destruction of spawning populations. The investigations undertaken at Carp Creek and the Ocqueoc River were designed to learn the requisites of an effective sea lamprey weir on a small and on a large stream, the cost of such structures, and problems in their operation and maintenance--in addition to the biological information which would be forthcoming through the operation of these structures. It was also intended that the repeated use of these weirs in succeeding seasons might provide some index of the relative abundance of the sea lampreys in the general area of northern Lake Huron in those years. It would be of obvious value to know if the population is increasing or decreasing, or if it has become relatively stable in numbers. Furthermore, continued operation of these weirs over a period equivalent to at least one larval cycle might provide a test as to whether the "home stream" or "parent stream" theory applied to this species in any degree.

The general area of the Ocqueoc River and Carp Creek watersheds was selected for study because of the intense local interest in the sea lamprey problem. This interest was engendered by the large runs which entered the Ocqueoc River in increasing numbers during the past decade. In the spring of 1944 and again in 1945, the East Presque Isle County Sportsman's Association operated a weir in the lower Ocqueoc River in cooperation with the Department of Conservation. In each year, a fair proportion of the sea lamprey run was captured (Shetter, 1949).

From 1946 to 1948 no weir was in operation for the capture of spawning migrants in the Ocqueoc River. The construction of a permanent sea lamprey weir in this river was undertaken in the summer of 1948 by the United States Fish and Wildlife Service. After completion of this structure in September of that year it was turned over to the Michigan Department of Conservation for operation and maintenance for a ten-year period.

Other than Shetter's report and general discussions by Applegate (1947, 1949), only one other published report of sea lamprey spawning runs in the upper Great Lakes has been presented: MacKaye and MacGillivray (1949) give data on the numbers of migrant sea lampreys captured in several types of traps in six Ontario streams tributary to the North Channel of Lake Huron.

Carp Creek investigations

(1) Carp Creek

Carp Creek is tributary to Hammond Bay of northern Lake Huron, flowing into that bay about four and one-half miles north of the outlet of the Ocqueoc River. The primary drainage area of this creek lies within Sections 1, 2, and 3, T36N, R2E, Presque Isle County. Carp Creek proper is 1.5 miles in length between its estuary and its origin in Carp Lake. The latter is about 70 acres in surface area and has a maximum depth of 24 inches! The shoreline on nearly all sides is encroaching. Approximately six square miles of swampland drains into Carp Lake primarily as surface drainage. No discrete year-around streams flow into the lake, as many recent maps would lead one to believe.

The potential sea lamprey spawning areas of the Carp Creek drainage basin lie in the 1.5 miles of the creek proper between Carp Lake and its mouth. This portion of the stream has a moderate overall gradient. Gravelly riffle areas alternate with deeper pools (1 to 4 feet) which have a barren clay bottom. Little shifting sand is present until the creek enters the beach line just upstream from the estuary. Cover, composed predominantly of cedar and birch, is heavy, and more than a mile of the stream lies in dense shade. Reportedly, in very dry years Carp Creek is reduced to a mere trickle in midsummer but local opinions on this matter are very conflicting. During 1947, a moderate volume of flow was present throughout the entire summer months. Although classified as a "trout stream", high water temperatures in summer (78 degrees F. to 82 degrees F.) give little evidence of suitable trout habitat. The color of the water is typical of many northern streams draining swampland, being generally quite tea-colored. Water chemistrys varied little during the spring months. A typical analysis on June 29, 1947, a windless, partly overcast day, was as follows (previous weather clear):

Station------U. S. 23 Highway Bridge	CO_2--------0.0 ppm.
Time---------9:45 A. M.	Phenolphthaline Alkalinity---------2.0 ppm.
Air Temp.----70 degrees F.	Methyl Orange Alkalinity------118.0 ppm.
Water temp.--72 degrees F.	O_2--------7.3 ppm.

Sea lamprey runs had been noted in this stream by Conservation Officers and local residents for several years prior to 1947. I strongly suspect that its history in this regard dates back to the first runs noted in the neighboring Ocqueoc River by local residents (circa 1934-35) for both streams undoubtedly draw from a common stock of adults living in, or entering, Hammond Bay. Being thus assured of a run upon which we could experiment, a site for the construction of a sea lamprey weir was selected just below the U. S. 23 highway bridge crossing the stream. This site, located within the highway right-of-way, was easily accessible for construction and maintenance, and was only a few hundred feet above the estuarine waters of the creek. This latter point is of importance in control since to be most effective, a sea lamprey weir should be placed ideally downstream from the lowest potential spawning area.

(2) The Carp Creek sea lamprey weir

The weir and trap constructed in Carp Creek was of the single "V" type with the trap placed at the apex of the "V". The stream is 22 feet wide at the point of construction and each wing of the "V" was 18 feet long (Figures 7-10). This structure was originally built as a temporary weir, pending the completion of a more elaborate, permanent device. Due to difficulties in installation, the latter was abandoned and the temporary structure was improved and made more nearly permanent. For supporting the screen face of the wings, 9-foot, steel, snow-fence posts were driven into the bottom; each was buttressed on the downstream side with an identical post. Four additional posts were driven as anchors for the box-type trap. Sections of salvage rock and gravel screening, 28 inches by 9 feet, were wired to the upstream side of the steel posts. Placing them in pairs, one above the other, gave each wing a height of 56 inches. This screen was of inch mesh, heavy gauge wire (3/16-inch diameter) reinforced along one edge with angle iron, and therefore quite rigid. Using this coarse grid for support, hardware cloth of 1/2-inch mesh was laid against the upstream side of the heavy screening and wired to it. The wings were joined at the shore to a baffle of double

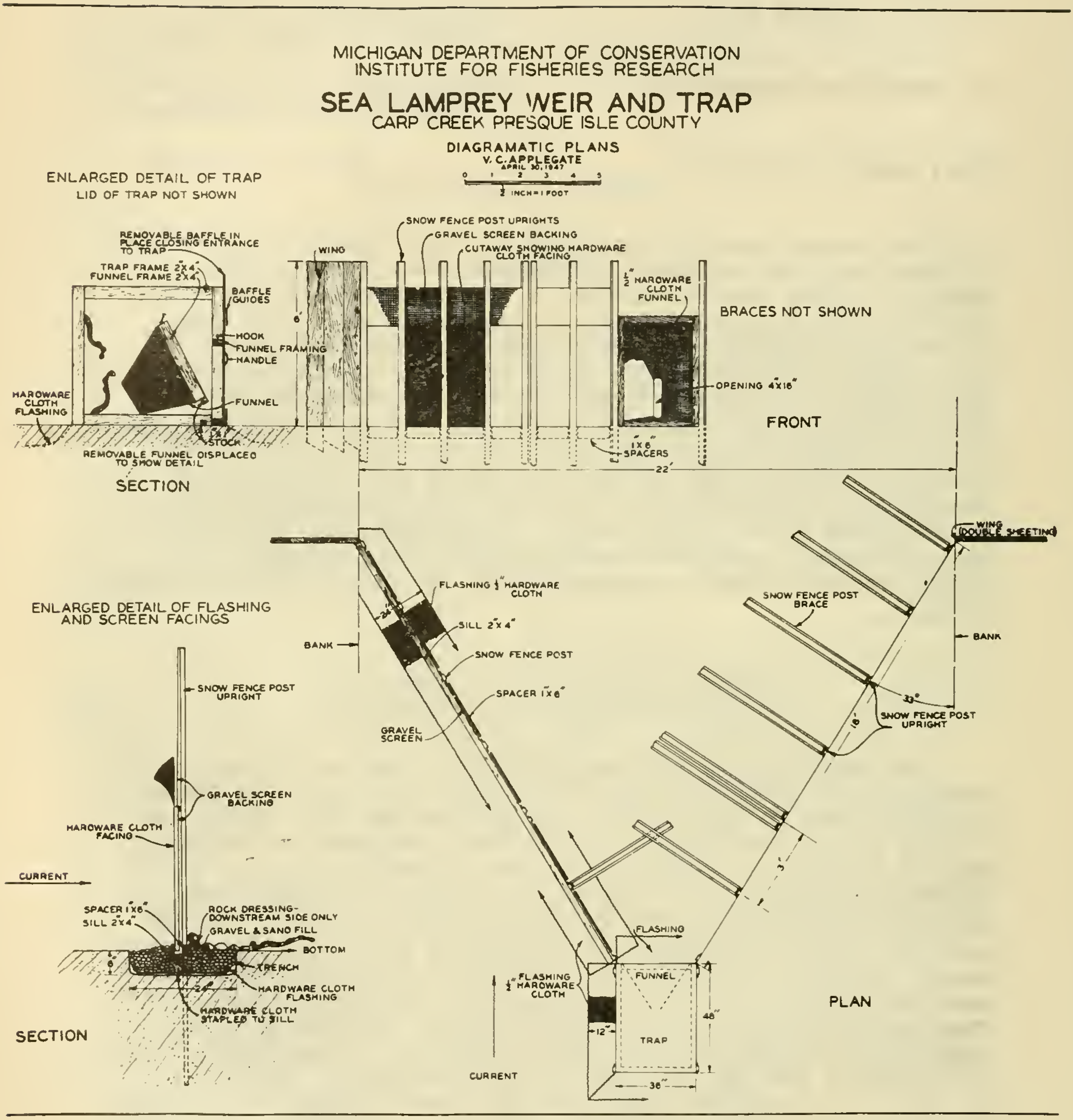


Figure 7.--Diagrams of Carp Creek sea lamprey weir.

Figure 8.--Carp Creek weir, May 5, 1947. Note damming action of weir screen prior to cleaning. This screen had been cleaned six hours earlier.

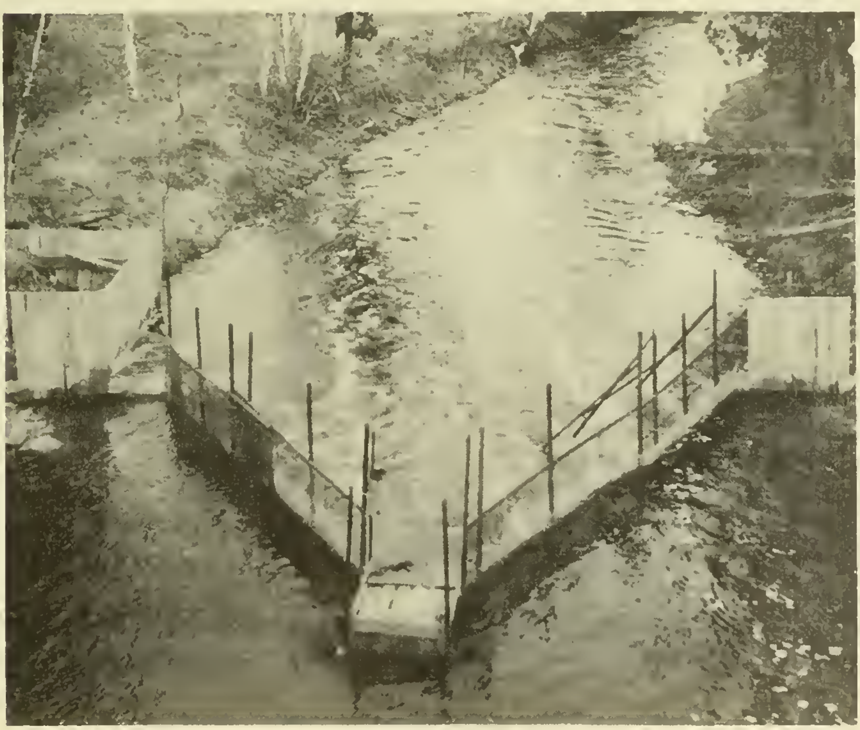


Figure 9.--Carp Creek weir, May 5, 1947. Looking downstream.

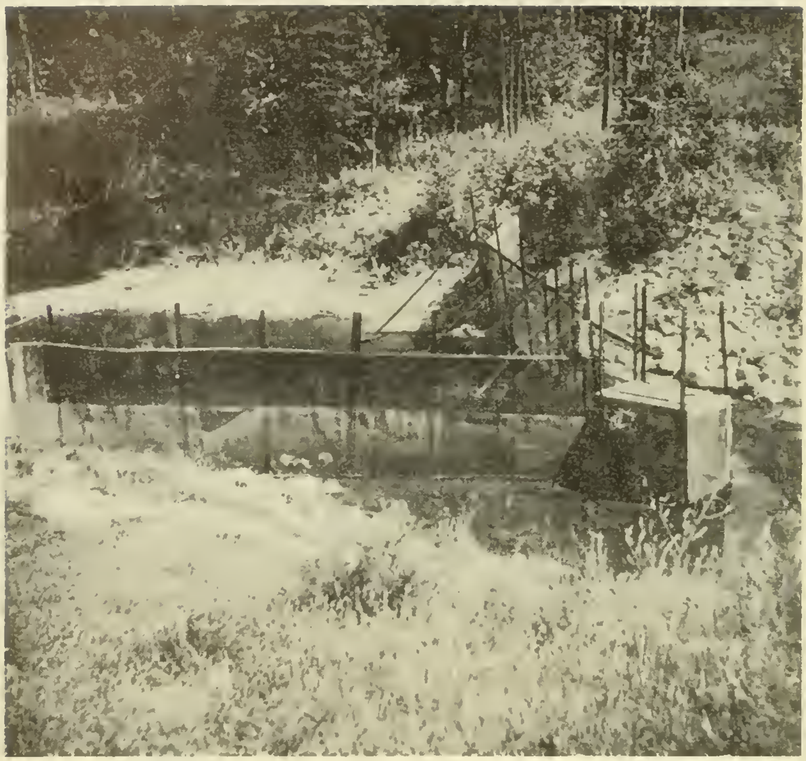


Figure 10.--Carp Creek weir at low water stage. July 1, 1947.

sheet piling, driven into the softer bank; they were also secured at the trap, on each side of its entrance. The greatest problem was anchoring the wings and trap to the stream bottom in order that no undercutting would take place. It was impossible to drive sheet piling for this purpose since beneath a shallow layer of gravel the stream bed was composed of very hard clay. To circumvent this, a trench two feet wide and six inches deep was dug astraddle the line of fence-post uprights. A strip of hardware cloth the length of the wing and 24 inches wide was nailed to a 2 inch by 4 inch wood sill of equal length and placed, hardware cloth down, in the trench, with the sill braced against the upstream side of the uprights. The bottom edge of the lower gravel screen rested on this sill. Spacers of 1 inch by 6 inch wood planking were added on the downstream side, between the uprights, to prevent any buckling of the gravel screen backing (see detail, Figure 7). After the hardware cloth had been added, the trench was filled with heavy gravel and sand. A dressing of larger rocks was placed on the downstream side to prevent scouring.

The trap was a simple box-like frame (36 inches by 48 inches by 48 inches) of 2 inch by 4 inch lumber covered with 1/4-inch mesh hardware cloth and built as a single movable unit. Its funnel, fabricated of hardware cloth and a 2 inch by 4 inch wood frame, was removable after insertion of a closing baffle on the front of the trap. This facilitated taking out both lampreys and fish.

The original structure without the subsequent improvements was fabricated and installed in two working days by four men. Problems in construction were minimized by low water levels and the relatively small size of the stream. The sill and flashing of hardware cloth which was substituted for sheet piling proved very satisfactory and is strongly recommended for semi-permanent structures on those sites where the nature of the bottom prevents the driving of piling; it is inexpensive to fabricate and very easily installed.

On or about August 1 of each intervening summer, all of the weir except the steel upright parts and the sills and flashing was removed from the creek and stored overwinter until reinstallation just prior to the beginning of the sea lamprey runs in the early spring.

The basic requirements of an effective sea lamprey weir are that it be strong enough to withstand the impact of maximum flood waters and that it be high enough and wide enough to remain fish-tight under like conditions. The Carp Creek weir withstood severe flood conditions on three occasions. On May 31, 1947, the north wing partly buckled due to improper bracing during a period of very high water. This wing was completely removed and rebuilt on May 31 and June 1, 1947.

The weir in its final form was essentially lamprey-tight. I consider that over 99 percent of the sea lamprey run was captured in the years 1947 and 1948 and that the complete run was captured in 1949. We discovered early that a sea lamprey will find and make use of the smallest, and perhaps only, aperture in a large barrier. Consequently, we continually checked all possible loci of escapement with our hands as part of the routine visits to the weir. On May 9, 11, 14, 29, and July 1, 1947, the creek was patrolled from Carp Lake to the weir. On all but the last date, no trace of sea lampreys was found. On July 1, I found five nests about three-quarters of a mile above the weir. Eggs were found in two nests and promptly destroyed. The other three nests contained no eggs although they had evidently been completed for several weeks. I suspect that the escapement accounting for all these nests, which probably did not exceed ten individuals, occurred during the period May 31-June 1 while the north wing of the weir was being repaired.

In 1948, the creek was patrolled on May 31, June 14, and July 2. The only evidence of escapement was two sea lamprey nests about one-half mile above the weir, found on May 31. One was completed and contained developing eggs which were promptly destroyed by maceration of the nest. The other nest was only partially completed and contained no eggs. No adult lampreys were seen. Subsequent visits indicated no further work on the incomplete nest and no other nesting activity.

In 1949 the entire stream course was patrolled on June 10 and June 28. No evidence of any escapement above the weir was discovered.

(3) Collection of data

The Carp Creek sea lamprey weir was in effective operation from April 21-August 1, 1947, April 6-July 15, 1948, and from April 8-July 19, 1949. Normally, the weir-trap, while in operation, was inspected and the fish and sea lampreys removed three times each day. I scheduled these visits to be made as close as possible to 8:00 A. M., 5:00 P. M. and midnight each day. All specimens removed at each of these times were recorded as separate collections.

Of the entire sea lamprey run in 1947 (1,617 specimens), all but 17 specimens were examined for sex, length, weight, stage of maturity, and contents of the digestive tract. More detailed examinations were made of 328 specimens. All sea lampreys of the 1948 run (2,939 specimens) except eight individuals were examined for sex, length, stage of maturity, and contents of the digestive tract. All specimens examined in both of these years were scrutinized for evidences of parasitism, pathological conditions, and structural abnormalities. In 1949, the sex of all sea lampreys composing the run (2,763 specimens) was determined and length data were obtained from all, or almost all, sea lampreys entering the creek during alternate 24-hour periods (1,371 specimens).

All individuals of other species taken in the trap were examined for evidence of sea lamprey attacks and these data were recorded.

A maximum-minimum thermometer was maintained in the creek just above the weir from April 16-June 30, 1947, April 6-July 15, 1948, and April 5-July 18, 1949. Readings were made daily during the morning visit and the water temperature at this time was noted with a pocket thermometer in order to verify records on the fixed thermometer. On June 30, 1947, the maximum-minimum thermometer was found to have been broken by some inquisitive visitor and thereafter only readings at the time of the visit were recorded in that year. Frequent records were made of the surface water temperatures at the mouth of the creek and in Hammond Bay itself. Water gauge readings were made and recorded in inches and fractions and represent absolute depth in midstream just below the weir. Daily records of wind and other weather conditions were made and these data were supplemented with similar records maintained by Mr. G. W. Hansen, 40 Mile Point Light Station, Lake Huron.

Since virtually all sea lamprey migratory activity in Carp Creek occurred during the hours of darkness, the data were arranged so that all individuals entering the trap during any one night were tabulated as a unit. Thus the catches subsequently designated for any given day (which are listed at the time of the morning visit) represent the migration into the trap since the morning visit of the preceding day (approximately 23 clock hours since the trap would be closed about an hour each day while the fish were being removed). Maximum, minimum, and mean water temperatures recorded likewise reflect conditions which existed during the 24-hour period prior to about 8:00 A. M. on any date.

Ocqueoc River investigations

The sea lamprey run in the Ocqueoc River during 1947 and 1948 was not impeded by any weir, trap, or other man-made structure. For this reason, it was used in those years as an area for the study of the migratory and spawning habits and spawning requirements of the sea lamprey. In addition to these observations, a series of samples of the sea lamprey run were obtained in 1947 to augment the materials collected at Carp Creek. In the summer of 1948, a sea lamprey weir and trap was completed in the Ocqueoc River and was operated during the spring and summer of 1949 to capture the spawning run. Since the data for both streams are combined or drawn upon in the subsequent analyses, a brief description of the river and methods and places of collection are presented herewith. Further details of the physical characteristics of the Ocqueoc River watershed will be presented in the section on spawning habits and spawning requirements of the species. A description of the sea lamprey runs entering this river in 1944 and 1945 has been published by Shetter (1949).

(1) The Ocqueoc River

This river is by far the largest stream entering Hammond Bay. It flows in a northerly direction from its headwaters to Ocqueoc Lake and from there, almost due east into the bay. Its watershed drains most of six townships. Its depth in the spring months varies from about 8 inches in the riffle areas to 9.5 feet in its deeper pools. The river varies from 24 to 80 feet in width during the same season. Throughout the upper third of its course where it flows through a chain of lakes, the current is predominantly sluggish and the bottom silted. The balance of the stream, flowing first through pastured land and woodlot, and then through a wooded valley, is characterized by swifter currents and bottom types of rock, rubble, gravel, and sand.

In 1947, sea lampreys spawned in varying concentrations throughout the entire lower two-thirds of the river. The farthest point upstream at which spawning occurred was 16.5 miles above the mouth (T34N, R4E, S.19). It is estimated (on the basis of nest counts and specimen samples obtained) that between 10,000 and 11,000 sea lampreys entered the Ocqueoc River in 1947. On the same basis, it was estimated that 13,000 sea lampreys entered the river in 1948. Of four permanent tributaries of the Ocqueoc River, a small number of sea lampreys entered two, and spawned. These were the Little Ocqueoc River and Silver Creek. The remainder, Indian Creek and the Orchard Lake Outlet (tributary to Ocqueoc Lake) did not contain subsidiary runs.

(2) The Ocqueoc River sea lamprey weir

In August and September, 1948, a large sea lamprey weir with both upstream and downstream traps and of a semi-permanent type of construction, was installed in the Ocqueoc River about 1,000 feet (of stream course) above the mouth of the river. It is located on the right-of-way of U. S. Highway 23 just above the road bridge. This was the lowest practical point of construction in the watershed. No potential sea lamprey spawning grounds exist between it and the mouth of the river.

Plans of this structure are too large and too detailed for inclusion here. Briefly, its basic construction was as follows. The weir is of the straight, 90 degree angle type, i.e., it is built straight across the stream at right angles to the current. Its functional width (from solid abutment to solid abutment) is 80 feet. It is effective as a fish barrier to a height of 5 feet, 4 inches above its own deck. A downstream trap is located at midstream in the weir and two upstream traps, each located midway between the downstream trap and each abutment, are present (Figures 11, 12).

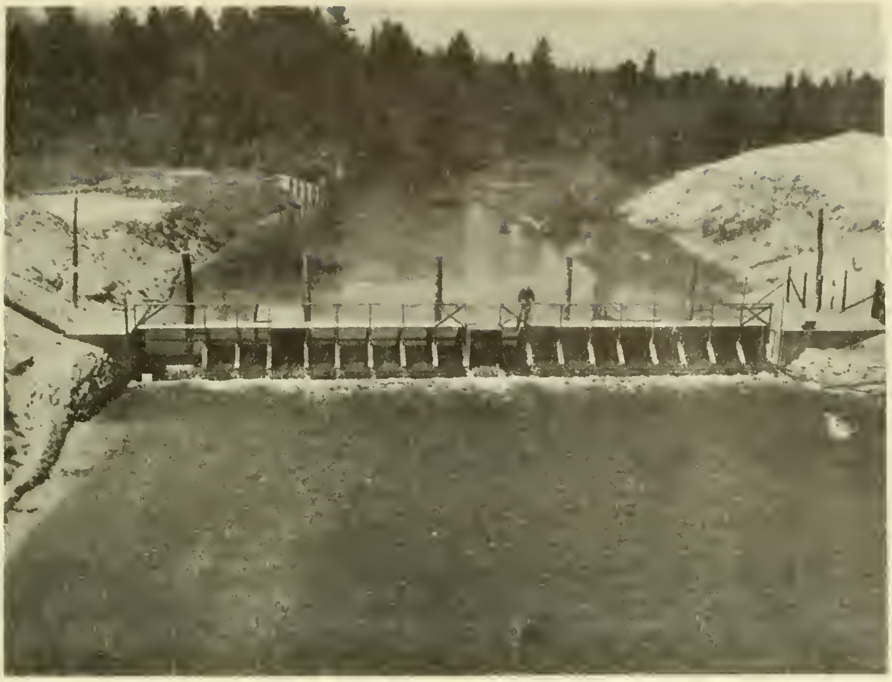


Figure 11.--Ocqueoc River sea lamprey weir. View from downstream.

Figure 12.--Ocqueoc River sea lamprey weir. View from upstream.

The weir substructure consists of a plank deck, 2 inches in thickness, and 12 feet wide by 80 feet long, which is anchored to the stream bed by three rows of Wakefield piling driven 5 feet into the bottom. The plank deck was initially flush with the stream bed. A 4 inch by 6 inch timber beading is anchored to the "head" and "tail" of the plank deck.

Large A-frames, sitting on the deck and between the beadings, form the supporting members of the superstructure. These are removable, being anchored to the beadings by drift pins. Against the upstream face of the A-frames lie sectional steel grates measuring 4 by 7 feet. These grates pivot on their stream-bottom edge and may be thrown over to lie on the bottom to allow the passage of unusual floods. The spacing between each bar of the grates is 1/2-inch.

The inside dimension of all traps is 4 feet by 5 feet. Funnels leading into the traps are of 3/16-inch mesh hardware cloth and the funnel openings measure 4 inches by 12 inches.

Substructure and superstructure are sealed to the river banks by earth filled abutments, 12 feet wide and slightly higher than the weir. A plank catwalk for access completes the structure.

This weir and trap were operated for the capture of the spawning run from March 31-September 30, 1949. Following certain improvements, the weir functioned satisfactorily and was, like the Carp Creek weir, essentially lamprey-tight. On various dates between May 15 and July 15, 1949, four complete patrols of all sea lamprey spawning grounds in the Ocqueoc watershed were made. Several spawning areas, used extensively in former years, were visited six or seven times.

On June 6, 1949, some evidences of a small escapement above the weir was found in a one-half mile stretch below the Ocqueoc Falls. Six nests were present, about half completed and without eggs. Two adults, one on each of two nests, were found and removed by spearing. One was a ripe, unspawned male, 14.2 inches long--the other was a ripe, unspawned female, 12.5 inches long. Forty-seven sites of very preliminary nesting activity were likewise observed in this area. Since a male sea lamprey will frequently make several trial nests before settling on a final site, the above figures do not imply that an equivalent number of lampreys were present in the watershed. Subsequent visits indicated continued nesting activity at five sites but no adults were seen. I estimate from the above observations that not more than 50, and probably only about 35, sea lampreys passed the Ocqueoc weir. In view of the fact that nearly 25,000 sea lampreys were captured by the weir and its traps, I consider this escape encouragingly small.

Like the Carp Creek weir, the Ocqueoc structure was continually checked for points of escapement. In view of this procedure and the small size of the two specimens recovered in the watershed, I conclude that those that negotiated the weir did so by working through the steel grates. A check of the spacing between bars of the grates, which was made late in the season, indicated that several bars had become spread so that the intervening space was as much as 5/8 inch. It seems certain, then, that the smaller migrants can work their way through vertical bars spaced at 5/8 of an inch.

(3) Methods, places and times of sampling, and collection of other data in 1947 and 1948

Sea lampreys in the Ocqueoc watershed tended to concentrate at two points during their upstream migration. The first concentration place was in Ocqueoc Lake, 2 1/4 miles above the mouth of the river. This was accidentally discovered on May 29, 1947, when netting operations were begun to determine if any predation upon resident game fish occurred while the sea lampreys were passing through the lake. On that date an 18.2-inch male sea lamprey in an advanced state of sexual maturity was taken in the 1 1/2-inch stretch mesh of an experimental gill net set in the north end of the lake. Thereafter, gill nets set in the northern half of the lake always yielded one or more sea lampreys in the 1 1/2-inch mesh portion of the nets. The greatest catch was on June 19 when 16 sea lampreys were taken in a 125-foot, 1 1/2-inch stretch measure gill net; this was a 20-hour set. Concentration in Ocqueoc Lake was evidently due to the inability of the run moving into the lake to find immediately the inlet of the Ocqueoc River. Ocqueoc Lake is long, narrow and irregular in outline; its outlet where the sea lampreys migrate into the lake is at the extreme northern end of the lake and its inlet enters the southernmost extension. Captures in the gill nets were made at all depths from 2 to 18 feet. Furthermore, specimens taken were traveling in all possible directions which would seem to indicate that they were searching more or less aimlessly for the inlet stream. On several occasions during the second week in June, sea lampreys were seen from the bank moving along the shoals in a direction opposite to that which would lead them to the inlet of the river.

Altogether, 69 sea lampreys in advanced stages of sexual maturity were collected by this method. They varied in total length from 14.3 to 20.5 inches and presumably indicate the size range most efficiently trapped by this method. Actually, the sea lamprey does not become "gilled" in the net but is trapped by its own natural reactions. Swimming normally with their buccal funnel closed, their immediate reaction to any restriction, such as forcing their head into the mesh of the net, is to open the funnel. The net then catches them between the branchial "basket" and the opened funnel. Subsequent "tailing" through innumerable meshes of the net eliminates any chance of escape (Figure 13).

It has been suggested that netting operations be attempted in the Great Lakes proper to obtain specimens of sexually immature adults and to test the possibility of a fishery for these individuals. Although this method of capture was practical and productive in Ocqueoc Lake where the concentration of individuals was abnormally high in a small body of water, I believe it would be of little or no value in the Great Lakes where the sexually immature, adult populations are undoubtedly greatly dispersed.

The second and most obvious concentration of migrating sea lampreys in the Ocqueoc River system occurred at a series of three falls located about one-third of the way upstream (T35N, R3E, S.22). Two natural falls (Figures 4 and 5), 4.5 and 6.0 feet high,

Figure 13.--Sea lampreys captured in a gill net in Ocqueoc Lake, June 25, 1947.

and the spillway of an old mill dam form obstructions below which the upstream migrants tend to accumulate. Periodic collections were made at both of these natural falls. This was done by dipping with scap-nets or by capturing by hand in the white water on the face, or at the base, of the falls. A total of 511 sea lampreys were collected in this manner.

In addition to the 580 unspawned, upstream migrants collected in Ocqueoc Lake and at the falls in the river, 99 spawning, or spent and dying or dead sea lampreys were collected on, or near, the various spawning grounds in the river.

Water temperature and water gauge readings were recorded for the Ocqueoc River at a station situated 100 feet below the outlet of Ocqueoc Lake. As in the Carp Creek, a maximum-minimum thermometer was maintained and minimum, mean, and maximum water temperatures were recorded for the period April 15-August 4, 1947. The same water temperature and water gauge station in the Ocqueoc River was maintained in 1948 and records were kept for the period April 11-August 20.

(4) Collection of data in 1949

The Ocqueoc River sea lamprey weir was in effective operation for trapping upstream migrants from March 31-September 30, 1949. The trap was operated, inspected, and the fish removed in accordance with the procedure followed for the Carp Creek weir. All data pertaining to the runs of sea lampreys and other fishes were recorded in the same manner as that for Carp Creek.

The sex of all sea lampreys composing the 1949 run (24,643 specimens) was determined. Length data were obtained from all sea lampreys entering the river during alternate 24-hour periods when the total run at any visit did not exceed 100 individuals. When the run during any visit of a sampling period exceeded that number, a random sample of 100 was measured (total length sample--3,830 specimens).

Maximum-minimum thermometers were maintained at the weir for records of air and water temperature throughout the period of weir operation. Water gauge readings are in inches and represent absolute depth across the deck of the weir.

Sea lamprey spawning runs per se

(1) Time limits and general character of the runs

Sea lamprey runs in the northern Lake Huron tributaries studies began as early as April 9 (1949) and as late as April 19 (1947) and varied with the climatic conditions in any given year (Figures 15-18). For this reason, calendar dates can only give approximate predictions of when the runs will occur. As subsequent data on the factors affecting these migrations will indicate, water temperature is the best guide as to when migratory activity will begin as well as to fluctuations in its intensity once it has started.

Prior to the beginning of the run, sea lampreys congregate off the mouths of the streams. Before any enter a watercourse, they may appear for a number of nights on the alluvial fan off the mouth of a stream (Figure 14) and then drop back into the lake each day rather than enter the stream. This action is evidently induced by temperature differences between the lake and the stream, the latter being colder than the lake when this behavior was studied.

Migratory activity during the early weeks of the run is sporadic (Figures 15-17). Peak migratory activity generally lasts for a 35- to 50-day period, occurring sometime between April 25 and June 15 with the date of greatest activity being in early or mid-May. Generally, between 85 and 99 percent of the run enters the creek during this period.

Even at its peak, migratory activity is erratic, particularly in a small stream, and reflects varying climatic conditions (Figures 15-18). Cold, wet spring seasons have a depressing effect on the runs, and movement into a stream on any given day in such a season is never very great. A natural corollary of this is that the upstream movement of the bulk of the migrants is extended over a greater period of time. The runs in warmer spring seasons are characterized by large, sporadic influxes of migrants on particularly warm nights which may sometimes be of spectacular proportions. In warm seasons, the period when the bulk of the migrants enter a stream is thus reduced.

The runs may terminate in small streams between July 6 and 13 depending largely on water levels in the stream. In larger streams, such as the Ocqueoc River, where an appreciable volume of water is discharged in the summer months, the last migrants may enter the river as late as September 30 (Figure 18). It may be added, however, that migratory activity after July 1 is generally limited to a few scattered individuals.

Specific information relative to the sea lamprey runs in Carp Creek and the Ocqueoc River in several years (presented by stream and by year) is as follows:

Carp Creek, 1947:--The earliest migrants observed at Carp Creek were four individuals seen by the writer between 11:00 and 12:00 P. M. on the night of April 14. These sea lampreys were spotted with the aid of a jack-light about 100 feet offshore on the gravel "fan" which extends from the mouth of Carp Creek into Hammond Bay (Figure 14).

During the time they were observed, they made no effort to move up into the creek mouth but clung persistently to the same rock until deliberately frightened by the observers. When frightened, they darted off across, or with, the current and dropped into the deeper waters of the bay. At the time of these observations, the water temperature on the "fan" was 39 degrees F. and the air temperature was 32 degrees F. Floe ice was still present in the bay.

Figure 14.--Observer standing on the alluvial fan in Hammond Bay off the mouth of Carp Creek where sea lampreys were first observed on April 14, 1947.

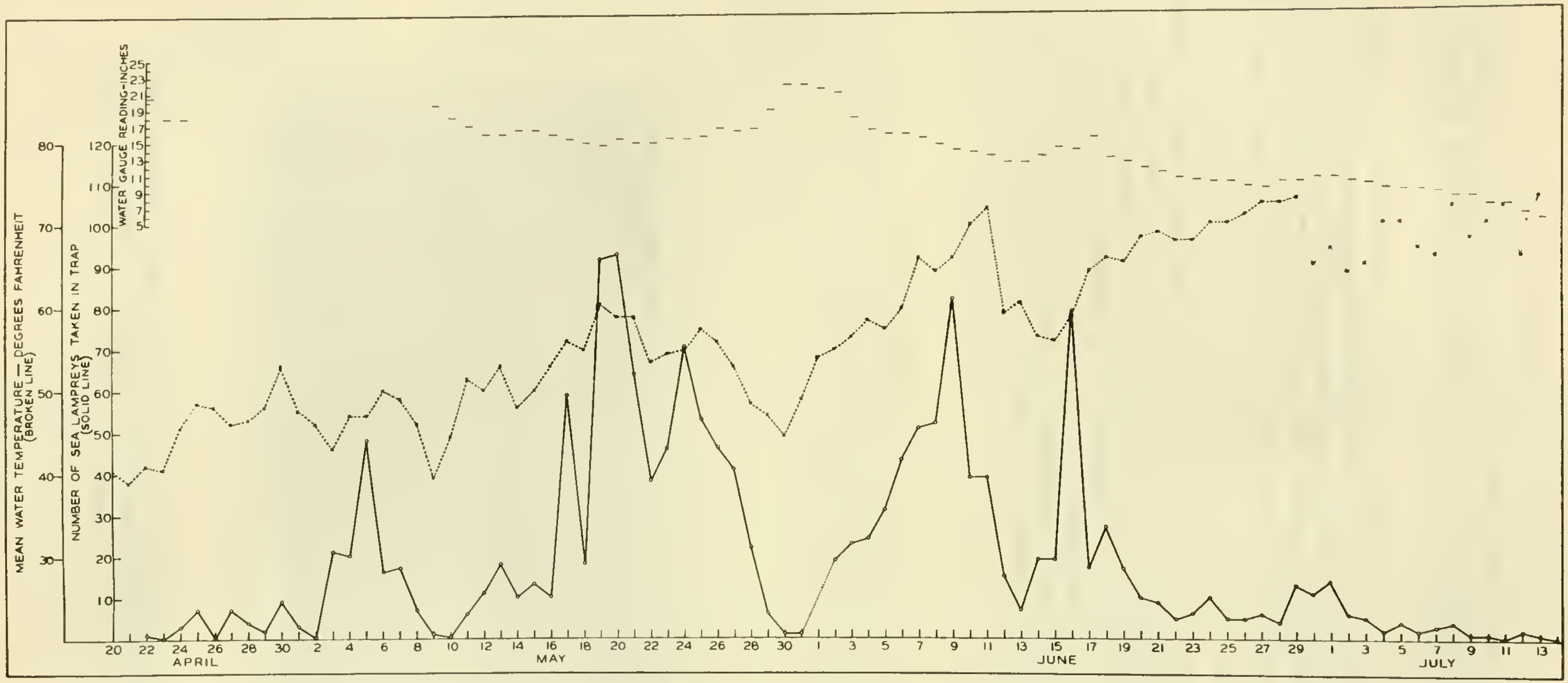


Figure 15.--Number of sea lampreys taken each day in the Carp Creek weir between April 22 and July 13, 1947, and the mean water temperature and water gauge readings for this period.

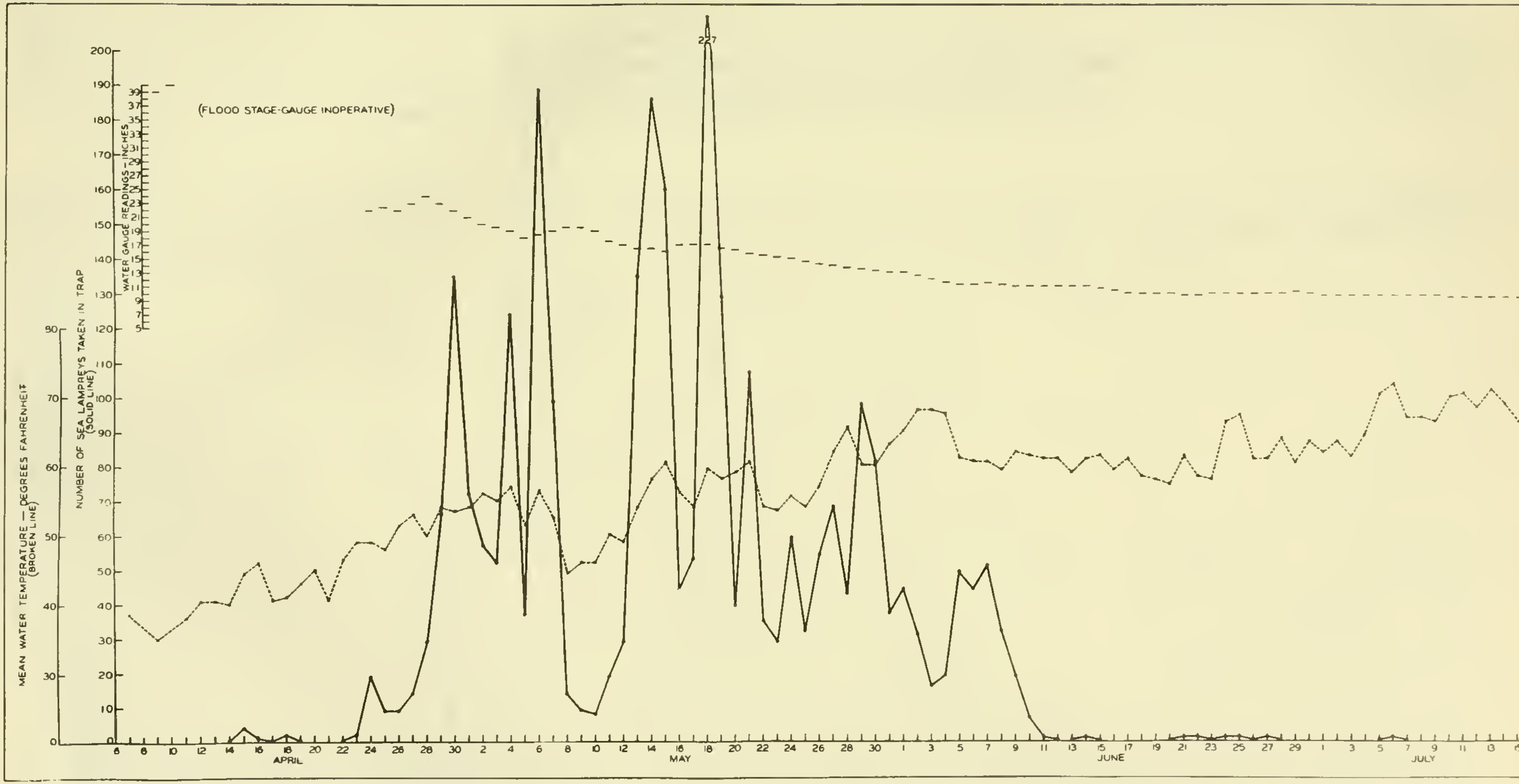


Figure 16.--Number of sea lampreys taken each day in the Carp Creek weir between April 7 and July 15, 1948, and the mean water temperature and water gauge readings for this period.

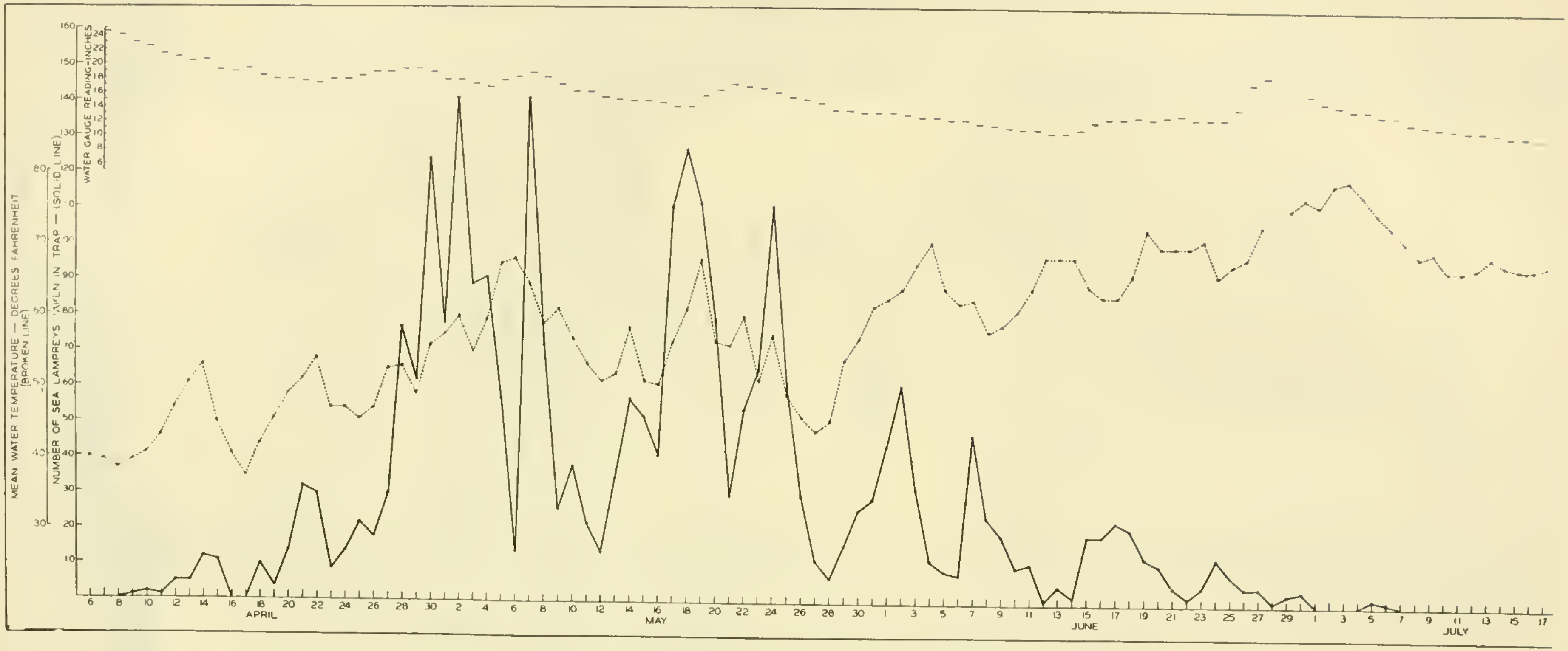


Figure 17.--Number of sea lampreys taken each day in the Carp Creek weir between April 6 and July 18, 1949, and the mean water temperature and water gauge readings for this period.

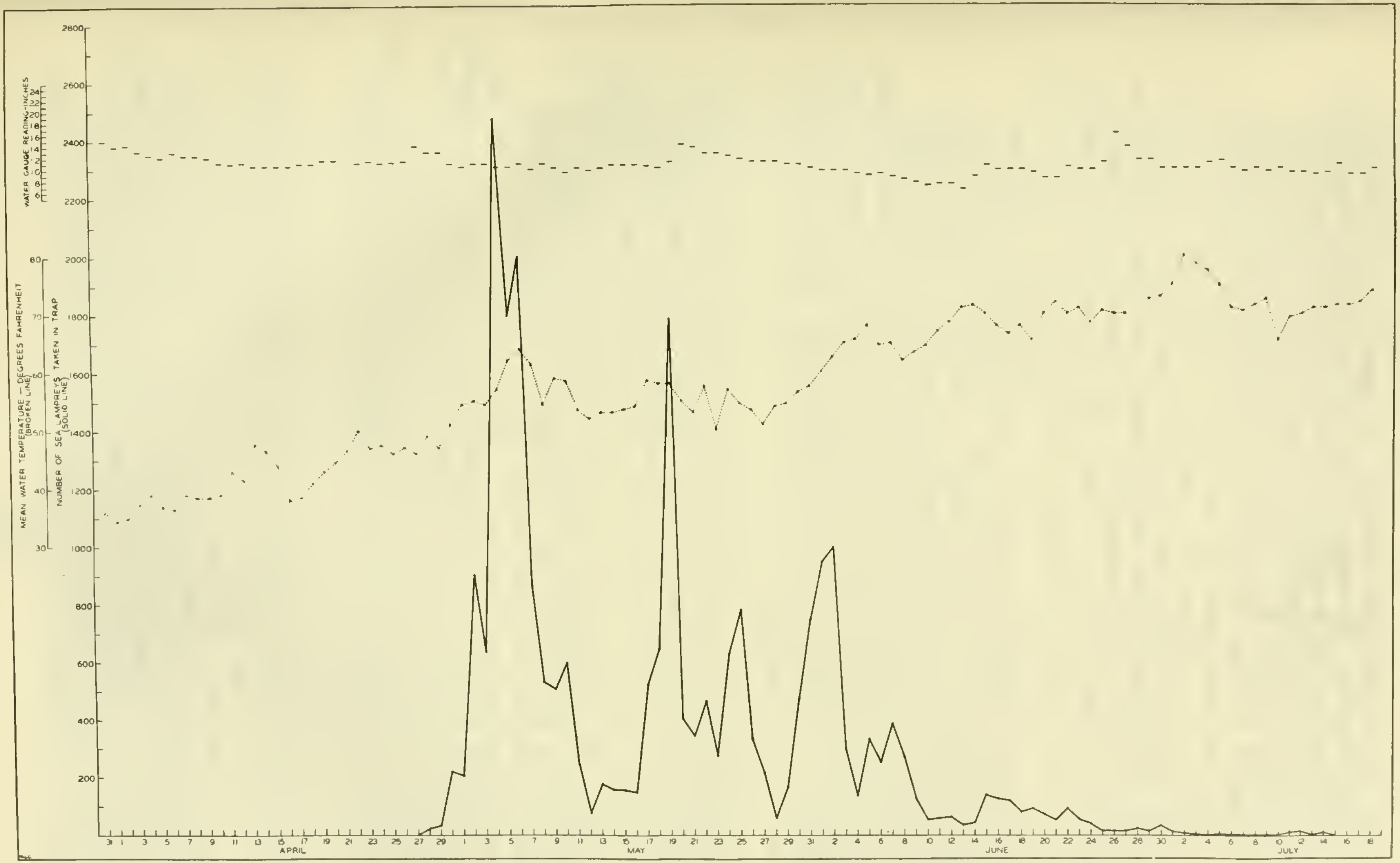


Figure 18.--Number of sea lampreys taken each day in the Ocqueoc River weir between March 31 and July 18, 1949, and the mean water temperature and water gauge readings for this period. (Lampreys entering the river after July 18 not shown. See Table 15.)

During the period April 15-April 19, repeated trips were made to the gravel "fan" at all times of the day and night by the writer, Mr. Robert Frank (formerly with the Fish Division, Department of Conservation), and Mr. Edward Karsten of Ocqueoc, Michigan. On April 15, about 11:00 P. M., a male sea lamprey 19.3 inches long and a female 16.7 inches long were seen and captured by spearing. Three others were seen later in the night. On the following night, about midnight, two females, 15.3 and 17.2 inches long, were likewise taken. Again, at least two more were seen in the following hours. On both nights, the water temperature remained at 40 degrees F. during the hours of observation--the air temperature varied from 24 degrees F. to 32 degrees F. A total of six sea lampreys were observed under similar circumstances on the succeeding three nights.

From these observations, made at all hours of the day and night during this period, we gained the impression that the sea lampreys observed were making no effort to enter the Carp Creek proper at that time. None were ever observed during the daylight hours. About two hours after full darkness they seemed to appear suddenly on the central and outward portions of the "fan" where they apparently remained until dawn. They were never in evidence in the estuary or lower creek proper at the times inspections were made on the "fan". I presume from this that they dropped back into the bay with the coming of daylight.

Unfortunately, we cannot fix the exact date when the actual upstream migration began. The weir and trap were put in operation on April 21 and by the following morning (April 22) one specimen had entered the trap. During the period April 15-18, water in the creek proper was one degree or more colder than that in the bay. This was due primarily to melting snow run-off in the watershed. On April 19, 20, and 21 the temperature of the water rose above that of the bay for a few hours each afternoon. I believe that these temperature differences between the creek and the bay were responsible for the behavior of the lampreys noted on the "fan" insofar as it slowed or inhibited their entrance into the creek proper. No appreciable number of lampreys entered the trap until April 25 when the mean temperature of the creek water had risen six degrees above that in the bay (Figure 15). In view of these facts I believe that the upstream migration of the sea lampreys entering Carp Creek began not earlier than April 19 and obviously not later than April 21.

During April 23-May 2 upstream migrants entered the trap sporadically, the daily catch varying from none to seven individuals (Figure 15). The bulk of the migration as reflected in the trap catches occurred between May 2 and June 21. Of 1,617 individuals taken during the entire operation of the weir, 1,471 or 91.0 percent of the total captures were taken during this 50-day period. There was no single peak of greatest migratory activity. Instead, during the period May 3-June 21, four pronounced peaks occurred, of which those on May 20 and June 9 are the most significant (Figure 15). On May 20, 93 sea lampreys and on June 9, 82 sea lampreys were removed from the trap.

These two peaks were separated by a sharp decline in migratory activity which reached a minimum between May 29 and May 31 when the run virtually ceased. This decline was apparently induced by a severe drop in water temperatures resulting from sleet, hail, and cold rain storms which began on May 26 and lasted for four days. Had this unseasonably cold weather not arrived with its resultant effect upon the creek water temperatures, I believe a single major influx of upstream migrants would have occurred between May 15 and June 7.

From June 22 on, a small and generally declining number of sea lampreys entered the trap each day until July 13 when the last migrant, a male, was taken. The weir and trap were inspected regularly until August 1 but no additional sea lampreys were captured.

Carp Creek, 1948:--The earliest migrants entering Carp Creek were four specimens taken on April 15. The weir was placed in operation on April 7 but was inoperative during April 9-13 due to severe flood conditions. During this period, creek water temperatures were as low as, or lower, than the temperatures in Hammond Bay (Appendix C). Subsequent checks of the watershed for escapement indicated that one, and perhaps two, sea lampreys may have entered the creek during this period. A small number of lampreys (11 individuals) entered the trap between April 15 and 22 (Figure 16). Thereafter, the run rose abruptly to its peak. Most migrants (99.0 percent) entered the creek during the 46-day period which followed (to June 9). A cold "snap" between May 8 and 12 interrupted this major movement for a period of four to five days. During 1948, trap catches in excess of 100 sea lampreys during a 24-hour period occurred on nine different occasions. The greatest movement was on the night of May 17-18 when 227 sea lampreys were taken between nightfall and daylight.

After June 9, only a very small number of lampreys entered the trap and the run was discontinuous in character. On July 6, the last migrant into Carp Creek was taken in the trap.

The total run in 1948 amounted to 2,939 sea lampreys.

Unlike the spring of 1947, which was cold, wet, and late, that season in 1948 was warmer, drier, and earlier. The sea lamprey run in 1948 was characterized by sudden movements of large numbers of migrants which generally occurred on warm nights. As a result, many abrupt peaks of migratory activity occurred during the period of major upstream movement. In contrast, the 1947 run displayed far less abrupt increases in migratory activity and such peaks as occurred were fewer in number.

Carp Creek, 1949:--The first lamprey entering the creek was taken on April 9. The weir had been placed in operation on April 7. Prior to that date, creek temperatures were as low as or lower than the temperatures in Hammond Bay (Appendix C). Subsequent checks of the watershed indicated that no lampreys entered the creek prior to the beginning of weir operations. Only a small number of lampreys (49 individuals) entered the trap between April 9 and April 19 (Figure 17). Thereafter, the run increased slowly until April 28 and on that date began to rise abruptly to maximum activity. Most migrants (87.8 percent) entered the creek during the 39-day period which followed (to June 5). As in previous years, the period of major upstream movement was roughly cleft by a cold spell. In 1949, this interruption of the run occurred during May 9-16.

Trap catches in excess of 100 sea lampreys during a 24-hour period occurred on seven different occasions. The greatest movements in this season were on the nights of May 1-2 and May 6-7. On both occasions, 141 sea lampreys were taken.

From June 6 to 30, trap catches were small and movement upstream was erratic although continuous. The last migrant to enter the creek was taken on July 6.

The total run in 1949 was composed of 2,763 sea lampreys.

The spring of 1949 was somewhat earlier than and equally as warm as that in 1948. The sea lamprey run displayed characteristics very similar to the run occurring in 1948. Sudden movements of large numbers of migrants occurred during hot, humid periods although without quite the intensity of this phenomenon in 1948. It was likewise noted in the field that these periods of hot weather in 1949 were not as intense as those occurring in 1948 (refer to air temperature and weather data in Appendix C).

Ocqueoc River, 1947:--Data collected for the Ocqueoc River run in 1947 were concerned almost entirely with the arrival, extent of activity, and disappearance of the lampreys on their spawning grounds. Conclusions as to the time limits and peaks of migratory activity, as they might be measured by a weir and trap near the river's mouth, are based entirely on field observations and a consideration of migratory activity at the Ocqueoc falls, 8.8 miles upstream from the mouth of the river.

It was reported to me by Mr. Enos Brege of Ocqueoc, Michigan, that on or about April 10, 1947, he saw "several" sea lampreys off the mouth of the Ocqueoc River while he was prospecting for the beginning of the smelt run. Data presented by Shetter (1949) for the 1945 sea lamprey run show daily trap catches of no or solitary sea lampreys for the period April 22 (first day of trap operations) to April 28, during which time, the average daily water temperature varied from 42 degrees F. to 44 degrees F. In 1947, mean daily water temperatures in the Ocqueoc River remained below 40 degrees F. until April 21 (Appendix C). After consideration of these data and those presented in this report for Carp Creek for the period April 14-21, I believe that little or no upstream migration occurred until on, or about, April 20, 1947.

The greatest concentrations of sea lampreys at and on the Ocqueoc falls were present during the period June 4-17. Water temperatures at the falls during this period varied from 56 degrees

F. to 64 degrees F. (all recordings made between 10:00 and 12:00 P.M.). The individuals composing this peak concentration obviously required some time to make the journey upstream (and through Ocqueoc Lake) from the mouth of the river. Since the mean daily water temperatures (in the lower river) rose and remained above 50 degrees F. on May 16 (Appendix C), I presume that the peak migration into the river began on that date and continued until about June 10.

The last spawning migrants observed in the entire river were a pair of sea lampreys which, on July 19 and 20, built a nest and spawned in the lower river about 350 feet below the outlet of Ocqueoc Lake. It was impossible to ascertain whether these spawners had come up the river from Hammond Bay or had dropped down from Ocqueoc Lake where they may have been unsuccessful in locating the inlet of the Ocqueoc River. No spawning sea lampreys could be found in the upper river during the second week in July. Since individuals could still be taken in Ocqueoc Lake by means of gill nets as late as July 15 (Appendix C). I consider the lake as the most probable source. Netting operations undertaken in the lake on August 1 and August 31 to September 1 did not yield any additional sea lampreys.

Ocqueoc River, 1949:--The earliest migrants to enter the Ocqueoc weir and traps were 21 sea lampreys taken on the night of April 27-28. These were not the earliest migrants to enter the lower river from Hammond Bay. During the period April 12-14, sea lampreys were first observed at night in several pools immediately below the weir and at several points in the estuary. In succeeding days, the accumulation of sea lampreys below the weir increased and they were more often in evidence. Conditions were favorable for upstream migration on and after April 11 but no lampreys entered the traps until the date indicated (see subsequent discussion of effect of water temperature upon the runs) (Appendix C). I judge from these facts that the weir structure acted as a temporary barrier until a greater urge to move on upstream drove the lampreys to search out the trap entrances to continue their journey.

The run, once started, rose immediately and abruptly in a seven-day period to its greatest peak (Figure 18). On the night of May 3-4, 2,476 lampreys entered the traps between nightfall and daylight. The bulk of the migrants (95.0 percent) entered the traps between April 28 and June 10, a 44-day period. During this time of greatest activity, the run was depressed by cold weather between May 9 and 16 and briefly inhibited by cool nights from May 26 to 29 (Figure 18).

During the period of greatest migration, 24-hour trap catches exceeded 2,000 sea lampreys on two occasions and exceeded 1,700 individuals on four occasions.

The run declined sharply after June 10 but remained continuous in character until July 12. Relatively few lampreys were taken each day during this period. Thereafter the run was discontinuous--scattered migrants being taken sporadically until the last sea lamprey entered a weir-trap on September 24.

A total of 24,643 sea lampreys was taken in the Ocqueoc River weir in 1949.

In general, the Ocqueoc River sea lamprey run resembled the runs occurring in Carp Creek in 1948 and 1949 insofar as large upsurges of migratory activity occurred during periods of particularly warm weather. The initial "surge" was accentuated, of course, by the large stock of temporarily blockaded lampreys below the weir which suddenly began to move upstream.

The Ocqueoc River run differed most noticeably from the runs in Carp Creek in its more continuous character. Fewer sudden increases and decreases in migratory activity from one 24-hour period to the next occurred. Being a considerably larger stream than Carp Creek, it is less profoundly and more slowly affected by changes in climatic conditions.

(2) Factors affecting the runs

There is a very close relationship between water temperature and the amount of migratory activity of the sea lamprey (Figures 15-18; Appendix C). It is very seldom that any upstream movement occurs at mean daily water temperatures of 40 degrees F. or lower. Such infrequent activity as does occur is always associated with temperatures very close to the 40-degree level. Migratory activity at mean daily temperatures between 40 degrees F. and 50 degrees F. is, as a rule, light and is very sensitive to fluctuations within this range. In general, activity increases as the 50-degree level is approached. The greatest migratory activity occurs at mean temperatures of 50 degrees F. to 65 degrees F. Water temperatures above this optimum range have an inhibiting effect upon the upstream movement (Figures 15-18; Appendix C).

If daily catches of weir-traps are plotted against mean daily water temperatures, a curvi-linear relationship is evident. Both within and without the optimum range, however, the response in migratory activity is not always proportional to the amount of change in water temperature. On certain occasions, a negative response may occur. These deviations are, in part, attributable to the period during the run in which they occur. During the latter part of the run, evident reactions to temperature fluctuations reckoned in numbers of migrants are obviously less than in the early part since the stock of mature individuals in the lake (from which they are drawn) has been considerably reduced. Declining migratory activity in a small stream, in the presence of increasingly favorable water temperatures, may also be caused by strong onshore winds at the mouth of the streams. Such winds deflect the creeks' discharge into the zone of wave action and apparently cause lampreys, searching for a stream in which to spawn, to by-pass the creek.

Mean daily water temperatures in Carp Creek during the periods of operation of the weir varied from 39.0 degrees F. to 73.0 degrees F. in 1947, from 35.0 degrees F. to 72.0 degrees F. in 1948, and from 37.5 degrees F. to 79.5 degrees F. in 1949 (Figure 15-17; Appendix C). Due to the small size of the creek and the extremely shallow character of its source, Carp Lake, these temperatures fluctuated widely, reflecting closely even moderate changes in weather.

In 1947, from April 21 until May 15, water temperatures were predominantly below 50 degrees F. and the run during that period was, on the average, light (Figure 15). At mean temperature levels of 41 degrees F., or lower, virtually no migratory activity occurred (April 21-23 and May 9). On May 16 the mean daily water temperature rose above 50 degrees F. and, except for the period May 28-31, remained well above that temperature for the balance of the run. Concurrently, the greatest migratory activity began. The most pronounced interruption in the run occurred during the period May 28-31 when the mean water temperatures fell to a low of 44.5 degrees F.

In 1948, from April 7-14, mean water temperatures were at or below 40.5 degrees F. No migratory activity occurred. A brief rise on April 15 and 16 to the mid-forties brought in the first migrants (Figure 16). A brief recession to near 40-degree levels followed, which interrupted the run. A continuous, light run began on April 22 as the water temperature rose rapidly towards 50 degrees F. On April 26 the water temperature rose and remained above 50 degrees F. At the same time, the major upstream movement began. A recession in water temperatures to a low of 44.5 degrees F. between May 8 and 12 interrupted the major upstream movement. On May 28 and June 1-5, the mean water temperature rose above 65 degrees F. and migratory activity was depressed. Cooling of the water between these two periods, and following the second, was accompanied by increased activity.

In 1949, from April 6 to 9, mean daily water temperatures fluctuated at or below 40.0 degrees F. (Figure 17). One sea lamprey entered the trap on the last day of this period. A brief rise to 53 degrees F. (April 10-15) brought in the first migrants of the run. A brief recession (April 16-17) to a low of 37.5 degrees F. interrupted the run. The run resumed on April 18 with rising temperatures and was thereafter continuous, though light, until the mean daily water temperatures rose, and remained above 50 degrees F. on and after April 27. Following this rise the major upstream movement took place. Two general temperature recessions to, or below, the 50-degree level occurred during May 9-16 and May 26-29. Recessions in migratory activity corresponded to these periods. On June 3 and 4 and during June 12-14, the mean water temperature rose above 65 degrees F. A very noticeable decline in migratory activity accompanied this condition. Cooling of the water to means below 65 degrees F. between these two periods, and following the second one, was accompanied by an increase in upstream movement.

Mean daily water temperatures in the Ocqueoc River in 1949 varied from 34.5 degrees F. to 80.0 degrees F. during the period of weir operation (Figure 18). No migrants were taken in the weir-traps until April 28 although water temperatures of 40 degrees F. to 50 degrees F. had prevailed during nearly all of the 17 preceding days. Migrants were present, however, below the weir. This delayed movement during water temperatures satisfactory for migration is attributed to the blocking action of the weir structure in the river. Early migrants are apparently more easily discouraged from continuing their journey than those migrating later when higher temperatures prevail. On May 30, mean daily water temperatures rose, and remained above 50 degrees F. Almost immediately an upstream movement of great intensity began (Figure 18). Presumably, this sudden, great movement was composed of fresh migrants from the lake and the accumulation of blockaded individuals that had been seen below the weir. The run was continuous in character, thereafter, until July 3. Two general recessions in water temperatures and migratory activity occurred corresponding to those which occurred in Carp Creek in the same year (May 9-16, May 26-29). These data agree with the observations of Shetter (1949) for the 1945 sea lamprey run in the Ocqueoc River for which he noted that the greatest migratory activity occurred at water temperatures of 51 degrees F. or higher. The effect of high water temperatures upon the Ocqueoc River run was less pronounced than that at Carp Creek. On June 4 and 5 the mean daily water temperature rose above 65 degrees F. and migratory activity decreased. Cooling of the water in the succeeding five days brought a brief increase in migratory activity. On June 11, water temperatures rose again, and remained above 65 degrees F., and upstream movement once more declined.

It should be noted that the erratic character of the sea lamprey run in Carp Creek is probably characteristic of most small sea lamprey spawning streams where temperatures respond rapidly to climatic changes. Data presented by Shetter for the Ocqueoc River run in 1945 and those collected by the writer in 1947 and 1949 (Figure 18; Appendix C) for the same stream indicate that in a larger stream with more stable temperatures the sea lamprey run has a correspondingly more continuous character.

Certain inexplicable declines in the number of migrants entering the Carp Creek trap were not always preceded or accompanied by a proportionately rapid drop in water temperature, and sometimes occurred on a slightly rising or stable temperature. This fact seems to be related to the effect of certain onshore winds upon the water discharged from the creek into the zone of wave action along the Hammond Bay shore. The creek water was always identifiable until thoroughly diffused into that of the bay by its distinctive brown color and usually higher temperatures. Under such conditions I could ordinarily wade to a point beyond the band of deflected creek water and seldom be standing at a depth greater than two feet.

It appears that sexually mature sea lampreys when seeking a tributary stream in which to spawn are attracted into that stream, possibly among other things, by a strong positive rheotropic response and/or a positive thermotropic reaction to the higher temperature of the creek's discharge. If either or both of these responses exist, then conditions which deflect the creek's discharge into a narrow, shallow band in the zone of wave action would materially reduce the chances of a sea lamprey finding that stream as it moves along the lake shoreline. Erratic declines in migratory activity that are not satisfactorily explained by water temperature variations occurred on April 26 and 28, May 4, 6, 16, 18, and 22, and June 13 and 17, 1947 (Figure 15). In most every case these can be associated with periods of easterly, onshore winds.

I do not believe that moderate to strong onshore winds would have any appreciable effect upon the discharge of larger streams such as the Ocqueoc River. It would take a gale of storm proportions to deflect the discharge from such a stream under most conditions.

No correlation exists between stream volume as reflected by depth gauge readings and the sea lamprey run except insofar as rapidly rising water levels (resulting from cold rains or melting snow) were generally accompanied by declining water temperatures (Figures 15-18).

Observations on turbidity and routine oxygen and carbon dioxide determinations of the streams studied in 1947 showed no evident relationship of these properties to the run. It would seem that the amount of turbidity and the chemical quality of the water as found in the streams studied have little or no relation to the incidence or magnitude of Great Lakes sea lamprey runs. Both clear and turbid waters are entered by migrants. Carp Creek and the Ocqueoc River are both relatively clear when runs occur. On the other hand, in the Manistique River, Schoolcraft County, below the paper mill in that stream, sea lampreys enter channels in the estuary which carry a very heavy suspension of wood pulp waste. Furthermore, upon reaching the paper mill which blocks the river, large numbers of them formerly entered a pipe discharging the combined hot pond and plant sewage wastes and traversed this pipe to reach a small seepage channel above the mill (this latter condition can no longer occur due to alterations in the level of the waste pipe outlet).

(3) Time of migration during the day

It has been previously observed that the greatest upstream movement of sea lampreys occurs during the hours of darkness. For example, among the runs of three years captured in Carp Creek, the proportion of individuals entering the trap during the hours of full daylight varied from 0.4 to 1.9 percent of the total run in any year. From 98.1 to 99.6 percent moved upstream during the hours of darkness. Of those lampreys migrating between 6:00 P. M.

and 8:00 A. M., 33.2 to 38.0 percent entered the trap between 6:00 P. M. and 12:00 P. M. while 60.1 to 66.4 percent were taken between that latter hour and 8:00 A. M. Time of migration into the Ocqueoc River, a larger stream, was almost the same. In that stream in 1949, 0.8 percent of the run entered the traps during full daylight, 32.7 percent between 6:00 P. M. and 12:00 P. M., and 66.5 percent between 12:00 P. M. and 8:00 A. M. This agrees generally with Shetter's data (1949) on the Ocqueoc River for which he noted that 55 percent of the run occurred between the hours of midnight and 6:00 A. M.

Only slight, and probably not significant, differences were displayed in the time of migration of the two sexes in all runs studied. For example, of all males taken in Carp Creek in 1949, 0.8 percent entered the trap during full daylight (prior to 6:00 P. M.), 35.9 percent between 6:00 P. M. and 12:00 P. M., and 63.2 percent between 12:00 P. M. and 8:00 A. M. Of all females taken, 1.0 percent entered the trap during the hours of full daylight, 34.0 percent between 6:00 P. M. and 12:00 P. M. and 65.0 percent between 12:00 P. M. and 8:00 A. M.

Changes may occur in most runs in the daily time of migration during the course of the run. The Carp Creek run in 1947 may be cited as an example. Until May 29, no sea lampreys entered the trap except during the hours of full darkness. Furthermore, during this same period, the bulk of the upstream movement occurred between the hours of midnight and 8:00 A. M. After the end of May, sea lampreys began to appear in the trap during the daylight hours and an increasing number entered during the earlier hours of the evening. If we break down the data for the period April 24–June 21, 1947, into two arbitrary periods we find that the following occurred: Of 898 sea lampreys taken in the trap between April 24 and May 31, only 1 or 0.1 percent entered during the hours of full daylight (prior to 6:00 P. M.), 265 or 29.5 percent between 6:00 and 12:00 P. M., and 632 or 70.4 percent between the latter hour and 8:00 A. M. Between June 1 and June 21, 623 sea lampreys were trapped. Of these, 28 or 4.5 percent moved into the trap during daylight hours (prior to 6:00 P. M.), 313 or 50.2 percent entered between 6:00 and 12:00 P. M., and 282 or 45.3 percent entered between midnight and 8:00 A. M.

However, this shift in time of migration was not repeated in this stream in 1949. The run of this year displayed a proportionate increase in migratory activity in the latter half of the season between the hours of midnight and 8:00 A. M.

Field observations during 1947 and 1948 revealed that, at the beginning of the spawning run, sea lampreys displayed a very strong negative response to light. This response becomes less and less pronounced among later arrivals as the season progresses. The data from the Carp Creek and Ocqueoc River weirs are confirmatory. A variation of this was shown by Shetter (1949) for the Ocqueoc River run in 1945. He found a somewhat greater proportion of migrants moving during the hours of daylight. In view of the generally negative response of upstream migrants to light, I believe the differences in our data may be attributed to the very shallow and more exposed character of both streams in their lower reaches than farther upstream. The weir from which Shetter's data were drawn was located well upstream in a well-shaded area of the watershed.

Other species of fish taken in the weirs

(1) Kinds and numbers

In addition to the sea lampreys taken in the Carp Creek weir each year, individuals or runs of as many as 18 other species of fish and one other species of lamprey were taken as they migrated upstream (Appendix D). The total number of fish taken was 9,583 in 1947, 34,656 in 1948, and 29,856 in 1949. Two silver lampreys (*Ichthyomyzon unicuspis*) were trapped in 1947 and seven appeared in 1948.

In the Ocqueoc River in 1949, a total of 9,865 fish of 16 different species was captured moving upstream and 3,198 fish of 16 species were taken moving downstream (Appendix D).

The bulk of the fish taken moving upstream in Carp Creek was composed of spawning runs of the white suckers (*Catostomus c. commersonnii*), smelt (*Osmerus m. mordax*), lake chubs (*Couesius plumbeus*), and Great Lakes longnose dace (*Rhinichthys c. cataractae*).

In the Ocqueoc River (in 1949), the principal upstream runs were of white suckers, golden redhorse suckers (Moxostoma aureolum), and Great Lakes longnose dace. The principal downstream runs were of yellow perch (Perca flavescens) and white and golden redhorse suckers returning to the lake after spawning.

(2) Times of migration

The times of migration of other species of fish (Appendix D) are significant insofar as some might represent potential competitors of the sea lamprey for spawning grounds. Others (primarily the minnow species) might be egg predators during the spawning activities of the sea lampreys. No direct evidence of either relationship has as yet been obtained, however, since practically all lampreys were removed from the streams in which the weirs were operated. In the Ocqueoc River in 1947 and 1948, the suckers completed their spawning activities prior to any extensive nesting on the part of the sea lampreys which would tend to eliminate them as a competitor in this regard.

White suckers, as a rule, migrated concurrently with the sea lampreys (Appendix D). Like the lamprey, their greatest migratory activity came at temperatures of 50 degrees F. or higher. Golden redhorse suckers moved during very short periods between late April and mid-May and usually before the peak of the sea lamprey run. Lake chubs attained the peak of their migration during and shortly after the major upstream movement of sea lampreys and white suckers. The maximum ingress of Great Lakes longnose dace was generally prior to that of the aforementioned two species. Smelt runs took place, and ended, as the scattered early migrants among the sea lampreys penetrated the stream.

Other species entered the traps in small numbers throughout the periods of weir operations. Numbers taken, however, were insufficient to reveal periodicity in migratory activity (Appendix D).

(3) Species and numbers bearing lamprey scars

All suckers, trouts, northern pike, rock bass, and bullheads taken in the traps were examined for evidence of lamprey attacks. Of those individuals which were lamprey scarred, few bore wounds so fresh that they could have been inflicted while the fish was traversing the short distance from the stream mouth to the trap. For the same reason they could not have been inflicted in the trap itself. Comparison of these fish with a series of scarred whitefish and "chubs" (deepwater ciscoes) taken in Lake Huron, on some of which the lampreys were still attached when the nets were lifted, supports this view. On the latter, the scars had a bright red, raw appearance which was seldom approached in freshness of appearance in the specimens taken in the trap. Furthermore, only one instance of recent feeding was found among the captured sea lampreys (the digestive tracts of nearly all trapped lampreys taken in 1947 and 1948 were opened and found to be empty). The exception was a 17.3-inch, female sea lamprey taken on May 1, 1947; its intestine was partially distended with blood. This specimen was in a retarded state of sexual maturity as evidenced by the condition of its liver and the underdevelopment of the gonad. This evidence that trapped, scarred fish were attacked sometime prior to their entrance into the stream is emphasized since the concentration of so many fish and lampreys moving in the narrow confines of a stream might lead the casual observer to believe that the incidence of attacks noted was directly related to coincident spawning runs of predator and prey.

In order to relate extent of scarring to possible trends of population, a summary of the pertinent data follows:

Carp Creek, 1947:--Of the 3,700 white and redhorse suckers transferred upstream, 257 or 7.0 percent of the run bore one or more relatively fresh or recent scars. Occasional fish had two lesions and two instances were noted of three on a single fish.

On May 2, a rainbow trout, 26.0 inches in total length, was confiscated from a sucker spearer who had taken it in the estuary of the creek. This fish had a fresh lamprey injury 2 1/4 inches in diameter and nearly 1/4 inch deep. A 24.5-inch female rainbow trout which came downstream on May 12 bore two recent lamprey scars and one which was nearly healed. A third rainbow trout, 17.9 inches long, taken in the trap on May 26 had an old, healed-over scar. One northern pike, 19.6 inches long, taken on May 1 had two fresh lamprey wounds. No bullheads or rock bass had lamprey marks.

Carp Creek, 1948:--Of 2,848 white and redhorse suckers transferred upstream, 6.8 percent bore one or more relatively fresh or recent lamprey scars. The degree of scarring of these species was hardly different from that existing in 1947 although the size of the run had declined appreciably. No other species had any evidence of lamprey attacks in this year.

Carp Creek, 1949:--Of 1,811 white and redhorse suckers taken in the trap, 311 or 17.2 percent bore one or more relatively fresh or recent lamprey scars. In this year, the degree of scarring increased very markedly and the size of the sucker runs continued to decline at a rapid rate. No other species gave evidence of lamprey attacks.

Ocqueoc River, 1949:--A total of 3,137 white and redhorse suckers was taken moving upstream. Of these, 801 or 25.5 percent bore relatively fresh or recent lamprey scars, exceeding the Carp Creek data by 8.3 percent. Of 104 rainbow trout transferred upstream, 23 or 22.1 percent had been scarred by lampreys. No individuals of any other species taken carried marks.

(4) Occurrence of lamprey-scarred sea lampreys

In 1948, the first evidence of what might be termed cannibalism was observed! Twenty-four sea lampreys were taken in the Carp Creek weir which bore lamprey scars. Approximately the same incidence of similarly injured sea lampreys was observed in 1949 although no exact records were kept in that year. Some of these scars upon the lampreys were quite superficial and may, perhaps, be attributable to some premature manifestation of the spawning urge. Most, however, were deeper scars which penetrated the musculature. The implications of these scarred lampreys are somewhat obscure since we know so little of the feeding habits of the species. They may, in some degree, indicate an increasing shortage of the species which comprise their usual victims or they may be entirely fortuitous in nature.

Relative abundance of sea lampreys

One function which the weir-traps operated during these studies may serve is to provide information on annual fluctuations in abundance of the sea lampreys in northern Lake Huron. Changes in the size of sea lamprey runs and in the size and degree of scarring of the concomitant sucker runs seem to indicate strongly that the sea lampreys increased in numbers during the period 1947-1949. The greatest augmentation appears to have been in the last year of this period (May, 1948-May, 1949?). Observations made in the commercial fishery indicate that the sea lampreys are feeding extensively upon the suckers and for this reason they may provide an index of lamprey abundance. Following is a tabulation of the total sea lamprey runs, total white and redhorse sucker runs, and percentage of scarred suckers for three years in Carp Creek and one year in the Ocqueoc River. Data on the size of sea lamprey runs for the Ocqueoc River in 1947 and 1948 are included and are estimates based on counts of nests that were found in the watershed:

		Total sea lampreys taken	Total suckers taken	Percentage of suckers scarred
Carp Creek	1947	1,617	3,700	7.0
Carp Creek	1948	2,939	2,848	6.8
Carp Creek	1949	2,763	1,811	17.2
Ocqueoc River	1947	(10,000)	...	...
Ocqueoc River	1948	(13,000)	...	...
Ocqueoc River	1949	24,643	3,137	25.5

A very decided increase has occurred in the size of the Ocqueoc River spawning run of lampreys in this three-year period, the rate of increase being greatest between the 1948 and 1949 spawning seasons. The comparative size of the run in Carp Creek in the last two years does not negate this conclusion as the figures would lead one to believe. The flowage in Carp Creek in 1949 is estimated to have been at half the volume of that occurring in 1948. A lesser discharge would normally result in fewer lampreys being attracted to the creek as they sought along the lake shore for a spawning stream. In spite of this decreased volume of flow, the run was not significantly different in size than that occurring in 1948.

In Carp Creek, with the abrupt increase in scarring of suckers in 1949, came a continuation of the rapid decline in the size of the sucker spawning runs. Observations in 1947 and 1948 indicate that sucker runs in the Ocqueoc River too were much larger in those years than in 1949. The size of these runs almost certainly reflects the size of the sucker stocks in Lake Huron proper. Increase in the degree of scarring in conjunction with a decline in abundance of these species provides some circumstantial evidence that the sea lampreys are currently increasing in numbers. Two factors must be considered, however, in evaluating this latter evidence: (1) sucker populations are reportedly suffering a cyclic decline in abundance at the present time in which the lampreys may only be an accelerating factor; and, (2) lake trout, upon which lampreys seem to prefer to feed are now relatively scarce in Lake Huron. With the reduction in numbers of this species and with lamprey stocks increasing, there would naturally follow some diversions of lampreys to other fishes. Evidence collected both at weirs and in the commercial fisheries indicate that the Lake Huron sucker population may now be bearing the brunt of such a shift.

Some biological characteristics of spawning runs

(1) Sex ratio and differential migration of sexes

Of the 1,617 sea lampreys taken in the Carp Creek weir in 1947, sex data were obtained from 1,600 specimens. Of these 1,600 sea lampreys, 997 or 62.3 percent were males and 603 or 37.7 percent were females. This is a ratio of 165 males : 100 females. Of 2,939 sea lampreys taken in the same weir in 1948, sex data were obtained from 2,931 specimens. Of these, 1,824 or 62.9 percent were males and 1,089 or 37.1 percent were females. This is a ratio of 169 males : 100 females. In 1949, the sex of all sea lampreys comprising the run, 2,763 individuals, was determined. Of these, 1,866 or 67.5 percent were males and 897 or 32.5 percent were females. The resultant ratio is 208 males : 100 females.

In the Ocqueoc River in 1947, 679 sea lampreys were examined for sex data. Of these, 364 or 53.6 percent were males and 315 or 46.4 percent were females. This ratio of 116 males : 100 females is open to question since data on the sex composition of the entire run and any differential migration by sexes is lacking. Of 24,643 sea lampreys taken in the Ocqueoc River in 1949, 16,798 or 68.2 percent were males and 7,845 or 31.8 percent were females. The sex ratio was 214 males : 100 females.

A trend toward an increasing proportion of males among mature lampreys composing the runs is evident in these figures. The slight proportionate increase in the numbers of males between 1947 and 1948 is not necessarily significant but that increase occurring between 1948 and 1949 most certainly is indicative of a growing imbalance in the population. I do not believe that even the earliest sex ratio recorded (Carp Creek, 1947--165 males : 100 females) is a natural ratio for the species, which if their spawning habits are any indication, must possess under normal circumstances a near-balanced or balanced sex ratio. In support of this contention, is a sample of 52 ocean-run sea lampreys taken in the Sheepscot River in Maine (1949) which I had the opportunity of examining. This sample had a sex ratio of 79 males : 100 females.

What factor or factors (genetic or environmental?) are operating against the females or in favor of the males is in no way apparent. Whether the trend will continue is uncertain, but should it do so it could hardly avoid having some effect on the sea lamprey population concerned.

The picturesque characteristics of spawning runs ascribed to this species wherein the males predominate among early migrants and females among the late ones (with more or less even division at the peak of the run) (Surface, 1899) are barely suggested in the runs studied (Appendix C, Tables 3, 6, 9, 13). For instance, cumulative 5-day totals of migrants entering the Carp Creek weir in 1947 display a 1.5 : 1 ratio between males and females quite generally throughout the entire season. The only suggestion of the aforementioned phenomenon occurred between May 1 and 10 when the ratio of males to females was about 2 : 1. At the termination of the run, between July 1 and 13, the males suddenly began to outnumber the females by a ratio of almost 3 : 1.

In 1949, in both streams studied, a 2 to 2.5 : 1 ratio between males and females prevailed throughout most of the run. After June 15 in the Ocqueoc River, the numbers of the sexes became more nearly equal but males continued to predominate at all times.

I presume that the failure of the females to predominate at the end of the run, as they reportedly do in this species (Surface, 1899), is an expression of the unbalanced sex ratio which is here extant.

(2) Length composition of spawning runs

The extreme range in size of 10,411 migrant sea lampreys, sexes combined, that were examined for length during these investigations was 11.0 to 23.5 inches (279 to 597 mm.). The average length, sexes separately or combined, varied slightly from year to year but was generally very close to a mean of 17.0 inches. There is no gross sexual dimorphism in length (Table 2 and Figure 19).

The largest specimens of both sexes were taken at the beginning of the run and for both males and females the mean total length gradually decreased almost regularly during the course of the run. This was more pronounced among the females than among the males (Appendix C, Tables 3, 6, 9, 13). For example, periodic averages of the total length of females taken during the first half of the Carp Creek run in 1947 ranged from 17.4 to 18.3 inches. Thereafter, these means declined to a low of 16.4 inches toward the end of the run. Comparable averages of total length among the males were generally more consistent. The dominant periodic average of total lengths of

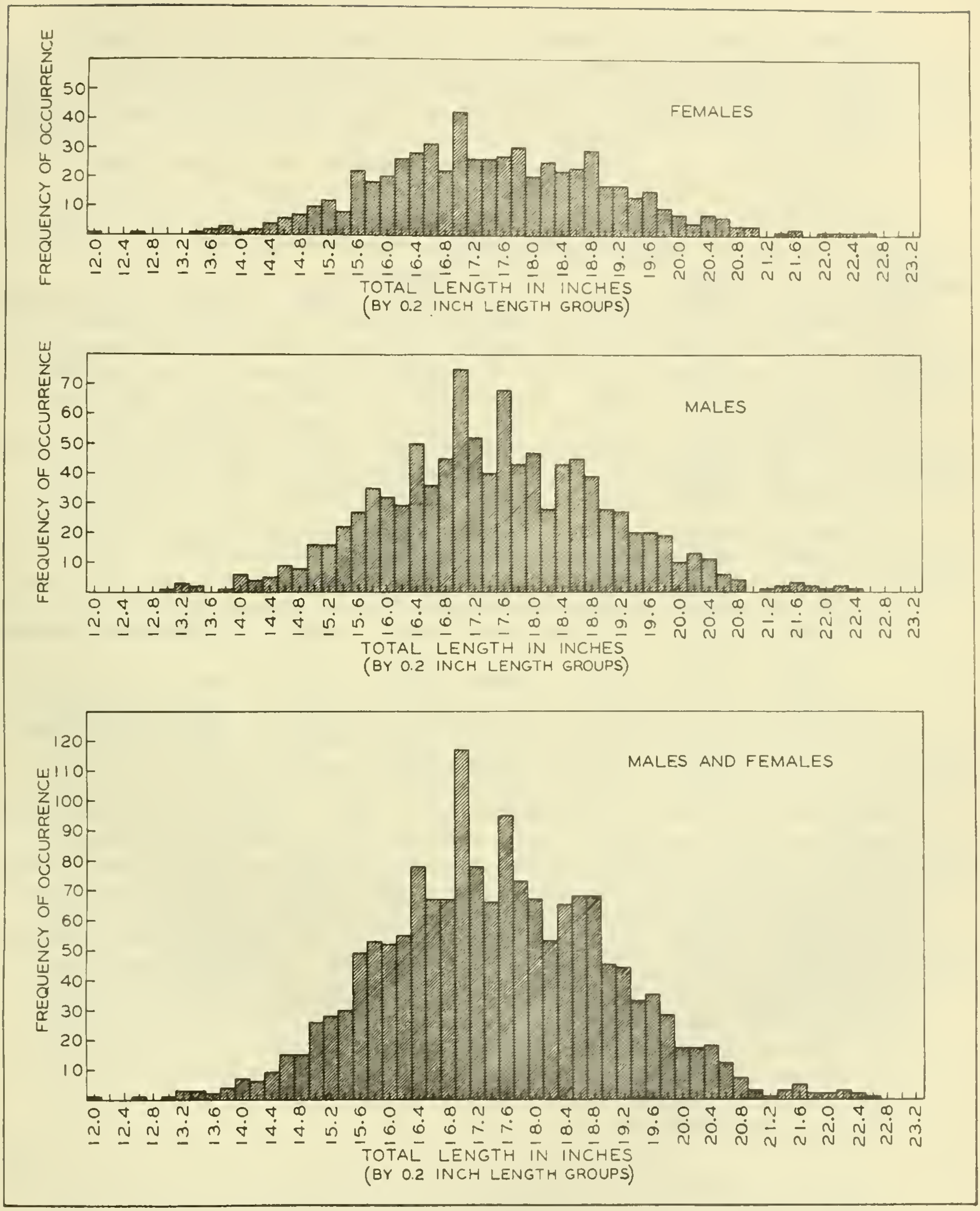


Figure 19.--Length-frequency diagrams for migratory sea lampreys taken in Carp Creek, Presque Isle County, in 1947.

males during the first half of the run was 17.6 inches. This was reduced, as among the females, in the latter half of the season to values ranging very close to 17.0 inches. This decline in the size of migrants may be attributed to an earlier attainment of sexual maturity among larger specimens than among the smaller ones.

Both range and average length values for the Ocqueoc River run in 1947 are appreciably lower than those given for all other runs studied. An analysis of the sampling procedure as undertaken in the Ocqueoc River in 1947, however, suggests that it was selective in favor of the smaller specimens. During the latter part of the spawning season, there was a visible decline in the size of males and females on the spawning grounds. The very smallest specimens seen and collected during 1947 were found on the upper Ocqueoc River spawning grounds during the last week in June and the first three days of July. These field observations agree with the data presented for all other runs wherein it was found that the average size of the upstream migrants declined during the latter half of the upstream movement. My collections in the Ocqueoc River were made primarily at the falls during and after the peak concentrations of migrants there. Furthermore, collections on the spawning grounds were made almost entirely in the latter half of the period of spawning activity. For these reasons, I conclude that the data on the range and average of size for the Ocqueoc River run in 1947 were influenced by the period during which collections were made.

Graphic and tabular length-frequency data indicate a platykurtic distribution of lengths in the spawning populations entering these streams (i.e., the length-frequency distribution is somewhat flatter than a normal curve of distribution would be) (Appendix E, Tables 1 and 2; Figure 19). The standard deviations of the lengths of the sexes both separately and combined are high. There is no significant evidence of poly-modality in curves constructed for any of these data. Possible interpretations of such data may be ambiguous. Platykurtic distributions accompanied by high standard deviations reflect either high variability or some heterogeneity in the sample. In the case of a fish population such as these sea lampreys, this heterogeneity could be one of either age or origin. By heterogeneity of origin it is meant that the individuals composing this sea lamprey run may have come from widely separated localities of diverse characteristics in Lake Huron. Irregularities in the length composition of certain lake fish taken within the limits of Saginaw Bay alone have been attributed to this phenomenon according to Dr. Ralph Hile (verbal communication).

The determination of which of the characteristics, heterogeneity or high variability, is displayed in the spawning run data is of considerable importance in determining the biology of the species. For example, it would be of value to know if the sexually mature sea lampreys entering a stream to spawn are homogenous as to age or

Table 2. Range in length and mean length with standard deviation of male and female sea lampreys entering Carp Creek in 1947, 1948, and 1949 and of those entering the Ocqueoc River in 1947 and 1949 (all measurements are of total length, taken in inches and tenths to the nearest tenth; millimeter equivalents are given in parentheses beneath each figure).[1]

		Total length in inches						Sexes combined
		Males			Females			
Stream	Year	Min.	Aver.	Max.	Min.	Aver.	Max.	Aver.
Carp Creek	1947	13.0 (330)	17.4 $\sigma \pm 1.52$ (442)	22.4 (569)	12.0 (305)	17.4 $\sigma \pm 1.60$ (442)	22.6 (574)	17.4 $\sigma \pm 1.55$ (442)
Carp Creek	1948	11.0 (279)	16.7 $\sigma \pm 1.53$ (424)	23.4 (594)	12.0 (305)	16.9 $\sigma \pm 1.57$ (429)	22.3 (566)	16.8 $\sigma \pm 1.55$ (427)
Carp Creek	1949	12.5 (318)	16.9 $\sigma \pm 1.53$ (429)	22.3 (566)	12.9 (328)	17.4 $\sigma \pm 1.51$ (442)	21.1 (536)	17.1 $\sigma \pm 1.55$ (434)
Ocqueoc River	1947	12.5 (318)	16.2 ... (412)	19.4 (493)	12.0 (305)	16.3 ... (414)	21.1 (536)	... ...
Ocqueoc River	1949	12.0 (305)	17.0 $\sigma \pm 1.68$ (432)	22.2 (564)	11.3 (287)	17.2 $\sigma \pm 1.67$ (437)	22.6 (574)	17.1 $\sigma \pm 1.69$ (434)

[1] Based on length samples constituting 99 plus percent of the runs entering Carp Creek in 1947 and 1948. Data for that stream and the Ocqueoc River in 1949 are based on random length samples (see "Collection of data", page 36 and page 46). At the Ocqueoc River in 1949, extremely small or large specimens were occasionally selected out in periods when length data was not being collected and these lampreys were measured. Selected specimens above, or below, the range given in this table were as follows: two males, 11.4 and 11.8 inches respectively; one male, 23.1 inches, and two females, 23.2 and 23.5 inches long.

whether runs are composed of individuals of several age groups. Should the latter condition obtain, it would render any determination of length of the parasitic period based on collections of sexually immature individuals from the Great Lakes more difficult to make (as yet, no method has been discovered for determining accurately the age in years of adult sea lampreys). Data presented subsequently on periodic collections of specimens in the parasitic phase made in the Great Lakes proper indicate that all, or nearly all, individuals comprising a spawning run are of a single age group.

However, in view of our inability to make precise age determinations in this species, we must consider that several possible interpretations exist for the characteristics of the length frequency data: (1) either the spawning populations studied are characterized by a high morphological variability and are homogenous as to age and/or origin, or, (2) they are characterized by a lesser morphological variability (in length) and are heterogenous as to age and/or origin. The preponderance of evidence presented in the current study favors the first contention.

(3) Weight composition of spawning runs

Weights were obtained for 1,599 sea lampreys taken from Carp Creek in 1947 (Appendix E, Table 3; Figure 20). Male sea lampreys varied from 59 to 400 grams (2.1-14.1 ounces) and averaged 181.6 grams (6.4 ounces). Females ranged in weight from 61 to 436 grams (2.1-15.4 ounces) and had a mean weight of 186.6 grams (6.6 ounces). Weight-frequency polygons for both males and females display a positive skewness (Figure 20). As a result, the modal weight values (i.e., most frequently encountered weights of migrating sea lampreys) for both sexes are appreciably lower than computed mean weights. The marked asymmetry of the weight-frequency distributions may again indicate some form of heterogeneity in the spawning run, as previously suggested by the lengths.

The actual total weight of all individuals comprising a run is surprisingly small. The total weight of the 1,617 sea lampreys taken in Carp Creek in 1947 (which constituted 99 plus percent of the run) was 654 pounds. If we utilize the maximum estimate for the run entering the Ocqueoc River in 1947, 10,000 sea lampreys, and assign these migrants an average weight of 6.5 ounces for both sexes combined, we find that the total weight of the run in that river was very close to 4,062 pounds. These data indicate that even where large sea lamprey runs are present, the total poundages that might be removed for commercial purposes are not of encouraging proportions.

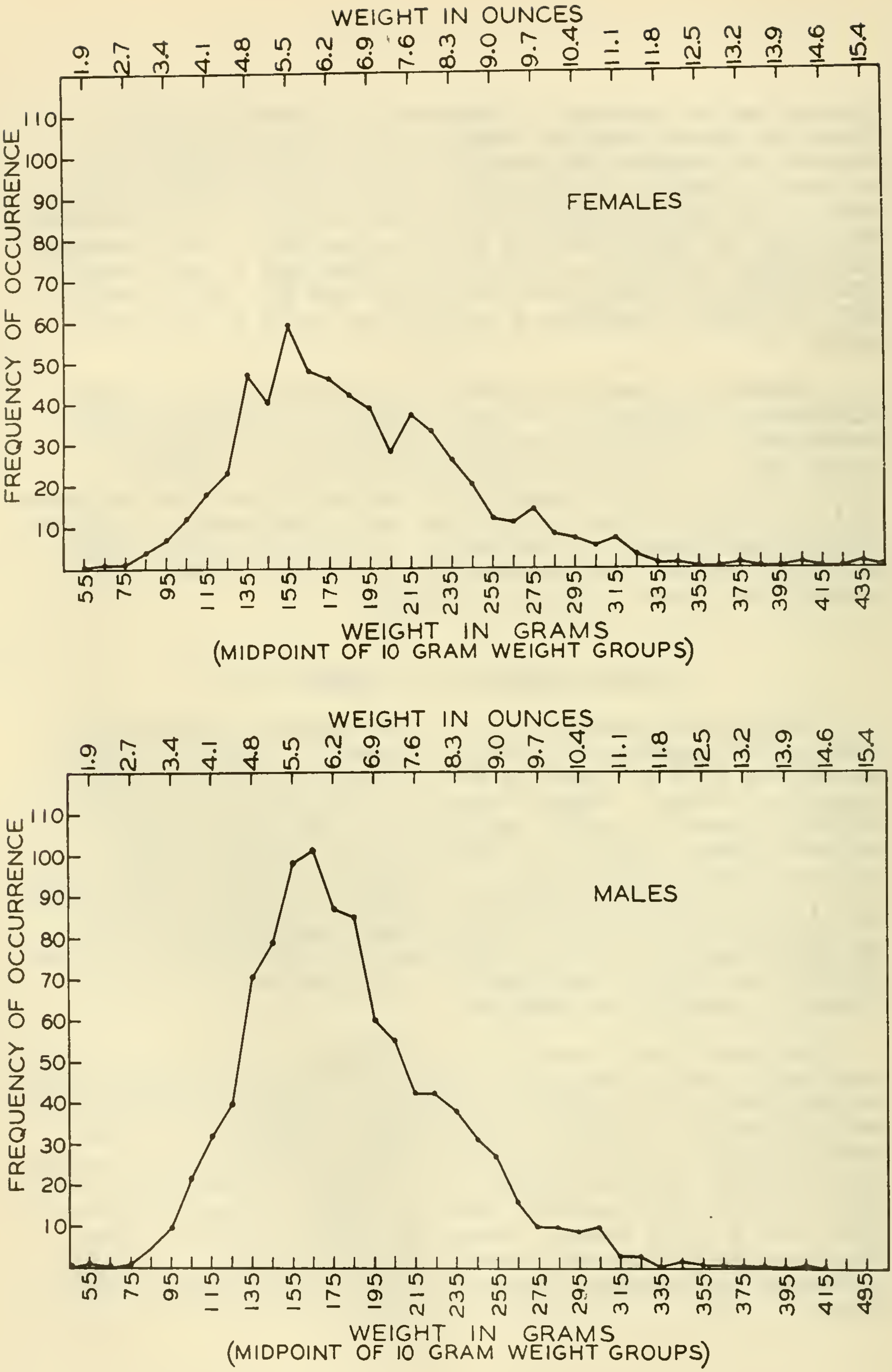


Figure 20.--Weight-frequency diagrams for male and female sea lampreys taken in the Carp Creek weir and trap in 1947.

(4) Relationship between length and weight in spawning runs

Both length and weight data were obtained for 2,180 sea lampreys collected during 1947, 1,303 of which were males and 877 females. Of the total, 1,599 were taken in Carp Creek and 581 in the Ocqueoc River. Average weights by 0.2-inch length groups were computed separately for the males and females of each of the two runs. A comparison of corresponding sexes from both watersheds indicated no significant differences in the length-weight relationship. For this reason, the length and weight data for both runs were combined, sexes separate (Appendix E, Table 4). For summary, empirically determined averages of the males and females were plotted separately on graphs, and curves were fitted to these points by inspection (Figures 21 and 22).

In general, the weight of sea lampreys does not increase as rapidly with length as does the weight of many higher fishes (Beckman, 1948). This is attributable to their more attenuate or snake-like body form; it is most evident in the male sea lampreys whose weight remains more or less directly proportionate to the length until a size of 19.5 to 20.0 inches is attained. Thereafter, weight increases rather rapidly with length (Figure 21).

Among the females, weight increases more noticeably with length but the validity of this relationship is questionable due to the profound effect of the developing ovary upon the total weight of the female (Figure 22).

The variation in weight at any given length is generally great and increases with increase in length. Occasionally, the heaviest specimen in a 0.2-inch length group exceeded twice the weight of the lightest specimen in the same group. This is illustrated in Figure 21 where the range in weight for each 0.2-inch length group of males has been plotted.

(5) Migratory habits and behavior

Sea lampreys swim with a whip-like, undulatory motion which in its mechanics appears to be identical with that of the eel (Anguilla) as described by Breder (1926) and termed by him: "anguilliform locomotion." This is very similar to the familiar movement of a snake traveling on the ground.

Sea lampreys swim normally with the oral disc closed giving the head a bullet-shaped conformity. The anteriorly cylindrical and posteriorly compressed body, covered with copious amounts of friction-reducing slime, adapt the species well to rapid locomotion. These characteristics may be particularly useful when the animal negotiates rapids and falls. During their upstream migration and

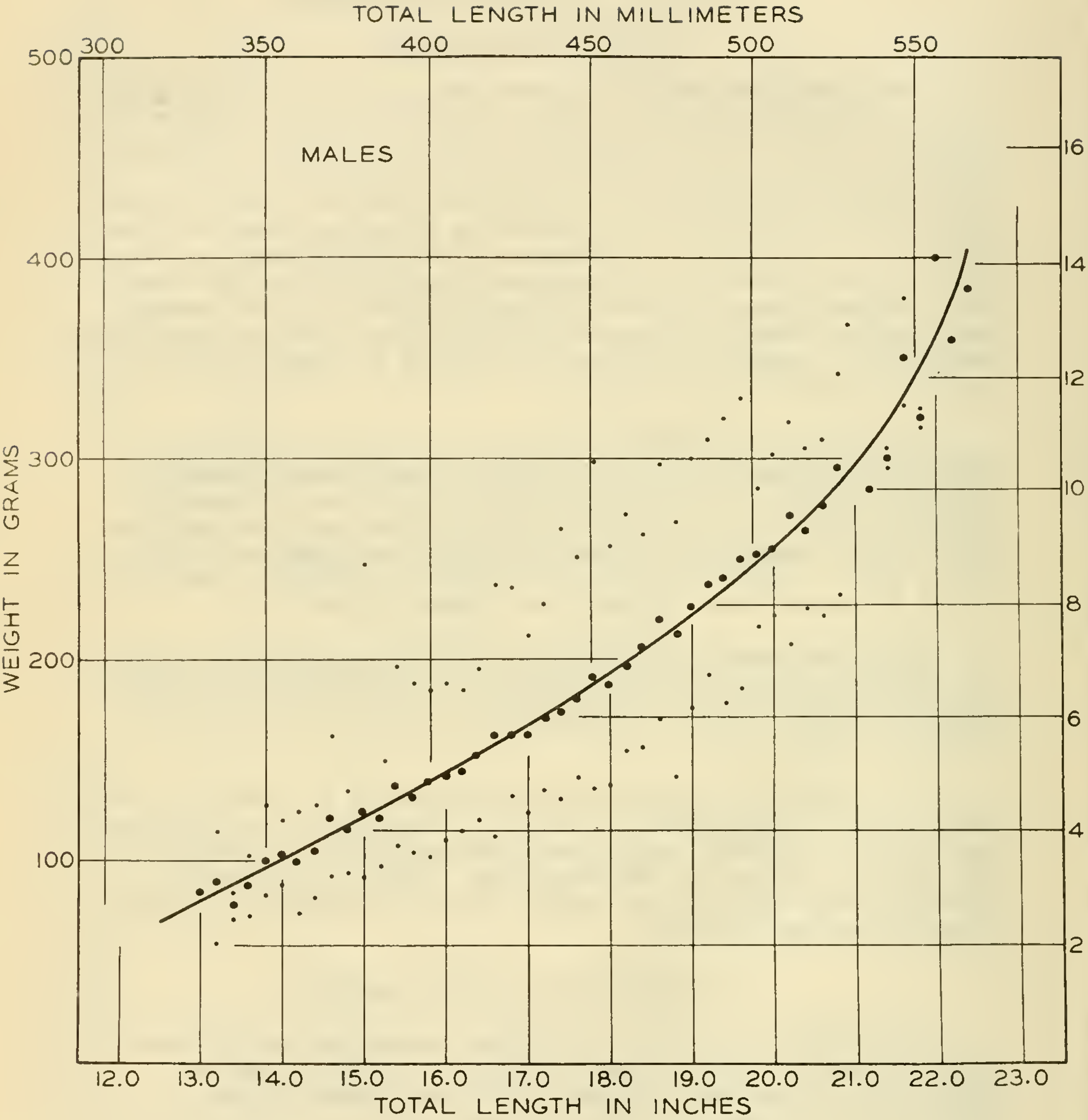


Figure 21.--Length-weight relationship and range in weight at given lengths of male sea lampreys taken in Carp Creek and the Ocqueoc River.

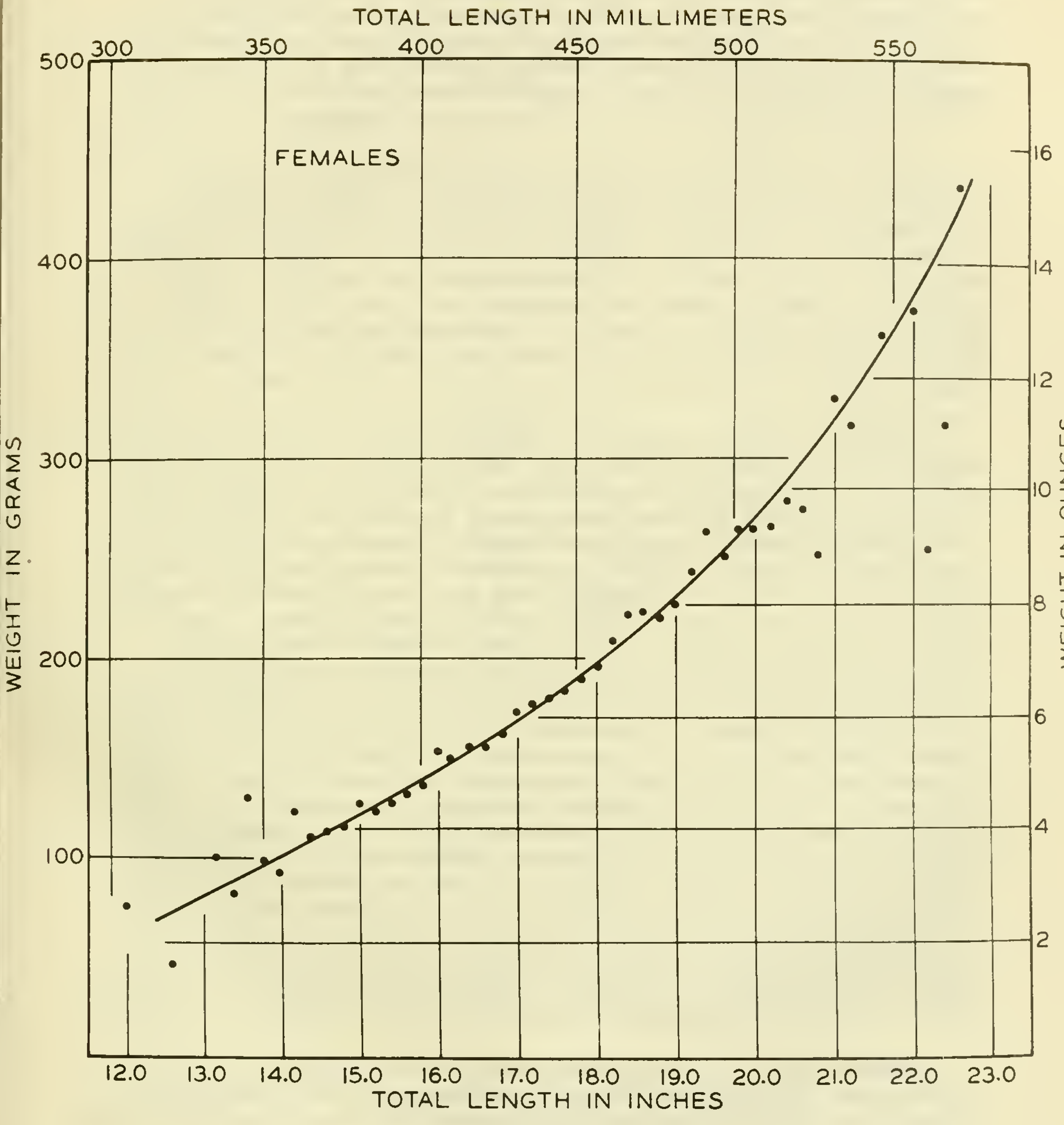


Figure 22.--Length-weight relationship of female sea lampreys taken in Carp Creek and the Ocqueoc River.

presumably during all of the adult phase of their life cycle they are, on occasion, very fast swimmers. When traversing areas of swift water, and when surmounting obstacles such as dams or natural falls, or when frightened, (presumably also when overtaking their prey) they are capable of amazing spurts of speed. However, these sudden spurts undoubtedly represent the terminal swimming velocity of the species and it seems unlikely that they could sustain such speeds for any appreciable distance.

When not taxed to their utmost by circumstances, the swimming habits (in migration) of the sea lamprey differ materially from those of other fishes. They seldom rest in midwater by maintaining their position and balance in the current through continual movement. Rather, when not deliberately moving upstream, changing position, or seeking their way around or over an obstacle, they cling by their mouths to a rock or log or any available solid object. This behavior was noted even under conditions of little or no current and among individuals resting in static water.

Related to their capacity for sudden bursts of speed is their ability to work their way over many natural falls and man-made dams of low or irregular construction. Surmounting such obstacles is not accomplished by spectacular leaps as among the salmons, but by throwing themselves upward and forward in short, wriggling thrusts and securing each gain by attaching themselves firmly in a new position by their oral disc. Each gain is followed by a seemingly long period of rest before another attempt is made to move farther. In this fashion, they progress slowly up and over the faces of falls, following crevices and fissures which offer the least resistance by current or vertical surface. Air chambers behind the falling water are traversed by the sea lampreys with no apparent difficulty. I have seen masses of them in such locations that were wet only by spray or occasional turbulent surges. Where falls and low dams offer vertical surfaces to be negotiated, it was noted that the sheer mass of the accumulation of migrating individuals occasionally forced the topmost individuals to a position where the barrier could be cleared in a single thrust. Mass action in these instances ensures that at least some individuals may gain the spawning grounds. The preceding observations were made in the falls of the Ocqueoc River and at several low dams on that river where it was possible to trace the routes of the lampreys over these obstructions by exploring the face of the falls by hand.

Observations on the Ocqueoc and at several high dams, such as those on the Cheboygan and Manistique rivers, indicate that sea lampreys can seldom "jump" vertically more than two feet although they have been occasionally observed leaping as much as four feet in a forward and slightly upward direction at the base of a natural falls. It is of interest to note that they can, and occasionally do, leap out of a 10-gallon milk can containing about 12 inches of water.

Locomotor and other behaviorisms are of interest when trapping operations are considered. Sea lampreys observed arriving on the downstream side of the Carp Creek weir and trap did not lead immediately along the wings of the weir. In general, they tended to prod and explore both downstream and upstream along the barrier, seeking some small aperture through which to pass; eventually the trap entrance was always discovered and entered. As a result of this searching behavior, these lampreys had phenomenal success in finding and passing through the smallest of apertures in a weir face. When in a trap or a live-crate, the same behavior was noted--an almost ceaseless searching for some means of escape. In 1947, I tested the ability of sea lampreys to find an opening large enough to permit their passage through a barrier screen. Eighteen migrating adults were placed in the lower of two compartments of a large live-crate that was situated in a moderate water current. The crate measured 3 feet by 3 feet by 6 feet and was made of 1/2-inch mesh hardware cloth on a light wooden frame. The depth of the water within the live-crate was approximately 20 inches. A small hole, one inch in diameter, was made in the center of the hardware cloth partition dividing the live-crate. Within four hours, all but two of the sea lampreys had found, and passed through, this hole into the upstream half of the box. For this reason, great care must be exercised in the construction and maintenance of weirs, traps, and holding pens.

The physical characteristics of the lampreys and many of their natural responses make them extremely difficult to handle during trapping operations. All nets used for removing trapped specimens must have deep bags since the lampreys tend to jump and thrash violently when removed from the water. Unless considerable practice has been had, it is almost impossible to hold on to an adult sea lamprey with bare hands. When held out of the water they weave and twist violently and attempt to fasten by their mouths to the nearest solid object. Specimens which succeeded in attaching themselves to my hand or arm did nothing more than hold on--they never harmed me with either teeth or tongue. In handling live specimens, they are best grasped just behind the last gill opening in a finger lock between the middle finger and the index and fourth fingers. They may also be held by grasping them strongly between the funnel and first gill opening with the thumb and forefinger.

Data relative to the differential migration of sexes during the spawning run and changes in its generally nocturnal nature have been presented in a preceding section (p. 54 and pp. 47-49).

The negative response of migrating sea lampreys to light is particularly marked during the first half of the run in streams. In the Ocqueoc River watershed a period of six to eight weeks elapses between the entrance of the first migrants into the river and the beginning of spawning activity. Although towards the end of this period a great number of sea lampreys are present in the drainage, they are seldom if ever seen during the daylight hours. However, visits at night to areas apparently devoid of sea lampreys during the day reveal many migrants clinging to rocks or working their way upstream. In daylight hours, they are found wedged among and under rocks, logs, brush tangles, or retired under overhanging banks or on the bottom of the deeper pools. When prodded from these hiding places they dash blindly away with little regard for the direction taken. In several instances, disturbed specimens darted at right angles to the current with such force that they slithered several feet up onto a low, grassy bank or mud flat. Generally, after traveling but a short distance, they sought to conceal themselves again by utilizing whatever cover was available. When disturbed at night by having an observer shine an artificial light on them, the lampreys flee also with apparent lack of direction. I have been unable to drive them ahead of me at night with a jacklight accompanied by splashing. Again they tend to scurry in all directions, mostly downstream and often between the legs of the drivers. Their fellow migrants, the suckers (Catostomus spp.), behave differently. They move systematically away from such disturbances in more or less of a growing school.

Prior to any spawning activity, migrant sea lampreys taken in streams are very tenacious of life, particularly in cool weather, and will survive much longer when held out of water than most other fishes. Specimens retained in a milk can without water for six hours at about 35 degrees F. on a spring night showed no apparent ill effects of their confinement when placed in water again. The pumping action of the gill pouches is very persistent, and will last as long as 1 1/2 hours in specimens that have been drawn (gutted).

Both negative phototropism and vitality change with the advent of peak spawning activity. Migrants become more and more evident during daylight hours, particularly at obstructions to migration, and nest building and spawning activity becomes as great in the light as during the hours of darkness. Among those sea lampreys engaged in spawning, this is most probably due to progressive loss of vision which accompanies the physical degeneration taking place at this time. Nearing the completion of spawning, most individuals were judged to be blind or nearly so. The tendency of migrating sea lampreys to be more in evidence in daylight during the latter half of the run may be due to this ocular degeneration and/or to an urge to reach suitable grounds and commence spawning. Both or either may offset to some degree the displayed response to light of earlier migrants.

The great vitality noted in early migrants likewise disappears; late migrants die on little handling or removal from the water.

The question has been raised often as to whether or not sea lampreys feed during migration. I have evidence that they feed very little if at all. This evidence was obtained by analyzing the contents of lamprey digestive tracts and by examining other fish present in the same waters, during a migration, for lamprey scars. The dissection of migrants taken from both Carp Creek and the Ocqueoc River presents very strong evidence that feeding ceases with approaching sexual maturity and with upstream movement. Of 2,249 migrating sea lampreys opened in 1947 from Carp Creek and the Ocqueoc River, only one specimen showed any evidence of recent feeding.

Between May 29 and July 15, 1947, netting operations were undertaken in Ocqueoc Lake utilizing 125-foot experimental gill nets. Twenty-eight sets were made averaging 24 hours each. During the period of netting operations, migrant sea lampreys were concentrated in greater or lesser numbers in the lake while in passage to the upper reaches of the watershed. A total of 69 adult sea lampreys and 114 game, pan, and coarse fishes of assorted average length were taken as follows: 27 northern pike, 21.7 inches; 41 rock bass, 6.3 inches; 2 black bullheads, 9.5 inches; 4 bluegills, 4.0 inches; 28 yellow perch, 5.7 inches; 2 largemouth bass 11.9 inches; 6 white suckers, 13.3 inches; 2 walleye pike, 11.5 inches; and 2 pumpkinseed sunfish, 3.5 inches.

Although the ratio of migrant sea lampreys to resident game fish taken in the nets was high, none of the fish bore any evidence of lamprey attacks except one 30.6-inch northern pike, taken on May 29, which had an old, healed scar. However, on May 24, 1947, a smallmouth bass about 14 inches in total length which carried a large, fresh lamprey scar was seen swimming in shoal water. Since smallmouths migrate into the Ocqueoc watershed from Lake Huron during this season and since many individuals of game species taken in the Carp Creek weir and trap were lamprey marked, it is quite possible that this scarred fish may have been attacked on a recent date while in Lake Huron.

One experimental gill net set for a 36-hour period in Ocqueoc Lake on April 21, 1948, yielded the following: 17 northern pike averaging 19.7 inches; 2 rainbow trout averaging 15.3 inches; 1 largemouth bass of 11.0 inches; and 3 suckers averaging 12.6 inches. Again, none had lamprey marks.

(6) Distance of migration

In spite of the physiological drain of stream migration without feeding and the energy demands of surmounting countless obstacles of current and falls, sea lampreys travel considerable distances upstream to reach suitable spawning grounds. Approximated maxima for present known spawning grounds show a range of from 19 to 49 miles. Obviously this fish is capable of penetrating well toward the headwaters of most Michigan tributaries of the Great Lakes, unless blocked by barrier falls or dams. Exemplary distances from the Great Lakes shoreline to nesting areas follow:

Region 1. (Upper Peninsula)

Sturgeon River, Alger County......................39.0 miles
Trout Brook, Chippewa County......................22.5 miles

Region 2. (Lower Peninsula)

Ocqueoc River, Presque Isle County...............19.0 miles
Au Gres Watershed:
Hale Creek, Iosco County........................34.0 miles
Hope Creek, Iosco County........................25.5 miles
E. Br. Au Gres River, Iosco County............23.0 miles
Au Gres River, Iosco County...................24.0 miles
Rifle River, Ogemaw County........................39.0 miles
Houghton Creek, Ogemaw County....................45.0 miles
Little So. Br. Pere Marquette, Lake County.......47.0 miles
Baldwin Creek, Lake County........................48.0 miles
Bear Creek, Manistee County.......................32.0 miles

(7) Pathology, parasitism, and predation

(a) Pathology

Of 5,135 sexually mature, migrant sea lampreys examined in 1947 and 1948, none displayed any macroscopic evidence of either bacterial or sporozoan induced infections, at least insofar as any such disease would exhibit itself by internal or external inflammations, ulcerous tissue, other obvious pathological conditions of the viscera, or by abnormal behavior.

In the samples examined, however, there were a few individuals which displayed developmental or structural abnormalities such as those which ordinarily appear in any population of vertebrates. In the Carp Creek spawning run in 1947 (1,599 specimens examined), 3 sea lampreys (2 males, 17.1 and 18.4 inches in total length; 1 female, 14.7 inches in total length) had deformed caudal fins. A fourth specimen (male, 16.4 inches in total length) had a deformed second dorsal fin. One male sea lamprey was taken which was grotesquely short in body length in relation to its girth and other bodily development. The largest sea lamprey captured in 1947, a female, 22.6 inches in total length (weight: 436 grams), possessed a severely malformed ovary; the development of individual ova in this gonad was so retarded that the sex of the specimen could only be determined with the aid of a microscope. A similarly malformed and underdeveloped gonad was found in a male sea lamprey, 18.0 inches long (weight: 152 grams).

In the Carp Creek spawning run in 1948 (2,938 specimens examined), 2 sea lampreys (female, 15.0 inches, and male, 13.0 inches in total length) were taken which had deformed caudal fins. One male, 11.0 inches long, had a disproportionately short body in relation to its other structural features. Two females were noted each with a small, healed perforation in the anterior body wall. In at least one of these cases the perforation opened into the body cavity; their origin is not clear.

It is concluded from these observations, that the migratory populations of sea lampreys examined were quite perfect physically and displayed no gross evidence of any maladjustment to their relatively new habitat in the Lake Huron basin. These observations agree, in general, with those of Gage (1928) for the dwarf sea lamprey (lake lamprey) on its spawning grounds in inland New York waters. Among these he noted only occasional instances of abnormal structure or development.

(b) Parasitism

During the 1948 spawning runs, a random sample of 100 migrating sea lampreys was carefully examined for the presence of internal parasites. This sample was collected between June 2 and 8, 1948, in the Ocqueoc River falls (69 specimens) and in Carp Creek (31 specimens). Fifty-six of the sea lampreys were males ranging from 12.6 to 18.9 inches in total length (average: 16.6 inches) and 44 were females ranging from 12.9 to 19.6 inches in total length (average: 16.4 inches).

Twenty sea lampreys (10 males and 10 females) or 20 percent of the total sample contained one or more individuals of several types of parasitic organisms within their digestive tracts. The most common of these were adults of the acanthocephalan, *Echinorhynchus coregoni*[2] which occurred in 17 of the sea lampreys examined (9 males and 8 females). With the exception of one sea lamprey which contained three adult worms, all specimens examined had but one of these parasites in the digestive tract. This parasite has commonly been reported from whitefish and various other northern fishes.

---

[2] Identified by Dr. H. J. Van Cleave of the University of Illinois.

Single, immature specimens of cestodes were found in the intestines of three sea lampreys; two of these tapeworms were identifiable--the third was not. Identified from the scolex only, was a plerocercoid larva of Trianophorus (crassus?).[3] Larval cysts of Trianophorus crassus are found frequently, and occasionally in some abundance, in the flesh of the whitefish and tullibee (Cameron, 1945; Kennedy, 1948). It has been observed that sea lampreys are now feeding extensively on whitefish in northern Lake Huron. Presumably, then, this larval tapeworm is traceable to this source. It is considered doubtful if it (the plerecercoid larvae) could mature since the sea lamprey is an unnatural final host for it.

The other identifiable tapeworm was an immature specimen of Abothrium sp.[4] This parasite infects trouts, coregonids, and smelt (Plehn, 1924) and burbot (Van Cleave and Mueller, 1934; Bangham, 1946). However, since the larvae are normally found imbedded in the intestinal wall of hosts, the manner in which the sea lamprey carrying this parasite became infected is somewhat obscure.

Occasional sea lampreys were taken in 1947 and 1948 which had small tumor-like cysts in the wall of the intestine. Five such specimens were taken from Carp Creek in 1947 (1,599 sea lampreys examined) and 11 similarly afflicted specimens from the same stream in 1948 (2,938 sea lampreys examined). The majority of these swellings were examined and proved to be cysts. However, in each case the contents of the cysts were in a disintegrated condition and could not be identified. The circumstances suggest strongly that these cysts were those of nematode larvae which had died, according to A. E. Woodhead (verbal communication).

Although a large percentage of the total sample of sea lampreys contained internal parasites of one form or another, no single specimen contained enough parasites to constitute a severe or apparently harmful infection.

Occasional sea lampreys taken in the Carp Creek trap in 1948 had leeches attached to them. One of these, identical with the others observed, was identified as Piscicola milneri (Verrill, 1847).[5]

---

[3] Identified by Prof. A. E. Woodhead, Dept. of Zoology, University of Michigan.
[4] Identified by Prof. A. E. Woodhead, Dept. of Zoology, University of Michigan.
[5] Identified by Dr. Marvin Clinton Meyer of the University of Maine.

(c) Predation

Since the beginning of the present investigation, occasional observations were made, or reports received, of predation upon migratory or spawning sea lampreys by fishes, birds, and mammals. Perhaps the most interesting observations are those of predation by fishes. On June 27, 1947, a walleyed pike, 17.0 inches in total length, taken on a lure in Ocqueoc Lake, was found to have swallowed a mature, adult, female sea lamprey 14.5 inches long. At the time of capture, several inches of the sea lamprey's tail were still protruding from the walleye's mouth. In the stomach, digestion of the head region had barely begun. Conservation Officer Charles Vanderstar of Naubinway, Michigan, reported that a 16-inch (sea) lamprey was removed from the stomach of a 7 1/2-pound (northern) pike taken from Millecoquin Lake, Mackinac County, on June 17, 1948. This watershed is known to support a moderately large sea lamprey spawning run. Mr. B. L. Foresman of Alger, Michigan, reported finding a 13-inch sea lamprey in the stomach of a 4 3/4-pound brown trout. This trout was taken in the Rifle River, Ogemaw County, during the month of May, 1948. Like the Millecoquin, the Rifle River has a sizable sea lamprey run.

These records would indicate that mature sea lampreys, regardless of their size or habits, are not immune to attack by large, predatory game fishes. Many more are undoubtedly destroyed by such fishes than ever come to the attention of interested observers.

The sea lamprey appears most vulnerable to attack by birds and mammals while on its spawning bed. On June 22, 1947, the partially devoured carcasses of several sea lampreys were found on the bank adjacent to a crowded spawning riffle in the Little Ocqueoc River, Presque Isle County. Tracks of a raccoon at the carcasses and lamprey teeth found in nearby raccoon scats identified the predator. Less conclusive evidence found several days later on the Ocqueoc River indicated that a mink may have captured and partially devoured a sea lamprey. I have also noted several domestic dogs which enjoyed capturing spawning sea lampreys and dragging them out on the bank; they were seldom eaten by the dogs in the presence of the observer.

During late June, 1948, a great blue heron was observed on several occasions fishing in one of the scattered spawning riffles in the Ocqueoc River (T36N, R3E, S.33). Although this bird could not be approached closely at any time, it was observed on one occasion in the act of swallowing a spawning sea lamprey.

The peak of spawning activity in the Ocqueoc River in both 1947 and 1948 was accompanied by daily concentrations of gulls (presumably herring, ring-billed, and Bonaparte's gulls) which flew into the most heavily used spawning areas each morning. They were observed picking up both spawning, and spent and dead sea lampreys.

Their activities may account, in part, for the seeming scarcity in some spawning areas, of dying and dead lampreys which have completed their spawning activities.

Migratory sea lampreys, even in areas of deep water, are preyed upon by the gulls. Several employees of the Manistique Pulp and Paper Co. and Mr. Howard Loeb of the Fish Division reported observing (in 1947) "sea gulls" capturing migratory sea lampreys as they came to the surface in "boils" below the tail-race of the paper mill on the Manistique River. This phenomenon is so common during the peak of migration in that river and the actions of the gulls so comical as they attempt to swallow 14- to 18-inch lampreys that they provide consistent amusement for mill employees during this period.

Of all avian and terrestrial predators, gulls apparently constitute the only significant natural enemy of the sea lamprey during its migration and spawning in Michigan streams. However, the total effect of the activities of these birds has not kept this lamprey from becoming more abundant up to the present or from increasing its range.

The basic source of references in the literature to natural enemies of adult sea lampreys is the study of Surface (1899) for the Cayuga Lake region, New York. Surface presented records of predation upon adults by: (Mammals) raccoons, muskrats, rats, mink, weasels, foxes; (Birds) hawks, owls, herons, bitterns; and (Reptiles) the water snake. He reported also having seen a bowfin eat an adult sea lamprey in an aquarium. All of these kinds of animals, along with other potential predators, are present in Michigan and probably feed occasionally on migrant or spawning sea lampreys.

(8) Reproductive potential of sea lampreys

(a) Collection of materials

All field observations upon which this study of the reproductive potential of the sea lamprey is based were made between April 9 and July 10, 1947, on the Ocqueoc River and Carp Creek. The degree of maturity of nearly all sea lampreys entering Carp Creek in that year was estimated as was that of large samples of specimens taken from the Ocqueoc River. The entire ovaries were removed from 70 migrant females and preserved in F-A-A (a solution of formalin, acetic acid and alcohol). Fifty-eight of these specimens were taken in Carp Creek, eight in the Ocqueoc River, one in Ocqueoc Lake (taken in a gill net, presumably while migrating through the lake to the spawning grounds in the river upstream from the lake), and three were captured in the Cheboygan River below the power dam in the city of Cheboygan, Cheboygan County. Pertinent mensural data were collected on all specimens at the time of capture. The specimens utilized were deliberately selected for length so that all size-groups in the migrant population would be adequately represented among the data. To obtain a better measure of the variability in egg production at a given size, additional specimens were collected in the 17.0- to 18.0-inch (432-457 mm.) size group. This group embraces the mean length (17.4 inches, 442 mm.) of the 603 females which entered Carp Creek in 1947.

The earliest specimens represented in my series of 70 migrant females (Nos. 1, 2, and 3) were speared just before midnight on April 15 and 16 in Hammond Bay, about 100 feet offshore from the mouth of Carp Creek. They undoubtedly represent the earliest migrants arriving from deeper waters of Lake Huron as determined by repeated observations during the period April 9 through April 15. Those observed were making no effort to enter the creek at that time. They arrived on the gravel fan off the mouth of the creek about two hours after dark and dropped back into deeper water with the beginning of dawn. Upstream migration began on or about April 19. After April 15-16, specimens for this study were collected at five- to ten-day intervals throughout the migratory period.

In addition to the gravid females, 40 spent and dead or dying specimens were collected in the Ocqueoc River, the Little Ocqueoc River (a tributary of the former) and in the Manistique River (a tributary of Lake Michigan). Schoolcraft County (one specimen). The remnants of the ovaries and all eggs remaining in the body cavity were removed and preserved in F-A-A.

(b) Egg development and maturity in spawning migrants

Female sea lampreys when sexually mature and ripe have a single, elongate ovary extending nearly the entire length of the body cavity (Figure 23). The anterior tip of the ovary begins just behind the last pair of gill pouches and the organ extends posteriorly to the anus. The ovary, when the eggs are ripe, or nearly so, constitutes a large percentage of the total weight of the female. In 18 ripe or nearly ripe females collected between June 12 and June 26, the ovaries averaged 22.4 percent of the total weights of the females and ranged from 13.6 to 29.5 percent. On the other hand, in eight less mature females collected between April 15 and April 30, at the beginning of the run, the ovaries averaged only 11.3 percent of the total weights of the females and ranged from 8.2 to 15.8 percent.

When the eggs are fully ripe, they are shed into the coelom (body cavity) and are forced to the exterior during the spawning act through a pair of genital pores. One of these pores enters each side of the urogenital sinus which is provided with a median pore to the outside on a papilla situated behind anus. No Müllerian ducts (nor vasa efferentia in the male) are present, unless the

Figure 23.--Dissection of a ripe female sea lamprey showing size, extent, and position of ovary. Note atrophied remains of digestive tract lying on and within the ovary. (Photo by George Skadding.)

paired pores represent these. The ripe eggs are spherical to pear-shaped in form and sandy to light tan in color. At the time of extrusion, they are non-buoyant and somewhat adhesive; sand grains stick to them readily.

In order to determine the nature of the ova present throughout a given ovary, and the degree of egg development (i.e., stage of maturity) in females at different times during the spawning run, diameter measurements of ova were made from eight specimens. Measurements were made by means of an ocular micrometer in a compound binocular microscope; calibration of the ocular micrometer with stage micrometer indicated a value of 0.05 millimeters for each micrometer unit; diameters were therefore determined to the nearest 0.05 millimeter.

Due to the effects of preservation and the natural shape of many of the eggs, very few were perfectly symmetrical. In order to avoid any selection of the longest or shortest diameter, the micrometer was fixed in a vertical position upon the field of vision and the diameter parallel to the graduations on the micrometer measured. This gave the longest diameter of some eggs, the shortest of others, or intermediate measurements between the two. Clark (1925) tested this method and found it to be reliable. It was used again by the same author (Clark, 1934) and by Carbine (1944) with excellent results. Although the eggs appeared equally turgid and well-formed both after preservation and when examined fresh, I do not know if any small shrinkage occurred because of preservation. If any did occur, it could hardly have been an appreciable amount. In any event, the relative values obtained would keep their identity.

The first ovary analyzed was from a 12.6-inch (320 mm.) female taken in the Carp Creek weir on June 16, 1947. The weight of this female was 70 grams and the ovary weighed 13.50 grams or 19.2 percent of the weight of the specimen. Sections were removed from the anterior, middle, and posterior thirds of the ovary. The eggs were teased out of the sections, a random sample of 500 eggs was obtained, and these eggs were measured. A frequency diagram of these ova measurements appears in Figure 24. For each section, the average diameter and range were as follows:

Anterior section -average: 0.87 mm., range: 0.35-1.10 mm.
Midsection -average: 0.90 mm., range: 0.50-1.15 mm.
Posterior section-average: 0.82 mm., range: 0.35-1.15 mm.

It is apparent from these data that the ova in the midportion of the ovary are slightly larger than those developing in the front and back portions. The difference is so small, however, 0.03 millimeters and 0.08 millimeters, that no appreciable error is involved in the other measurements and calculations made from midsections only.

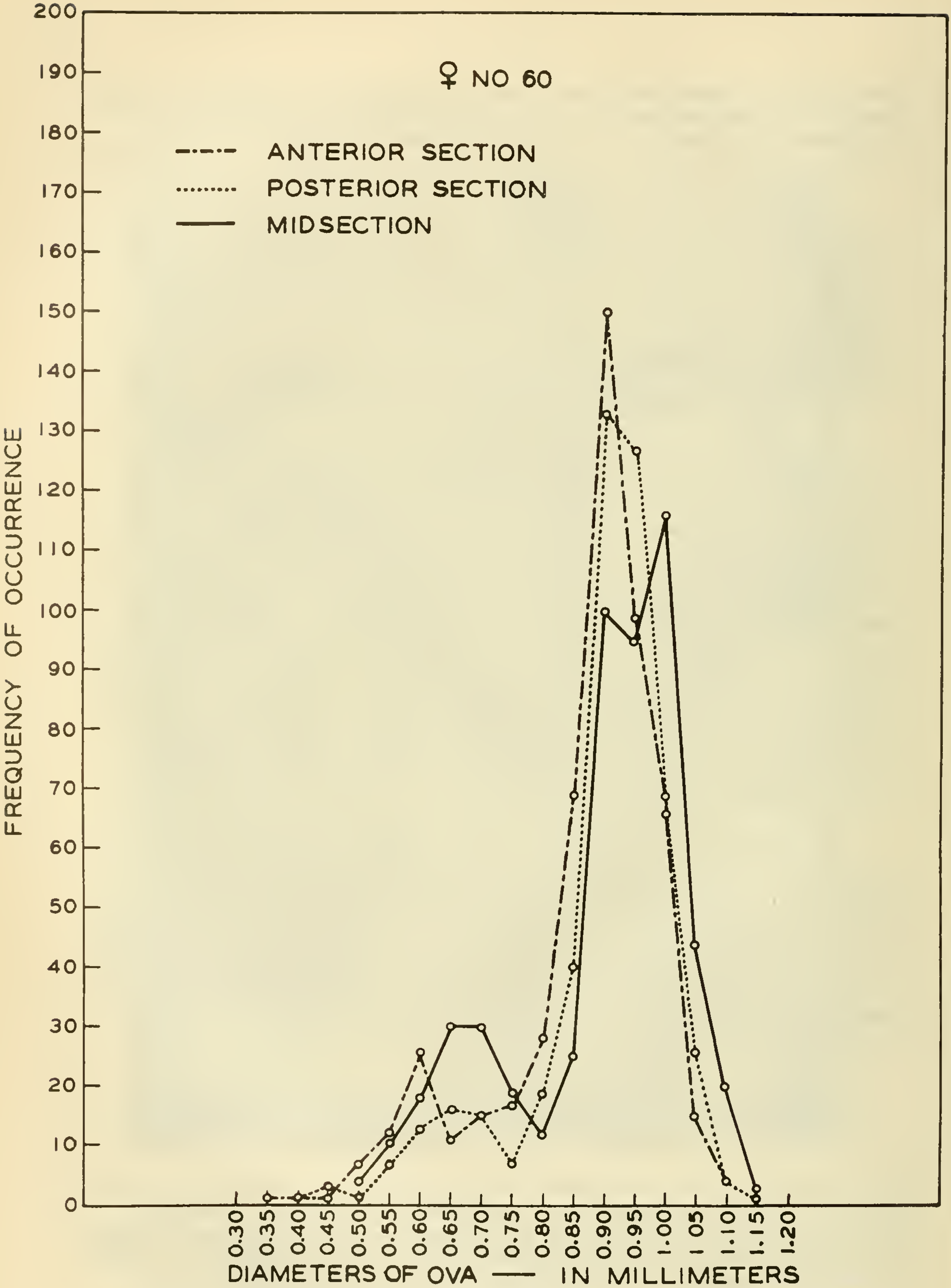


Figure 24.--Frequency distributions of ovum diameter measurements made from samples taken from the anterior, mid, and posterior sections of the same ovary.

Jordan (1905) reported that "A. Mueller, in 1865, showed that all of the ova in the lamprey were of the same size, and that after spawning, no small reproductive bodies remained to be developed later." It is not quite clear to which species he has reference. In the light of the examination of this and subsequent specimens of the sea lamprey, this statement is in need of qualification. Three categories of ova were present in the material examined. First, there are the developing ova (represented by the highest modes in Figure 24). These are by far the most numerous in the ovary and are the eggs which are destined to be spawned very shortly. Second, there are ova of apparently retarded development which I term "partially developed ova" (these are represented in Figure 24 by each low mode to the left of the high ones representing the developing ova). The partially developed ova are scattered throughout the ovary and differ from the larger ones only in size and amount of contained yolk; the form appears similar. Such eggs are present in variable numbers in all females but are more commonly found in the smallest specimens and are quite infrequent in the larger ones. The individual represented in Figure 24 is believed to have contained the largest number of partially developed ova in the entire series studied. It probably represents the greatest proportion of this kind of eggs present in the females of an average spawning run. In examining females in which the eggs had burst into the coelom, I found that some of these retarded ova were extruded with the fully developed ones. The majority, however, remained trapped in the remnants of the ovary. Other experiments have shown that those retarded eggs that are extruded with the mature ova can become fertilized but it is not known if full development to hatched larvae occurs. Ova in the third category are microscopic in size, generally between 0.20 and 0.30 millimeters in diameter. They are variable in number in different females, but as a rule they are quite numerous although their total number is always less than that of the more mature eggs. These ova, unlike those of the other two categories, are translucent, contain little or no yolk, and are still firmly attached to pedicles in the gonad. Since they could readily be found only in the frayed ovarian tissue of spent females, they do not enter into any of the measurements or counts that were made. They were too small to be seen with the mignification used in making the counts and measurements of the other two kinds of eggs. It seems logical to conclude for the sea lamprey that mature ova develop at the expense of the retarded and undeveloped ones and/or that some mechanical impediment aborts the development of the latter. I do not believe that either of the latter categories could be construed to represent a potential reserve stock that would enable the female to spawn again in the following year.

Jordan (1905) further states that "....the most careful microscopical examination of ovaries or testes has failed to reveal any evidence of new gonads or reproductive bodies." My preliminary examinations seem to confirm this. Even if it should be demonstrated that the ovaries or testes of some spent sea lampreys contain spermatogonia (and spermatocytes) or oögonia (and oöcytes), the presence of such germ-cell stages need not necessarily indicate that these specimens would have lived to spawn in another season. Weisel (1947) has shown the presence of these germ cells in spent, land-locked sockeye salmon (Oncorhynchus nerka) of both sexes. Individuals of this species become sexually mature and spawn only once, dying very shortly thereafter. Weisel concluded that some factor, other than a potential supply of germ-cells, limits the spawning of this Pacific salmon to a single season.

In general, the developmental stages of the ova found in the sea lamprey are similar to those found in other fishes that spawn during a single brief period, i.e., the maturing eggs constitute a single size group more or less discrete from the immature ova. The sea lamprey, however, differs fundamentally from such fishes in one respect. In females of those species that spawn in several or many seasons, the immature eggs greatly outnumber the maturing eggs at the time of spawning (Carbine, 1944). It is here demonstrated that in the sea lampreys studied, the maturing eggs outnumbered the undeveloped ones present. This fact, the absence of any germ-cell stages, and the nature of other physiological changes at spawning I consider very strong evidence that the sea lamprey spawns but once and then dies.

Ovum diameters were obtained from seven additional specimens. Six of these were selected from the series available so that one of the earliest and one of the latest migrants and four migrants taken on scattered intervening dates were represented. For uniformity these were selected to fall within the range of 17.0 and 17.5 inches (432 and 445 mm.) in total length. These factors only governed the selection of the specimens. A seventh specimen (No. S-41) of comparable length (16.4 inches, 417 mm.) taken on the spawning grounds, was chosen for examination since in this female the bulk of the eggs had burst into the coelom and presumably represented fully mature eggs. The data for six specimens are based on sample sections removed from the previously described midregion of each ovary. These samples were teased apart and a random sample of 500 ova from each was measured. For specimen No. S-41, a random sample of 500 ova was taken from the total number that were loose in the coelom. The data obtained for all seven specimens are presented in Table 3, and those for six of the specimens (including No. S-41) are graphically portrayed in Figure 25.

Ova from the earliest spawning migrants entering a stream are about 3/4 of a millimeter in diameter (average: 0.75 mm., range: 0.40-0.85 mm.). Fully mature eggs average about 1.10 millimeters in diameter and range from 0.80 to 1.25 millimeters. Migrants entering the stream on progressively later dates demonstrate progressively more advanced stages of egg development (Table 3). It

Table 3. Diameter of developing ova in seven female sea lampreys collected at intervals during the spawning migration.

Specimen number	Place of collection	Date of collection	Total length (inches)	Total length (millimeters)	Weight in grams	Condition of ovary	Ova diameters (in millimeters)[1]	
							Average	Range
2	Hammond Bay—off mouth of Carp Creek	April 16, 1947	17.2	437	222	Green	0.75	0.40–0.85
4	Carp Creek weir	April 25, 1947	17.2	437	134	Green	0.76	0.50–0.95
14	Carp Creek weir	May 12, 1947	17.2	437	165	Green	0.83	0.40–1.00
23	Carp Creek weir	May 25, 1947	17.5	445	168	Green	0.91	0.45–1.10
36	Carp Creek weir	June 10, 1947	17.2	437	246	Green	0.98	0.45–1.20
73	Carp Creek weir	July 2, 1947	17.0	432	178	Ripe	1.03	0.60–1.25
S-41	Ocqueoc River	June 28, 1947	16.4	417	203	Eggs loose in coelom	1.10	0.80–1.25

[1] Range and averages for each specimen based on random sample of 500 ova taken from the midsection of the ovary.

Figure 25.--Frequency distributions of ovum diameter measurements from sea lampreys taken on successive dates. The upper left specimen was a very early spawning migrant; the upper right and two central specimens were captured prior to, and during, the peak of the run; the lower left specimen was taken after the peak of the run and that in the lower right was a female in which the fully ripe eggs had burst into the coelom.

should be pointed out, however, that the smooth progression of increasing average ovum diameters with later dates of capture in Table 3 is most likely fortuitous. In examining nearly a thousand females, I found that many degrees of maturity were represented among the specimens taken on a single day, particularly in midseason. The mean values listed in Table 3 are considered to represent the average degree of egg development in females entering the stream on the dates indicated.

In migrants entering the stream in mid-April, 68.4 percent of the development of the ova had still to take place while the female was in the stream (computed on the basis of the relative volumetric proportions of individual ova with the assumption that they are perfectly spherical). In females that entered the stream from mid-June until the end of the run, the eggs were very nearly fully developed, but not so far along as to have burst into the body cavity. In only a few of the late migrants, including the last ones taken in July, were any eggs found in the coelom.

In the frequency polygons presented in Figure 25 a uniform horizontal scale was used for all six projections. Thus the relative degree of maturity of the specimens examined is apparent in the progressive shifting of the frequency distributions from left to right. Of particular interest is the great scarcity of partially developed eggs found in most of the samples represented.

(c) Egg production

Of the 70 specimens utilized to determine egg production, actual numerical counts were made of the ova in 10 specimens. These included the largest (21.1 inches, 536 mm.) and the smallest (12.6 inches, 320 mm.) females in the series and eight of intermediate size. Prior to making each of these counts, the total volume and the total weight of the ovary were obtained. A sample section was removed from the middle of the length of the ovary and the volume and weight of the sample were likewise determined. Volumes were secured by a system of displacement of water into a cylinder bearing 0.2 cc. graduations and were read to the nearest 0.1 cc. Weights were obtained to the nearest 0.01 gram on a chemical balance. Excess moisture was removed as consistently as possible from all ovaries and sections before any determinations were made. Eggs in the sample sections were counted first and the total production was computed by direct proportion for both the volumetric and the gravimetric data. When the balance of the ova had been counted, the calculated totals by both techniques could be compared for accuracy. This procedure was followed for all ten specimens.

There was really very little difference in the accuracy of the two techniques (Appendix F, Table 1). By the volumetric technique the calculated totals differed from the actual totals (numerical counts) by amounts varying from 0.0 to 10.4 percent. The mean percentage error was plus 3.2 percent. By the gravimetric technique, deviations from actual totals varied from 0.0 to 9.7 percent with a mean percentage error of plus 2.5 percent. The mean percentage errors of the two techniques are based on an algebraic average of the individual percentage errors. Although in most cases this statistic might produce an inaccurate result, it is felt that in this instance its application is justified. A mean error based on the algebraic sum of deviations expressed in numbers of eggs allows individual specimens (such as a small one of low egg count) to influence the results unduly, i.e., a female, for example, containing only 25,000 eggs and for which there is a plus or minus 1,000 egg deviation between calculated and actual totals has a large percentage error. This latter statistic is a very real measure of the efficiency of the calculating technique in that particular case. However, an equal numerical deviation in a larger and more productive specimen results in a much lower percentage error. It follows, then, that if errors expressed in numbers of eggs tend to remain more or less constant (as they may if there is some small bias in the technique), too many small test specimens or too many large test specimens in a series will undoubtedly render too high or too low a mean error.

The preponderance of positive errors in calculating total egg production suggests some small bias in the techniques or procedures used. It is felt that the mean percentage error, as computed, provides the best measure of any bias, if it exists, resulting from some defect in the procedure. The mean percentage errors in this study are so small, however, that they may very well fall within the limits of chance occurrence. Consequently, the application of any small correction factor to the calculated data on egg production is not suggested.

The gravimetric method was utilized in calculating total egg production for the remaining 60 specimens because, apparently, the smallest error was involved in this technique and because the laboratory procedure is more rapid by this method. Data on size, weight, and egg production were tabulated in order of increasing total length of specimens (Appendix F, Table 2). Where there was more than one specimen of a given length, these were listed in order of increasing egg production. These data have been plotted upon two graphs to illustrate the relationship between egg production and total length (Figure 26) and between egg production and weight (Figure 27).

The first property evident in these figures is that the number of eggs produced by the sea lamprey varies greatly at any particular length or weight. Mean egg production was computed by one-inch size groups and by 50-gram weight groups and these values were plotted upon the respective graphs. The curves appearing in

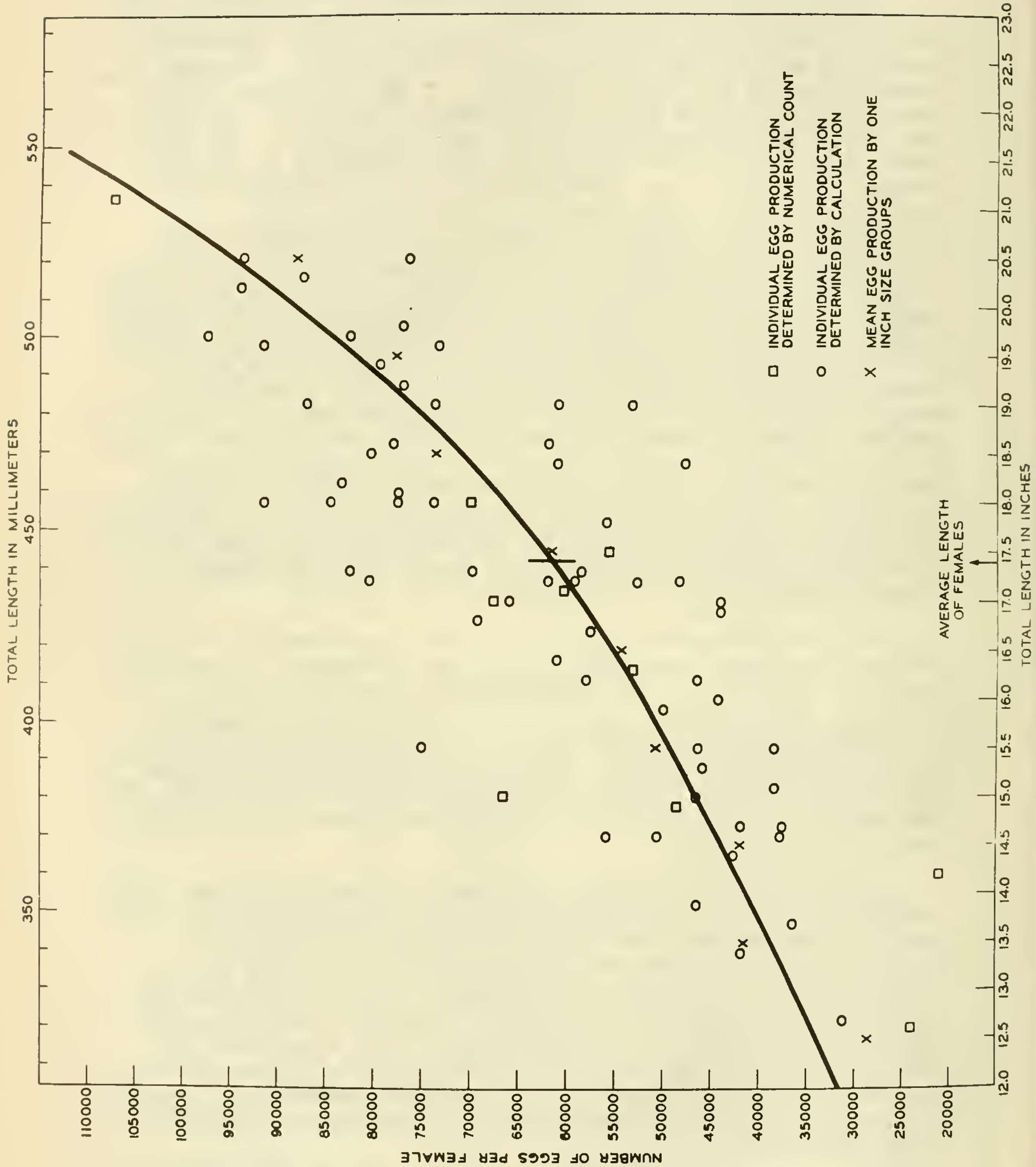


Figure 26.--Relationship between the number of eggs produced and the total length of the fish for seventy sea lampreys.

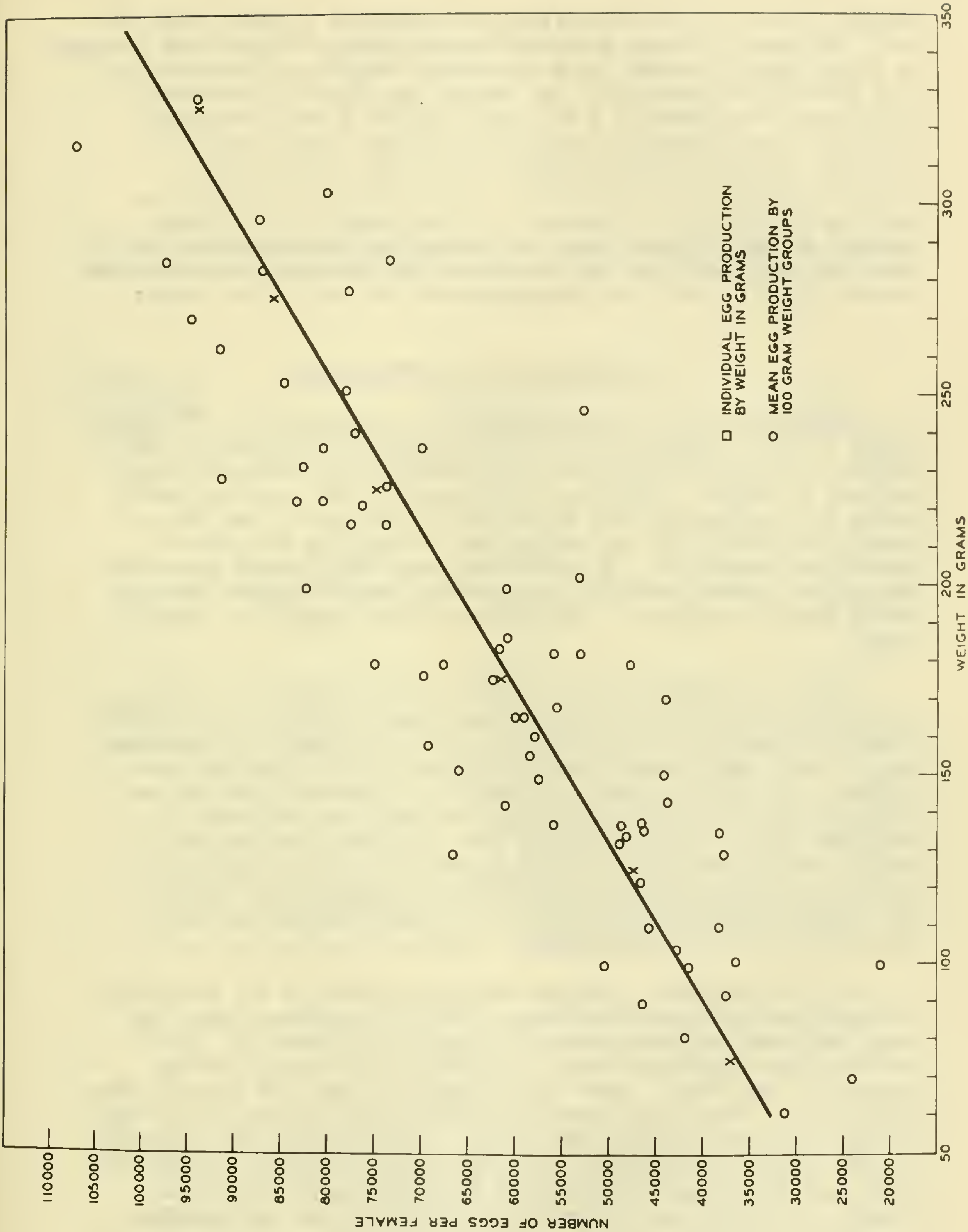


Figure 27.--Relationship between the number of eggs produced and the weight of the fish for seventy sea lampreys.

Figures 26 and 27 have been fitted by inspection to these mean values. The number of eggs produced increases quite rapidly with increase in total length; however, with increasing weight egg production is more directly proportional. The lowest egg production recorded, 24,021 eggs, was found in a 12.6-inch (320 mm.) female weighing 70 grams. The greatest recorded, 107,138 eggs, was found in a 21.1-inch (536 mm.) female weighing 316 grams. Using values obtained from the curve projected in Figure 26, we find that the mean egg production for females of average length (17.4 inches, 442 mm.) is 61,500 eggs. Mean egg production data, as estimated from the curve in Figure 26, for successive one-inch size groups are listed in Table 4 with the mean deviation for each of the groups.

(d) Percentage of unspawned eggs

The egg production determined for the sea lamprey in the preceding section represents the basic reproductive potential of the species in the region studied. This potential is obviously never realized in nature. Many factors inherent in the organism itself and in its environment tend to nullify the potential, and the actual productivity of the species may be very low when these factors are considered. A preliminary experiment in the number of ammocoetes (larvae) produced per spawning female suggests that the larval hatch per number of eggs produced (and spawned) is quite small.

One of the inherent factors which may contribute to a low productivity is the percentage of ripe eggs remaining in the female after the spawning act is completed, i.e., the number of unspawned eggs. Forty spent females were collected to determine this percentage. In order to avoid any doubt as to whether they had completed as much of their spawning act as they were destined to, only dead (30) or obviously dying (10) specimens were collected. Most collections were made in the deeper pools below spawning riffles or in sloughs into which the dying lampreys had drifted. The females obtained ranged from 11.8 inches (300 mm.) to 18.1 inches (460 mm.) in total length.

For ten specimens, separate counts were made of the partially developed and fully developed eggs. For the remainder, only the fully developed eggs were counted (Appendix F, Table 3). The partially developed eggs were, as a rule, still trapped in the remnants of the ovary. Some fully developed eggs were found in like position, but when larger numbers of these were present, by far the bulk of them were loose in the coelom. The potential egg production of each female was determined from the curve projected in Figure 26. Using this figure and the number of developed eggs retained in females, the estimated percentage of unspawned eggs was computed (Appendix F, Table 3). The partially developed eggs were not considered in estimating this percentage since their occurrence is variable with the length of the fish. They are present in nominal numbers only in all but the very smallest size groups.

Table 4. Estimated mean egg production by one-inch size groups as determined from the curve projected in Figure 26 and mean deviation for each of these groups.

Midpoint of size group (inches)	Mean egg production	Mean deviation
12.5	34,000	...[1]
13.5	38,700	4,449
14.5	43,800	7,805
15.5	48,300	8,960
16.5	55,200	7,287
17.5	62,200	8,541
18.5	70,600	10,560
19.5	81,900	9,896
20.5	94,800	6,853
21.5	110,300	...[1]

[1] Too few specimens to warrant computation.

As a general rule, only a very small percentage of developed (mature) eggs remain unspawned; the estimated average percentage was 5.00 percent. Among the specimens there are, however, several notable exceptions. For two individuals, the estimated percentages of unspawned eggs were 28.6 and 37.2. Two others were identical in having an estimated 19.4 percent of their eggs unspawned. All the females displaying a relatively high percentage of unspawned eggs were late migrants, appearing at the very end of the spawning season. Observations made upon late migrants of both sexes indicate a very low vitality at that time. I suspect that these specimens examined which contained a large number of unspawned eggs were unable to complete their spawning act before approaching death made them incapable of doing so. In view of this, the average percentage of 5.00 unspawned eggs is believed to represent the maximum average that occurs; indications are that this average would be lower if computed for specimens found spent nearer the beginning of the spawning season.

V. Spawning habits and spawning requirements of the sea lamprey

The date upon which the following discussions are based were collected exclusively in the Ocqueoc River watershed between April 29 and July 3, 1947, and April 11 and August 10, 1948, when the spawning run of sea lampreys in each year was observed. In 1947, the beginning, peak, and conclusion of spawning activity were observed, and a survey ofthe physical characteristics and intensity of spawning in each area of the river was made; spawning behavior, spawning sites, and nest construction were likewise studied.

In 1948, the onset, peak and cessation of spawning were again observed in detail in selected areas of the river. Regular visits were made to these sites so that all degrees of spawning activity could be noted and compared with related environmental conditions. Further observations on the spawning behavior of the sea lamprey were made in this year.

Daily records of air and water temperature, water level, and weather were obtained in both years so that the effect of these factors upon the spawning and other activities of the sea lamprey could be determined (described for 1947 in Section IV and in Appendix C, and for 1948 in Appendix G, Table 3).

Physical characteristics of the Ocqueoc River watershed

The geographic location and a generalized description of the Ocqueoc River are given in Section IV. Briefly, this river drains in a northerly direction to Ocqueoc Lake and thence easterly into Hammond Bay of Lake Huron (Figure 28). It reportedly embraces 89 miles of watercourse (determined on large scale maps with a

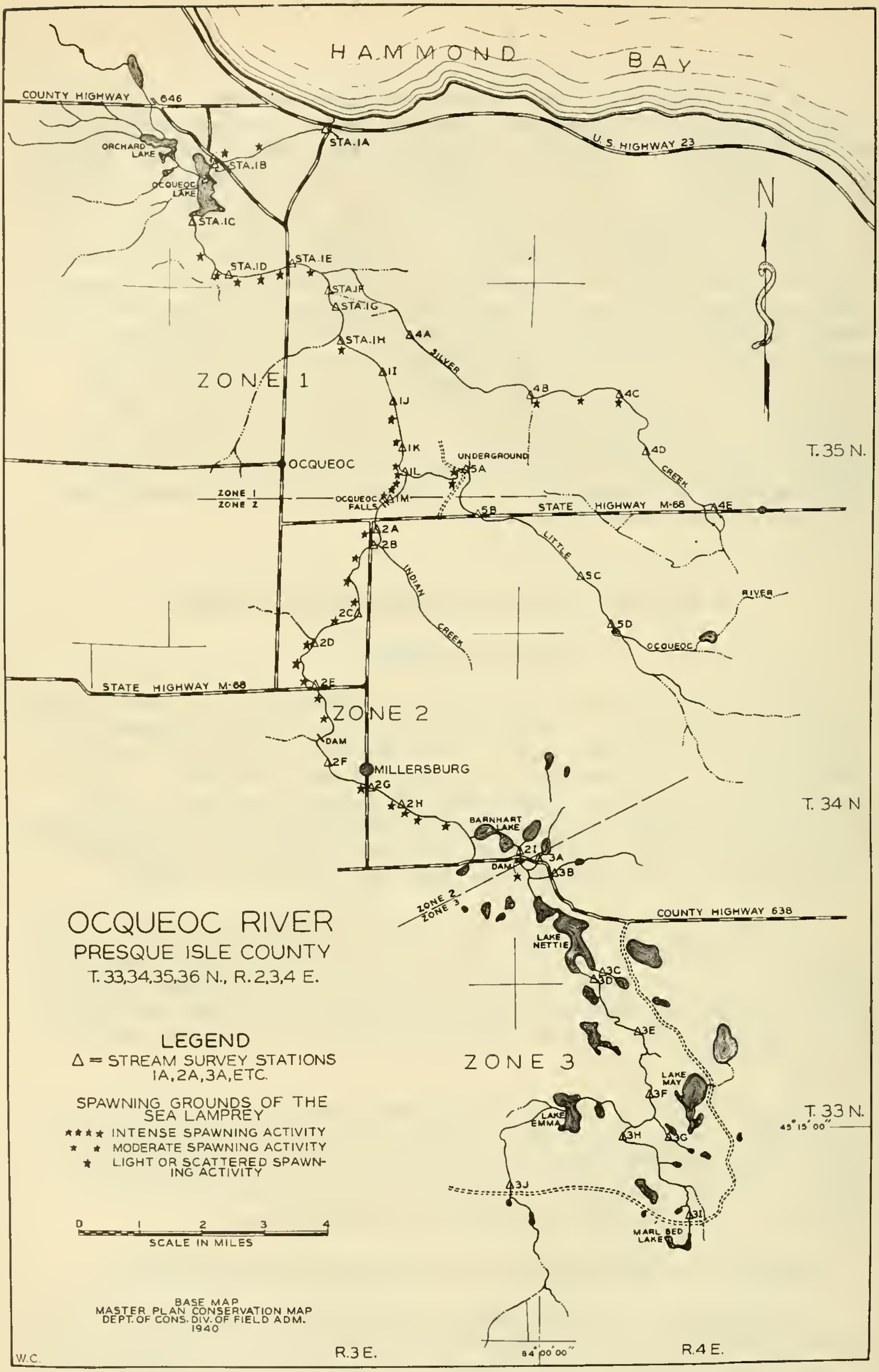


Figure 28.--Map of the Ocqueoc River watershed showing zones and survey stations described in this study and the spawning areas of the sea lamprey in the watershed.

map measurer).[6] A sizable portion of this area is occupied by intermittent tributaries, many of which flow only during a short period in the spring. From the standpoint of physical characteristics, the river is divided, rather sharply, into three zones (Figure 28), each representing about one-third of the watershed. These zones form the basis of subsequent discussions relating to the spawning behavior of the sea lamprey. A description of each zone, beginning at the headwaters of the river and working downstream to the estuary follows.

Zone 3.--(Stations 3A-3I, Figure 28) The river rises in Marl Bed Lake (T33N, R4E, S.28) and from a chain of lakes and marshes in T33 and 34N, R42E, which are scattered over 25 square miles of an irregular, sandy drift area (Leverett, 1912). Both main channel and tributaries, except where lakes interrupt the course, flow almost continuously through wide, open marshes, bog meadows, or cedar swamps. In this, the upper third of the river where the main channel travels approximately 8.5 miles, the width of the stream varies from 4 (Station 3I) to 30 feet (Station 3H) and the depth from 12 to 36 inches. The bottom is predominantly muck or silt; the velocity of flow is seldom more than sluggish and occasionally in the main channel it was barely discernible (Station 3H). All tributaries examined were essentially of the same nature (Appendix G, Table 1). No channel velocity measurements were made.

The character of the river and its watershed alters rather abruptly in the neighborhood of an old, cement dam (head: 18 inches) located just upstream from the crossing of County Highway 638. This point delimits Zone 3 from Zone 2, next downstream.

Zone 2.--(Stations 2A-2I, Figure 28) Zone 2, the midportion of the watershed, extends from the aforementioned cement dam (Station 2I) downstream to the Ocqueoc Falls through boulder-clay plains (Leverett, 1912). Between these points, the main channel runs about 7.7 miles. At nine survey stations the river ranged from 18 to 50 feet in width and from 5 to 12 inches in depth. Pools were infrequent and, where present, seldom more than 24 inches deep. The gradient is greater in this zone than elsewhere in the river and the mean channel velocity was generally moderate, varying from 2.5 to 3.1 feet per second. Bottom types in the lower half of this zone (Stations 2A-2E) are composed predominantly of a mixture of boulders, rubble, and coarse gravel distributed more or less uniformly in both riffles and shallow pools. Limestone outcroppings near Station 2C produce several low falls (12 to 24 inches). Shallow riffle areas 25 to 100 yards long in which the current is quite rapid are common in this area. Most of the remainder of the

---

[6] Main stream: 13 miles (?); tributary streams: 76 miles (?); estimated drainage area: 160 sq. miles. (from) Brown, C. J. D., 1944, Michigan streams--their lengths, distribution and drainage areas. Mich. Dept. Cons., Inst. Fish. Res., Misc. Publ. No. 1, July, 1944.

zone is characterized by small rubble and gravel except for the area just west of Millersburg. Here, from an old dam located one-half mile below Station 2F, upstream for 1.2 miles, the stream is slow or sluggish and the bottom is sandy or silted. The watershed is wooded, or, in the neighborhood of Millersburg, composed of farmland and pasture (Appendix G, Table 2).

One small, permanent tributary (a spring feeder), Indian Creek, enters the river from the southeast near Station 2A. This creek has a uniformly sandy bottom.

Zone 1.--(Stations 1A-1M, Figure 28) At the foot of the previously described zone, the river drops over the broken spillway of an old mill dam, 3 feet high, and over two limestone outcrops, 6.0 and 4.5 feet high. The latter are called the Ocqueoc Falls. Below these falls, the character of the river changes again as it flows for 8.8 miles to its mouth through clay and sandy lake bed formations. At thirteen survey stations in this zone, the river ranged from 28 to 50 feet in width and from 15 to 29 inches in depth. It meanders broadly in this zone and deep pools alternate regularly with short riffle areas. Pool depths varied from 24 to 114 inches (9.5 feet). The gradient is somewhat less steep here than in Zone 2 and the mean channel velocity varied from slow to moderate ranging from 2.0 to 3.5 feet per second with current velocities in pools being considerably less than 2.0 feet per second. Bottom types were predominantly sand or sand and gravel, the ratio between the two varying in different areas within the zone (Appendix G, Table 1). Gravel riffles were characteristic of the first mile of stream bed below Ocqueoc Falls; thereafter, this bottom type became less and less common being almost entirely supplanted for long distances by sand or sand and clay (Stations 1F-1J and 1G-1D). Exposures of clay frequently formed the bed of the stream in the latter areas. Deeper pools had silt or sand bottoms while most shallow pools had bottoms of sand, rubble, and gravel except in predominantly sandy areas.

Snags and waterlogged cut timber are abundant in all parts of the river in the lower two-thirds of this zone (Stations 1A-1J). Old sawlogs lie like jackstraws in many of the deeper pools. Between Stations 1E and 1K, there are about a dozen stream improvement devices in various stages of decay which still produce riffle areas.

The watershed in Zone 1 is a rather densely wooded bottomland with high, steep banks in the upstream half of the region and lower, though no less open banks, in the downstream half.

The river is interrupted in its third mile upstream from the estuary by Ocqueoc Lake which is 132 acres in extent. This lake is narrow and about one mile long--the river enters at one extremity and flows out at the other.

Three permanent tributaries (other than spring feeders) enter the river in this zone: The Little Ocqueoc River, Silver Creek, and Orchard Lake Outlet.

Physical and chemical properties common to all zones at the time of the nesting survey in 1947 were observed as follow. The river was approximately at its mean level or volume of flow for the season (128 cubic feet per second at Station 1B); the color of the water was light brown; the water was clear. Differences found in the chemical quality of the water were small among the several stations in Zones 1 and 2 (Appendix G, Table 2). Dissolved oxygen varied from 7.1 to 8.5 p.p.m., no free carbon dioxide was present. The water was hard; phenolphthalein alkalinity ranged from 1.0 to 4.5 and methyl orange alkalinity from 106 to 134 (p.p.m. expressed as $CaCO_3$). The only pollution known to enter the river was derived from scattered cattle watering points, street drainage from the village of Millersburg (Stations 2F-2G), and septic tank overflow from the Ocqueoc Lake Group Camp (Station 1B).

Simultaneous readings of water temperatures by two observers at different stations indicated that an irregular temperature gradient existed in the river. The headwaters (and Zone 3) were warmer than elsewhere in the watershed. For Station 2I, the water temperature averaged 3.0 degrees F. warmer than Station 1B. In Zone 1, above Ocqueoc Lake, the water was the coolest. At stations 2A-2B, the temperature averaged 2.0 degrees F. colder than at Station 1B. This cooling of the water in the upper portion of Zone 1 is due to the presence of numerous spring feeders in that area and to the spring fed tributaries, the Little Ocqueoc River and Silver Creek. Warming of the water at Station 1B, below Ocqueoc Lake, is probably the result of its passage through that body of water.

Duration of the spawning season

The spawning of the sea lamprey, like that of many fishes, is strongly influenced by water temperature. In the Ocqueoc River, spawning activity commenced at mean daily water temperatures of 52.5 to 53.0 degrees F. at a time when daily fluctuations remained about 50 degrees F. The peak of spawning activity occurred when mean daily temperatures rose above 58.0 degrees F. to 60.0 degrees F. and when, at the same time, daily fluctuations seldom dropped severely below 60 degrees F. Spawning occurred among late migrants at mean daily temperatures as high as 76 degrees F. with daily fluctuations to 78 degrees F. Rapid drops in water temperature, up to and during the peak of spawning activity, caused very noticeable declines in both nest building and spawning. Following the peak, fluctuations above the 60-degree level had no perceptible effects upon spawning activity.

Fluctuations in water level and volume of flow and the presence of some turbidity with rising waters had no evident influence upon sea lamprey spawning except insofar as they were related to changes in water temperature.

The weather in successive years varies so greatly, with consequent effects upon stream conditions, that the assignment of the spawning season to calendar periods is an unreliable procedure. In general, however, sea lamprey spawning in the Ocqueoc River may begin as early as the last week in May and continue until the last week in July. The peak of spawning activity evidently occurs sometime during the first three weeks in June and usually lasts about two weeks.

In 1947, the first sea lamprey nest was constructed on the night of June 3-4 about one-half of a mile below Ocqueoc Falls (Station 1L-1M; 8.8 miles above mouth). The mean water temperature during this period was 53.0 degrees F. (range: 50-55 degrees F.). Forty-eight hours later, when the mean daily water temperature had risen to 56.0 degrees F., 28 nests had been built in an area 750 feet long which included the first nest. The peak of spawning activity in the 0.5-mile stretch immediately below the Ocqueoc Falls (Station 1L-1M) occurred between June 16 and 23 when the mean daily water temperatures ranged between 58.0 and 67.0 degrees F. and the daily fluctuations seldom fell below 60 degrees F. Sustained drops below the 60-degree level brought corresponding declines in nest building and spawning activity. By July 3, spawning activity in this area was virtually concluded; only 21 spawning or spent sea lampreys were found in the river between Stations 1L and 1M on this date.

In Zone 2, the peak of spawning activity followed that below the falls in Zone 1, by about five days. On June 25, neither spawning nor spent sea lampreys could be found in this area.

On June 25, spawning activity was first noticed below Ocqueoc Lake (Stations 1A-1B). It continued sporadically there until July 19 when the last spawning pair was observed (mean daily water temperatures, June 25-July 19: 66 to 73.0 degrees F.).

In 1948, all areas of the river were watched closely for the beginning of spawning and after that was observed, spawning activity was followed closely in six sample areas distributed throughout Zones 1 and 2.

The spring of 1948 was warmer and earlier than in 1947. The first nest was constructed on May 22 in precisely the same riffle, a short distance below Ocqueoc Falls, on which the first nest built in 1947 was found. The mean daily water temperature on this date was 53.0 degrees F. (range: 51-55 degrees F.). On May 24, in a 750-foot reach below Ocqueoc Falls, 14 nests had been started and in two of these nests spawning had been completed. On May 26, construction had been started on, or spawning had been completed in, 85 nests in this area. The mean daily water temperature on this date had risen to 55.0 degrees F. (range: 52-58 degrees F.). Further temperature rise was accompanied by two waves of spawning activity in the 0.5-mile portion from Stations 1L to 1M; one was between June 1 and 5 and the other between June 10 and 16 when the mean daily water temperatures rose to and varied between 60.5 and 66.5 degrees F. and when daily fluctuations seldom dropped below 60 degrees F. The decline in nest building and spawning activity between June 6 and 9 accompanied a recession in water temperatures from the initially high temperatures of the period, June 1 to 5. The last spawning activity observed in this area was on July 5 when eight spawning or spent sea lampreys were observed between Stations 1L and 1M. The mean daily water temperature on this date was 70.0 degrees F.

Spawning activity, which commenced just below Ocqueoc Falls, was restricted until June 1 to a 0.5-mile area (Stations 1L-1M) immediately below the falls. On that date nest construction began at Stations 1E and 1K in the lower reaches of the zone. Peak activity at these stations followed that in the area immediately below the falls by an appropriate period, as in the previous year.

On June 5, spawning activity commenced more or less uniformly throughout Zone 2 above the Ocqueoc Falls (Stations 2A, E, H, and I). At this time, mean daily water temperatures were 66.0 degrees F. or higher. The peak of spawning activity occurred between June 8 and 15 and had ceased entirely in Zone 2 by June 22.

Again, as in 1947, belated spawning activity took place below Ocqueoc Lake (Stations 1A-1B). First spawning was observed here (Station 1B) on June 16; thereafter, it continued erratically until July 28 when two pairs, the last seen in this season, spawned. Mean daily water temperatures during this period varied from 63.0 to 75.0 degrees F.

A graphic comparison of the duration and intensity of sea lamprey spawning in 1948 below Ocqueoc Lake (Station 1B), below the Ocqueoc Falls (Stations 1L-1M), and at the head of Zone 2 (Station 2I) is presented in Figure 29. Mean daily water temperatures have been plotted in this figure to show their variation in relation to the onset and initial increase in the intensity of spawning activity.

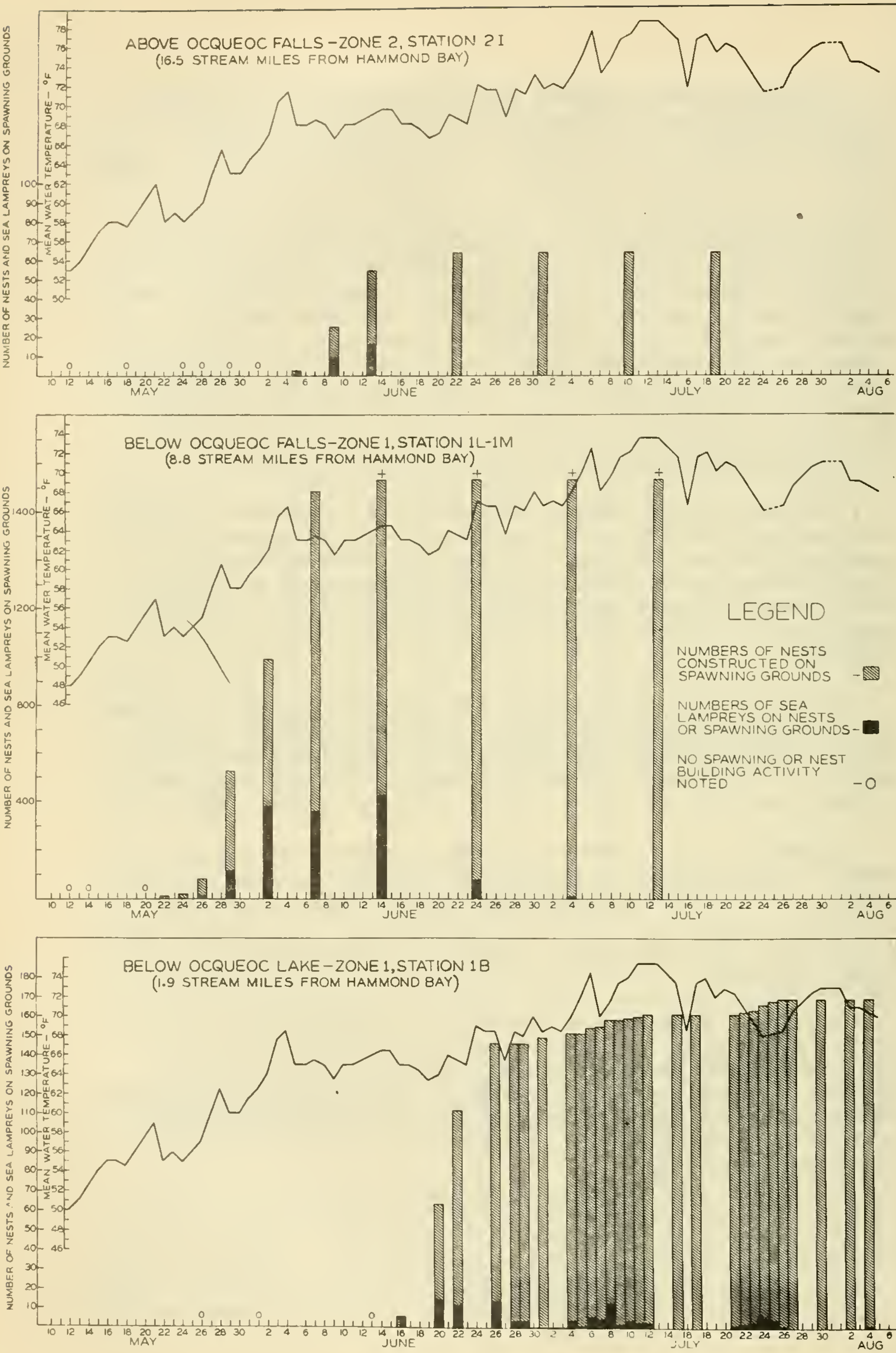


Figure 29.--Numbers of nests and sea lampreys on the spawning grounds at certain stations on various dates during the 1948 spawning season.

Pattern and extent of spawning activity and its relation to certain stream characteristics

In 1947, 5,664 completed sea lamprey nests were counted in the Ocqueoc River. Of these, 2,768 or 48.9 percent were found between the mouth of the river and the Ocqueoc Falls (Zone 1), and 133 or 2.3 percent were found in Silver Creek and the Little Ocqueoc River, tributaries of the main stream in this zone. In Zone 2, above the Ocqueoc Falls, 2,763 or 48.8 percent of the total were present. No spawning activity occurred in Zone 3 (Table 5). It is estimated from these figures, with due consideration for the spawning habits of the species, that between 10,000 and 11,000 sea lampreys spawned in the Ocqueoc River in 1947.

On the basis of a comparison of sample areas, it is concluded that the distribution of spawning activity in 1948 was essentially the same although there is some evidence that the run was larger in this year than in 1947. A comparison of sample stations follows:

Station (and length of station)	Number of completed nests 1947	1948
(Below Ocqueoc Falls)	...	...
Station 1B (1,500 feet)	67 1/	169*
Station 1E (200 feet)	20 2/	97*
Station 1L-1M (2,640 feet)	2,163 3/	1,483 plus
(Above Ocqueoc Falls)	...	...
Station 2E (700 feet)	52*	58*
Station 2H (1,200 feet)	147*	95*
Station 2I (400 feet)	68*	63*

*Spawning activity in area completed.
1/Count on July 3, 1947.
2/Count on June 20, 1947.
3/Count on June 28, 1947.

Spawning populations in Zone 2 (above Ocqueoc Falls) were slightly reduced from those present in 1947. I attribute this to lower water levels in 1948 which rendered the Ocqueoc Falls impassable to the sea lampreys at an earlier date. However, an increase, disproportionate to the decline noted above, was observed in spawning activity below the falls. Nesting sites below the falls became so overcrowded that after June 8, when 1,483 nests were counted between Stations 1L and 1M, further counts of the nests in this area could no longer be made accurately. Other areas in the zone displayed an appreciable increase in spawning activity over the 1947 season.

In the various areas in Zone 1 (from the estuary to Ocqueoc Falls), the amount of sea lamprey spawning activity in a given area was directly proportional to the amount of gravel, in riffle areas or otherwise, that was present. As will be subsequently demonstrated, gravel or gravel and small rubble are essential for sea lamprey nest construction and without these particular elements (or some suitable substitute) nest construction and spawning do not take place. Between Stations 1L and 1M, immediately below the falls, the stream is characterized by short graveled riffles alternating with deep pools. Bottom types in general are gravels of assorted sizes except the deeper pools which are silted or sandy. The heaviest spawning concentration in the zone (and in the river, for that matter) occurred in this 0.5-mile area. Actually, 78.1 percent of the spawning activity in Zone 1 occurred here. (Table 5, Figure 28, and Appendix G, Table 1.)

Downstream from this area gravel bottom types disappear rapidly, giving way to sand, and sea lamprey spawning activity decreased accordingly. Between Stations 1F to 1J (1.9 miles) the bottom type was almost exclusively sand and the 12 sea lamprey nests found there in 1947 were limited to about eight small patches of gravel primarily located at, or near, old stream improvement devices. A recurrence of scattered gravel riffles and isolated gravel bars in the lower reaches of the zone above Ocqueoc Lake (Stations 1C-1E) was accompanied by a complete utilization of these areas by spawning sea lampreys.

Seventy percent of the spawning below Ocqueoc Lake (Stations 1A-1B) took place in a 900-foot area immediately below the outlet of the lake. This area is characterized by riffles with bottom types of gravel, mussel shells, and sand. The balance of the spawning between this area and the estuary took place on the patches of gravel which infrequently replaced the generally sandy bottom.

Spawning in the tributary, Silver Creek, was limited to small patches of gravel at, and between, Stations 4B and 4C. These gravelly spots were located at highway crossings and were the result of erosion of the road grade. Spawning in the Little Ocqueoc River was limited to a 200-yard area of gravel riffles

Table 5. Extent of sea lamprey spawning activity in the Ocqueoc River watershed in 1947 by zones and areas as determined by counts made of completed nests present after the peak of spawning activity.

Zone	Area (that between stations listed)	Approximate distance (in miles)	Number of nests	Total nests for area, areas, or zone	Percentage of total nests
1	1A-1B	2.0	67		
	Ocqueoc Lake	1.0	...	...	...
1	1C-1D	1.0	81		
	1D-1E	0.8	131		
	1E-1F	0.7	78		
	1F-1G	0.3	0		
	1G-1H	0.5	9		
	1H-1I	0.7	0		
	1I-1J	0.4	3		
	1J-1K	0.6	122		
	1K-1L	0.3	114		
	1L-1M	0.5	2,163		
	Ocqueoc Falls	...	...		
	(1A-1M)	(8.8)	...	2,768	48.9
1 (Tributaries)	Little Ocqueoc River				
	1L-5A	1.0	124		
	"Underground"	...	...		
	5A-5D	3.7	0		
	Silver Creek				
	Ocqueoc River-4A	1.7	0		
	4A-4B	2.2	0		
	4B-4C	1.4	9		
	4C-4E	2.5	0		
	(Tributaries)	(12.5)	...	133	2.3
2	Ocqueoc Falls-2A	0.3	0		
	2A-2B	0.3	94		
	2B-2C	1.0	729		
	2C-2D	0.8	683		
	2D-2E	0.8	401		
	2E-2F	1.2	340		
	2F-2G	0.5	60		
	2G-2H	0.5	0		
	2H-2I	2.2	388		
	2I-Dam	0.1	68		
	(Ocqueoc Falls-2I; Dam)	(7.7)	...	2,763	48.8
3	3A-3I	(No spawning activity)			
Totals				5,664	100.0

at Station 5A. Passage upstream, beyond this point, is denied the sea lamprey by an area where the river disappears underground. Here it percolates through the sub-surface limestone formations for several hundred yards, reforming at the surface by the union of numerous, small, spring-like feeders. Downstream from the graveled area at 5A, the river has a sand, or sand and clay bottom not utilized for spawning.

Bottom types in Zone 2 were predominantly rock, rubble, and gravel and this combination occurred more or less uniformly throughout the zone varying only, from place to place, in their relative proportions to each other. Sea lamprey spawning activity was more or less uniformly distributed throughout this zone (Table 5, Figure 28, and Appendix G, Table 2). Within it, spawning activity did not take place in the sandy-bottomed area extending from one-half mile below Station 2F to Station 2G nor did it occur in those areas, occasionally intermediate between riffles, which were characterized by bottom types of boulders and large rubble imbedded in silt and/or clay. The farthest point upstream utilized by the sea lampreys for spawning occurred at the head of this zone at Station 2I. This locality is 16.5 stream-miles from the mouth of the river.

No spawning occurred in either year in Zone 3. The stream bed in this zone is predominantly covered with muck or silt.

Changes in the geographical pattern of spawning activity during the spawning season were consistent for both years. Spawning occurred initially in the area immediately below Ocqueoc Falls (Zone 1, Stations 1L to 1M) and reached its peak there earlier than anywhere else in the river. Six to ten days after the beginning of spawning in the aforementioned area, spawning activity spread rapidly in a progressive fashion downriver as far as Ocqueoc Lake (Stations 1L to 1C). Peak spawning activity in each area, progressing downstream, was proportionately later than that peak which occurred just below the falls.

In Zone 2, spawning activity commenced uniformly over the entire zone 5 to 12 days later than in the area immediately below Ocqueoc Falls, although water temperatures were consistently higher than in Zone 1. I attribute this to generally less suitable spawning facilities which resulted in a delay on the part of the migrants entering this zone in selecting an acceptable place for nest construction. This delay lasted until an increasing urge to spawn forced them to accept what were evidently sub-optimum nest-building conditions. As it will be shown in a later discussion, the shallow, rock- and rubble-strewn riffles characteristic of Zone 2, offer acceptable, although not eminently suitable, sea lamprey nest-building sites.

The duration of spawning activity was very brief in Zone 2, lasting from 9 (1947) to 17 (1948) days. This brevity is attributed to several factors: (1) The spawning run in this zone appears to be composed of early migrants which seem to seek the farthest reaches of the watershed for spawning. Their greater vitality, and high and favorable water levels at the Ocqueoc Falls, facilitate their passage over this obstruction; (2) Later migrants, which might prolong the spawning activity in this zone, are denied access to it by their decreased vitality and increasingly less favorable water levels for passage over the falls. This may, in part, account for the prolonged spawning season and overcrowding of nesting sites immediately below the falls in the last third of the spawning season; (3) The sea lampreys present in Zone 2, having delayed their spawning activity at suitable spawning temperatures while searching for optimum nesting sites, which did not exist, were compelled (by an increasing urge to spawn) to build their nests and spawn in the briefest possible period.

The appearance, late in the season, of spawning sea lampreys below Ocqueoc Lake has been noted previously. This shift of spawning activity to the lowermost reaches of the river concludes the spawning season. Spawning areas here are scattered and poor and the occurrence of such activity is attributed to migrants, which, being unable to locate the inlet of Ocqueoc Lake, eventually drop downstream (through the outlet) in order to spawn. Furthermore, some late migrants of low vitality may elect to spawn here without attempting to travel further.

Spawning habits and behavior

(1) Pre-spawning behavior

As has been observed in a previous section, adult sea lampreys of both sexes are present in the watershed in the spawning areas for as much as six to eight weeks prior to any attempt on their part to initiate spawning activity. Anatomical studies and the absence of external secondary sexual structures indicate that these early migrants are much less mature sexually than later migrants and evidently must complete the maturation process while in the spawning stream. Later migrants displayed more advanced stages of maturity on entry into the stream. Individuals attaining the nesting areas during and after the peak of spawning activity commence their nest building and spawning in a very short period of time.

The first evidence of spawning activity on the part of either sex is the construction of a nest in which the fertilized eggs will be deposited. This is done by clearing the gravel, rubble, and small stones from a more or less circular area and by depositing them in a crescentic ring about the downstream margin of the clearing (Figure 30 to 38). Occasionally, gravel or stones are moved upstream so that in some cases, the nest has a crater-like appearance. Each pebble or stone is moved singly by picking it up with the oral sucker. Great persistence is shown on occasion where an unwanted stone is firmly imbedded in the bottom. A sea lamprey will return time after time to such a stone and tug at it until eventually it may be dislodged. Very large stones are occasionally moved out of the center of the nest area by dragging them along the bottom with the aid of the current. The largest stone I have seen moved measured about 4 by 5 by 5 1/2 inches and was dragged about 2.5 feet from the center of a nest area by a 17-inch, male sea lamprey.

The total amounts of material moved by a pair of sea lampreys during nest-building and spawning seem extraordinary. All dislodged materials from three nests in Zone 1 in which spawning had been completed were carefully collected and weighed. In the three nests, 13.2 pounds, 18.0 pounds, and 23.5 pounds of small and large gravel and stones had been moved respectively by each of three pairs of spawners.

Nest construction is usually begun by the male. Early in the season the male may work for 48 to 72 hours on a nest before being joined by the female. In this time, a major portion of the nest's construction has usually been completed, and further elaboration by both sexes may only occur in the interval between spawning acts. About the middle of the spawning season, the male is frequently joined by the female shortly after the nest has been started and both contribute to the building done prior to spawning. Toward the end of the spawning season, when females frequently appear to be numerically dominant on some spawning beds, nest construction may be initiated by them.

Within acceptable spawning areas, some selectivity is exhibited by male sea lampreys in establishing a nesting site. Males frequently begin several nests in trial locations before settling on a final locus. Abortive or trial nests vary from mere clearings of a dozen or more pieces of large gravel to structures about one-quarter completed. This selective behaviorism is generally observable only during the earliest part of the nesting period or in areas where spawning facilities are not crowded. Later migrants readily occupy many of these trial nesting sites and elaborate them into completed nests.

Prior to the beginning of the actual spawning process, secondary sexual characteristics develop among both sexes which aid in the identification of the sexes upon the spawning beds. Among the males a very pronounced, median, rope-like ridge gradually appears on the back. This prominence, when complete, extends from the branchial region to the anterior edge of the first dorsal fin. Females lack such a dorsal elevation but develop a fleshy keel ventrally from the anus to the caudal fin. The lower margin of the tail fin likewise becomes somewhat thickened. Females may also be indentified from some distance by the swelling of the body proper by the egg mass which makes it bulge beyond the lines of the head and branchial region. In spawning males, the branchial region becomes somewhat distended and has a greater diameter than the rest of the body.

(2) Spawning behavior; the spawning act

The spawning behavior of sea lampreys observed in the Ocqueoc River was primarily monogamous, occasionally polygamous, and very infrequently promiscuous. On certain visits to the sample spawning areas studied in 1948, 954 nests upon which sea lampreys were present were studied. In 245 of these nests, spawning had not yet begun and the lampreys present were engaged solely in the construction of the nest. In 393 nests, spawning had been completed and only spent individuals, primarily males, were there.

Spawning was observed in 338 nests. It was undertaken by a single pair in 261 nests or 77.2 percent of all instances observed. All observations of the complete spawning activities of pairs indicated that they remained mated for the entire spawning venture. In 44 nests or 13.0 percent of the total observed, one male was spawning with two females. Other polygamous combinations observed with one male were: three females (6 nests); four females (2 nests); and five females (1 nest) (Total: 9 nests--2.7 percent of total). Promiscuous spawning was observed in 6 nests (1.8 percent of total). Combinations of sexes present were two males and two females (1 nest); two males and three females (1 nest); two males and seven females (1 nest); three males and two females (2 nests); and four males and two females (1 nest) (Appendix G, Table 4). Polygamous and promiscuous spawning were generally observed after the peak of spawning activity and may be attributed to having the females outnumber the males on some spawning areas during the late part of the season, and/or to local overcrowding of the spawning beds.

Polyandrous spawning, i.e., one female with several males, was observed in 18 nests. In almost all of these, various degrees of antagonism were exhibited by the males towards one another. This was usually expressed in attempts by one male to drive another from the nest. The aggressor would usually succeed in fastening his mouth firmly to the victim. The latter would reply in kind, and firmly locked together, they would go thrashing downstream with the current. This antagonism was particularly marked in males of a single spawning pair. When casual males intruded upon their spawning activities, they were promptly driven away in the manner described above. I consider this further evidence that under optimum conditions, spawning among sea lampreys is undertaken by pairs which remain mated for the entire spawning period.

The spawning act of the sea lamprey has been more or less elaborately described by Surface (1899), Hussakof (1912), Coventry (1922), and Gage (1928). The following description agrees in general, but not always in detail, with the statements of these workers. Briefly, my observations show that the act is accomplished in the following manner: The female orients herself in the bottom of the nest and anchors firmly with her oral disc to a stone or larger piece of gravel lodged in the anterior floor of the nest or to a similar object which has been placed in the upstream margin of the nest during its construction. The male approaches the female generally along the long axis of her body which is parallel to the current. In doing so, he frequently runs his mouth lightly over the anterior half of her body until the branchial zone is reached. At this point the male fastens himself firmly to the female with his mouth. Almost immediately he wraps the posterior third of his body in an abrupt half-spiral about that of the female so that their vents are approximated (Figures 30-31). The extrusion of the eggs and milt is preceded and accompanied by a very rapid vibration of the bodies of both individuals for 2 to 5 seconds. Following that, the male releases the female immediately.

The fertilized eggs are carried by the current into the face of the downstream rim of the nest where the majority of them lodge in the interstices of the gravel rim that has been built there. Very shortly after the spawning act, one or both of the sexes anchor again to a rock near the head of the nest. With violent body vibrations, they stir up a small cloud of sand from the bottom of the nest which, like the eggs, is filtered by the current into the spaces in the gravel and stone nest-rim and which imbeds the eggs in place. Reportedly, 20 to 40 eggs are extruded during each act (Surface, 1899). My observations tend to confirm this, although I never found a satisfactory way of checking the accuracy with some mechanical device. Thereafter, both male and female move about, adding more gravel or stone to the downstream rim of the nest structure. This latter activity may occur between each spawning act or between groups of two or three successive spawning acts.

The interval between spawning acts usually varies from one to five minutes through most of the spawning activity. When both male and female are nearly spent, this interval may last ten minutes or longer.

The duration of spawning by a pair (or other spawning combinations) may be from 16 hours to three and one-half days. The latter interval was displayed by one pair of very early spawners in 1947. During the peak of spawning activity in the river, all combinations whose activities were followed closely completed their spawning in approximately 36 to 48 hours. Late in the season, during the month of July, three pairs observed at Station 1B

Figure 30.--Male and female sea lampreys at moment of extrusion of eggs and milt. Note small cloud of sand grains behind the pair which have been stirred up by the vibration of their bodies during the act. (Ocqueoc River, Stations 2L-M, June 9, 1948.)

Figure 31.--Male and female sea lampreys in spawning act. Note how the tail of the male is locked about the body of the female. (Ocqueoc River, Stations 2L-M, June 9, 1948.)

(Figure 28) (below Ocqueoc Lake) completed their spawning in approximately 16, 19, and 20 hours respectively as determined by placing hardware cloth fences around the nests.

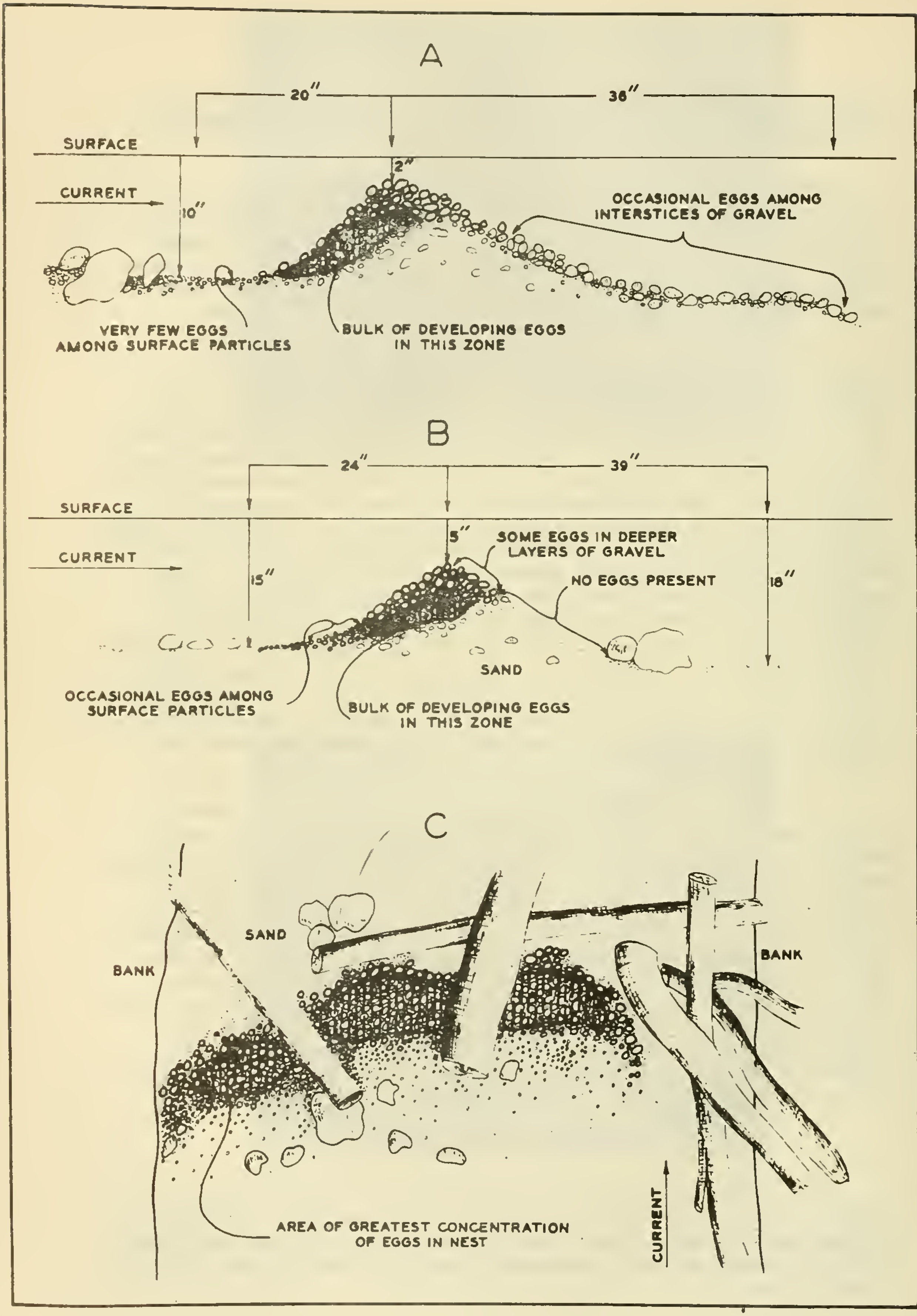
The location of the eggs deposited in the nest and those lodging in surrounding areas was determined by carefully dissecting, stone by stone, a series of ten nests in which spawning had been completed. Dislodged eggs were caught in a stream-bottom sampler and the relative proportions in different layers and different areas of the nests were estimated therefrom.

The distribution of the eggs found in these nests was logical considering the spawning position, spawning act, and the action of the water current passing through and over the nest. In all nests examined, the bulk of the developing eggs was found in a spindle-shaped layer (in both vertical and horizontal dimensions) in the upstream face of the crescentic, downstream margin of the nest. Here they were mixed with fine and coarse sand which filled the interstices among the pieces of gravel and stone. Superimposed upon this egg-bearing stratum was a 2- to 5-inch layer of medium and coarse gravel among which few eggs or sand grains were present. The water percolated freely through this layer. It was found that among the eggs first deposited by a spawning pair, some were buried as deep as 8.5 inches beneath the highest point of the nest rim. The egg-bearing stratum itself, varied from 2 to 4 inches at its maximum thickness (Figure 32a, b). In the lateral plane, the eggs were most commonly distributed over an area equivalent in breadth to the downstream quadrant of the nest (Figure 32c).

In an area of moderate current, with a generally gravel bottom type, a few eggs were found lodged in the gravel just past the crescentic rim of the nest. Occasional eggs were lodged among the gravel of the stream bed directly behind the nest for a distance of three to four feet (Figure 32a). In generally sandy areas, where the reverse slope of the nest rim (downstream side) was predominantly sand, eggs carried over the rim of the nest by the current had nowhere to lodge and I observed that these eggs generally were carried by the current into deeper and usually silted areas (Figure 32b). I believe that there is a high mortality among these eggs due to their being exposed to predation by small fishes and other organisms and, ultimately, to their being smothered by silt deposition.

(3) Nest construction

The manner and form of sea lamprey nest construction in the Ocqueoc River varied with the area in the watershed selected for spawning, with the bottom types that were present, and with specific locations within the stream (i.e., particular nest-building site selected).



a. Vertical and linear distribution of eggs in a nest in a gravel-bottomed area.
b. Vertical and linear distribution of eggs in a nest in a gravel and sand-bottomed area.
c. Area or plan of distribution of eggs in three adjoining nests.

Figure 32.--Diagrammatic sketches of the distribution in depth and area of the eggs in some typical sea lamprey nests.

In Zone 1 (see Figure 28), the general type of nest built was one of various size gravels in riffles, bars, and flat beds, or on scattered patches of gravel (Figure 33). Ultimately, all available graveled locations of every description in this zone were completedly used, although certain types of locations were more suitable for nest construction than were others. In a 0.4-mile area between Stations 1L and 1M, the specific sites of 1,820 nests present were determined. Of this total, 1,043 nests were built on ten long, gravel riffles totaling 1,070 feet of linear stream distance (range in length of individual riffles; 35-500 feet); 434 nests were constructed on isolated, large, transverse gravel bars and short riffle areas; 120 nests were made on scattered, small, transverse bars; 60 nests were built at the upstream or downstream margins of pools or in the deeper areas intermediate between isolated bars or riffle areas; 63 nests were located on linear (parallel to current) graveled areas and 60, on scattered patches or pockets of gravel. These last two types of sites were in generally sandy-bottomed areas of the river. Of the remainder, 34 nests were constructed on flat and ridged gravel beds on the outside margin of deep pools at bends in the river, and 6 in a like location on the inside of a river bend.

Figure 33.--Sea lamprey nest; type characteristic of graveled or gravel bar areas. (Ocqueoc River, Zone 1, Station 1M, June 10, 1948.)

Under such conditions, preferred nest-building sites could only be determined by ascertaining in limited areas the serial order in which they were occupied. A gravel riffle area, 80 feet long, which lay between deep pools at two bends of the river (Stations 1L-1M), a predominantly sandy-bottomed area at Station 2C, a gravel bed in a bend of the river at Station 1E, and gravel riffles in a small stream (Station 5B) were observed during the spawning season. It was found that, in general, the upstream face of the gravel bars forming the longer riffle areas and that of transverse gravel bars of all descriptions were utilized first for nest construction. Following this, the depressions between, and occasionally the crests of, these bars were used. In such areas, the last sites taken were those within the foot of the pool proper, upstream from the riffle, and those at the head of the pool lying just downstream from the riffle (Figure 34). When all such sites had been preempted, nests appeared on flat, graveled areas along the outside margins of pools, and on linear bars, patches, and pockets of gravel in the sandy areas of the river.

In the lower reaches of Zone 1, above Ocqueoc Lake, graveled areas frequently appeared on the outer portion of bends in the river. These graveled areas were generally composed of a series of crescentic gravel bars, dipping from the shoreline to the deepest water in midstream. Within the limits of such an area, nests were built first on the upstream face of the bars at depths of 12 to 24 inches. Thereafter, similar sites were occupied in shallower water right to the water's edge and to depths of three and one-half feet near the midstream limits of the bars. Areas intermediate between, or upstream or downstream from, the gravel ridges were settled on last (Figure 35).

In a small stream, the Little Ocqueoc River, a continuous series of closely spaced gravel riffles was present, although the profile of these bars was quite low. Here the sea lampreys selected nest-building sites initially on the upstream face of the gravel bars and laterally in the intermediate areas without much discrimination (Figure 36).

In Zone 1, sea lamprey nests were built at depths ranging from 5 inches to 5.5 feet. Most spawning occurred, however, in depths between 12 and 25 inches (depths to center of floor of nest).

In the generally graveled area between Stations 1L and 1M, the average depth of 46 nests was 22.1 inches (range: 8.5 to 24.0 inches) (Appendix G, Table 5); between Stations 1K and 1L, the average depth of 34 nests was 20.2 inches (range: 11.0 to 32.0 inches) (Appendix G, Table 6); and in the generally deeper waters between Stations 1E and 1F, the average depth of 74 nests was 22.4 inches (range: 7.5 to 38.0 inches). It was in this last

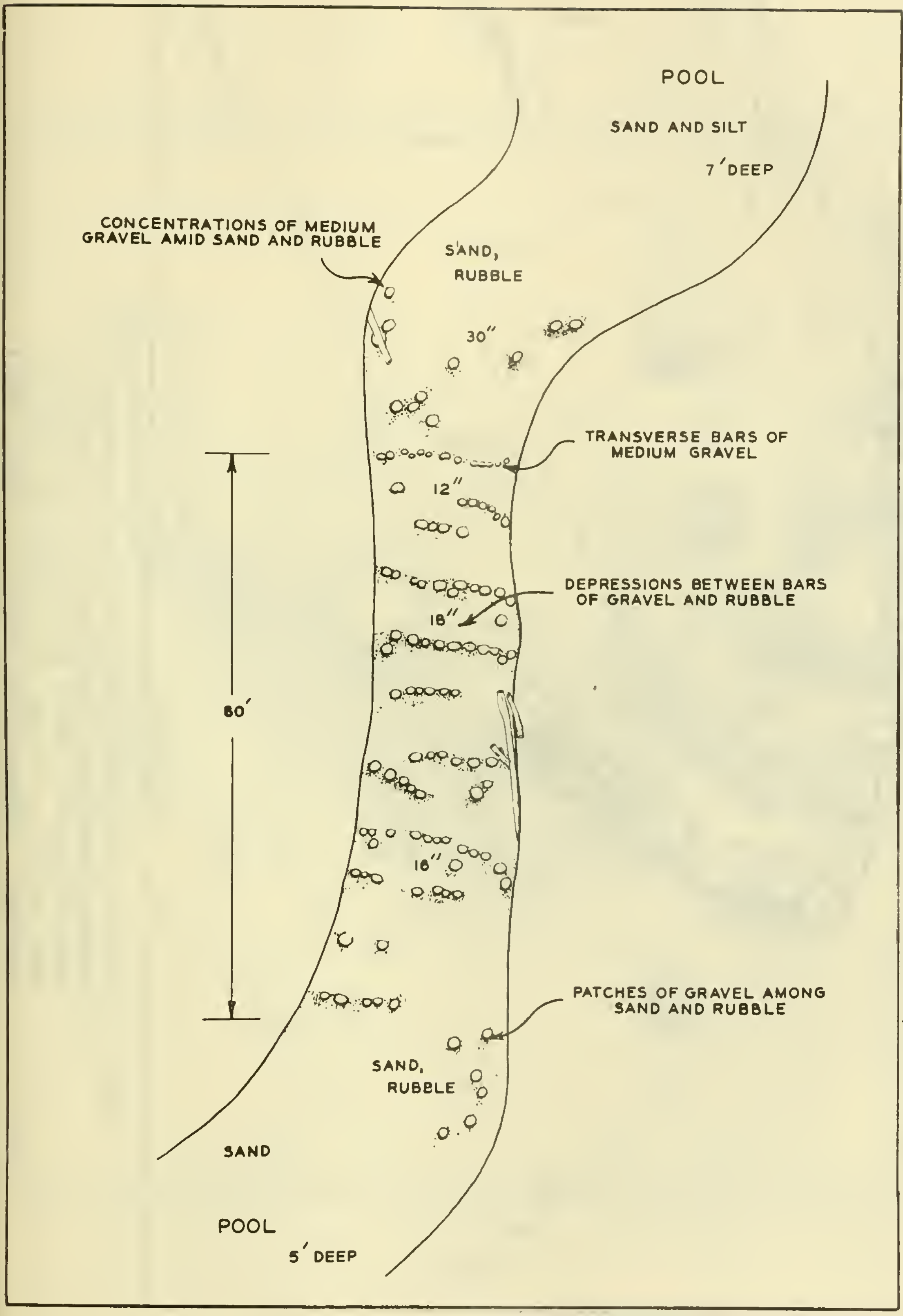


Figure 34.--Diagram of a gravel riffle in the Ocqueoc River utilized by sea lampreys for spawning. Stippled areas are bars or concentrations of gravel; the location of sea lamprey nests in the area is indicated by unshaded circles. Current flows from top to bottom of figure. (Station 1L-M, 1947.)

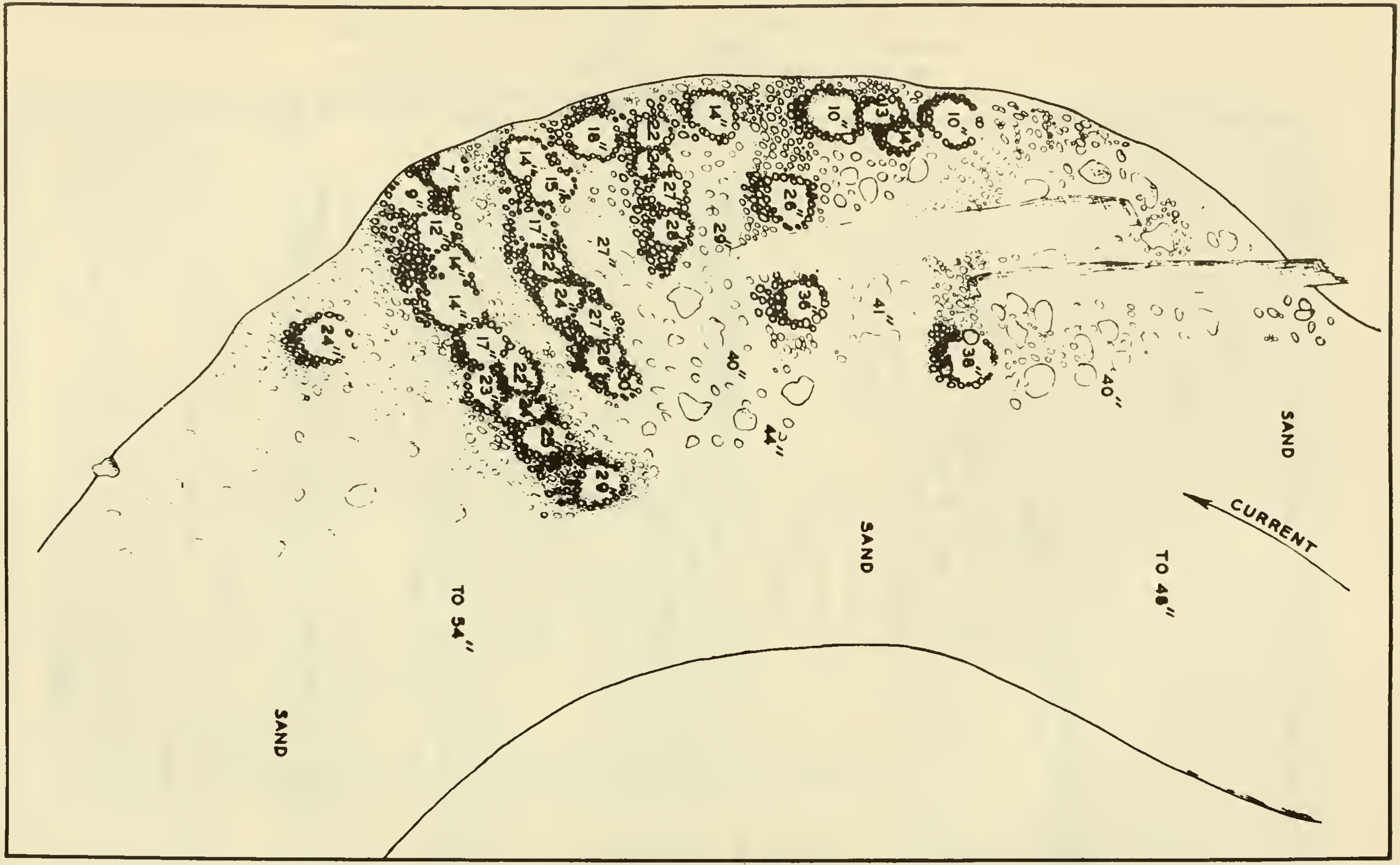


Figure 35.--Diagram of the location of sea lamprey nests on a series of crescentic gravel bars in the outside of a bend in the river. Depth in inches to the floor of each nest and at various points within the area are indicated. (Ocqueoc River, Station 2C, June, 1947.)

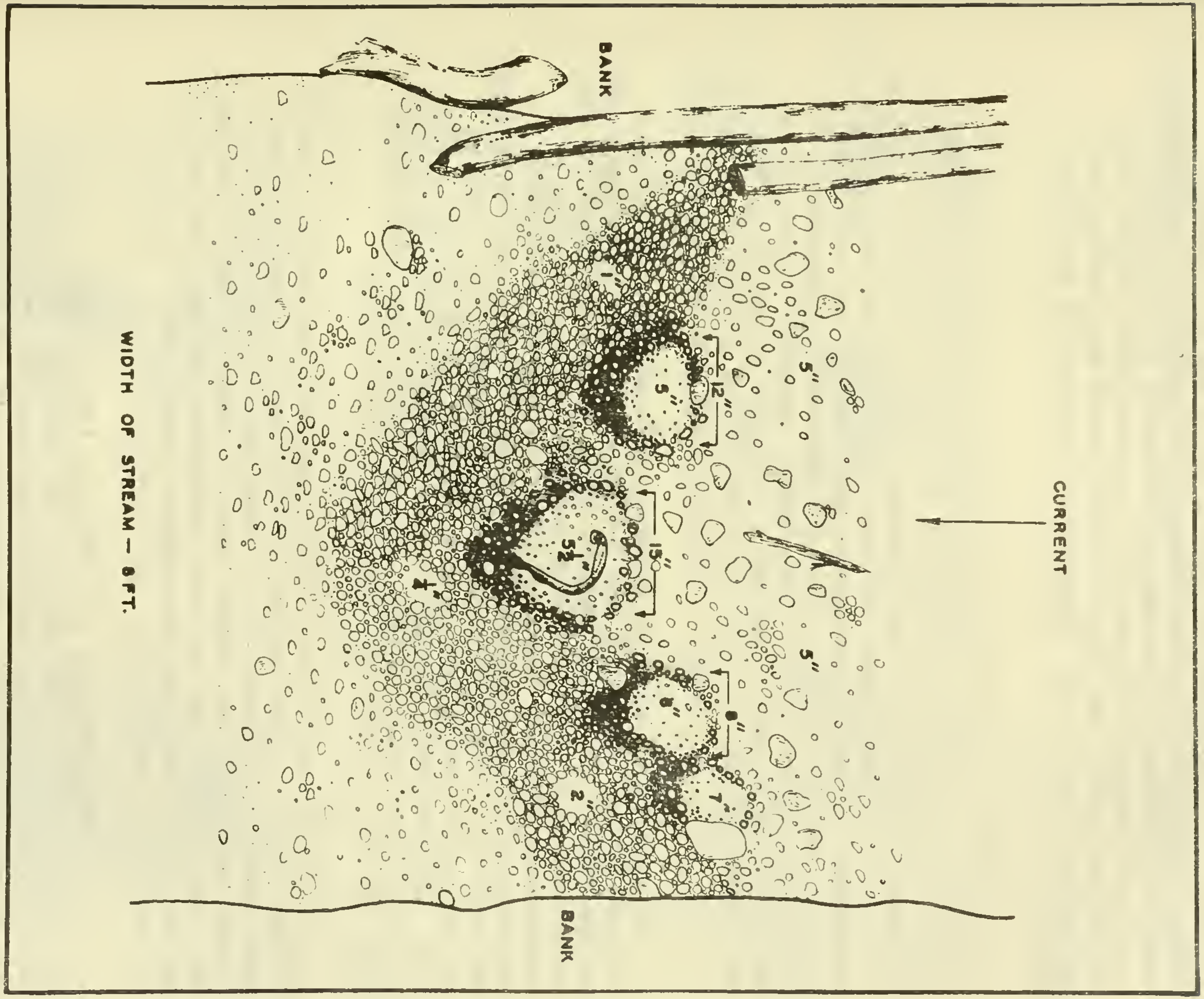


Figure 36.--Diagram of the location of four sea lamprey nests on a gravel bar in a small stream. Depth in inches to the floor of each nest and at various points within the area are indicated. Bracketed dimensions indicate average diameters of nests. The sea lamprey pictured in the center nest is lying in the bottom of the nest in the characteristic position of a spent male. (Little Ocqueoc River, Station 5B, June, 1947.)

area that sea lampreys were observed on six nests built on a gravel bed on the bottom of a deep bend of the river. The depth to these nests was 5.5 feet. In the Little Ocqueoc River (Station 5B) the average depth of 31 nests was 9.0 inches (range: 6.0 to 15.0 inches) (Appendix G, Table 7). For three nests not included in this sample, depths of 5.0, 5.5, and 6.0 inches were recorded (Figure 36). It is curious to note that in the last cases, one inch or less of water was passing over the rims of these nests. Spawning had occurred at a similar water level.

Completed nests varied in size from 10.0 to 39.5 inches in diameter. The average was about 19 inches and varied from one sample area to another as follows: Stations 1L-1M, 22.1 inches; Stations 1K-1L, 21.0 inches; Stations 1G-1H, 19.8 inches; Stations 1E-1F, 18.1 inches. These stations are listed progressively downstream and the decreasing average diameters are correlated with diminishing amounts of suitable nest-building materials (Appendix G, Tables 5, 6). The average diameter of nests in the shallow Little Ocqueoc River was 17.7 inches (Appendix G, Table 7). These measurements were taken from rim to rim except for asymmetrical ones for which a mean of greatest and least diameter was taken.

Two generalized patterns of nest construction occurred where adequate amounts of gravel were present. The most common of these two was that built on the upstream faces of bars or ridges. These nests were characterized by high downstream rims, very low or non-existent upstream rims, and tended frequently to be asymmetrical in outline shape and in structure (Figure 37b). This type was found most often in midstream locations where the current was moderate to swift and where the bottom had an irregular profile. In such nests, the downstream rims were frequently elaborated to a considerable height--occasionally as much as 10 inches above the floor of the nest (Appendix G, Tables 5-7).

The second general type of nest was characterized by a rim of uniform height, a circular outline form, and a generally symmetrical appearance (Figure 37a). These nests were found at the quieter margins of the stream, along the edge of, and at the head and foot of pools, and in areas intermediate between bars and riffles. Such areas had relatively slower current velocities and the bottom had a flat or low profile.

In all types of nests and under all circumstances, I have seen sea lampreys moving stones to the upstream rims of their nests although their success in maintaining this part of the nest structure varied with the nest site and the velocity of the current, as evidenced above. I see no basic functions of this portion of the nest structure other than an additional repository

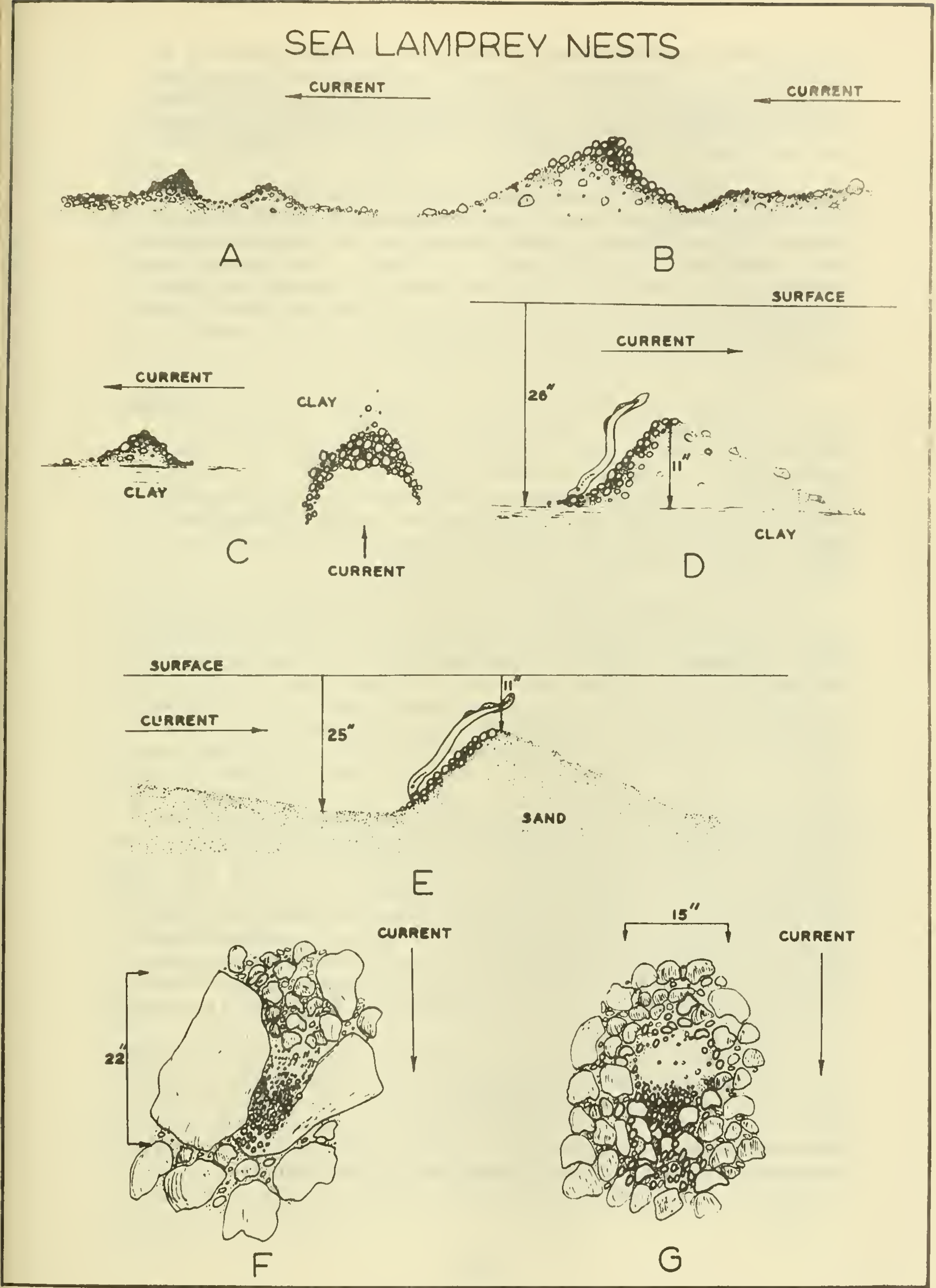


Figure 37.--Sea lamprey nests (see text for discussion).

for materials removed from the center of the nest area and as a provision for anchorages to which the female may attach herself during the spawning act. A single large piece of gravel, a small imbedded stone or stick, or even a hardpan clay bottom has been observed to suffice for the latter requirement.

Nest-building on sites less favorable than the foregoing variously alters the form of the structure. Occasional nests were built by clearing an area between two or more large stones which formed walls on each side of the nest. The erratic water turbulence on such sites caused the nest to suffer from some scouring when the spawners were no longer present to maintain it. An examination of these nests proved that an excessive mortality of eggs and developing larvae resulted.

Where nests were built from a thin layer of gravel and sand over hardpan clay, the upstream margin of the nest was soon swept away by the current as were the contents of the floor, leaving only a modified crescentic ring of gravel for the nest (Figure 37c). With no anchorage upstream or down, this structure was slowly demolished by the current and again I found from a dissection of such nests before hatching had occurred that a heavy mortality of eggs or larvae resulted.

In the preceding instance, and in those sandy areas where small, scattered patches of gravel provided nesting sites, the apparent minimal conditions acceptable for sea lamprey nest construction are represented. In the latter case, where pockets of gravel lay ahead of, or against, small hummocks of sand or sand bars, the gravel was placed by the lampreys against the upstream face of such rises (Figure 37d). The amount of gravel utilized varied, of course, with the available supply. One such nest consisted of a double layer of 3/4- to 1-inch gravel, approximately one square foot in area, which had been built against a small, sand hummock. All available gravel in the area had been utilized (Figure 37e). A pair had previously been observed spawning in this poor nest. Examination of the nest after the completion of this act disclosed very few fertilized eggs. The potentially high mortality of eggs on such sites as these has also been noted elsewhere. Nest construction and spawning were never observed on sites providing a lesser volume of hard, bottom-type elements than in that situation noted just previously.

A miscellany of nests were located oddly under snags, waterlogged timber, and partly submerged brush. Immediately below Ocqueoc Lake (Station 1B), riffle areas were created by extensive beds of clam shells. These, with some gravel were the basic material utilized by lampreys for nest construction. The relative success of spawning on such sites was not determined.

The re-use of nests or nesting sites by late migrants was only observed after all suitable nest-building locations had been utilized. In the latter half of the season in Zone 1, immediately below Ocqueoc Falls, unfavorable water levels at the falls and reduced vitality among the sea lampreys ultimately forced many of them to spawn in locations that had already been completely utilized. On many transverse gravel bars, this condition resulted in a complete obliteration of the outlines of the original nests. The result was what appeared to be a continuous, straight nest across the entire face of the bar (Figure 38). Even under such circumstances, several pairs spawning on these ill-defined, continuous structures tended to remain discrete as pairs and spawned across a consistent and limited breadth of the reworked composite structure.

(Zone 2)

In Zone 2 (see Figure 28), the general type of nest was one built of gravel, rubble, and small rocks in an area which was more or less uniformly composed of varying amounts of these three bottom types (Figure 37f, g). Little choice was offered the sea lamprey in selecting sites for nest construction in this area of the watershed. Riffle areas of gravel and rubble were more or less level in bottom contour containing few if any bars or ridges as found in Zone 1. Nests were found across the length and breadth of these riffles in a well-distributed pattern--they were seldom built in groups or close to each other. Many of these rubble-strewn riffles had relatively swift currents, and where this occurred, nests tended to be concentrated in the less swift waters nearer the banks.

Individual nesting sites were generally selected where gravels were relatively abundant among the rubble and slab rock (Appendix G, Table 8). These nests were usually symmetrical in form where the rubble was of such a size that it could be moved and/or utilized in nest construction (Figure 37g). In rocky or large rubble areas, many asymmetrical types were built (Figure 37f). Limited amounts of gravel and swift currents restricted most construction in such areas to a downstream rim in which the eggs were to be deposited. In predominantly rubble and slab rock areas, so little gravel was occasionally available that a very meager nest structure was completed and the ultimate success of spawning on such sites was limited. Below these nests, eggs could be found lodged (and exposed) among the rubble for many feet.

Among a sample of 25 nests on one of the more favorable nesting riffles in this zone (Station 2B), the depths of the nests averaged 10.9 inches (range: 8.0 to 13.5 inches). These nests averaged 18.8 inches in diameter, varying from 13 to 26 inches (Appendix G, Table 8).

Figure 38.--Two pairs of sea lampreys spawning on a transverse gravel bar; a continuous nest which has been reworked by late spawners so that outlines of original nests have been obliterated. (Ocqueoc River, Station 1L-M, June 10, 1948.)

Although a considerable amount of spawning in the Ocqueoc River occurred in this zone, nest-building and spawning conditions are obviously less suitable than those areas characterized by gravel bars and ridges in Zone 1. Initially, bottom contours, particularly in most riffles, are low or flat and offer neither resting places for the working sea lamprey nor sites which facilitate the construction of a nest as would the abrupt upstream face of a gravel bar. Heavy and/or unwieldy pieces of rubble must be cleared from the nesting site with some considerable effort by the sea lampreys. These larger materials and the inadequate amounts of gravel available do not permit formation of an adequate nest structure. Swift currents over the riffles hinder nest construction and combined with inadequate nest structures result in the sweeping away and probable mortality of many newly-spawned eggs.

In both Zones 1 and 2, some visible current was present at every nesting site. The least current velocity in any one spawning location was 1.3 feet per second.[1] The maximum velocity in an area where spawning occurred was 5.2 feet per second in a rubble and gravel riffle. Current velocities in four long and heavily used riffles were 3.6, 3.8, 4.0, and 4.4 feet per second. Two less extensively used riffles (poor bottom-type) had velocities of 1.9 and 2.3 feet per second. In areas other than riffles where it occurred, velocities of 1.5, 2.3, 2.8, 2.9, and 3.5 feet per second were recorded.

In the Ocqueoc watershed, there was no evident relationship between the degree of cover and/or shade and the incidence of spawning activity. The earliest, and subsequently one of the most widely used spawning riffles in the river was relatively shallow, contained no cover within the stream and was completely exposed to the direct rays of the sun throughout the day. At the other extreme, spawning in the Little Ocqueoc River at Station 5B occurred in dense shade where the sun seldom struck the water. However, since among the earliest spawning sea lampreys somewhat more activity was displayed during the hours of darkness than during daylight, I suspect that under optimum conditions, all other factors being equal, a preference would be shown by the sea lamprey for covered or shaded nesting sites.

(4) Summary of spawning requirements

It is concluded from these data collected in the Ocqueoc River that two essential physical conditions, other than suitable water temperatures, must be fulfilled before sea lampreys may spawn with any degree of success. First, gravel, 3/8-inch to 2 inches in diameter, or gravel mixed with some other acceptable hard bottom-type (rubble, clamshells, etc.) must be present as the basic elements for nest construction. Furthermore, some small amounts of sand must be available to which the eggs will adhere and which will imbed them in the interstices of the gravel in the nest rim. Excessive amounts of larger hard bottom-types (bed rock, boulders, large rubble) hinder or prevent spawning. In predominantly sandy areas, some small amount of gravel must be present before nest construction and spawning will be attempted by the sea lamprey. Probably the minimal acceptable quantity of gravel under such circumstances is typified in the nesting site described on p. 108 (Figure 37e).

---

[1] Current velocity: surface velocity X factor of 1.33.

Second, at least some current, passing consistently in one direction over the nest, is essential to successful spawning. This is concluded from the mechanics of the spawning act, from the spawning behavior of the sea lamprey, and from the distribution of nesting sites in the river. Very swift currents hinder or preclude successful mating and when it does occur under these conditions, many eggs are swept beyond the nest which are lost through exposure, abrasion, and predation.

In the total absence of either gravel of the specified sizes, or current, I have never observed spawning to take place and where minimal quantities of either or both exist, the success of this activity, measured in terms of hatched-fry production, is very low.

These basic reproductive requirements of sea lampreys as evidenced in the Ocqueoc River are substantiated by observations made in other watersheds. Data relevant to the characteristics of sea lamprey spawning grounds were recorded by field observers for 29 other tributaries of Lakes Huron and Michigan (Appendix G, Table 9). Any of the recorded physical or mechanical properties such as width, depth, amount of current, color, and turbidity (with accompanying variations in the chemical quality of the water) of a spawning stream or spawning area varied widely with but one exception. Gravel, in combination with sand, or sand rubble, was always present. All records thus obtained of stream width, depth, and degree of current at spawning areas fell well within the range of these properties as observed in the Ocqueoc River.

Water temperatures suitable for spawning are tentatively identified as those extant in the Ocqueoc watershed during the period April-July when the runs are entering the river. There is some evidence that certain cold, spring-fed tributaries, otherwise suitable for sea lamprey spawning, are abandoned by spawning migrants (sometime after entry) when the water fails to warm rapidly during the months of May and June. This condition has been encountered in Pendill's Creek, Chippewa County (Lake Superior basin). However, since my temperature records in this stream are limited to intermittent pocket-thermometer readings, no critical comparisons can be made.

The question has been raised: do sea lampreys spawn on the gravelly shoals of the Great Lakes proper when blocked from their spawning areas in streams by dams or other obstructions. There is no direct evidence that they do or do not. If it does occur, the success of this spawning must indeed be very low. Nest construction, the spawning act itself, and the normal, and presumably successful, deposition of the eggs in the nest are predicated on an unidirectional current passing over the nest; the entire spawning behavior of the sea lamprey reflects a positive orientation to this consistent, uni-directional current. Shoal areas of the Great Lakes frequently possess a bi-directional, or reversing, water movement induced by wave action upon the shore. It seems unlikely that an ebb and flow water movement (or still water) would elicit the presumably normal responses in the lamprey which would result in an effective nest construction or spawning act. Such water action would inhibit both of these activities. Furthermore, in the shallowest areas of the lake shoals, one to three feet in depth, which are comparable to the depths selected in streams by the lampreys for spawning, there is little likelihood of the survival of eggs because of molar action of bottom materials subjected to wave action in such areas.

(5) Post-spawning behavior

Following the completion of spawning, spent females drop away from the nests almost immediately, drifting downstream to die in quieter eddies or pools. When held experimentally in enclosures, they expired sooner after spawning than did the males. Males, however, cling to the nest for one to three days after spawning is completed, only dropping downstream when completely spent physically and very near death. Spent males curl themselves in the deepest depression of the floor of the nest where they receive the most protection from the current. In this position they cling weakly to a stone (Figures 36, 39). This attitude is so characteristic that spent individuals were readily spotted on the spawning beds.

Figure 39.--Spent male sea lamprey clinging to nest after the completion of spawning. (Ocqueoc River, Station 1M, June 8, 1948.)

Males and females, dropping downstream and no longer possessing the strength to swim against the current, generally moved tail-first with weak swimming movements against the current. Even at this stage, they still retained a positive response to the stream current.

(6) Adults prevented from spawning

A preceding discussion considers one possible fate of sea lampreys prevented by barrier dams from reaching suitable spawning areas in streams, i.e., they might spawn on gravel shoals in the lake proper. Such a situation was considered unlikely.

There is evidence that a diversion of some individuals of such barred runs to other streams along the shoreline, with accessible spawning areas, occurs. In 1949, a small, portable weir and trap were operated intermittently in Milligan Creek, Presque Isle County (T37N, R2E, Secs. 4, 5, 8, 9). This stream is 6.5 miles and 9.0 miles NW of Carp Creek and the Ocqueoc River, respectively, on the Lake Huron shoreline. In each year, 1947-1949, it was observed that a run estimated at from 600 to 1,000 sea lampreys entered this stream in the early spring. It was also observed in each year that for some as yet undetermined reason all of these migrants abandoned this stream without spawning. Conditions were comparable, therefore, to those where a mechanical barrier prevented access to spawning grounds.

Ninety-one sea lampreys were taken in this weir-trap during eight 24-hour periods of operation on May 15 and during May 20-26 inclusive. Eighty-six individuals were moving upstream and five were moving downstream at the time of capture. All of these lampreys were tagged with numbered, celluloid button tags and released in the direction in which they were originally traveling (3/8-inch diameter tags; applied with 2 1/2-inch, nickel-plated bank pins through the dorsal musculature, just anterior to the first dorsal fin).

Six of these marked sea lampreys (7.0 percent of total tagged) appeared in the Carp Creek and Ocqueoc River weirs. These streams represent the two nearest potential spawning streams SE of Milligan Creek along the Lake Huron shoreline. One recovery in Carp Creek was taken 10 days after tagging; the five in the Ocqueoc River at 2, 6, 10, 17, and 30 days after tagging.

An additional tagged sea lamprey was recovered in the Mackinaw Straits by a commercial fisherman on, or about, July 15, 1949, some 51 days after it had been tagged. It was taken 3 1/2 miles NE of Mackinaw City in 78 feet of water on a mud bottom. The lamprey was caught when its tag became entangled in the twine of a gill-net set.

It is logical to assume that some lampreys die before they succeed in finding suitable spawning grounds. This they may experience in streams, when blocked by a large dam, or in the Great Lakes, when unable to locate an adequate stream. In order to measure the effect of such frustration experimentally, I imprisoned migrants as follows: In 1947, 50 migrant sea lampreys (30 males and 20 females) were taken from the Carp Creek weir on May 20 and 24 and on June 15, and placed in live-crates anchored in Ocqueoc Lake at depths of 2 to 4 feet. Ten lampreys were placed in each of five compartments which averaged about 1 1/2 cubic yards of space apiece. An equivalent number of 8- to 11-inch black bullheads were placed in each compartment (none of these bullheads were ever attacked by the imprisoned lampreys). The bottoms of three compartments were of planed wood, and of the remaining two, wood covered with a layer of silt and sand. Lake water temperatures here varied from 53 degrees F. to 75 degrees F. during the course of the experiment.

Initially, all imprisoned lampreys were very restless and moved about almost continuously searching for a way out of the crate. This restlessness became very pronounced on June 25. Between then and June 28, 12 males and 5 females died. Between the latter date and July 3, 9 males and 15 females likewise died. Of the remainder (all males), two died on or before July 11, six on or before July 18, and the remaining specimen expired on July 25.

With the exception of the retention of the unspawned eggs or milt, anatomical and degenerative changes among these dead specimens were like those in spent sea lampreys. The color of the liver, the degree of reduction of the digestive tract, loss of vision, and sloughing of skin were all similar (subsequent discussions treat in more detail upon these changes among migrant and spawning individuals).

In this experiment, the specimens were held at higher water temperatures unlike those which normally blocked migrants would have found had they moved back from a barrier structure into the Great Lakes proper. These elevated temperatures probably accelerated the normal rate of mortality or hindered a possible recovery from the anatomical changes accompanying sexual maturity. However, 4 migrant adults taken from Carp Creek on May 29, 1947, and held in running water aquaria at the Oden State Fish Hatchery at an average water temperature of 49 degrees F. (range: 48 to 52 degrees F.) also died. Either suckers or trout were also placed in the aquaria.[8] The lampreys were very active for several days, apparently seeking a way out of the tanks. Thereafter, they quieted down and were never active unless disturbed. At no time did they attack either suckers or trout placed with them. Three specimens were killed on June 12, June 28, and August 5, respectively, and examined. Liver color and reduction of the

---

8/Experiment conducted and observations by Mr. R. F. Sharkey of the Oden State Fish Hatchery.

digestive tract in the last two specimens were comparable with that of spent sea lampreys. The fourth lamprey died on September 3 bearing no evidence of a recovery from the degenerative changes accompanying sexual maturity.

This slender evidence suggests that colder water temperatures merely prolong the existence of an organism that, if barred by circumstances from the climactic act of its life cycle, is destined to die when it has burned up its reserves of energy.

IV. Physical degeneration of migrants and mortality of post-spawning adults

Although the preponderance of evidence presented by earlier investigators (and substantiated by my data) points rather conclusively to the death of the sea lampreys after the completion of spawning, doubt is still expressed in some quarters as to whether or not this actually occurs. Surface (1899) and Gage (1928) noted an anatomical degeneration of the gut (and liver; Gage, 1928) among migrant and spawning populations of lampreys of this species. Surface (op. cit.) likewise noted a tendency towards blindness and a shedding of the epidermis among post-spawning adults. Both writers refer to the absence of "minute ova" in the ovaries of spent females as evidence that these lampreys spawn only once and then die.

If sea lampreys die after spawning, one would expect to find large numbers of dead, spent fish near the spawning grounds. However, this is not so; such fish are not seen in abundance. Surface (1899) attributed this dearth to the fact that most dead and dying lampreys were deposited in the deeper, silted pools of a stream and to the fact that immediately after death the lampreys decayed with great rapidity under any circumstances. An experiment performed by Surface confirmed these contentions. Both Surface (1899) and Gage (1928) noted instances where the presence of the long, tape-like, persistent notochord was the primary evidence in the stream of a post-spawning mortality of adults.

Gage (1928) performed experiments in holding spawning sea lampreys under various conditions favorable to their recovery and observed that all specimens ultimately died. The most conclusive evidence of mortality in spent lampreys was presented by Surface (1899) for a spawning run of lampreys in a New York stream. He reported that only dead or dying sea lampreys (often badly fungused and barely alive) drifted downstream to a weir and trap operated on the inlet of Cayuga Lake, New York.

All of my evidence, from both field observations (direct evidence) and anatomical studies (indirect evidence), confirms the conclusion that sea lampreys die after spawning once.

Observational or direct evidences to support these statements are of two types: Those derived from observations on the spawning grounds and those obtained in connection with the operation of sea lamprey weirs and traps. During the 1947 and 1948 seasons, sea lamprey spawning activity was studied in detail in the Ocqueoc River watershed. During and after the peak of spawning activity, spent and dead or dying adults could always be found on those spawning grounds where thorough examination was possible. Admittedly, spent and dead sea lampreys were never very much in evidence to the casual observer but a careful search under brush tangles, in sloughs, backwaters, and in the deeper silted pools revealed many that would ordinarily escape notice. Details of one day's observations will illustrate this. On June 24, 1947, a 0.6-mile stretch of the Ocqueoc River was carefully censused for spawning and dead sea lampreys. Of 194 individuals seen, 155 were occupied with spawning activity. The remainder, 39 (20.1 percent), were dead or very nearly so, and were picked up in quiet water or in locations where their bodies would catch under or against logs, brush, and stones. Furthermore, an investigation of the deeper, silted pools revealed many dead lampreys in advanced stages of decay which, because of fragmentation, could not be counted. The remains of most dead sea lampreys present in the watershed lay at the bottom of these deeper pools. The depth of the pools (many to 10 feet or more), the tea-colored water of the river, and the rapid decay and silting-over of the bodies all combined to conceal the many dead individuals deposited there by the river current.

In pools, particularly below much-used spawning riffles, dredging activities produced numerous white, tape-like structures; on comparison these proved to be sea lamprey notochords. These notochordal "tapes" were all that remained of decayed sea lampreys. These persistent structures were also found caught against brush and other snags in other parts of the stream.

A contributing factor to the paucity of observable dead in the shallower waters is the activities of the gulls and other scavengers as described in a previous section of this study.

This direct evidence that some or most sea lampreys die following spawning, does not refute the contention that perhaps some individuals recover to spawn in another season. However, the operation of the Ocqueoc River weir in 1945 which has been reported upon by Shetter (1948) offers excellent testimony that very few if any recover from the spawning act. This point has not been elaborated by Shetter. A weir and trap was operated in the Ocqueoc River from April 22 to July 15, 1945. The river overtopped the weir on April 25-28 and again, during the peak of migration, on May 28-June 6. Although 4,608 sea lampreys were trapped, an escapement of perhaps 40 percent of the run occurred. Those that passed the weir were observed spawning subsequently in the watershed. During the entire period of effective operation of the weir (June 6–July 15) following the second overtopping of the structure, only 29 sea lampreys were taken moving downstream. The inclusive dates of operation allowed ample time during this interval for most, if not all, of any adults that had recovered from spawning and were returning to the lake, to have reached the weir. Furthermore, although the 29 downstream migrants were not examined to determine their condition, it is probable that they were merely upstream migrants moving around within the confines of the stream while seeking a place to spawn. Data collected in 1948 during the operation of a trap in the Carp Lake River (Emmet County) supports this assumption.

In addition to the preceding observations, data obtained from laboratory examination of migrant and spawning sea lampreys offers further supporting evidence, of a less direct nature, on the post-spawning mortality of adults.

First it has been concluded from a study of the ovaries of both unspawned and spent female sea lampreys that the maturing eggs greatly outnumbered the undeveloped ones present which would have enabled the female to spawn again in another year. Furthermore, no germ-cell stages were present in the ovaries of the spent females.

Secondly, a group of consistent manifestations of a physical degeneration of migrant and spawning adults was found in all specimens examined. Although these phenomena of decadence are discussed separately under following subheadings, they should be considered in the light of their cumulative effect upon the individual sea lamprey in order that their significance can be appreciated fully.

(1) Progressive blindness

All spent and dying sea lampreys on the spawning grounds were quite blind. The corneas of the eyes of these specimens had lost their sharp, clear quality and were quite milky or cloudy in appearance. These individuals would respond weakly to tactile stimuli—never to visual ones. The onset of this condition was first noticed during and after the peak of spawning activity when it was observed that nearly all of the spawning adults nearing the completion of spawning were already blind. As the termination of the spawning period approached, blind individuals were found in progressively less advanced stages of their spawning activities. At these times, the observer could stand astraddle a nest in which a pair was spawning and place the fingers of one hand on each side of the head of one of the spawners as if to grasp it. No response or awareness of the observer's presence was elicited until a physical contact was made with the lamprey's head or body. Only then did the usual avoiding reaction result.

All of the stragglers which composed the end of the Carp Creek run in 1947 displayed some evident loss of vision. In several of the migrants taken during the month of July, the eyes were already milky-white and opaque and those specimens did not respond to visual stimuli. This was likewise true of the late migrants captured in Ocqueoc Lake during July of the same season.

A general increase in migratory activity during daylight hours as the spawning season progresses has been described previously. The increase in activity during the daytime is much more pronounced on the spawning grounds during the same period and is climaxed with equal spawning activity occurring at all hours of the day and night. It appears that loss of vision parallels ripening of the gonads, that it progresses in severity as spawning time approaches, and that it culminates in total blindness by the time an individual is spent. Other evidence indicates that loss of vision occurs more rapidly among late migrants than among early ones.

(2) Loss of epidermis

In all dying and freshly dead sea lampreys it was observed that large, irregular patches of outer skin had been lost. With the layer that had been sloughed-off, went its mucous coating and the pigmentation of the variety of spawning colorations which occurred. The deeper layers of the integument which were exposed were a dull, blue-black in color with a vague overprinting of the characteristic black mottling. Those areas upon which the outermost layers still remained could easily be denuded of their covering by a firm stripping action with the hand.

Skin loss was first noticeable in mid-breeding season among live adults which were nearing the completion of spawning. As the spawning period progressed, increasing numbers of individuals were found on the nests which displayed some loss of body covering. At the close of the season, all adults observed at the peak of their spawning activity, or later, had suffered a similar loss. Among live individuals, the most noticeable loss of areas of the skin was found among spent males. These males characteristically cling to, or remain in the bottom of, the nest for a variable period following the completion of spawning. On observation, it seems hardly possible that these males, with their lifeless behavior, with white, opaque eyes and with scaly, broken skin, could still be alive or could live to spawn again.

Much of this loss of body covering may be attributed to abrasion against hard bottom materials during the violent exertions of nest building and spawning. Among the females, further scarring and abrasion of the head region occurs from the male grasping her in that region with his mouth during each spawning act.

Since there is no evident repair or replacement of the lost layers, the scarring effects of all abrading agents are cumulative. Some dying individuals were almost completely denuded of the outer layer of skin. These conditions rendered the sea lampreys very vulnerable to fungus infections, which many displayed.

(3) Degeneration of the digestive tract and changes in the color of the liver

Two changing phenomena are readily apparent in the dissection of sea lampreys collected during the entire season of migration and spawning. One is a series of changes which occurs in the color of the liver; the other is a striking reduction in the size of the digestive tract.

The liver of sexually immature and actively feeding adults is normally a pale reddish-orange. Among male sea lampreys the livers of the earliest migrants still retain this color. However, as the migratory season progresses and the run is composed of individuals in more advanced stages of sexual maturity, a series of color changes of this organ appears. Successively, the color of the liver becomes orange-yellow, sometimes mottled, sometimes of a uniform intermediate shade; yellow; yellow-green, either mottled or of a uniform intermediate shade; and finally, a bright, light green. The livers of virtually all male migrants examined during and after the peak of the spawning run were in advanced stages of change; the colors occurring were yellow, yellow-green, or light green. The color of the liver of all spawning and spent males examined was light green.

The liver color of the earliest migrant females likewise is the reddish-orange characteristic of the organ in sexually immature adults, although it is of a somewhat darker shade. Changes in the color of the liver with increasing sexual maturity differ from those of the males and are less elaborate. The liver in migrant females on successive dates becomes: reddish-brown; brownish-green, either mottled or of an intermediate shade; and finally, dark green. In the latter half of the run, all females fell in the last two color categories. The livers of all spawning and spent females are dark green in color.

These color changes of the liver are very pronounced in character and differ so distinctly between the two sexes that accurate sex determinations can be made upon sexually maturing or mature adults solely upon an examination of the color of this organ.

When the above observations were made, records were obtained of the stage of sexual maturity, color of the liver, and intestinal and rectal diameters of 478 male and female sea lampreys collected at intervals throughout the migratory and spawning season (Data are presented in Appendix G, Tables 10 and 11, sexes separately. The proportion of individuals displaying the color changes described above at various times during these periods may be derived from these tables).

The direct or indirect causes of these color changes in the liver of the sea lamprey are not known. Surface (1899) noted that the livers of spent specimens were green in color and ascribed it to a general accumulation of catabolites. It has been suggested that these color changes result from the successive accumulation in the liver of dominant quantities of various bile pigments (bilirubin, urobilin, and biliverdin) following conversion from one to the other by either oxidative or reductive processes. However, the sequence of reactions that would necessarily be involved seems somewhat irrational. Certainly, these color changes in the liver signify a profound alteration in the normal metabolism of the organism which, perhaps, is associated with the process of sexual maturation. They further signify, if not an actual degeneration of this organ, at least a serious, and possibly irreversible, physiological change in it.

An atrophy of the digestive tract of migrating and spawning sea lampreys was reported by earlier workers (Surface, 1899; Gage, 1928); I too observed this condition. Specifically, with increasing sexual maturity and associated cessation of feeding, the diameter of the digestive tract gradually decreases until, at the time of actual spawning, it is reduced to a mere hollow thread, one to two millimeters in diameter.

The digestive tract of the sea lamprey may be likened to a straight tube which travels directly from the mouth to the anus. The regional differentiation of the tract, present in higher vertebrates, is only obscurely indicated. Anteriorly, a short gastral or stomach zone is present; posteriorly, a short rectal zone is more readily distinguishable. Between these lies the intestine which is identified by thicker walls and greater structural rigidity than the other zones possess and by the presence of a typhlosole.

In order to demonstrate the reduction in this organ, measurements were made of the diameters of the intestinal and rectal zones of the digestive tracts of 478 sea lampreys. All measurements were made to the nearest half-millimeter with dividers and a steel rule. The samples utilized for these measurements were collected at intervals throughout the migratory season and upon the spawning beds (Data are presented in Appendix G, Tables 10 and 11, sexes separately. For each sex, the range and average of intestinal and rectal diameters have been tabulated first by date of collection and as to whether migrant or spawning sea lampreys were examined. Secondly, these data have been further subdivided and grouped according to the color of the liver of the specimen examined as it was observed that this character was the most simply recorded measure of the individual's degree of sexual maturity. The validity of this association may be verified in the striking correlation between the two changes).

A spawning run, as it progresses in time through migratory and spawning periods, is composed of individuals in increasingly advanced stages of sexual maturity. Among the earliest migrants studied, the average diameters of the intestine varied from 7.4 to 10.8 millimeters. The average diameters decreased throughout the run until among late arrivals maximum intestinal diameters averaged 4.1 millimeters. Further reduction occurred during the journey upriver and upon the spawning grounds. The diameter of the intestine of specimens collected while spawning never exceeded 2.5 millimeters; they were occasionally reduced to a diameter of 1.5 millimeters. Rectal diameters were consistent throughout in their progressive reduction, like those of the intestine, although invariably somewhat lower in value.

It is important to note that these gut diameter measurements represent only a partial measure of the decrease in the digestive capabilities of the intestines of the specimens studied. An increasingly greater amount of potential digestive and absorptive surface of the intestine is lost with each small decrease in diameter. The word "potential" is used advisedly since my studies indicate that no feeding takes place during the time in which this reduction is occurring.

Cross-sections were prepared from the mid-portion of the intestines of a series of sea lampreys to determine more precisely the changes in gross structure and histology which were associated with its reduction in size (Figures 40-48). This material was collected from sexually immature, actively feeding adults, from migrants in varying stages of sexual maturity, and from adults taken from their spawning redds. In all, intestinal sections from 20 specimens taken before and during migration and during and after spawning were examined. With the exception of the sexually immature specimens, intestines were removed from live material and preserved in F-A-A solution. Sections were imbedded, cut at 10μ, and stained in Harris' Hematoxylin and Eosin.

The intestine of a sexually immature adult is circular or ovoid in outline; its lumen is U-shaped. Into the lumen projects a typhlosole which commences anteriorly on the dorsal side of the intestine, describes a partial spiral, and terminates on the ventral side. The typhlosole does not usually extend more than half way across the lumen. It carries both an artery and a larger vein. Many slender, closely-spaced longitudinal folds or rugae arising from both the walls of the intestine and from the typhlosole likewise project into the lumen (Figure 40).

Figure 40.--Section of intestine of sexually immature and actively feeding adult taken in Grand Traverse Bay; total length--9.6 inches; color of liver-orange. X23.2.

Figure 41.--Section of intestine of migrant sea lamprey; male; total length--13.1 inches; color of liver--orange. X23.2.

Figure 42.--Section of intestine of migrant sea lamprey; female; total length--16.5 inches; color of liver--brown-green. X23.2.

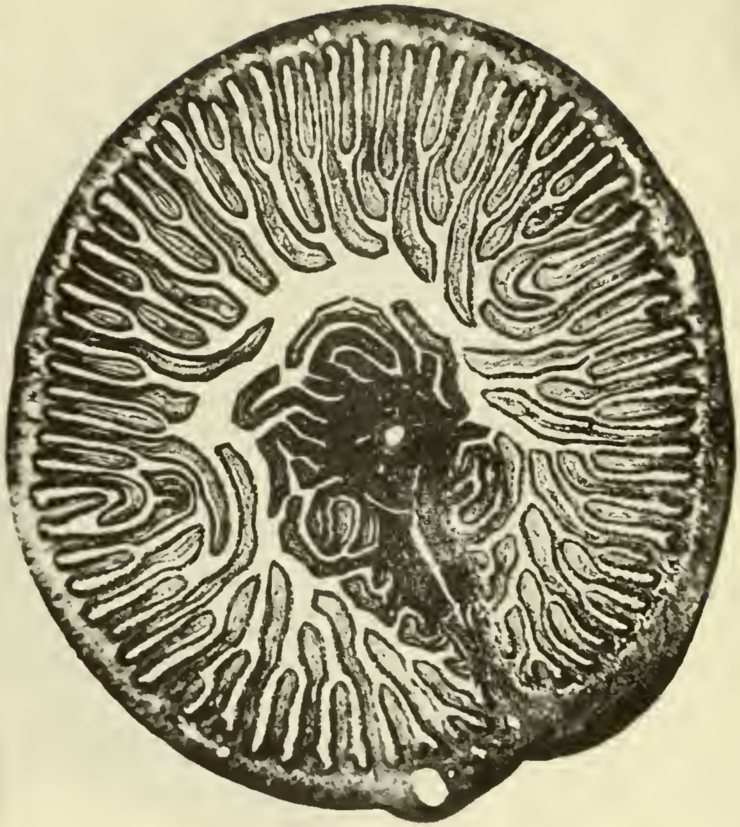


Figure 43.--Section of intestine of migrant sea lamprey; male; total length--16.3 inches; color of liver--yellow-green. X23.2.

Figure 44.--Section of intestine of migrant sea lamprey; female; total length--15.8 inches; color of liver--brown green. X23.2.

Figure 45.--Section of intestine of migrant sea lamprey; female; total length--16.9 inches; color of liver--dark green. X23.2.

Figure 46.--Section of intestine of migrant sea lamprey; female; total length--15.9 inches; color of liver--dark green. X23.2.

Figure 47.--Section of intestine of spawning sea lamprey; male; total length--14.6 inches; color of liver--light green. X23.2.

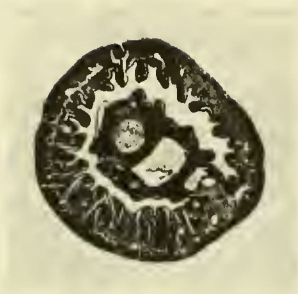


Figure 48.--Section of intestine of spawning sea lamprey; female; total length--17.8 inches; color of liver--dark green. X23.2.

The intestine is covered with a visceral peritoneum (serosa) composed of both simple and stratified squamous epithelia cells in different places. Beneath this lies a relatively undifferentiated muscular layer. The lumen is lined with pseudo-stratified columnar epithelial cells, which may or may not be ciliated, and a variable number of secretory cells. A mucosa of connective tissue forms a core for each of many ruga and is present at the base of the folds also. Many small capillaries enter the rugae from the walls of the intestine.

Even among the earliest migrant sea lampreys some constriction of the lumen is evident (Figure 41). As this cavity becomes more severely constricted, the rugae become contorted and bent upon themselves (Figure 42); a part of the evident reduction in the lumen is due to crowding of the folds as the intestine first shrinks. Following this, these structures become increasingly truncated and aborted in shape as the diameter of the intestine declines in size. A fusion seemingly occurs at the bases of the rugae and many disappear entirely (Figures 43-46).

In spawning sea lampreys the rugae are reduced, in cross section, to blunted, misshapen knobs. Many disappear and some of the remaining ones are broadly fused at their bases. At this, the most reduced stage, the typhlosole is essentially devoid of rugae, and with its large artery and vein, occupies almost all of the lumen of the intestine because it has regressed relatively less per se than the remainder of the gut (Figures 47-48).

Aside from a gradual loss in the volume of tissue present, no specific changes appear to occur in the serosal and muscular layers. However, some very striking changes occur in the structure of the epithelial lining of the intestine. This tissue is composed of pseudo-stratified columnar epithelium in the sexually immature adult. A virtual retrogression of this layer occurs along with the gross changes previously recorded. Among migrants in the earlier stages of sexual maturity, more and more simple columnar cells form the lining of the lumen apparently replacing the pseudo-stratified columnar ones. As maturity advances and the intestine becomes more and more constricted, the simple cell type increasingly dominates the lining. In subsequent stages the columnar cells become progressively shorter and broader. This culminates, in specimens taken on the spawning grounds, in a lining composed almost exclusively of simple, cuboidal cells.

Although reduced in number and size, the blood vessels and capillaries retain a highly functional appearance. This is particularly so in the artery and vein of the typhlosole (Figures 40-48). Furthermore, very few degenerate or dead cells, either free or attached, could be distinguished in any of the sections studied; only apparently living, if somewhat altered, cells appeared to be present. No marked or progressive dehiscence of lining cells into the lumen of the digestive tract was observed. These facts suggest that the general regression of all tissue layers present in the intestines of sexually maturing sea lampreys results from an active autolysis, i.e., a resorption and digestion of these tissues. It seems entirely feasible that such resorbed cellular material could be utilized by the sea lamprey; subsequent to the time that it ceases feeding it must migrate often long distances upstream, and collaterally must complete the formation of its sexual products, and finally must construct its nest and spawn.

It is within the realm of possibility that a regeneration of tissues might take place in the intestine of a spawned-out adult. However, this is deemed highly unlikely. The functional characteristics and the digestive capabilities of this organ have been so severely reduced that such a regeneration could hardly occur.

(4) Discoloration of flesh

The flesh of sexually-immature, adult lampreys taken in the Great Lakes was found to be uniformly white and of an appearance not unlike that of many other fishes. In virtually all migrating sea lampreys, certain localized areas of the flesh display varying amounts of a bluish discoloration. This discoloration occurred primarily in a band immediately beneath the integument, along the dorsal septum, and around the median skeletogenous elements (notochord, etc.). Furthermore, in the most mature specimens, a light bluish tint was imparted to all portions of the flesh.

Presumably this discoloration is the result of the deposition of catabolic wastes in the flesh consequent to the decline in the functional capabilities of the digestive tract and associated organs of elimination.

VII. Some economic characteristics of spawning runs

This discussion is not concerned with the matter of control of lamprey populations in the upper Great Lakes, but rather with the potential commercial utilization of sea lampreys taken either by control devices or by a possible commercial trapping enterprise. This matter has been given some attention with the object of determining compensatory uses for this predator in the event that the control of its numbers is deemed either physically or financially impractical.

The major uses to which sea lampreys, trapped on their spawning runs, might be put are as follows: (1) Food--for human consumption or as animal farm (mink, fox ranches, etc.), or fish hatchery rations; (2) reduction for oil, fertilizer, meal or derived by-products; (3) reduction for medicinal products; and (4) sale as biological specimens.

Certain of these uses have been tentatively explored and the results are herewith summarized and discussed.

Preliminary experiments indicated that spawning run sea lampreys were quite unpalatable. In 1947, 12 fresh sea lampreys taken from the Carp Creek weir were smoked by a Mr. Emil Plath of Rogers City, Michigan. Mr. Plath has smoked meat and fish commercially for 35 years and was particularly interested in determining if the lampreys would make a saleable smoked product. The results were discouraging. The smoked lamprey flesh was streaked with black from the original blue discoloration of the flesh (accumulated waste products); its appearance was unappetizing and the texture of the flesh was soft or "mushy". The most unfortunate characteristic, however, was an acrid, unpleasant odor, characteristic of the lampreys but unlike the usual "fishy" smell of other fishes, which the flesh gave off. This alone inhibited any enjoyment of the actual taste of the flesh itself.

I have prepared and cooked fillets from fresh specimens on two occasions. These preparations likewise displayed unpleasant discolorations of the flesh after cooking; its texture was somewhat soft. The taste of the flesh was not exceptional; its enjoyment was obliterated by the indefinable, acrid odor of a decaying lamprey which was present even in the cooked material.

Even if a cooking technique were developed which would allay the aforementioned odor, I believe that it would be extremely difficult to market fresh lampreys either in the round or drawn. Over a period of two years, the reactions of numerous laymen to the appearance of fresh specimens were noted. The slimy skin, the snake-like appearance, and the ugly mouth and head brought forth expressions from outright disgust to a complete disinterest in experimenting with them as food. I judge from this that if the lampreys are ever marketable as food they will only be so as fresh or canned fillets.

Reduction of sea lampreys for oil or associated medicinal products appears equally unpromising. In 1947, at the request of Dr. John Van Oosten, six specimens were sent to the Fishery Technological Laboratory, Seattle, Washington (U. S. Fish and Wildlife Service), for analysis of oil content and the vitamin A potency of that oil. The results of these tests are summarized in the following paragraph extracted from a letter from that laboratory to Dr. Van Oosten:2/

"With Vitamin A selling at about 11 cents per million units, it is evident that it would not be feasible to remove the livers or eggs from the lamprey as the cost of the labor involved would

---

2/Data quoted with permission of Dr. John Van Oosten, In Charge, Great Lakes Fishery Investigations, U.S. Fish and Wildlife Service.

probably be greater than the value of the material separated. We recognize that a sample based upon only six individuals may not be representative. However, even if the analyses had been ten times higher, the material would still be of doubtful value. It therefore seems unlikely that the sea lamprey will ever be a commercial source of Vitamin A. The only possibility would be to use the lamprey for reduction purposes. The oil thus obtained might be of a high enough potency to warrant its sale for its Vitamin A content."

The greatest obstacle to developing any of the proposed or tested uses of spawning run sea lampreys would be the excessive cost of each pound of lamprey flesh produced. It has been demonstrated that even large runs (in numbers) constitute a relatively small poundage of lamprey flesh. The sea lamprey run in the Ocqueoc River, estimated at 10,000 individuals in 1947, would have a total weight of 4,062 pounds. This weight would produce approximately 1,000 pounds of meal and 68 pounds of oil. To produce this number of pounds would require the operation of a weir and trap that would capture all migrants. Such a trap would have to be built according to certain minimum requirements in order to be efficient and be in operation for three and one-half months with a seasonal average of three salaried employees in continual attendance. At present wage levels and costs of construction of such traps, the cost of production per pound would obviously be out of all proportion to the profit that might be derived from the products. For example, had the trap been run in 1948 the estimated cost for labor and weir maintenance would have been about $1.00 per pound of whole lampreys. If the cost of weir and trap construction and development were distributed over a ten-year period and added in, the cost per pound of produced whole lampreys would be raised to about $1.40. Each pound of whole lampreys would produce one-quarter pound of meal and/or 7.6 grams of oil. The costs indicated are those "at the pier". Additional expenditures must be met for handling, transportation, processing, and marketing.

In spite of these data, it is suggested that whole, frozen sea lampreys be tested as supplementary rations for fish hatcheries and animal farms. Such sales (or consignments within an organization) and sales as biological specimens may in some small measure reimburse the agencies expending funds for sea lamprey control.

The picture painted by the preceding comments is quite discouraging. It is not intended to be so. It is merely an evaluation based on present known facts and figures relative to spawning runs, and the economic feasibility of the utilization of sea lampreys in the major categories of uses noted.

VIII. Investigations of the larval, non-parasitic phase of the sea lamprey's life cycle

Methods

Ammocoetes, or larvae, of the sea lamprey are extremely abundant in many parts of the Ocqueoc River watershed and were studied there in 1947 and 1948. They were collected by means of an electric shocker and several types of dredges. The shocker was a portable, 110-volt, A. C. generator driven by a gasoline engine. This device, in practice, passes an alternating current through the water or bottom between two electrodes. In collecting larval lampreys, the electrodes were operated at distances of from five to fifteen feet apart, depending on the locus of operations. The machine which I used had a fixed maximum output of 110 volts and 3 amperes. Voltages and amperages within the operating field of the electrodes would vary with the nature of the stream bottom and the chemical quality of the water but they would not exceed the maximum output indicated.

Within the electrical field, many ammocoetes are apparently overcome with convulsive movements which cause them to emerge from their burrows in the mud and sand. Some, emerging either head or tail first into the stream, are paralyzed and drift downstream or lie upon the bottom depending upon the amount of stream current. Others become paralyzed when half out of their burrows. All of these are easily collected with a scap net.

Many other ammocoetes are evidently paralyzed as they lie in their burrows. In collecting the larvae, the electrodes were moved forward very slowly, as a rule, and were often operated continuously in a very limited area for as much as five minutes. Quite frequently an area would appear devoid of lampreys for several minutes. If the position of the electrodes was shifted gently, however, larvae would soon begin to appear. In spite of intensive collecting efforts in a given area on any day, equivalent, or larger, numbers of ammocoetes could be removed from this same area on several succeeding days. One heavily populated silt bank was "worked over" with the shocker for seven consecutive days and collections made on each day; the largest collection was made on the third day of this series.

Lamprey larvae recover almost immediately when removed from the electrical field by the stream current or by the observer. No prolonged ill effects of subjection to the electrical current are apparent. Nearly all ammocoetes collected with an alternating current shocker display some evidence of hemorrhaging in the branchial region. The violent convulsions induced by the electrical current evidently cause ruptures of the many capillaries which lie very near the surface in that area. Among shocked specimens subsequently held in aquaria, all evidences of this hemorrhaging disappeared within a week.

Success in collecting with the electric shocker depends on being able to see the larvae in the water or on the bottom when they have left their burrows. Turbid water, poor lighting, and the more rapid recovery of the smallest individuals from the effects of the electric current may result in many of these being overlooked. Good random samples of all size groups could only be obtained by exercising greatest care and by working in areas of shallow, clear water.

Some collections were made by screening dredged bottom samples. I used a Peterson dredge most often and sifted the contents in a box having a bottom of fine-mesh screen. Ekman or other light dredges were unsuitable because the organic debris of the river silt beds frequently prevented the jaws from closing. Scoop-shaped dredges, although satisfactory for collecting, could not be used where measures of larval populations per unit of area were sought.

The Peterson dredge was selective for the smaller size groups of larval lampreys. It brought up only the surface layer of the stream bottom from about 2 to 2.5 inches in thickness. Such collections were composed almost entirely of young-of-the-year; sometimes a few yearlings were included. For this reason, they complement those made with the electric shocker since with the latter instrument, the smallest lampreys were most often missed. Both collecting techniques were utilized in seeking total populations of sample larval beds.

All measurements of the larger ammocoetes were made to the nearest half-millimeter in a small steel trough in which a steel ruler had been mounted. Similar measurements of smaller specimens were made on a Bogusch Measuring Slide. Recently-hatched larvae were measured with an ocular micrometer in a compound, binocular microscope. All lampreys were preserved in a 10 percent solution of formaldehyde shortly after capture and measured later; no estimates were made of the probable shrinkage due to preservation. Churchill (1945) reports a shrinkage of 3 percent among northern brook lamprey larvae after preservation in 5 percent formaldehyde for two months.

Altogether, 4,055 ammocoetes, other than recently-hatched specimens, were collected which presumably were larvae of the sea lamprey. Some qualification of the identity of the species is used advisedly. Five species of lampreys are present in Michigan waters: the American brook lamprey (Entosphenus lamottenii), the sea lamprey (Petromyzon marinus), the Michigan brook lamprey

(Ichthyomyzon fossor), the silver lamprey (I. unicuspis), and the chestnut lamprey (I. castaneus). The larvae of each of these various species, native and introduced, are notoriously difficult to distinguish from one another. As yet, no artificial key based on taxonomic characters has been presented which would aid in differentiating all forms present from each other.

Certain anatomical features characteristic of the adults of several species are distinguishable in the larval stage and identify the ammocoetes of these species at least to genera. Adult members of the genus Ichthyomyzon possess a single, continuous dorsal fin which is recognizable even among its very small larvae. Adult lampreys of the genera Entosphenus and Petromyzon have two distinct dorsal fins which are likewise present among their larvae. Vladykov (1949) has demonstrated that the number of trunk myomeres of the silver lamprey and Michigan brook lamprey (genus Ichthyomyzon) is less than in the general Entosphenus and Petromyzon. The ranges in number of trunk myomeres of the latter two genera overlap broadly and render identifications between them based on this feature impractical.

Utilizing the two features just described, 41 ammocoetes belonging to the genus Ichthyomyzon were sorted out of the collections. Two transforming silver lampreys were also removed. It is unlikely that any larvae of the chestnut lamprey were among those thus removed as the Ocqueoc River is outside the natural range of this species in Michigan.

Presumably larvae of only two species, the sea lamprey and the American brook lamprey remained in the collections. No effort was made to distinguish between the larvae of these genera. Admittedly, then, some infusion of Entosphenus larvae is present in my series of ammocoetes but I believe the number of these must be negligible. During three years of work in the Ocqueoc River watershed in which I became intimately acquainted with all lamprey spawning areas in the river, I have never seen either spawning or spent American brook lampreys. Among collections made in all types of habitats in all seasons of the year, only one transforming specimen of the non-parasitic American brook lamprey was ever taken. Obviously the species is sparse in the Ocqueoc watershed. On the other hand, spawning sea lampreys are annually abundant to the point of severe overcrowding in some spawning areas. Enormous numbers of their offspring appear in the silted and sandy areas of the river after each spawning season.

It may be concluded that my collections are almost entirely composed of ammocoetes of the sea lamprey and that the numbers of American brook lamprey larvae in the series are so small, if present at all, that they could not invalidate the analyses and conclusions subsequently drawn therefrom.

Age and size of larvae at time of departure from the nest, and production from the redds

At an average water temperature of about 71 degrees F., larval sea lampreys burrow out of, and leave, the nest 18 to 21 days after the completion of spawning by the parent fish. The greatest number leave the nest on the 20th day. All of them, upon leaving the nest, have completed their early developmental stages and are perfectly formed but diminutive ammocoetes. Preliminary experiments indicated that the production of larvae from these nests varied from 0.4 percent to 1.1 percent of the reproductive potential of the female spawning in a given nest.

These studies were made on the Ocqueoc River in June and July, 1947. A site was selected in the lower river where a natural spawning area was present. A wood-walled raceway was installed in the stream across several small gravel bars and parallel to the current (Figure 49). The enclosure was 12 feet long, 2.5 feet high, and 3 feet wide. The upstream end of this pen was blocked with copper screening having 20 meshes to the inch. A funnel of the same screen material was installed at, and as an extension of, the downstream end of the raceway. The mouth of a plankton tow net was fitted to the spout of the screen funnel; the net was anchored in an extended position. All seams, cracks, and joints were filled with marine pitch and the walls of the raceway were carefully sealed to the bottom. To the best of my knowledge, any larvae produced in this raceway had no point of egress from the device except into the trap of the plankton tow net (Figure 49).

In 1947, I succeeded in inducing two pairs of sea lampreys to build nests and spawn on the natural stream bed inside of the experimental raceway. Except for a slight diminution of current due to the head screen and the relative confining space of the raceway, conditions were believed identical to those existing naturally elsewhere in that area of the river. A third pair of lampreys, spawning on a site of their own selection near the raceway, were surrounded by a hardware cloth screen until they had completed their activities and died. This coarse screen was then removed and one of the screen material used in the raceway substituted for it. The downstream end of this second enclosure was a funnel and trap identical with that described for the larger, first one.

The time of completion of spawning was recorded in each case. The females, which died very shortly after spawning, were recovered, measured, and examined for residual eggs. Twice daily thereafter, the traps of the plankton tow nets were examined and when larvae were present they were removed and preserved. Routine inspections of the traps were continued for 20 days after the last larva was captured. Water temperatures were recorded with a maximum-minimum thermometer. During the period when development, hatching, and

Figure 49.--Raceway used in Ocqueoc River to determine length of hatching period and production of larvae from the redds. Left hand of attendant is on funnel from which plankton net extends downstream.

departure from the nests were occuring (June 25-July 21), mean daily water temperatures varied from 65.5 degrees F. to 75.5 degrees F.; the average temperature for the period was about 71 degrees F. Daily extremes ranged from 61 degrees F. to 79 degrees F.

Data obtained from each spawning pair and nest were as follows:

Nest No. 1 (in raceway):--Spawning was completed in this nest on June 25, 1947. The female, 16.7 inches in total length, had a potential egg production of 56,600 eggs (estimated from a curve based on egg production data which is presented elsewhere in this study). The following numbers of larvae left the nest and were taken in the trap on the following dates: 119 on July 14, 469 on July 15, and 34 on July 16; total--622 individuals. The production of larvae constituted 1.1 percent of the reproductive potential of the female.

Nest No. 2 (in raceway):--Spawning was completed in this nest on June 30, 1947. The female, 17.0 inches long, had a potential egg production of 58,700 eggs. The following numbers of larvae left the nest and were taken in the trap on the following dates: 3 on July 18, 47 on July 19, 150 on July 20, and 22 on July 21; total--222 individuals. Larval production constituted 0.4 percent of the reproductive potential of the female.

Nest No. 3 (in small enclosure outside of raceway):--Spawning was completed on June 30, 1947. The female, 15.0 inches long, had a potential egg production of 46,050 eggs. The following numbers of larvae left the nest and were trapped on the following dates: 1 on July 18, 109 on July 19, 204 on July 20, and 7 on July 21; total--321 individuals. Larval production amounted to 0.7 percent of the reproductive potential of this female.

The foregoing estimates of larval production, low as they seem, may even be somewhat above the average production. Water currents, slower than average at the experimental nesting sites, probably did not sweep as many newly-extruded eggs over and beyond the nest as often occurs. In addition, certain small fishes which can and do prey upon extruded eggs during the spawning act were excluded from the nesting sites.

Attempts to duplicate these experiments in 1948 were unsuccessful due to my inability to select a pair, both individuals of which were ready to spawn on the same date. Until such time when additional experiments are conducted, the larval production figures presented must be considered only indicative of the productivity of the species.

All recently-hatched larvae trapped from Nest No. 2 (222 individuals) were measured with an ocular micrometer in a compound, binocular microscope. Micrometer measurements were converted to millimeter units with the aid of a stage micrometer. These larvae which had just burrowed out of, and left, the nest ranged from 6.25 millimeters to 9.75 millimeters in total length and averaged 8.54 millimeters long. Their average age, dating from fertilization of the eggs, was 20 days. The distribution of the lengths of these individuals is presented as a frequency polygon in Figure 50.

Distribution in the Ocqueoc River, larval habitats, and population densities

The upper third of the Ocqueoc River is a region of sluggish currents, mucky bottoms, and considerable aquatic plant growth (Figure 28, Zone 3). No spawning occurs here. The central third of the watershed is characterized by long, continuous riffles of rock, rubble, and gravel interspersed with shallow pools (Figure 28, Zone 2). The lower third, below the Ocqueoc Falls, is at first

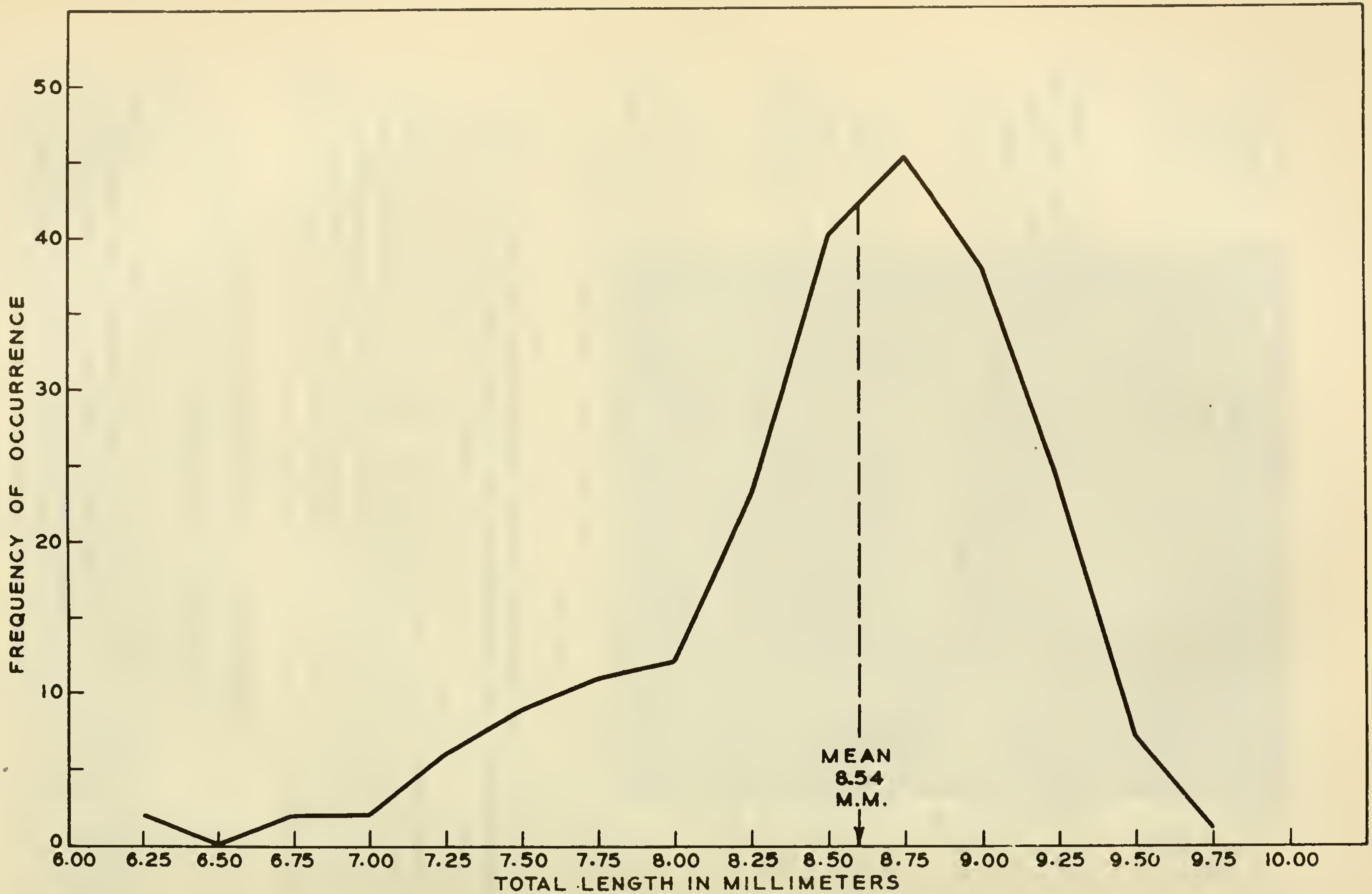


Figure 50.--Frequency distribution of the total lengths of the 222 recently-hatched sea lamprey larvae constituting the entire "hatch" from one nest.

an area of short, gravel riffles alternating with deep, sandy or silted pools. Continuing downstream, hard bottom types disappear rapidly and most of this lower zone of the river has a bottom of fine sands with occasional patches of gravel or exposed clay substrate (Figure 28, Zone 1). Sea lamprey spawning occurred with equal intensity in the middle and lower thirds of the river; in the former it was dispersed throughout the zone; in the latter, it was concentrated in a short distance immediately below the zonal boundary (Ocqueoc Falls).

During 1947 and 1948, an intensive survey was made of the Ocqueoc River for areas occupied by larval lampreys. Thirty-seven collecting stations encompassing all types of habitats were visited one or more times each. Ammocoetes were found in bottom materials from the beach line at the mouth of the estuary upstream throughout the lower two-thirds of the watershed. They did not occur above the highest point of spawning, 16.5 stream miles from the mouth of the river (Figure 28, Station 21).

Larval lampreys were found in greatest abundance where soft bottom types occurred. Here they can evidently make their burrows most easily and find the greatest abundance of the micro-organisms upon which they feed. The greatest concentrations of all age groups were present where at least four, or more, inches of black muck or silt, with some small admixture of sand, had been deposited by the current. These sites frequently contained much undecomposed organic detritus (twigs, leaves, etc.). Such deposits were normally situated in backwaters, eddies, sloughs, or along the inside of bends in the river where sluggish currents or slack water existed (Figures 51, 52). Larvae were abundant in beds in these locations, from the waters edge to depths of 3 1/2 feet (limit of visibility in collecting with shocker).

Three areas occupied by numerous larvae, within the 2-mile reach below the Ocqueoc Falls where the heaviest sea lamprey spawning occurs, may be cited as examples. One was a slough, formed in a quiet side channel around a small island in the river. In the months of July and August, a 226-square-foot area of this bed was found to contain 630 ammocoetes older than young-of-the-year or about 3 individuals per square foot. Young-of-the-year larvae were present at the rate of 6 to 17 individuals per square foot, averaging close to 14 per square foot.

Another area was a backwater along the bank of a swift flowing portion of the river (Figure 51). A 90-square-foot area of this bed was shocked on two succeeding dates in the month of October, 1947. A total of 107 larvae older than young-of-the-year were removed. No effort was made to collect the younger specimens but their concentration was estimated to average at least 10 individuals per square foot.

Figure 51.--Backwater along the bank of the lower Ocqueoc River. A high concentration of ammocoetes was present in this bed. The bottom type was of muck and silt containing much organic debris.

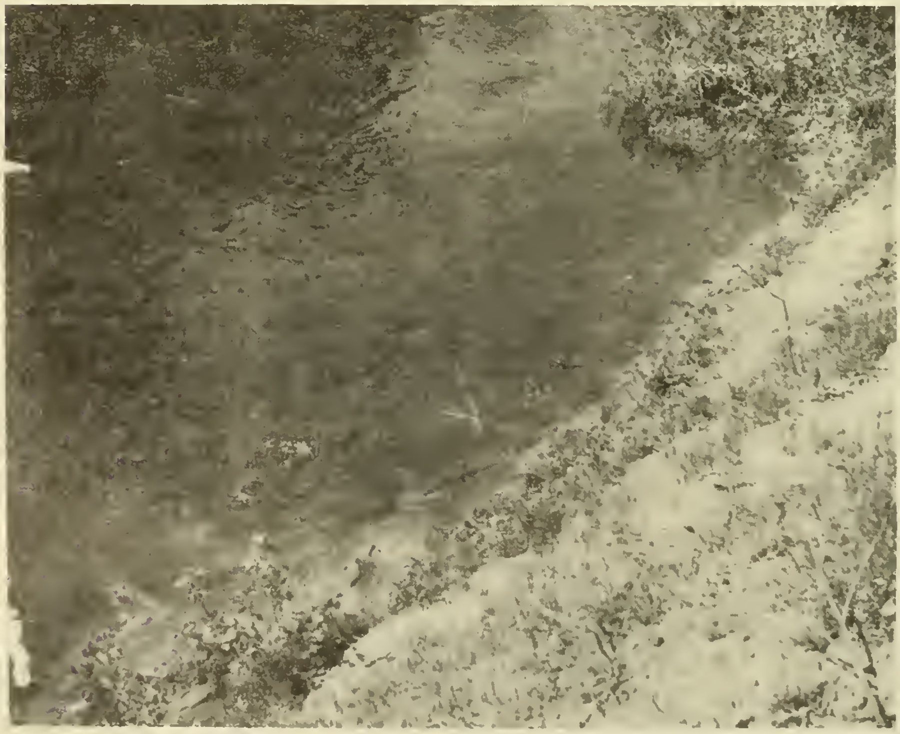


Figure 52.--Eddy along the margin of a deep gravel-bottomed pool in the lower Ocqueoc River. Muck and silt deposits as much as 1 1/2 feet deep harbored great numbers of lamprey larvae.

The third area was a silt bank on the inside of a bend of the river. The bed proper, consisting primarily of silt, muck, and organic debris, measured 34 feet long with an average width of 2 1/2 feet; water depths ranged from 2 to 20 inches and the bottom sloped at about a 45-degree angle. One collection was made with the electric shocker in the month of October, and 251 ammocoetes older than young-of-the-year were removed from this area of 85 square feet. Concentrations of young-of-the-year were estimated at about 8 per square foot.

The silted bottoms of pools as deep as 7 1/2 feet were found to contain fairly abundant populations as evidenced by Petersen dredge samples. Where cold, spring feeders (or spring seepages) drain into the head of silted or muck bottom sloughs, larval populations are small or absent. Aquatic vegetation is sparse in the lower two-thirds of the Ocqueoc River where ammocoetes occur. Those plants which were present where collections were made were predominantly _Najas flexilis_, _Potamogeton epihydrus_, and species of _Sagittaria_. Where small patches of these grew in a given larval bed the concentration of individuals was greatest.

Bottom deposits of more nearly equal mixtures of fine sand and silt, where they occur in quieter waters, contain heavy seasonal concentrations of young-of-the-year larvae but few if any of the larger and older age groups. By the late autumn or early spring of their first year of life, most of the young-of-the-year have dispersed to other areas, generally those with more mucky bottoms. Sandy sites, usually occurring at stream bends, below islands, or even in midstream are shifting and unstable in character; this apparently discourages permanent occupancy.

One sandy area in the Ocqueoc River was examined repeatedly over several seasons. This bed was situated on the inside of a bend in the river below a gravel spawning riffle. The current passing over it was slow or sluggish; the bed was 84 feet long and averaged 5 feet wide; maximum depth was 12 inches at mean water levels. In August, 1947, this bed was found to have an average content per square foot of 9 young-of-the-year (range: 3 to 12 individuals per square foot), and 1 larva of a larger (and older) size group, usually a member of age group I (33-59 millimeters in total length). Twenty feet below this bed was the quiet, muck-bottomed slough in a side channel of the river described in a preceding paragraph. Nearly simultaneous collections from this side channel displayed an equivalent concentration of young-of-the-year but a far greater proportion of the larger size groups. The distribution of sizes of larvae taken in both locations in August, 1947, is illustrated in Figure 53 (Figure 53 is an inaccurate representation of the proportion of sizes present because only a few of the young-of-the-year in the side channel, Station 3, seen to be disturbed by the shocker, were collected and measured on this date).

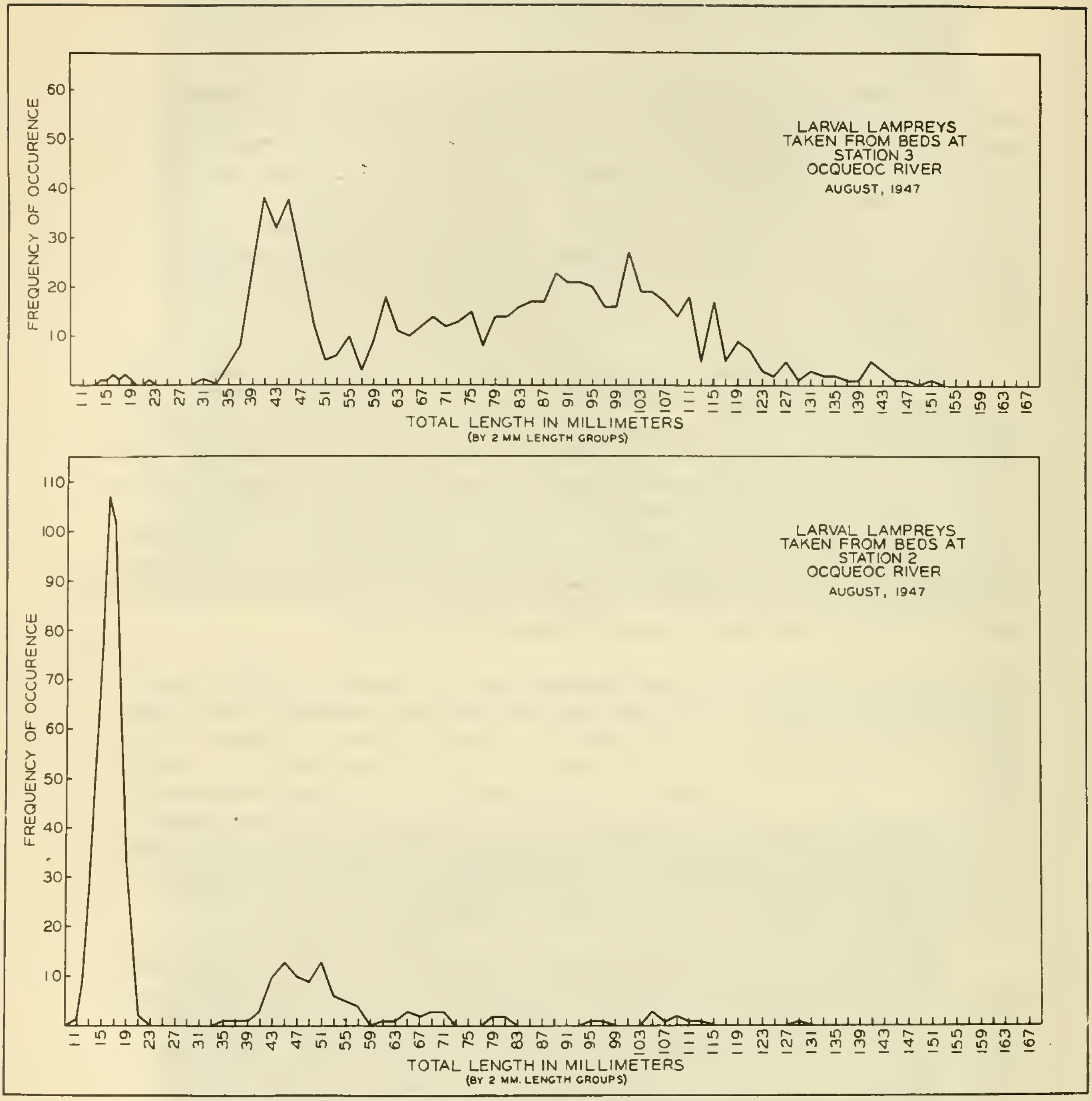


Figure 53.--Distribution of the sizes of larvae taken from two beds of differing characteristics in the Ocqueoc River:

Upper histogram.--Larvae taken from a silted and muck-bottomed channel. The stream bed here is relatively stable from year to year. Young-of-the-year larvae were equally abundant at this station as in the following but were not deliberately collected and measured. A few are represented to show the size range of this age group.

Lower histogram.--Larvae taken from a bed of mixed silt and sand situated on the inside of a bend in the river and just above the station for which data is presented in the upper histogram. This bed is unstable in character, changing its conformity each year with flood conditions. The young-of-the-year, represented by the most left-hand distribution, were twice as numerous as indicated; the scale of their occurrence was halved to render the diagrams more compact.

In May of the following year (1948), prior to the spawning season, the concentration of "yearlings" was considerably reduced and the larger and older larvae were quite scarce in the long bed of sand and silt (Station 2). The conformity of the bed itself had changed considerably as a result of the spring floods. Much greater numbers of the "yearlings", and nearly all of the larger (and older) individuals in the area were found in the nearby soft-bottomed channel (Station 3). Collections made in the summer of 1948, immediately after the spawning season, displayed a restoration of the concentrations by size and age of the larvae in these two types of beds.

These unstable habitats, under the impact of stream flood conditions, are evidently responsible for the dispersal of larvae not only into more suitable areas nearby but also throughout the entire lower watershed. Ammocoetes are present in the sandy bottoms of long reaches of the lower river in greater numbers than could be produced in the limited spawning areas present there. They were found to be present in the sandy fan in Ocqueoc Lake where the river empties into that body of water. This site is several miles below the nearest spawning riffle.

Within that portion of the river where ammocoetes occur most abundantly, a few larvae could be found in almost every location where the bottom permitted burrowing. Pockets of silt and sand between rocks and behind obstructions provided such locations. Below spawning areas, some larvae of all sizes were found in precipitous, muddy stream banks adjoining areas of swift currents in the stream proper. Areas of fine, compacted sands and ones of gravel occasionally harbored a few young-of-the-year. In late summer and fall, some of the largest larvae and partly transformed sea lampreys take up quarters in many midstream locations in burrows dug in sand amid the gravel and rubble of the stream channel proper. Such individuals apparently make a change from their customary larval habitat for an unknown reason.

Habits and behavior

Larvae of the sea lamprey, when ready to leave the nest, work their way out of the sand in which the eggs were imbedded, (in the interstices of the gravel forming the downstream rim of the nest) and enter the current. In spite of violent wriggling movements, they are generally no match for the currents prevalent in spawning riffles and are consequently swept downstream. When they are carried into backwaters, eddies, or deep pools where sluggish currents or slack water prevail they suddenly dive for the bottom. Such locations generally possess bottoms of silt into which the larvae rapidly burrow. Young-of-the-year ammocoetes of the sea lamprey when released in the quiet water of an aquarium dove immediately for the bottom without apparent regard for the consistency of the material there. Those that swam head-on into a chip or stone lay stunned for a time before wriggling about again in apparent search of soft bottom material. When this was found they immediately burrowed into it.

Larger ammocoetes, disturbed by the electric shocker and allowed to drift downstream, swam aimlessly with the current until sluggish or slack water was reached. Here they dove to the bottom and burrowed into it if its consistency was suitable. Since all of these larvae are quite blind it would seem that the diving and burrowing behaviorisms are primarily reactions to sluggish currents or slack water. In responding thus, they are automatically guided to optimum habitats.

All sizes of larvae burrow into soft bottom materials with great rapidity. Body motion in burrowing is a rapid undulation with the posterior third of the trunk describing a figure-eight motion. In somewhat compacted bottoms, such as those of fine sand, the larvae often rest several times before burrowing completely out of sight.

In the Ocqueoc River, young-of-the-year up to a length of 20 millimeters seldom burrowed more than 1/2-inch below the surface of the bottom. In aquaria, specimens 31 to 41 millimeters long seldom went more than 1 1/4 inches below the surface; the usual range was 3/4 to 1 inch. Larvae 50 to 90 millimeters in length generally tunnelled 2 to 3 inches into the bottom, the depth in this size group increasing with the size of the larvae. Larger individuals, 100 to 160 millimeters long, burrowed as deep as 5 inches. While excavating a silt bank in the Ocqueoc River, I discovered that some of the largest ammocoetes (130 to 160 mm.) may retreat to depths of 6 inches where bottom deposits are particularly soft.

Aquarium observations were made in running water aquaria in which an optimum bottom type, a heavy black muck, had been placed. About 70 ammocoetes of varying sizes were kept in these tanks for one- to four-week periods. When sand was substituted for the muck, the depth to which all sizes of larvae burrowed was appreciably less. If several inches of muck was present over sand, the larger subjects would cease burrowing downward upon reaching the sandy layer and would turn toward the surface.

The burrows in which the ammocoetes live are generally quite ill-defined. This is probably due to the unstable nature of the medium in which they are made. As a rule, these burrows are crescent- or broadly "U"-shaped (Figure 54).

Presumably the larvae must come to the surface of the bottom in order to feed. In the stomachs of young Entosphenus, Creaser and Hann (1929) found aquatic micro-organisms which are especially abundant in the thin surface layer of debris on the bottom. Such organisms are not present below this layer. When ready to feed,

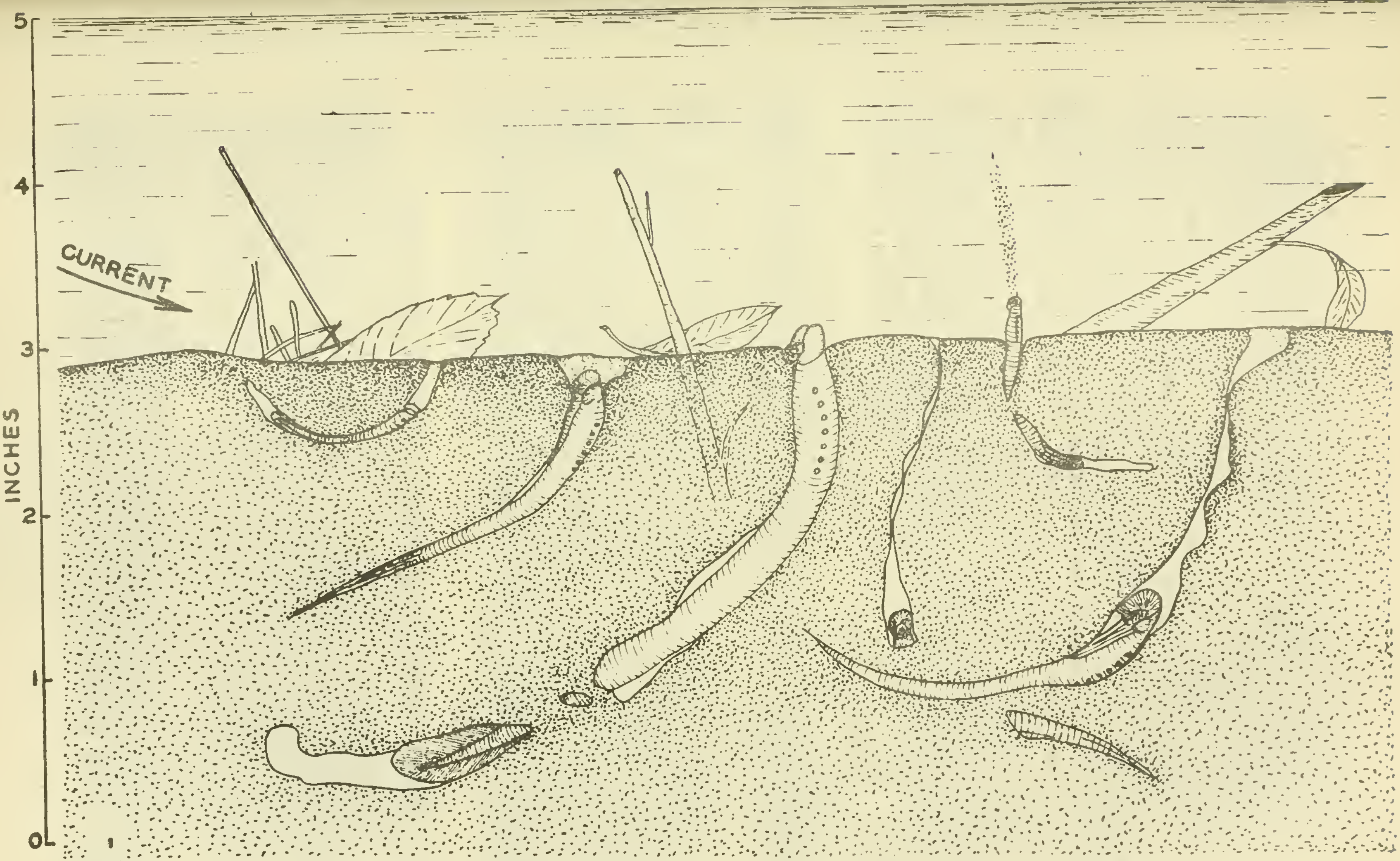


Figure 54.--Composite sketch of larval lampreys as they were observed in thin-section aquaria resting or feeding in their burrows. One individual is expelling accumulated detritus from its sieve apparatus.

the ammocoete squirms upward in its burrow until the oral hood is at or near the surface of the bottom (Figure 54). Here it may lie for long periods of time, the branchial area expanding and contracting as water is pumped in and out for respiratory and feeding purposes. Water is brought in through the oral hood and expelled through the gill openings. Pumping action into the oral hood is easily discernible by following bits of detritus suspended near the bottom as they are drawn into the hood. Microscopic organisms are drawn into the hood on the water currents. At least some of these organisms are separated out from the detritus by the sieve apparatus (anterior to the pharynx) and passed to the intestine for digestion (Gage, 1928). Periodically, the detritus accumulated on the sieve is blown out. The larva is seen to expand its branchial region, the gill openings close, and with a rapid, convulsive movement of that region and the head, a cloud of small particles is ejected from the hood. Typical pumping is resumed at once. Occasionally an individual will protrude its entire branchial region from the burrow during these activities; larvae of northern brook lampreys also do this (Leach, 1940). At irregular intervals, the ammocoetes retreat to the depths of their burrows for varying periods.

Similar observations of larval habits in aquaria were made by Gage (1928). He used ammocoetes of the sea lamprey from Cayuga Lake, New York. Our observations agree very closely.

Aquarium observations make it easily understandable why lamprey larvae are seldom observed in their "beds" in a stream. The vibrations set up by footsteps across the floor of a wooden building caused all aquarium-held specimens to retreat from the surface into the depths of their burrows. After several minutes, if all remained quiet, they returned to the surface again and resumed feeding. Along a stream, footsteps on the bank or in the stream bed undoubtedly also cause the retreat of larvae. For this reason, individuals of this life history stage are seldom seen, even by careful observers, in their natural surroundings.

Size of larvae and estimated length of larval life

My estimate of the length of the larval life of the sea lamprey is based upon analyses of the distribution of sizes of specimens taken in various seasons of the year. With the exception of age-group 0 which is positively identified, the length data assigned to older age-groups is subjective. They are valid only if I have correctly interpreted the age-groups present in the several collections.

Since the sea lamprey has a single spawning season each year, the ages of the larvae in any single collection, made over a short period of time, should vary by annual increments. Presumably then, if the ammocoete collection exhibits definite size classes, these may be taken to represent age-groups. Where any given size class is represented by a distinct mode in a length-frequency distribution, and this mode can be identified in later collections made over an extended period of time, the validity of this association and the identity of the assigned age group is further substantiated. Several investigators have attempted this method of age analysis with the larvae of other species and have met with varying degrees of success: their results have sometimes been disputed by other workers. Gage (1928) using this method with a "limited series" of larvae of the lake lamprey (Petromyzon marinus) estimated the length of the larval life to be not less than four, and probably five years.

For the purposes of this phase of my study, extensive collections of ammocoetes were made in the Ocqueoc River in August, 1947 (1,384 specimens). All of these collections were made in a restricted area of the river in relatively similar habitats so that growth differences arising from habitats of varying suitability would be at a minimum.

The first collection in August, 1947, indicated a discontinuous size distribution wherein the range in size of the young-of-the-year (age-group 0, 11.0 to 21.0 mm.) did not overlap with the next size class. Furthermore, the mode representing the latter group (45.0 mm.) was very distinct (Figure 55 and Appendix H, Table 1). This size class, termed age-group I, ranged from 31 to about 59 millimeters. That the size class designated as young-of-the-year was actually composed of age-group 0 was established by following the growth, month by month, of newly-hatched larvae through their first growing season (Figure 56 and Appendix H, Table 2). The balance of the distribution (59.0 mm. to 151.0 mm.) was continuous with the mode representing age-group I; other modes which might represent older age-groups were obscure. However, the configuration of the frequency polygon and the total size range involved suggested very strongly that at least two additional age-groups (II and III) might be present in the series.

A second collection, made in October, 1947, gave a length-frequency distribution very similar in character to that obtained for the August series; it differed in that the modes and size class limits had, in general, moved somewhat to the right indicating the growth attained in the 60-day interval between collections (Figure 55 and Appendix H, Table 1). The identity of age-groups 0 and I was substantiated by this second series. The balance of the distribution was again continuous with the mode representing age-group I. Distinct modes which might indicate additional age groups were lacking except for a pronounced peak at 101 millimeters. However, considering the range in length that may be accredited to age-group I (37.0 mm. to 65.0 (?) mm.) in this collection and the size range of the balance of the series (65.0 (?) mm. to 163.0 mm.) it was still evident that at least two, and probably not more than two, additional age groups were present in the material.

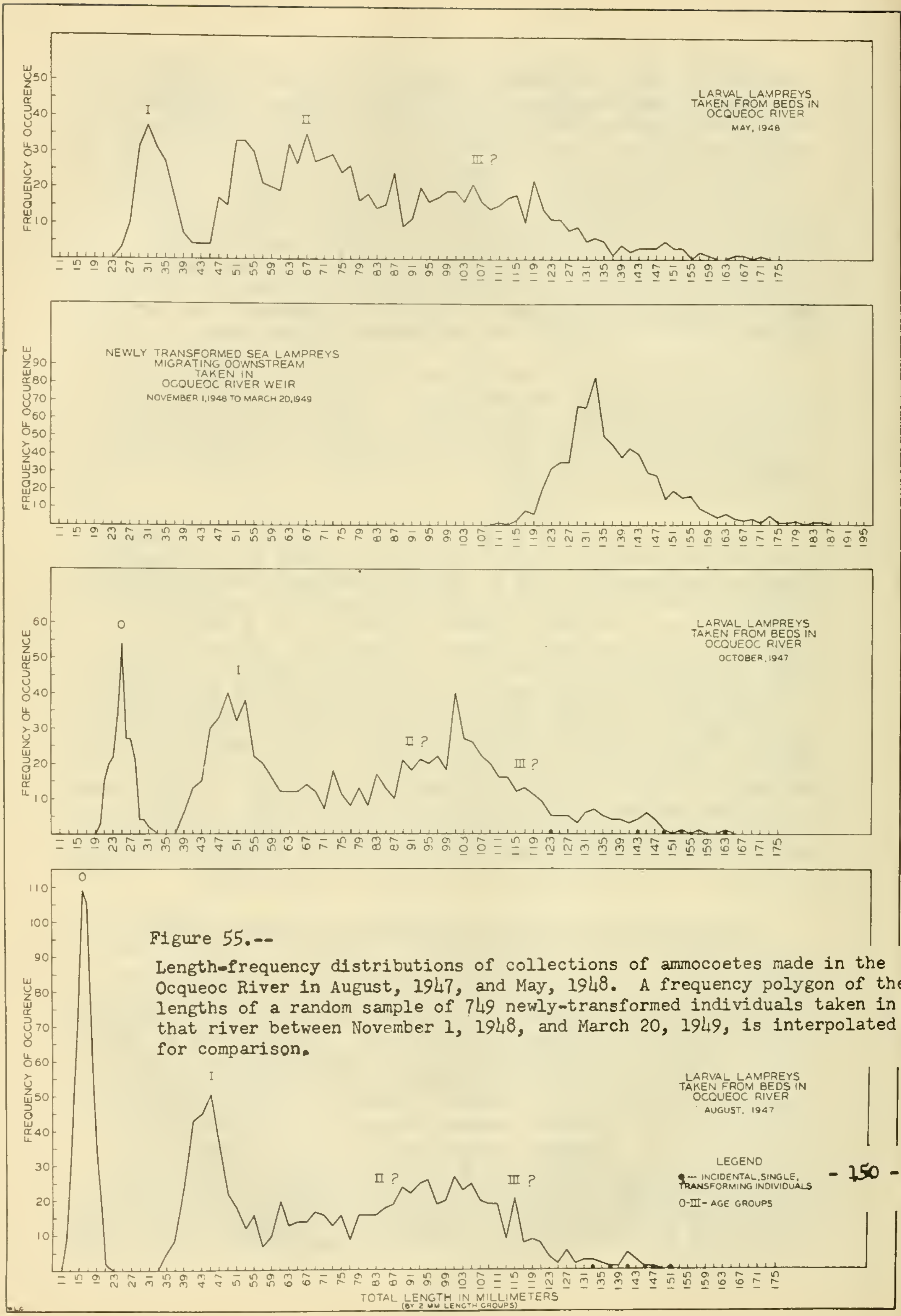


Figure 55.--

Length-frequency distributions of collections of ammocoetes made in the Ocqueoc River in August, 1947, and May, 1948. A frequency polygon of the lengths of a random sample of 749 newly-transformed individuals taken in that river between November 1, 1948, and March 20, 1949, is interpolated for comparison.

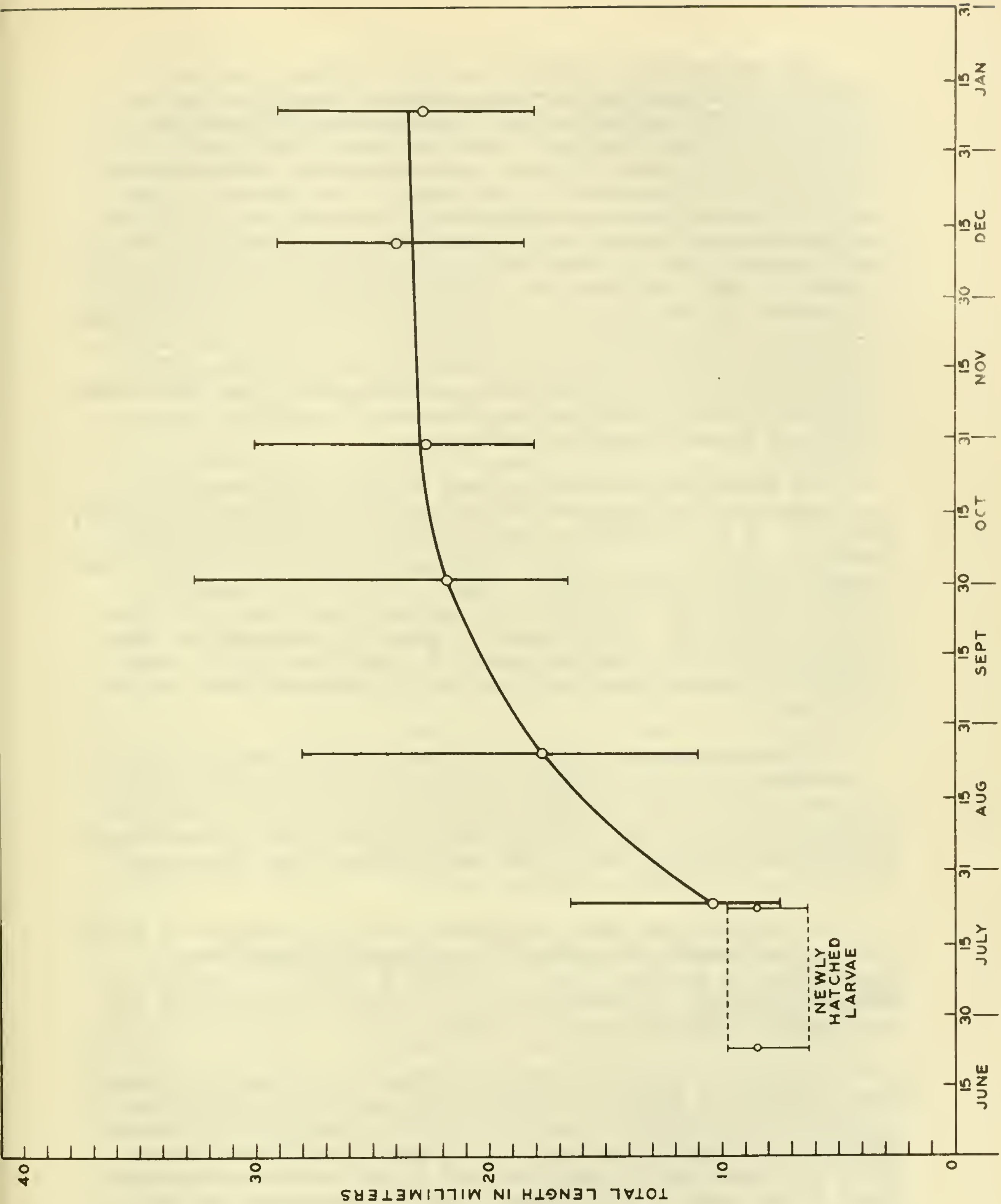


Figure 56.--Minimum, average, and maximum length of young-of-the-year sea lamprey ammocoetes collected at intervals during their first season of growth. An average growth curve has been fitted by inspection to the mean lengths of the individual collections. The range and average size of newly-hatched larvae is also shown projected over the period when the bulk of hatching occurs.

Data presented in following sections indicate that newly-transformed sea lampreys migrate downstream during the late fall, winter, and early spring months. Consequently, the age group which these migrants represent would be absent from spring collections made immediately after the termination of the downstream migration. To illustrate the size range of this departing age group, a length-frequency distribution of a random sample of 749 newly-transformed, downstream migrants is interpolated in Figure 55. These migrant juveniles were taken in the Ocqueoc River between November 1, 1948, and March 20, 1949; they ranged from 111 to 193 millimeters and averaged 136.4 millimeters in total length. Young-of-the-year (age group 0) would likewise be absent since spawning would not yet have occurred. Further, if age-groups 0 and I of the preceding year are identifiable as age-groups I and II of this new calendar year of growth, the existence of additional age-groups may be more readily determined.

The third large collection, made in May, 1948, revealed a continuous length-frequency distribution (Figure 55 and Appendix H, Table 1). A pronounced size group from 23.0 to 43.0 (?) millimeters (mode: 31 mm.) clearly represents the new age-group I (age-group 0 of the preceding year). Quite distinct from this size group of "yearlings" is a second, somewhat bimodal hump (43.0 to 83.0 (?) mm.) in the curve which is judged to represent the new age-group II (I of preceding year). A third hump in the curve bearing no distinct mode completes the distribution (83.0 (?) to 171.0 mm.).

If the presence of age-groups I and II in the May collection is accepted at the size ranges indicated (23.0 to 43.0 mm. and 43.0 to 83.0 mm.) and the range (111.0 to 193 mm.) and mean size (136.4 mm.) of the most recently departed age group is considered, it seems unlikely that more than one additional age group, age group III, is present in this series.

No allowance was made in examining the length-frequency polygons for any sexual dimorphism in length which might create a bi-modality in the size class comprising a given age group; none was present among the adults studied, hence, it was presumed that none would be present among the larvae.

Based solely on these interpretations of the length frequency distributions, I propose that only three age-groups (I-III) are typically represented in the spring months. Following the annual addition of young-of-the-year, four groups (0-III) are present until the downstream migration of the oldest and transformed age group begins late in the following fall. My estimates of the length of the larval life are based on this evaluation of the data.

It is estimated that the length of the larval life, including the period when transformation is occurring, varies from 41 to 47 months; or, for practical considerations, is four years. This is predicated on the peak of hatching occurring during the the month of June and the fact that newly-transformed sea lampreys leave the mud-banks to migrate downstream from November to April of the following year. Since the greatest downstream migration usually occurs in the month of March, it would seem that the majority of individuals are about 46 months old at the time of migration.

The possibility has not been considered in the preceding estimates that after attaining full growth, the larvae may enter a rest period for one year before transformation begins. Gage (1928) believed that larvae of the lake lamprey passed through this 12-month rest period. He based this belief on the behavior (time of transformation) of some aquarium held specimens and the fact that he frequently found larvae "as long or longer than many transforming ones any month in the year".

Although I have never found a larva as large as the largest, newly-transformed sea lamprey, many larvae in my series are as large as many of the transformed individuals. The distribution of sizes in my May series of ammocoetes indicated the presence of many individuals still in the river in the spring which were as large as the bulk of newly-transformed individuals leaving the mudbanks during the preceding winter months. This would tend to substantiate Gage's contention. I have no experimental evidence for this species in Michigan waters which would indicate whether this rest period does occur. Until such time as this evidence is obtained, the possibility must be considered that a 12-month rest period should be added to my estimate of the length of the larval life.

Transformation of larvae into parasitic adults

A detailed description of metamorphosis in Petromyzon marinus has been presented by Gage (1928). Very profound anatomical changes take place which adapt the adult for its free-swimming, parasitic existence. The most obvious external features of this change are as follows: (1) the U-shaped, hooded projections around the mouth of the larvae fuse ventrally and develop into the circular sucking-disc of the adult; the sieve apparatus of the larvae disappears; replacing it in the throat is a file-like tongue armed with horny teeth; numerous horny teeth appear also upon the circular sucking-disc (see frontispiece); (2) the deeply imbedded, rudimentary eye appears at the surface and develops into a highly functional organ which is one of the most distinctive features of the newly-transformed adult; (3) body color changes from the various shades of brown of the larvae to a light blue-gray dorsally and a silvery-white ventrally in the transformed individual; and, (4) the height of both dorsal fins becomes more pronounced. I have taken sea lampreys in advanced stages of transformation (for the external characters described) in larval beds in the Ocqueoc River during the latter half of the month of August. No such individuals were found in collections made during May and June. I deduce from this that some individuals probably begin the metamorphosis of these externally visible characters as early as the July preceding the winter when they will leave the silt beds. Transforming individuals were taken in all collections made from October to January; with each succeeding month of this period the frequency of their occurrence increased.

As early as October 17 (in 1947), I collected several sea lampreys from a silt bed which, on gross examination, appeared completely transformed; subsequently, additional individuals in this condition were taken from burrows. These data suggest that the metamorphosis of gross external features requires at least three and one-half months during which it is highly unlikely that the individual is capable of feeding. I do not know whether the onset of internal changes precedes the visible external changes in the sea lamprey. Should this occur, then it is likely that the minimum period of metamorphosis and the period when no feeding takes place would be of greater duration.

IX. Downstream movement of recently-transformed adults

Methods of study

At the inception of these investigations, some uncertainty existed as to precisely when the downstream movement of recently-transformed, adult sea lampreys occurred. Furthermore, ecological factors influencing these movements were unknown. Occasional field observations and studies of larval populations suggested that this movement took place during the winter and/or spring months. In order to obtain more precise information as to this phase of the sea lamprey's life cycle, two trapping devices of radically different design were operated in the Ocqueoc River, Presque Isle County, and the Carp Lake River, Emmet County, during 1948 and 1949.

(1) The Ocqueoc River weir and trap for newly transformed lampreys

A description of the design of the Ocqueoc River weir and traps has been presented in a preceding section (Pages 28--30). In order to trap the young sea lampreys moving downstream, framed sections of 3/16-inch mesh screen (hardware cloth) were set on the upstream face of the grates of the weir (Figure 57). Screens

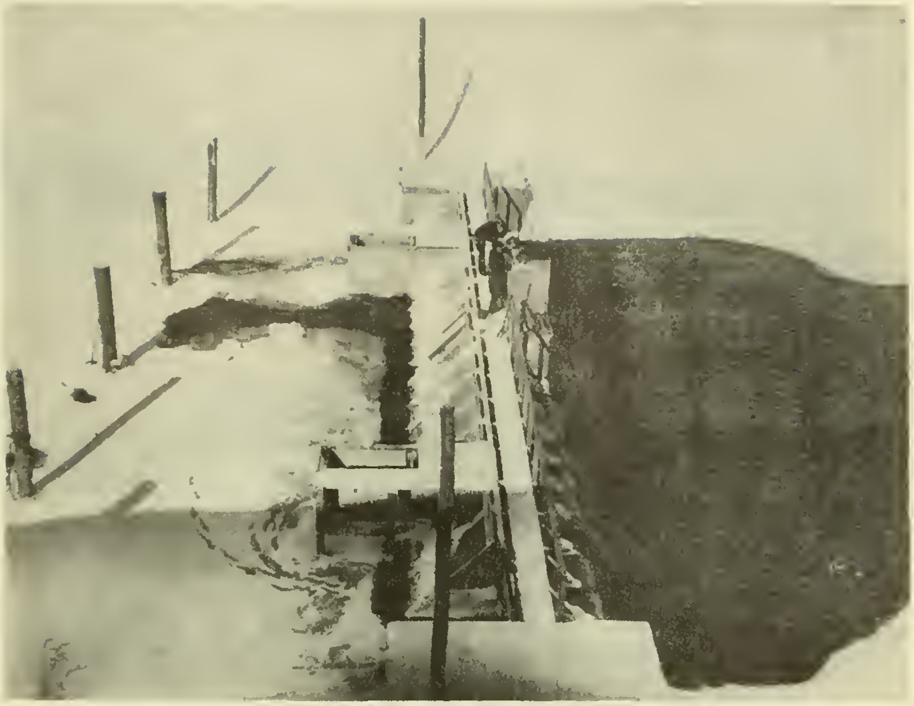


Figure 57.--Ocqueoc River sea lamprey weir and traps. Lateral view showing fine-mesh screens in place for trapping downstream migrants. February, 1949.

of the same mesh blockaded the upstream grates of the upstream traps and lined the downstream grate of the downstream trap; the funnel of the downstream trap was made of the same material. All screen sections were anchored firmly in place and all cracks, joints, or other possible points of escapement in the entire structure were caulked with oakum. To the best of my knowledge the structure was entirely lamprey-tight during the period of operation reported upon here.

The weir and trap was placed in effective operation on October 23, 1948, and was in continual operation with daily attendance until March 20, 1949 (Figures 57-58). During that period 1,404 newly-transformed sea lampreys were taken as they moved downstream. On March 20, operation of the weir for this purpose was discontinued due to failures in the supporting structure. Severe storms prevented the servicing of the weir and removal of captives on only three days during the winter. Otherwise, the presence of snow and ice, even at subzero temperatures, did not hamper seriously its operation although the attendant was frequently very uncomfortable (Figure 58). All sea lampreys taken were preserved in 10 percent formalin; their number, air and water temperatures, weather conditions, and water level gauge readings were recorded for each day.

Figure 58.--Ocqueoc River sea lamprey weir and traps during operation in winter months. February, 1949. (View from downstream.)

(2) The Carp Lake River dam and inclined-screen-trap for newly-metamorphosed sea lampreys

The Carp Lake River, Emmet County, drains into the Straits of Mackinaw on its southwest shore. The Carp Lake River proper, about 9 miles of stream course, arises in Carp Lake which is 1,823 acres in extent. One small tributary, Mud Creek, drains into Carp Lake.

A moderately large sea lamprey spawning run was observed in this river in 1947 and extensive spawning activity was noted. This fact plus extensive areas of suitable larval habitat suggested that the potential stock of downstream migrants might be large enough to justify the construction of a trapping device. Subsequent operations indicated that the river was very productive of newly-transformed sea lampreys.

The trapping device selected for this experiment required the construction of a dam. The lowest suitable site for this dam was about 1,500 feet above the mouth of the river; the stream was 32 feet wide at this point; very little spawning occurred below this site in 1947.

During the period January-May, 1948, a wooden dam, 60 feet wide and 5 1/2 feet high, was constructed on this location. The wall of the dam was constructed of a double row of 2 inch by 6 inch tongue and groove planks supported by heavy, round, wooden timbers. A spillway, 15 1/2 feet wide, 2 feet deep, and 9 1/2 feet long carried the water passing over the dam (Figure 59). In addition to appropriate bracing timbers, the dam wall was strengthened by piling large rocks against the downstream side.

The trapping device was composed of a sloping screen and a trap box.10/ The former consisted of a 1 1/2 inch angle-iron frame, 15 1/2 feet long and 30 inches wide, over which two layers of wire screen were stretched taut with a hydraulic jack; the lower layer was of 1/2-inch mesh, heavy gauge hardware cloth (for support), and the surface layer was of 18 mesh/inch copper screen. This screen

Figure 59.--Carp Lake River dam and inclined-screen-trap in operation during warmer months. June, 1948.

10/ Functional design adapted from plans provided by Mr. Philip Wolf of Malmoe, Sweden.

unit was installed 6 inches below the lip of the spillway and inclined downward and downstream at a 12-degree angle. An additional unit, 12 inches wide, was added later to carry larger water volumes. Below the lip of the screen and along its full width, a trap box was built. This box measured 30 inches wide by 24 inches deep and was lined with 14 mesh/inch screen. The level of the floor of the box was above normal water levels in the stream (Figure 59).

The device worked in this manner: All water passing over the spillway fell almost vertically or at least at a sharp angle into and through the screen. Algae, fine detritus, silt, etc., were forced through the screen by the impact of the water. The slope of the screen and the action of the water passing through it caused all larger elements (sticks, twigs, leaves, fish, lampreys, snakes, muskrats) coming down on the current to be forced (or pushed) downstream, off the screen, whereupon they fell into the trap box. In this regard, the screen itself was entirely self-cleaning and required little attention. Fish and lampreys accelerate their way off the screen by wriggling or flopping movements. During the winter months, ice did not form upon the inclined screen in such a manner as would hamper its functioning as described above. The entire device operated quite satisfactorily during long periods of bitterly cold weather, with one modification. The trap box tended to become heavily iced during freezing weather from the spray of the falling water striking the stream bed below it. This box was removed and in its place a simple wooden baffle plate (15 inches high) was placed across the foot of the inclined screen (Figure 60). Only a thin coat of ice formed on this baffle from day to day and it could be removed; lampreys, fish, and detritus collected in a windrow at the base of the plate.

The dam and trap was inspected at least once, and usually three times, each day by an attendant. Records were kept of all lampreys, fish, reptiles, and mammals taken in the trap. All lampreys taken, regardless of species or degree of development, were preserved in 10 percent formalin for later examination. Air and water temperatures were recorded daily from maximum-minimum thermemeters as were water level gauge readings and observations upon the weather and conditions prevailing in the watershed in general.

Time limits and character of the downstream movement and factors affecting this migration

The downstream movement of recently-transformed sea lampreys typically begins during the last week in October or the first week in November, extends through the winter and early spring months, and ends during the early part of April. A few scattered migrants may precede or follow this general movement. The migration is characterized by a lesser peak of activity in November

Figure 60.--Carp Lake River dam and inclined-screen-trap in operation during winter months. Trap box has been removed and replaced by a baffle across the foot of the inclined screen. February, 1949.

and a period of greatest activity during late March and early April. During the intervening winter months, at least a few come downstream nearly every day; sudden minor spurts of activity may occur during this winter period.

All increases in migratory activity appear to be associated closely with rising water levels. Late fall rains with resultant increases in volume of flow bring down the initial surge of newly-transformed individuals. Flood conditions resulting from mid-winter thaws are likewise accompanied by sudden increases in downstream movement in that season. The greatest peak of downstream migration occurs on the rise and crest of the floods resulting from the general spring break-up in late March or early April. For this reason, the calendar dates of this migration will vary from year to year and from one watershed to another according to existing climatic conditions.

Although nearly all of the downstream migration in both streams studied (Ocqueoc and Carp Lake rivers) occurred after the mean daily water temperature had fallen below 41.0 degrees F., there was no evident relationship between changes in water temperature and the amount of migratory activity.

In the Ocqueoc River in the 1948-1949 season, the first downstream migrant was taken at the weir on November 1, 1948; scattered individuals continued to reach the weir until November 20. On that date and on November 22, rainstorms caused the first appreciable increase in the river flow above the prevailing levels. Coincident with this rise in water level came the first surge of downstream movement (Figure 61 and Appendix I, Table 1). Frequent storms of rain and of rapidly melting snow maintained this increased volume of flow until December 8 when colder and more stable weather reduced the volume. Downstream movement was sustained during this period and fluctuated within it as the volume of flow varied; the activity declined abruptly as water levels declined after December 8. Thereafter, during the entire winter and early spring (to March 20), the run was minor and erratic. However, at least a few individuals came downstream nearly every day. During the periods, January 16 to 24 and February 27 to March 4, brief thaws and/or cold rains caused temporary rises in water levels. These were accompanied by small increases in the size of the downstream migration.

On March 22, two days after trapping operations were terminated, the Ocqueoc River began to rise as a result of the spring thaw and breakup and attained its major spring flood levels during the succeeding 22 days (to April 13). Between March 23 and 30, a varying but very large number of young sea lampreys were observed passing downstream during the daylight hours. These observations were made by a work crew and by myself while repairing the weir structure. The bulk of the downstream migration in this season (1948-1949) undoubtedly occurred during this 8-day period. Some downstream migrants were observed or were found caught somewhere on the weir structure until April 13. Field observations in the Ocqueoc River itself coupled with knowledge of the character of the Carp Lake River run (subsequently described) suggest that, except for a few scattered migrants, the downstream migration ended very shortly after the latter date.

In the Carp Lake River in the 1948-1949 season, a single fully-transformed sea lamprey came downstream into the trap on October 7, 1948; two additional individuals were taken on October 21 and 23. Sustained downstream movement began on November 2, reached a sharp peak on November 21, and subsided with equal rapidity. Some appreciable movement continued until December 9 (Figure 62 and Appendix I, Table 2). The early portion of this period was characterized by rising water levels resulting from light rains and wet snow. Heavy rains from November 17 to 19 increased the volume of flow; the flood crested on the night of November 20-21 and on that night a

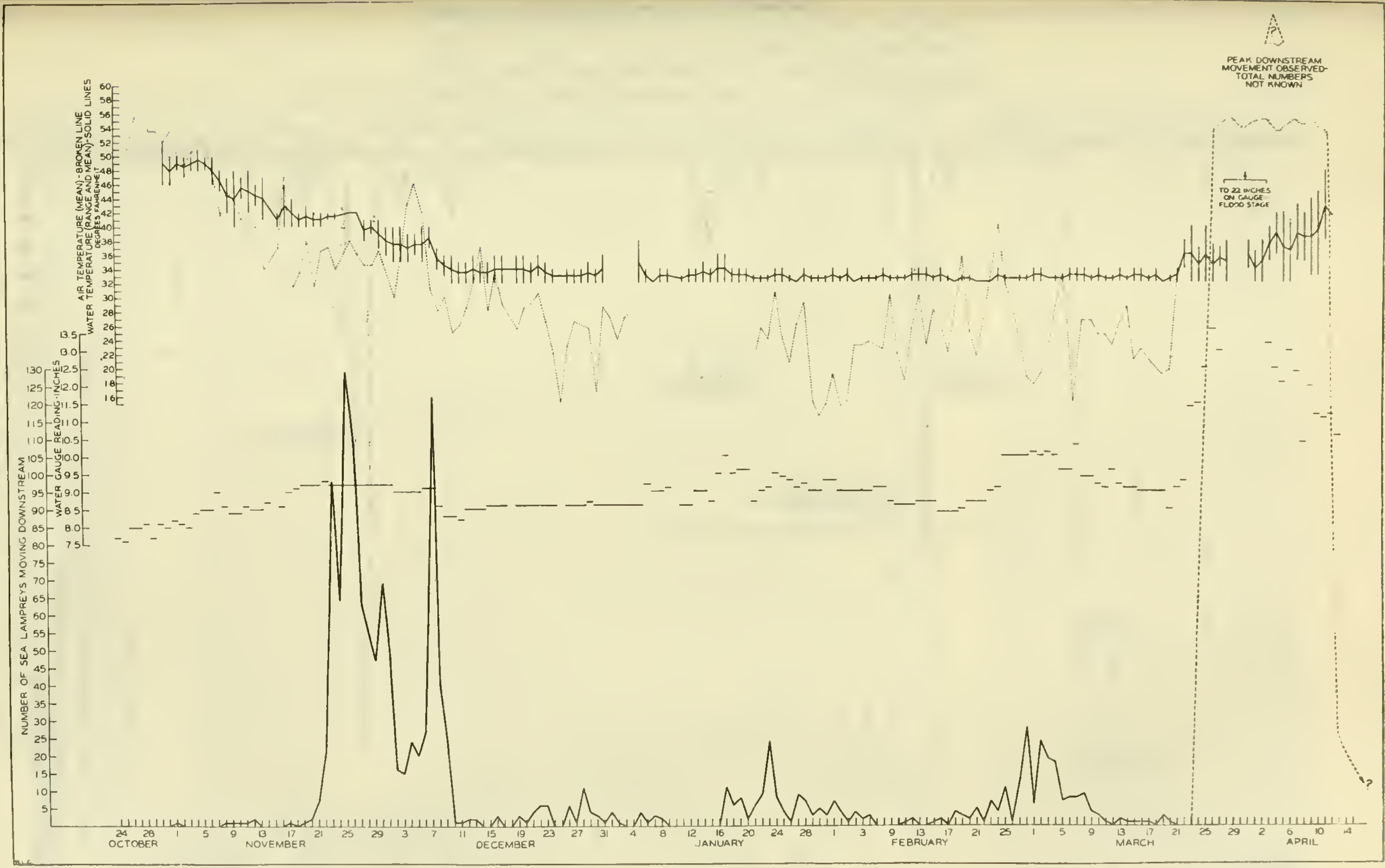


Figure 61.--Numbers of recently-transformed sea lampreys migrating downstream in the Ocqueoc River between October 24, 1948, and March 20, 1949, with water gauge readings, daily mean and range of water temperature, and mean daily air temperatures for the period.

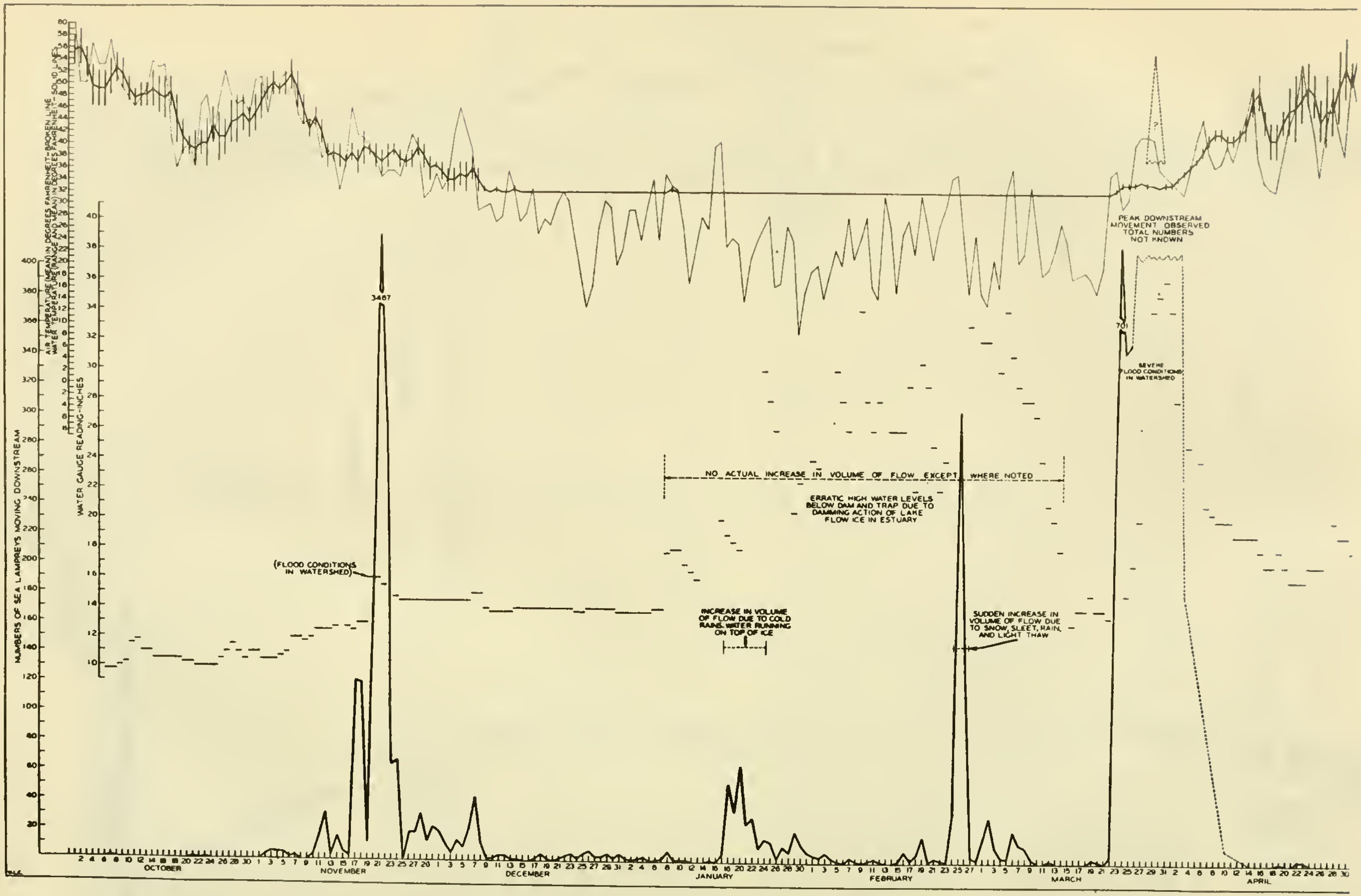


Figure 62.--Numbers of recently-transformed sea lampreys migrating downstream in the Carp Lake River between October 1, 1948, and April 30, 1949, with water gauge readings, daily mean and range of water temperature, and mean daily air temperatures for the period.

sudden surge of migrants appeared (3,467 individuals between nightfall and daylight). Subsiding water levels were accompanied by a decline in downstream migration until December 9. From this date until March 22, 1949, downstream movement was of a minor nature although, as in the Ocqueoc River, at least a few individuals came downstream on nearly every day during the interval. Between January 17 and 24, cold rains increased the volume of flow in the river. Most of this water was passed downstream on top of the ice which had covered nearly all of the river since mid-December. A similar condition prevailed between February 23 and 27 as a result of snow, sleet, rains, and a light thaw. Both of these brief increases in volume of flow were accompanied by spurts of downstream migratory activity (Figure 62 and Appendix I, Table 2).

Warm, thawing winds in the Carp Lake region from March 20 to 25 precipitated the spring break-up and severe flood conditions were created in the watershed as snow and ice melted rapidly. Water levels rose abruptly on March 22. On the same date and accompanying these conditions, the major downstream movement of lampreys began (Figure 62). On March 26, the water overtopped the dam and undercut one wing; the trap box was also destroyed. The structure was not restored to full operating efficiency until April 18. During the period March 26-April 3, a very great number of downstream migrants was observed passing over the dam during the daylight hours; migrants were most numerous between March 26 and 30. Some measure of the large size of this movement may be deduced from the following incident. A small, dead space (air space) existed between the lip of the spillway, the edge of the inclined screen, and the closest point where the spilled water struck the screen. This space, triangular in cross section, had a base on the screen about 5 inches wide. On March 26, 24 hours after the flood over-topped the dam, access was gained to a 30-inch length of this air space. We removed 614 sea lampreys from this limited area. It was also determined visually that an equivalent concentration was trapped beneath the entire lip of the spillway. It is estimated, therefore, that between 3,000 and 4,000 migrants had accumulated in this small air pocket in the first 24 hours after the trap had been rendered inoperative.

A few migrants were observed passing downstream during daylight hours between April 3 and 10; thereafter, none were seen. Water levels declined during this period and on April 18, when the trap was again operative, they had receded to about mean spring levels. Between April 19 and 23, seven individuals came downstream. From the latter date until June 30, when these records terminate, no others appeared.

In both rivers, the initial surge of downstream movement in November occurred during declining water temperatures and when the latter were generally at daily means of 41 degrees F. or lower. Midwinter increases in migration occurred at water temperatures which were stabilized at, or very close to, 32.0 degrees F. The greatest movement, in late March and early April occurred during rising water temperatures and almost entirely at daily means below 41 degrees F. (Figures 61-62 and Appendix I, Tables 1 and 2). There is no evident relationship between fluctuations in water temperature and the amount of migratory activity in any season. Furthermore, I do not believe that mean temperature levels below 41 degrees F. are a critical factor influencing the downstream movement. It appears, rather, that such temperatures are coincidental with that season when the lampreys have attained full transformation and are ready to move downstream. All evidence accumulated thus far indicates that the stimulus for this movement is primarily provided by sudden increases in the stream's volume of flow.

Length composition of downstream runs, and weight of downstream migrants

All of the recently-transformed sea lampreys taken on every other day in both rivers were measured for total length; some additional samples were also measured. This dimension was taken to the nearest millimeter on a measuring board. In all, 2,482 individuals from the Carp Lake River and 749 specimens from the Ocqueoc River were examined. Fully-transformed downstream migrants from the Ocqueoc River ranged from 111 to 193 millimeters in length and averaged 136.4 millimeters (σ equals 11.5 mm.) (4.3 to 7.6 inches; meaning 5.4 inches); those from Carp Lake River ranged from 95 to 189 millimeters and averaged 143.6 millimeters (σ equals 10.8 mm.) (3.7 to 7.4 inches; mean-5.7 inches). An examination of the length composition of each entire sample indicates a uni-modal distribution of lengths, and, for the Carp Lake River sample which was the most comprehensive of the two, the frequency polygon is quite symmetrical; that for the Ocqueoc River is skewed somewhat to the left. There is no indication of any sexual dimorphism in length at this phase of the life cycle insofar as it might be expressed in a bi-modality, or in an irregular "flattening", of the length-frequency polygons (these data for the Ocqueoc River sea lampreys are interpolated in Figure 55; those for the Carp Lake River are presented in Figure 63; combined data incorporated in Appendix I, Table 3).

The difference in average length (and conformity of length-frequency polygons) of the two samples is attributed to a differential migration by size during the period of downstream movement. The smallest individuals came downstream in the fall. A general increase occurred in the average total length of the samples taken during the winter months. These average lengths were greatest, as a rule, during the late winter and in the early spring when the peak migratory activity occurred (Appendix I, Table 1). No collections of the major downstream movement in the Ocqueoc River (in the spring) were obtained. I attribute the lesser average length of specimens from this river and the asymmetry (left skewness) of the length-frequency polygon for the total collection (Figure 55) to the absence of such samples.

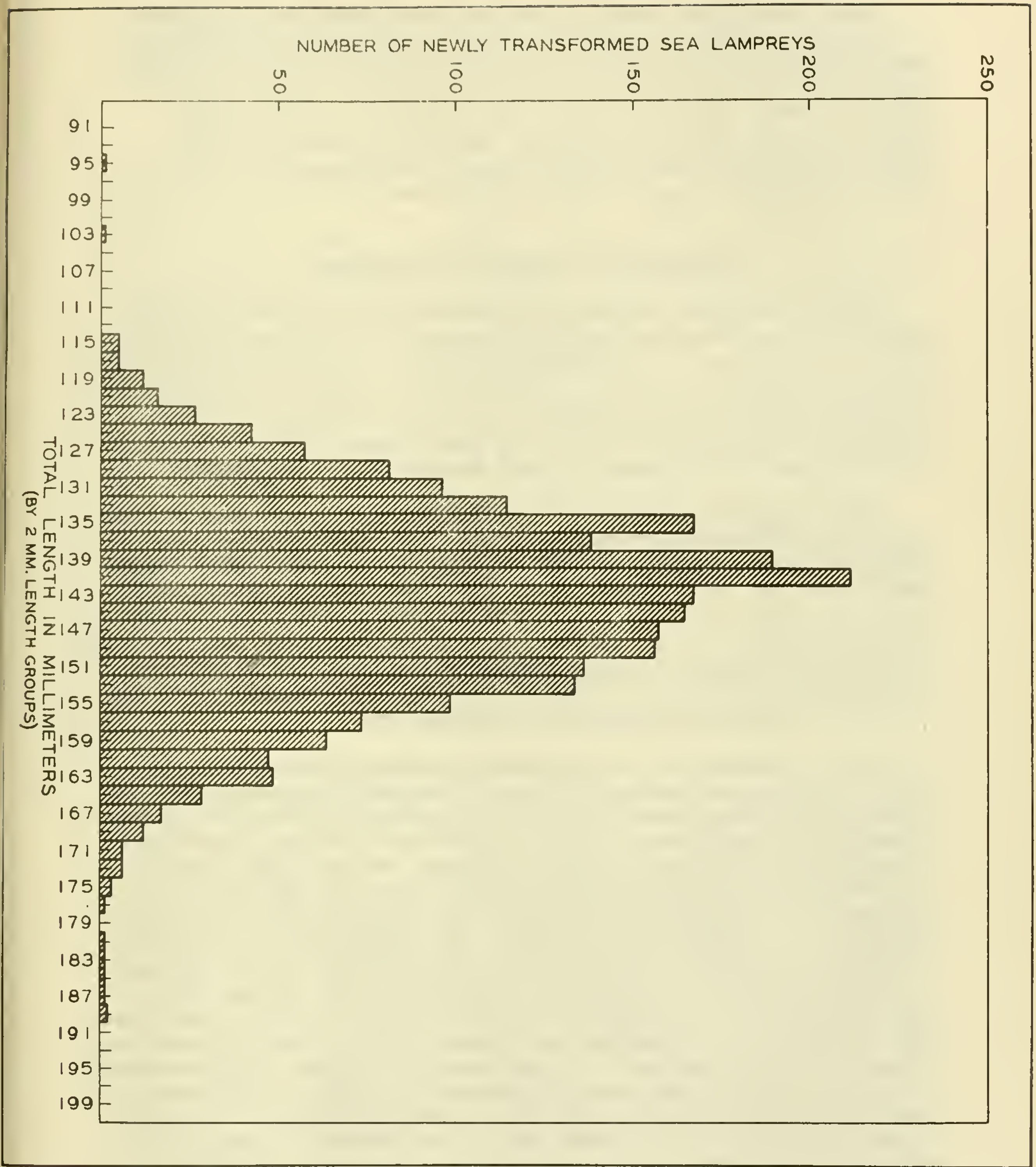


Figure 63.--Length-frequency distribution of 2,482 recently-transformed sea lampreys taken during their downstream migration in the Carp Lake River in the 1948-49 season.

From among those samples examined for length, one complete collection was taken at random and the weight of all individuals was determined to the nearest tenth of a gram upon an Ohaus dietary scale. This sample consisted of 216 migrants taken in the Carp Lake River trap on November 20, 1948. These individuals varied from 2.3 grams to 8.4 grams in weight and averaged 4.1 grams; their total length ranged from 121 millimeters to 172 millimeters with a mean of 143.0 millimeters.

Observations on habits and behavior

One of the most striking characteristics of the downstream movement of newly-transformed sea lampreys is the abruptness with which large numbers of individuals suddenly leave the mudbanks and move downstream. Under the impetus of rising waters, a virtual emergence takes place and hordes of the new adults travel downstream on the rise and crest of the floodwaters. This surge of movement downstream frequently ends as suddenly as it began.

Most of the individuals observed in migration displayed little deliberate effort towards accelerating their passage downstream. Such swimming activities as they affected in a downstream direction were casual and intermittent; some were seen to be drifting tail-first upon occasion. The whole movement downstream is characteristically passive on the part of the sea lamprey. The celerity with which these emergences of transformed individuals travel down to the lakes must therefore be attributed to the increased volume and velocity of the stream when such movements occur.

Field observations and laboratory examinations indicate that very few young sea lampreys attempt to feed while passing downstream to the "big" lakes. An exception to this occurs, of course, in those watersheds where large, inland lakes provide conditions suitable for the parasitic phase; at least two such lakes occur in Michigan. Where smaller inland lakes interrupt the downstream journey, the migrants apparently pass through such waters without attacking the resident fish species. For example, each year many thousands of recently-transformed adults pass through Ocqueoc Lake on their way down the Ocqueoc River to Lake Huron. Since 1947, many fish taken in all seasons of the year from this lake have been examined and none have borne scars that could be attributed to downstream migrants. Furthermore, the digestive tracts of 216 recently-transformed individuals taken on November 20, 1948, in the Carp Lake River trap were opened and none showed any evidence of having attempted their initial feeding after transformation (length and weight data for this sample presented in a preceding section).

Were it habitual for young migrants to begin feeding before reaching the big lakes, many reports would have been forthcoming of resident stream fish bearing young sea lampreys or their scars.

Those few reports that were received were traceable to the parasitic activities of native species of lampreys or to sea lampreys carried on fish that had migrated into a stream from a large body of water.

Several exceptions have been noted, however. On May 12, 1948, I examined a 5.0-inch, recently-transformed sea lamprey which was taken from a rainbow trout caught in the Ocqueoc River about 5 miles above its estuary. Shetter (1945) mentions four young sea lampreys being found on a rainbow trout caught on July 6, 1945, in the downstream trap of a weir in the Ocqueoc River. Gage (1928) reported that lake lampreys, kept in aquaria through their transformation, attacked fish immediately after leaving their burrows in the tank bottom (my similar specimens did not feed until various times after emergence, never immediately).

Those exceptions noted for a Michigan stream I attribute to stragglers of the general downstream movement which did not find their way out of the watershed immediately and/or to individuals which had been to Lake Huron once and rode back into the stream attached to some fish. Instances of this latter phenomenon were observed in 1949 when young sea lampreys were found on three occasions attached to migrating white suckers taken in the upstream trap of the Ocqueoc River weir.

<u>Downstream movement of partially-transformed sea lampreys</u>

<u>and of other species of lampreys and fishes</u>

Between June 1, 1948, and June 30, 1949, 44 partly-transformed sea lampreys came downstream into the Carp Lake River trap. The bulk of these were taken in late July and in the month of August (Appendix I, Table 4). Considering the time of year at which these individuals were taken, I believe their movement downstream may in some way be related to the shift in stream habitat affected by some of the larger larvae and transforming individuals of the sea lamprey (see previous discussion of larval lampreys). In the same 13-month period, a small number of adults and partly-transformed specimens of the silver lamprey were trapped, mostly during May and June. A few larvae of this species drifted downstream in almost every month of the year (Appendix I, Table 4). Adults of the American brook lamprey (197 individuals) were captured almost exclusively from mid-April through the first week in June.

A total of 492 larval lampreys identifiable only as either sea lampreys or American brook lampreys were taken in the Carp Lake River trap. A few of these came downstream in nearly every month of the year. The majority, however, were trapped in April and May. Some partly-transformed American brook lampreys accompanying the larvae and their coincident movement with that of the adult American brook lampreys makes it seem probable that these larvae were predominantly of that species.

In the Ocqueoc River during the period of weir operation (October 24, 1948, to March 20, 1949), no partly-transformed sea lampreys were taken. Four larvae of the silver lamprey were trapped in November and December, 1948, and one adult of that species, 9.9 inches long, was taken on January 20, 1949.

Other than the kinds and numbers of lampreys described, 7,119 fish of 21 species were taken in the Carp Lake River trap and 127 fish of seven species in the Ocqueoc River weir and trap during the operation of these structures. Predominant species captured in the Carp Lake River were Great Lakes longnose dace, common shiners, and common white suckers; presumably all were returning to Lake Michigan after spawning. Most fish trapped in the Ocqueoc River were yellow perch (*Perca flavescens*) and immature common white suckers. Very little downstream movement of these other species of fishes occurred during those seasons when the recently-transformed sea lampreys migrate downstream.

X. Investigations of the adult, parasitic phase of the sea lamprey's life cycle

Methods of study

In 1947, 1948, and 1949, commercial fishermen and others co-operated with me in obtaining parasitic, adult sea lampreys from the Great Lakes for the purposes of securing information upon their distribution and habits and to provide materials for estimating the duration of the parasitic phase of the life cycle. In all, 335 specimens comprising 114 separate collections were obtained. Of the total sample, 23 specimens were taken in 1947, 197 in 1948, and 135 in 1949. By location, 244 individuals were captured in Lake Huron, 78 in the Straits of Mackinac, 23 in Lake Michigan, 1 in Lake Superior, 3 in inland Burt and Mullet Lakes (Cheboygan County), and 6 in the Ocqueoc River weir and trap. Most lampreys taken were captured in conjunction with commercial catches of whitefish (*Coregonus c. clupeaformis*), chubs (primarily *Leucichthys johannae* and others), white and redhorse suckers, and yellow perch. Other species taken to which lampreys were attached were (in order of decreasing frequency): lake trout (*Cristivomer n. namaycush*), rainbow trout, burbot (*Lota lota maculosa*), and northern channel catfish (*Ictalurus l. lacustris*). Trapnet fishermen accounted for 63.9 percent of the sample of lampreys; gillnet fishermen took 33.2 percent during the open fishing season. The greater number taken by trapnet fishermen is due primarily to the fact that I had a greater number of contacts with fishermen using that type of gear than with those fishing gillnets. The remaining 2.9 percent of the lampreys were taken from fish caught by gillnet fishing through the ice, by angling (trolling), and attached to migrating fish captured in the Ocqueoc River weir and traps.

Fishermen cooperating in this project were provided with collecting jars containing a 10 percent formaldehyde solution. Attached to these jars were tags requesting the following information: Date of capture, specific locations of capture, main catch where sea lampreys were taken or species to which attached, depth at which nets were set, name of boat captain, and the name of the vessel. These fishermen were visited regularly and frequently with the result that accurate collection data were the rule rather than the exception. All specimens were examined in the laboratory for length, weight, and degree of maturity. Total length was obtained to the nearest tenth of an inch using a measuring board; weight was balanced to the nearest gram upon a Chatillon scale. Degree of maturity was estimated by examination and measurement of the gonads. The width and thickness of this single, median organ was measured to the nearest half-millimeter with dividers and a steel rule; the point of measurement was always one-third of the length of the gonad from its anterior tip.

Distribution in Lake Huron and its northern connecting waters

Based upon data obtained with the samples from this lake, and upon repeated interviews with fishermen operating in these waters, it is my observation that parasitic sea lampreys are present throughout the length and breadth of the lake, that the parasitic population is greatest in the northern three-fourths of this water expanse (from the neighborhood of East Tawas, Michigan, north), and that the maximum concentration is present in three contiguous areas: the northwestern extremity of Lake Huron, in the Straits of Mackinac, and in the northeastern extension of Lake Michigan. A comparable concentration also seems to have developed in the waters of the Detour Passage (Figure 64).

Sea lampreys were recovered in Lake Huron at depths ranging from 2.5 to 540 feet; they were commonly found, depending on the season, at depths of 10 feet to the maximum noted. The shallowest capture made was a sea lamprey which was taken attached to a Northern channel catfish caught by gillnetting through the ice over the shoals in Saginaw Bay. At the other extreme, several individuals were captured attached to chubs gillnetted at the depth indicated.

Seasonal variations in the ease with which specimens were obtained in the different fisheries and observations made by the commercial fishermen indicate that there is some systematic change in the bathymetric distribution of sea lampreys at different times of the year. During the months of May and June, chub fishermen, operating in deeper waters of the lake (200 to 500 feet) encounter the most lampreys; inshore fishermen, trapping or netting for whitefish, suckers, perch, etc., in the same season find relatively fewer lampreys. During the summer months there is a general shift and sea lampreys and lamprey-scarred fish become more abundant in the

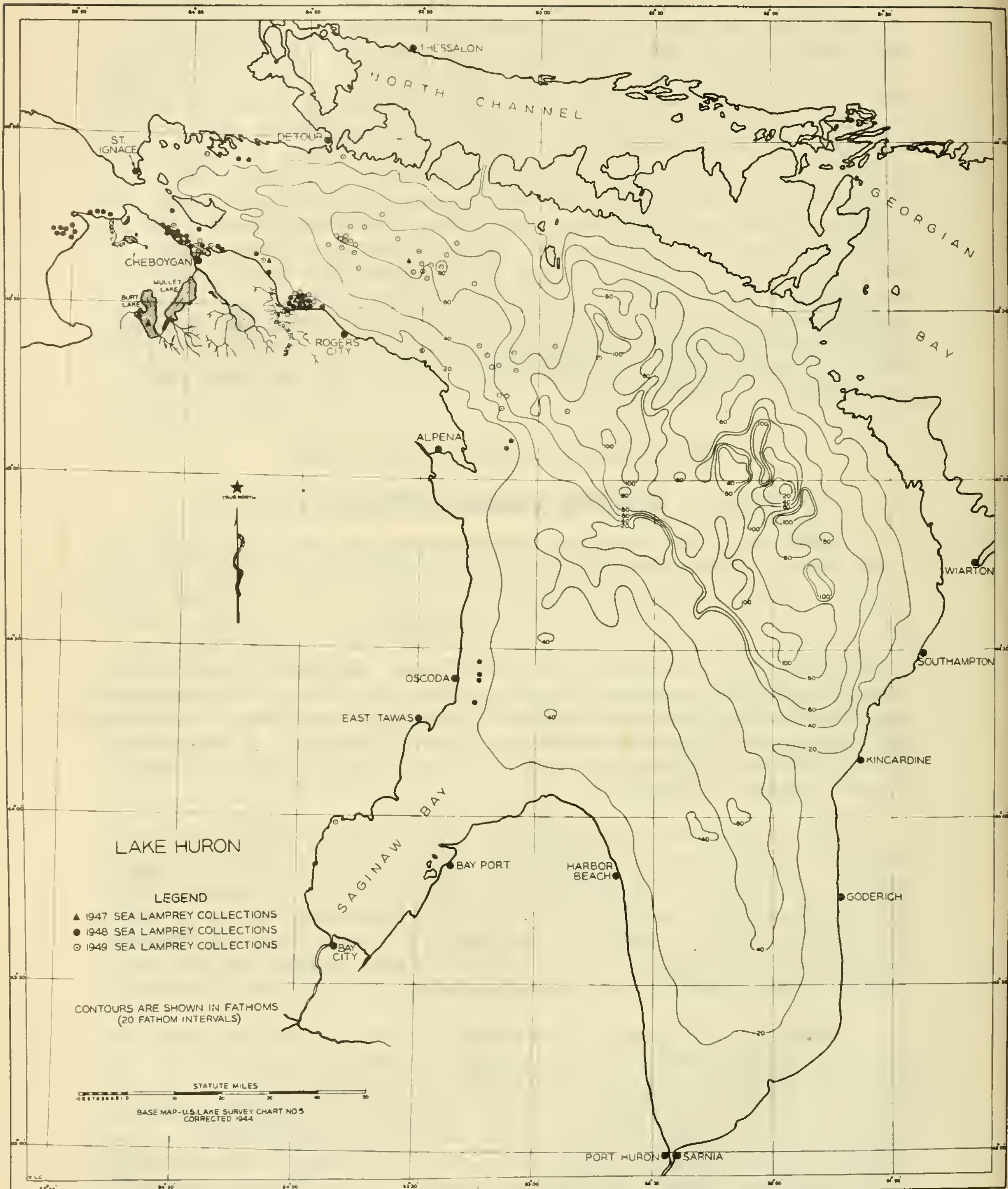


Figure 64.--Distribution map of 114 collections of parasitic sea lampreys taken in Lake Huron and its northern connecting waters.

inshore fisheries. At the same time, chub fishermen are finding proportionately fewer lampreys in the deeper waters. From September to December, the lampreys appear to concentrate in increasing numbers in the bays, shoreline indentations, and shoaler waters in general. Trapnet fishermen of northern Lake Huron, operating in 10 to 50 feet of water, notice this particularly in October, November, and early December when they suddenly begin to take many lampreys and scarred fish among catches of suckers and spawning whitefish (whitefish may not be taken in November by law but the statement applies to both species in general for the period noted); they did not make such abundant catches of lampreys and scarred fish during the summer months. This concentration of lampreys apparently remains in the shoaler waters through the winter months, for when fishing is resumed again in late March, great numbers of nearly-mature lampreys are found congregated off the mouths and in the estuaries of the larger rivers.

This shift of distribution is accompanied by a general increase in the size and maturity of the sea lampreys which is described in the following section. In view of the estimate of the length and character of the parasitic cycle, also presented subsequently, it appears that seasonal changes in the depth distribution of the species takes the following pattern: initial dispersal of recently-transformed adults migrating downstream in the fall, winter, and early spring to all parts of the lake but primarily to the deeper waters; these individuals shift generally to the inshore waters during the late summer and concentrate in the bays and along the shores during the fall and early winter; here they remain until the following spring when they congregate specifically off, and in, the mouths of rivers; as the spring progresses, these sea lampreys, now mature, move into the streams to spawn and die. During the winter and early spring of this latter period, a new group of recently-transformed individuals has come downstream and dispersed into the offshore waters of the lake.

Growth of parasitic sea lampreys and estimated length of parasitic life

From the time they enter the lakes as recently-transformed, parasitic adults, it now appears that sea lampreys may spend as few as 12 months or as many as 20 months in these bodies of water before returning to streams to spawn and die. Measured from the mean date of downstream movement to the peak of the upstream (spawning) migration, it is deduced that the mean length of the parasitic phase is about 17 months; the majority of individuals, however, probably spend only 14 to 15 months in this stage since the greatest downstream migration occurs at the end of that period of movement.

Strong evidence to support these contentions is found in an examination of the size composition of collections of parasitic sea lampreys taken from the Great Lakes in different months of the year in relation to the size composition and periods of migration of recently-transformed individuals downstream and sexually mature sea lampreys (upstream). Empirical data collected in 1947, 1948, and 1949 were combined upon a scale of all, or part, of three successive, hypothetical years for the purposes of estimating the duration of the parasitic phase (Figure 65).

As shown, spawning runs of mature, adult sea lampreys generally entered streams from April 1 to June 30 of each year; the peaks of these migrations occurred about the end of May. Individuals composing these spawning runs ranged from 11.0 inches to 23.4 inches and averaged about 17.1 inches in total length. During the early part of this period, two classes of individuals were present in the lakes: (1) nearly-mature sea lampreys which were about to enter streams to spawn and corresponded to spawning run individuals in size, and, (2) sexually immature sea lampreys which averaged between 7 and 8 inches in total length and among which none were as large as those in the preceding category (Figure 65, Table 6). After the peak of spawning run activity, when nearly all mature lampreys had entered streams, only the smaller size group of immature individuals was found in the lakes.

The size composition of this latter group increased constantly throughout the summer and fall. Their average length was approximately 8 inches in June, 10 inches in July, 12 1/2 inches in August, 13 1/2 inches in September, 16 inches in October, 17 inches in November, and slightly over 17 inches in December (Table 6). Among all of these parasitic specimens, a comparable development of the gonad (degree of maturity implied) was found in all individuals collected on any particular date or within any short period of time.

Data collected by means of weirs and traps demonstrated that recently-transformed sea lampreys came downstream and entered the lakes from about October 15 until April 15; a lesser peak of downstream movement occurred in mid-November and a greater one at the end of March in the following spring. These individuals ranged from 3.8 inches to 7.6 inches in total length with a mean of 5.7 inches. During this period when the annual contribution to the parasitic population was entering the lakes, the older adults already present had attained a size distribution comparable to that of the sexually mature migrants which entered streams in the following spring.

During the winter and early spring months these two groups, distinct in both size and degree of maturity, were present and showed little growth. With the advent of a new spring season, the largest size group (mature specimens) was present briefly in

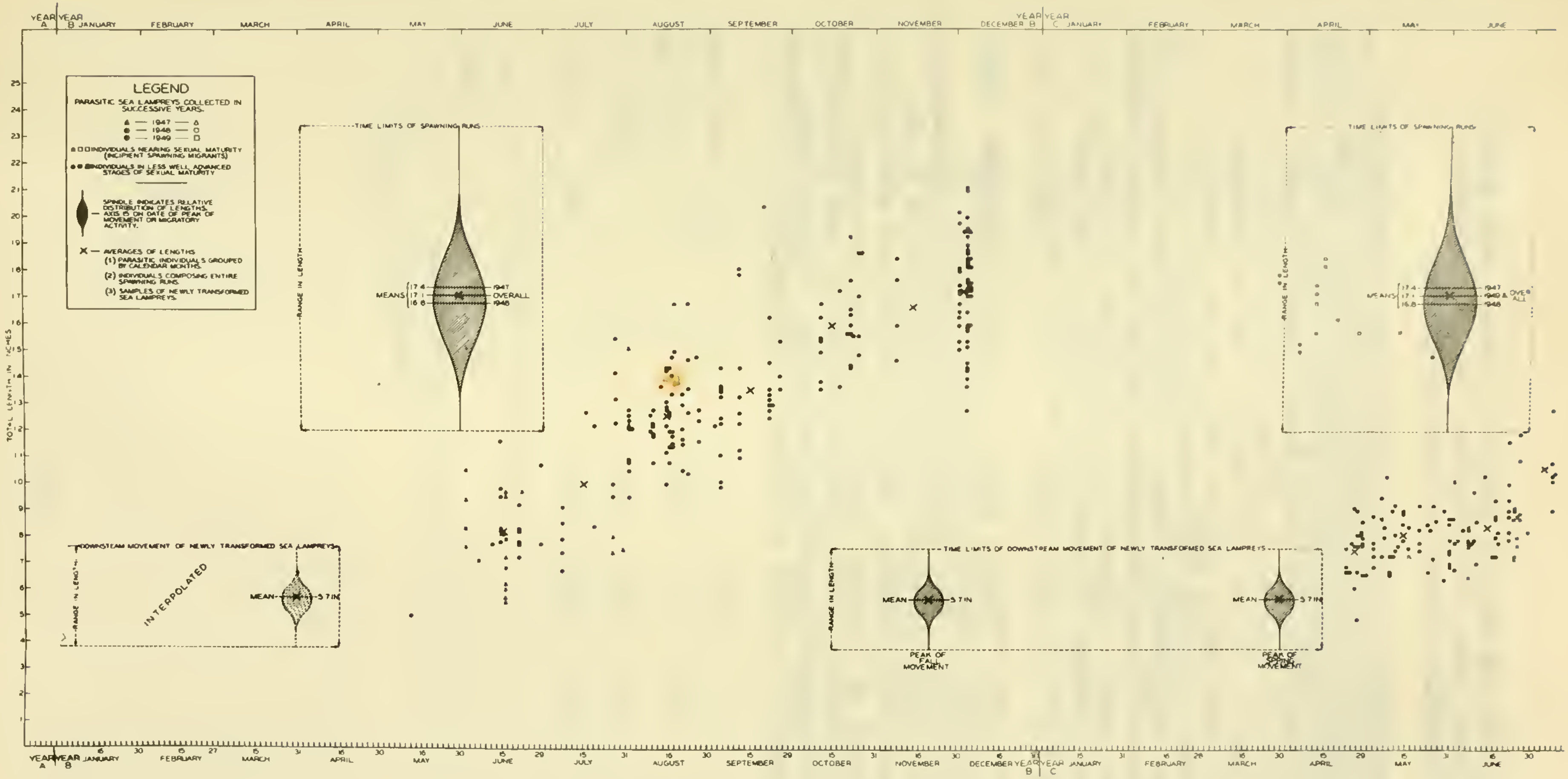


Figure 65.--Size composition of collections of parasitic sea lampreys taken from the Great Lakes in different months of the year in relation to the size composition and periods of migration of newly-transformed individuals and sexually mature sea lampreys. All data, which were collected in 1947, 1948, and 1949, have been projected upon a chronological scale of all, or part, of three successive, hypothetical years. For the purposes of clarity in presentation, infrequent stragglers of the spawning migration entering streams after June 30 (less than one percent of total runs) have not been plotted. For the same reason, very infrequent spawning run adults measuring less than 12.0 inches in length have not been included in the range and average presented.

the lakes until they had entered streams to spawn. Once again only one size group, that of the smaller, immature individuals which had just recently entered the lake, was present.

This interpretation of the data permits the generalization that sea lampreys, migrating downstream to the Great Lakes as recently-metamorphosed individuals in the fall, winter, and early spring of any given years A and B, may be expected to return (as mature individuals) to streams to spawn and die in the spring of year C. The shortest possible span of parasitic existence would therefore be from the early spring of year B to the same period in year C; the longest span from the fall of year A to the early summer of year C (end of spawning migration). I believe that the great range in length and weight noted for mature spawning migrants is attributable, at least in part, to this potential variance in the length of the parasitic existence within the time limits previously indicated.

Dymond, Hart, and Pritchard (1929) have presented length data for a collection of parasitic sea lampreys taken in the "autumn" in Lake Ontario. Two distinct size groups were present in their material which correspond in length distribution to the two groups present in my material collected in the same season. The authors thought it possible that their smallest size group represented individuals in their first season in the lake and the larger group, individuals in their second season. In this particular interpretation, our data are mutually substantiating.

Table 6. Number of specimens, minimum, average, and maximum total length, and minimum, average, and maximum weight of sexually immature sea lampreys taken in the Great Lakes proper in different calendar months of several years. (Selected samples utilized to determine average growth by months as plotted in Figure 67).

Date of collection	Number of specimens	Total length in inches Min.	Aver.	Max.	Weight in grams Min.	Aver.	Max.
June, 1947, 1948	32	5.5	8.2	11.6	5	21.0	51
July, 1947, 1948	17	6.7	10.0	15.5	7	40.1	102
August, 1947, 1948	58	9.5	12.6	16.8	37	80.4	193
September, 1948	32	9.9	13.6	20.4	35	103.2	307
October, 1948	24	13.6	16.0	19.3	67	152.6	260
November, 1948	4	14.7	16.7	18.5	97	171.3	229
December 1-5, 1948	51	12.8	17.3	21.1	78	169.6[1]	363
April 24-30, 1949	21	4.9	7.5	9.1	7	15.9	28
May, 1949	39	6.4	8.1	10.3	10	18.6	44
June, 1949	53	6.5	8.4	11.9	10	22.4	64
July 1-10, 1949	6	9.0	10.6	12.8	24	47.0	86
Total	337						

[1] Based on 21 specimens.

XI. Literature cited

Applegate, Vernon C.

1947. The menace of the sea lamprey. Mich. Cons., May, 1947, 16 (4): 6, 7, 10.

1949. The sea lamprey in Michigan. Mich. Cons., July-August, 1949, 18 (4): 13-15.

Bangham, Ralph V.

1946. Parasites of northern Wisconsin Fish. Trans. Wisc. Acad. Sci., Arts and Letters, 36 (1944): 219-325.

Beckman, William C.

1948. The length-weight relationship, factors for conversions between standard and total lengths, and coefficients of condition for seven Michigan fishes. Trans. Amer. Fish. Soc., 75 (1945): 237-256.

Bensley, B. A.

1915. The fishes of Georgian Bay. Contrib. Can. Biol., 1911-1914, 151 p.

Breder, C. M., Jr.

1926. The locomotion of fishes. Zoologica, 4 (5): 159-297.

Cameron, T. W. M.

1945. Fish-carried parasites in Canada. Can. Jour. Comp. Med., 9: 245-254, 283-286, 302-311.

Carbine, William F.

1944. Egg production of the northern pike, Esox lucius L., and the percentage survival of eggs and young on the spawning grounds. Pap. Mich. Acad. Sci., Arts and Letters, 29 (1943): 123-137.

Churchill, Warren S.

1947. The brook lamprey in the Brule River. Trans. Wisc. Acad. Sci., Arts and Letters, 37: 337-346.

Clark, Francis N.

1925. The life history of Leuresthes tenuis, an atherine fish with tide controlled spawning habits. Calif. Fish and Game Comm., Fish Bull., 10, 51 p.

1934. Maturity of the california sardine (Sardina caerulea), determined by ova measurements. Ibid., 42, 49 p.

Coventry, A. F.

1922. Breeding habits of the landlocked sea lamprey. Univ. Toronto Studies, Biol. Ser., 20 (Publ. Ont. Fish. Res. Lab., 9): 129-136.

Creaser, Charles W.
1932. The lamprey *Petromyzon marinus* in Michigan. Copeia, 1932 (3): 157.

1947 The size at metamorphosis of the sea lamprey (*Petromyzon marinus*) in the Great Lakes region and further extension of breeding area into Lake Superior. Anat. Rec. 99 (4): 73-74.

Creaser, Charles W., and Clare S. Hann
1929. The food of larval lampreys. Pap. Mich. Acad. Sci., Arts and Letters, 10: 433-437.

Deason, Hilary J.
1939. A second report on observations of the sea lamprey, *Petromyzon marinus*, in the Clinton River, Oakland and Macomb counties, Michigan. Unpubl. Rept., U. S. Fish and Wildlife Serv., Ann Arbor, Mich., June 12, 1939: 7 p.

Dymond, John R.
1922. A provisional list of the fishes of Lake Erie. Publ. Ont. Fish. Res. Lab., 4: 55-74.

Dymond, J. R., J. L. Hart, and A. L. Pritchard
1929. The fishes of the Canadian waters of Lake Ontario. Univ. Toronto Studies, Biol. Ser., 33 (Publ. Ont. Fish. Res. Lab., 37): 1-35.

Gage, Simon H.
1893. The lake and brook lampreys of New York, especially those of Cayuga and Senaca Lakes. (In) Wilder Quarter-Century Book. Ithaca, 1893, pp. 421-493.

1928. The lampreys of New York State--life history and economics. (In) Biol. Surv. of the Oswego River System, state of New York Cons. Dept., Suppl. to 17th Ann. Rept., 1927: 158-191.

Hubbs, Carl L., and Dugald E. S. Brown
1929. Materials for a distributional study of Ontario fishes. Trans. Roy. Can. Inst., 17: 1-56.

Hubbs, Carl L., and T. E. B. Pope
1937. The spread of the sea lamprey through the Great Lakes. Trans. Amer. Fish. Soc., 66 (1936): 172-176.

Huntsman, A. O.
1917. The lampreys of eastern Canada. Ottawa Nat., 31: 23-27.

Hussakof, Louis
1912. The spawning habits of the sea lamprey, Petromyzon marinus. Amer. Nat., 46 (1912): 729-740.

Jordan, David Starr
1905. A Guide to the Study of Fishes. Henry Holt and Co., New York, 1905, Vol. 1, 624 p.

Kennedy, W. A.
1948. Sufficient samples for quality control in whitefish. Bull. Fish. Res. Bd. of Can., 76, 11 p.

Leach, W. James
1940. Occurrence and life history of the northern brook lamprey, Ichthyomyzon fossor, in Indiana. Copeia, 1940 (1): 21-34.

Leverett, Frank
1912. Surface geology and agricultural conditions of the southern peninsula of Michigan. Publ. Mich. Geol. and Biol. Surv., 9 (Geol. Ser. No. 7), 144 p.

MacKay, H. H., and Earl MacGillivray
1949. Recent investigations on the sea lamprey, Petromyzon marinus, in Ontario. Trans. Amer. Fish. Soc., 76 (1946): 148-159.

Osborn, Raymond C., Edward L. Wickliff, and Milton B. Trautman
1930. A revised list of the fishes of Ohio. Ohio Journ. Sci., 30: 169-176.

Plehn, Marianne
1924. Practice of fish diseases. Typewritten Ms. (translation), 1941: 240 p.

Radforth, Isobel
1944. Some considerations on the distribution of fishes in Ontario. Contrib. Roy. Ont. Mus. Zool., 25, 116 p.

Shetter, David S.
1945. Results of the 1945 operations at the Ocqueoc River sea lamprey weir. Typewr. rept., Rept. No. 1015, Mich. Inst. for Fish. Res.: 18 p.

1949. A brief history of the sea lamprey problem in Michigan waters. Trans. Amer. Fish. Soc., 76 (1946): 160-176.

Surface, H. A.
1897. The lampreys of central New York. Bull. U. S. Fish Comm., 1897 (1898), 17: 209-215.

Surface, H. A.
1899. Removal of lampreys from the interior waters of New York. 4th Ann. Rept. N. Y. Comm. Fish, Game and Forests, pp. 191-245.

Trautman, Milton B., and Hillary J. Deason
1938. Observations of the spawning of the sea lamprey, Petromyzon marinus, in the Clinton River, Oakland and Macomb counties, Michigan, with suggestions for control. Unpubl. rept., U. S. Fish and Wildlife Service, Ann Arbor, Mich., 1938.

Van Cleave, Harley J., and Justus F. Mueller
1934. Parasites of Oneida Lake fishes. Pt. III. A biological and ecological survey of the worm parasites. Roosevelt Wild Life Annals, 3 (3): 161-334.

Vladykov, Vadim D.
1949. Quebec lampreys (Petromyzonidae). I. List of species and their economic importance. Conbrib. Quebec Dept. of fish., 26, 67 p.

Weisel, George F.
1947. Presence of oogonia and oocytes in spawned Pacific salmon. Copeia, 1947, (3): 193-194.

Zimmermann, J. H., and F. F. Bright
1942. Our inland seas: the Great Lakes. Row Peterson and Co., New York, 1942.

APPENDIX A

Table 1. Name and location of streams containing migrating or spawning sea lampreys in 1947 and 1948 with an estimate of the size of the run.

Tributary to	County	Stream	Specific location of observations	Spawning run verified (V) or reliably reported (R) in: 1947	1948	Estimate of size of run
			Upper Peninsula (Region 1)			
Lake Superior Basin						
Lake Superior	Alger	Sucker River	T49N, R13W, S.4	...	V	?
Lake Superior	Luce	Two Hearted River	T50N, R9W, S.27	V	...	?
Whitefish Bay	Luce	Tahquamenon River	T48N, R8W, S.12	...	V	Moderate (?)
Lake Superior	Marquette	Chocolay River	T46N, R24W, S.13	R	...	?
Lake Michigan Basin						
Lake Michigan	Alger	W. Br., Whitefish River	T45N, R22W, S.32	V	...	?
Whitefish River	Alger	Dexter Creek	T45N, R21W, S.32	...	R	?
Lake Michigan	Alger	Sturgeon River	T44N, R19W, (S.28?)	V	...	Moderate (?)
Little Bay De Noc	Delta	Rapid River	T43N, R23W, S.23	...	V	Moderate
Ford River	Dickinson	N. Br., Ford River	T43N, R28W, S.1	...	V	?
Millecoquins River	Mackinac	Furlong Creek	T43N, R10W, S.8	V	V	Moderate
Lake Michigan	Mackinac	Black River	T43N, R9W, S.1, 13	V	...	Moderate (?)
Lake Michigan	Mackinac	Brevoort River	T41-42N, R5W, S.11, 13	V	...	?
Lake Michigan	Mackinac	Sucker Creek	T40N, R4W, S.10	V	...	?
Whitefish River	Marquette	Deer Creek	T44N, R23W, S.23	...	V	Small
Green Bay	Menominee	Menominee River	T32N, R27W, S.1	V	...	Large
Green Bay	Menominee	Big Cedar River	T37N, R25W, S.23	V	...	?
Lake Michigan	Schoolcraft	Manistique River	Paper mill dam, Manistique	V	V	Large
Lake Michigan	Schoolcraft	Thompson Creek	T41N, R16W, S.32	V	V	Small
Lake Michigan	Schoolcraft	Johnson Creek	T40N, R16W, S.6	V	...	Small
Lake Michigan	Schoolcraft	Bureaw Creek	T40N, R16W, S.23	V	...	Small
Lake Michigan	Schoolcraft	Bulldog Creek	T41N, R13W, S.4, 9	...	R	?
Lake Huron Basin						
Pine River	Chippewa	Trout Brook	T44N, R3W, S.17, 18	V	...	Small
St. Martin's Bay	Mackinac	Carp River	T42N, R3W, S.19	V	V	Moderate (?)
Munuscong River	Mackinac	Taylor Creek	T34N, R1W, S.22	...	V	Small
			Lower Peninsula (Region 2)			
Lake Michigan Basin						
Lake Michigan	Antrim	Antrim Creek	T32N, R9W, S.14	V	...	?
Lake Michigan	Antrim	Elk River	Public service dam, Elk Rapids	V	V	?
Lake Charlevoix	Antrim	Jordan River	T31N, R5W, S.31 and T31N, R6W, S.(?)	V	V	?
Lake Michigan	Antrim	Mitchell Creek	T30N, R9W, S.22	V	...	?
Lake Michigan	Benzie	Platte River	T26N, R13W, S.6 and T26N, R14W, S.8	V	V	Large (?)
Lake Michigan	Benzie	Betsie River	T25N, R15W, S.2	V	V	Moderate (?)
Lake Michigan	Benzie	Crystal Lake Outlet	T26N, R15W, S.20, 29	...	V	Small
Lake Charlevoix	Charlevoix	Loeb Creek	T33N, R8W, S.1	V	...	Small
Lake Charlevoix	Charlevoix	Porter Creek	T33N, R6W, S.32	V	...	Small
Lake Charlevoix	Charlevoix	Horton Creek	T33N, R6W, S.6	V	...	Small
Lake Charlevoix	Charlevoix	Boyne River	T32N, R5W, S.5	V	V	Moderate
Lake Michigan	Charlevoix	McGeach Creek	T33N, R8W, S.(?)	V	...	?
Carp Lake River	Cheboygan	Mud Creek	T38N, R3W, S.20	V	...	Small
Lake Michigan	Emmet	Carp Lake River	T39N, R4W, S.29	V	V	Moderate
Lake Michigan	Grand Traverse	Boardman River	Dam in Traverse City	V	V	Moderate
E. Arm, Grand Traverse Bay	Grand Traverse	Mitchell Creek	T27N, R10W, S.7	V	...	?
E. Arm, Grand Traverse Bay	Grand Traverse	Acme Creek	T28N, R10W, S.34	V	...	?
Lake Michigan	Lake	Pere Marquette River	T18N, R14W, S.29, 30	V	R	Large (bracketed: Pere Marquette River system)
Pere Marquette R.	Lake	Baldwin Creek	T17N, R13W, S.10	V	...	
Pere Marquette R.	Lake	Little So. Br., Pere Marquette River	T17N, R13W, S.27	V	...	
Pere Marquette R.	Lake	Middle Br., Pere Marquette River	T17N, R12W, S.10	...	V	
Pere Marquette R.	Mason	So. Br., Pere Marquette River	T17N, R15W, S.27	...	V	
Lake Michigan	Mason	No. Br., Lincoln River	T19N, R16W, S.13	V	...	Small
Lake Michigan	Mason	Great Sable River	T20N, R16W, S.22	...	R	?
Lake Michigan	Manistee	Manistee River	T22N, R14W, S.36	...	V	Moderate
Manistee River	Manistee	Big Bear Creek	T24N, R14W, S.29	V	V	Moderate (?)
Manistee River	Manistee	Pine Creek	T21N, R14W, S.8	V	...	Small
Lake Michigan	Newaygo	Muskegon River	Below Newaygo power dam, T12N, R13W, S.24	V	...	?
White River	Newaygo	So. Br., White River	T14N, R14W, S.30	...	V	Small (?)
Lake Michigan	Oceana	Stony Creek	T14N, R18W, S.26	V	...	Small

APPENDIX B

Dams which stop upstream migrations of sea lampreys in Michigan

Region 1.

1. Menominee River

Menominee Lower Dam Number 1 in Menominee, Michigan; approximately 2.5 miles from mouth; built in 1924; concrete; 12-foot head; spillway 22 feet wide; fish ladder reported in operation in 1939.

2. Manistique River

Manistique Pulp and Paper Mill dam; about 1 mile from mouth; concrete; 27-foot head; flow passes through plant machinery; apparently blocked from upper river by this structure. However, sea lamprey spawning formerly occurred in seepage channel alongside flume of dam. Lampreys reached this channel via the "hot-pond" overflow and plant sewage disposal pipe. Recent changes in this drain have apparently blocked the lamprey from even this limited spawning area.

Region 2.

1. Cheboygan River

Michigan Public Service Company hydro-electric dam in Cheboygan, Michigan; 3/4 mile from mouth; built in 1868; wood and concrete; 14.5-foot head; flow through turbines or over spillway; fish chute reportedly inoperative; ship lock present; believed a barrier except when locks operated in spring months.

2. Au Sable River

Foote Dam (Consumers Power Company), T24N, R8E, Sections 34-35; approximately 10 miles from mouth; built in 1917; concrete; 38-foot head; spillway 72 feet side; flow through turbines or over spillway; fish ladder present but inoperative; believed to constitute barrier.

3. Elk River

Michigan Public Service Company power dam, Elk Rapids, Michigan; 1/10 mile from mouth; built in 1915 (reconstructed 1930) earth construction; 10-foot head; 20-foot wide spillway; flow through turbines or over spillway. No fish chute or ladder present; believed to constitute barrier.

4. Boyne River

Boyne City Power Dam (Michigan Public Service Company), T32N, R5W, Section 5; approximately 3-1/2 miles above Lake Charlevoix; built in 1903; concrete and earth; 33-foot head; 22-foot wide spillway; flow through turbines or over spillway; believed to constitute barrier.

5. Boardman River

Three dams are present within 5-1/2 miles of the mouth of the river. The first, a damaged rock and earth fill dam in Traverse City, constitutes only a partial obstruction to migration. Either of two hydro-electric dams, T27N, R11W, Sections 27 and 34 are believed to constitute effective barriers.

6. Betsie River

Homestead Dam, T25N, R15W, Section 2 (Benzie County); approximately 7 miles from mouth; concrete; flow through turbines or over spillway; fish chute present but reportedly inoperative; believed to constitute barrier.

7. Manistee River

Tippy Dam (Consumers Power Company), T22N, R13W, Section 31; approximately 18 miles from mouth; built in 1917-18; earth dam with concrete core wall; 56-foot head; 118-foot wide spillway; flow through turbines or over spillway; fish ladder present but reportedly inoperative; believed to constitute barrier.

8. Muskegon River

Newaygo Power Dam (Consumers Power Company), T12N, R12W, Section 19; approximately 30 miles above Muskegon Lake; built in 1900; concrete; 18-foot head; 96-foot wide spillway; flow through turbines or (overflow) through flume at base of dam—velocity of flow very high in flume when opened; fish chute present, but reportedly inoperative; believed to constitute barrier to migration.

Region 3.

1. Kalamazoo River

Allegan City Power Dam; approximately 21 miles from mouth; concrete; 16-foot head; 132-foot wide spillway; flow through turbines or (overflow) through drains at base—velocity of flow in latter very high when open; fish ladder present, but inoperative; believed to constitute barrier.

2. St. Joseph River

Power dam at Berrien Springs, Michigan (Indiana and Michigan Electric Company); approximately 20 miles from mouth; built in 1907; concrete; 23-foot head; 149-foot wide spillway; flow through turbines or over spillway; inoperative fish ladder cored into dam; believed to constitute barrier.

APPENDIX C

Table 1. Daily minimum, maximum, and mean water temperatures and water gauge readings for Carp Creek with air temperatures and wind and weather records for the locality: April 15–July 20, 1947.[1]

Date 1947		Time	Water temperature (Degrees F.) Min.	Mean	Max.	At visit	Water gauge[2]	Air temperature Time	Degrees F.	Wind[3] Strength	Direction and shift	Weather
April	15	1700	...	...	...	...	11.50	...	...	Light	NW	...
	16	0900	38	38.5	39	38	13.00	1000	36	"	"	...
	17	0930	38	38.5	39	39	15.50	1000	40	"	NW to W	...
	18	0930	37	38.0	39	39	17.25	1000	41	"	W to SW	Overcast
	19	0900	37	38.0	39	39	...	...	...	"	W	Clear
		1600	38	41.0	44	42	18.25	1600	40	"	W	...
	20	1600	37	40.5	44	44	19.25	1700	45	Strong	NE	Clear
	21	0900	36	39.0	42	41	19.50	0920	38	"	NE to E	Overcast
	22	0900	40	40.5	41	41	20.50	0830	41	Moderate	E to SE	"
	23	0830	40	40.0	40	40	18.00	0900	46	Light	SE	Rain
	24	0930	39	40.5	42	42	...	0900	50	"	W	Clear
		1600	42	45.5	52	52	18.00	...	...	"	W	...
	25	1630	45	48.5	52	52	...	0900	42	"	W	Overcast
	26	0900	44	48.0	52	45	...	0900	42	Moderate	NE to NW	Heavy rain
	27	1615	45	46.0	47	47	...	...	...	Strong	WNW	Clear, cold
	28	1600	44	46.5	49	49	...	1600	60	Moderate	SW	Clear, warmer
	29	0900	48	48.0	48	48	...	0930	68	Light	SW	Overcast
	30	0900	48	51.0	54	54	...	0845	52	Moderate	ENE	Rain, cold
May	1	0900	47	47.5	48	48	...	0930	52	Strong	ENE	Overcast, cold
	2	0930	45	46.0	47	45	...	...	...	Light	NE to E	Heavy rain
	3	0900	42	43.0	44	44	...	0930	54	Light	E to S	Overcast, cool
	4	0930	44	47.0	50	50	...	0930	64	"	E to S	Overcast, warmer
	5	0930	46	47.0	48	48	...	0830	54	"	W	Light rain
	6	0930	48	50.0	52	48	...	1100	44	Strong	NW	Snowflurries
	7	1030	46	49.0	52	46	...	1145	44	"	NW to NE	Overcast
	8	1030	38	46.0	54	40	...	1130	30	"	NE	Partly overcast
	9	1030	38	39.5	41	40	19.50	1045	41	Moderate	SW	" "
	10	0930	41	44.5	48	44	18.00	1230	60	Light	SW	" "
	11	1000	50	51.5	53	50	17.00	0815	50	"	SW to S	" "
	12	0930	48	50.0	52	52	16.00	0845	67	"	SW	Overcast, warm
	13	1000	49	51.0	53	52	16.00	0845	41	"	ENE	Rain, cold
	14	0930	47	48.0	49	47	16.50	0900	49	"	E	Clear, cold
	15	0930	48	50.0	52	52	16.50	0930	57	"	E to W	Overcast, warmer
	16	1000	52	53.0	54	54	16.00	0930	58	"	W	Partly overcast, warm
	17	1000	53	56.0	60	55	15.50	0945	65	"	E	Overcast, warm
	18	1030	52	55.0	58	56	15.00	1000	63	"	E	Clear, warm
	19	0915	59	60.5	62	61	14.75	0915	73	"	SE	Overcast, very warm
	20	0930	54	59.0	64	56	15.50	0900	51	"	E	Clear, cool
	21	1000	54	59.0	64	54	15.00	0845	43	Strong	E	Heavy, cold rain
	22	1000	52	53.5	55	53	15.00	0915	50	Moderate	E	Clear, cool
	23	1030	54	54.5	55	55	15.50	0945	51	Light	E	Overcast, cool
	24	1030	53	55.0	57	56	15.50	0900	56	"	E	Clear, warmer
	25	1045	55	57.5	60	55	15.75	0930	55	Moderate	E to SW	Rain
	26	1045	54	56.0	58	56	16.75	1000	52	Light	W	Rain squalls, cold
	27	1100	50	53.0	56	50	16.50	0930	42	"	E	Rain, cold
	28	1030	47	48.5	50	47	16.75	1000	47	"	ENE	Hail, rain, sleet
	29	1130	46	47.0	48	46	19.00	1015	40	Strong	SW	Rain, cold
	30	1030	43	44.5	46	46	22.00	0915	50	"	NW	Clear
	31	0915	47	49.0	51	49	22.00	0915	53	Light	W	Clear, warmer

Continued next page

Date 1947		Time	Water temperature (Degrees F.) Min.	Mean	Max.	At visit	Water gauge[2]	Air temperature Time	Degrees F.	Wind[3] Strength	Direction and shift	Weather
June	1	0945	52	54.0	56	56	21.50	0845	55	Light	W	Partly overcast
	2	1000	55	55.0	55	55	21.00	0945	47	"	SE	Clear, warm
	3	1030	55	56.5	58	56	18.00	0900	46	"	E	Clear, cool
	4	1045	57	58.5	60	58	16.50	0900	60	"	E	Clear, warm
	5	1030	57	57.5	58	58	16.00	0900	70	"	SE	Clear, warmer
	6	1030	58	60.0	62	61	16.00	1000	66	"	E	Clear, warm
	7	1100	62	66.0	70	62	15.50	0915	54	"	SE	Overcast, cool
	8	1100	62	64.5	67	62	14.75	0900	58	"	E to W	Clear, warm
	9	1000	63	66.0	69	65	14.00	1215	72	"	ENE	" "
	10	1030	68	70.0	72	72	13.75	0900	80	"	SW to SE	Clear, hot
	11	1000	68	72.0	76	68	13.25	1130	58	"	W	Overcast, cool
	12	1100	55	59.5	64	59	12.50	1015	56	"	NW	Clear, cool
	13	1100	59	60.5	62	59	12.50	1045	52	"	E	Rain, cool
	14	1045	54	56.5	59	57	13.25	1015	56	"	E	Overcast, cool
	15	1100	56	56.0	56	56	14.25	1115	53	Moderate	E	Clear, warmer
	16	1115	56	59.0	62	61	14.00	1030	56	Light	NW	" "
	17	1200	62	64.5	67	64	15.50	1145	59	"	W to E	Clear, warm
	18	1145	64	66.0	68	66	13.00	1145	62	"	W	" "
	19	1100	61	65.5	70	64	12.50	1030	64	"	W	" "
	20	1130	64	68.5	73	68	11.75	1115	68	"	SE	" "
	21	1015	64	69.0	74	66	11.25	0930	66	"	E	" "
	22	1045	63	68.0	73	66	10.50	1145	74	"	E	" "
	23	1100	65	68.0	71	68	10.25	1015	78	"	SE	" "
	24	1030	66	70.0	74	66	10.00	0930	62	"	SE	Rain, warm
	25	1445	66	70.0	74	74	10.00	1400	74	"	SE	Clear
	26	0945	68	71.0	74	68	9.50	0900	64	"	SE	Clear
	27	1000	71	72.5	74	71	9.25	0915	78	"	E	Rain squalls
	28	1045	70	72.5	75	70	10.00	0930	74	"	E	Clear
	29	0945	72	73.0	74	72	10.00	0930	70	Moderate	E	Light rain
	30	1050	Max.-min. thermometer broken			65	10.50	0945	66	Light	W	Clear, cooler
July	1	0930	...	...	...	67	10.50	0900	56	"	W to NW	Overcast, cold
	2	1030	...	...	...	64	10.00	1100	70	"	NW	Clear, cool
	3	1000	...	...	...	65	9.75	1030	74	"	W	Clear, warmer
	4	1100	...	...	...	70	9.25	1000	76	"	W to SE	Clear, hot
	5	1000	...	...	...	70	9.00	0930	68	"	E	Rain squalls
	6	0915	...	...	...	67	9.00	0945	62	"	E	Clear
	7	0945	...	...	...	66	8.75	1030	70	"	NW	Clear
	8	1215	...	...	...	72	8.25	0930	70	"	NW	"
	9	0945	...	...	...	68	8.25	1000	72	"	NW	"
	10	1030	...	...	...	70	7.25	1000	72	Moderate	ESE	"
	11	1200	...	...	...	72	7.25	1100	74	Light	E to NW	"
	12	1000	...	...	...	66	6.25	1015	70	"	NW	Overcast
	13	1630	...	...	...	73	5.50	1330	82	"	NE	Clear, hot
	14	...	...	...	...	...	...	...	...	"	E	Overcast, rain
	15	1030	...	...	...	69	5.75	1145	70	"	E	Rain, clearing
	16	0930	...	...	...	66	5.75	1000	72	"	ESE	Clear, hot
	17	1000	...	...	...	68	5.75	1145	82	"	E to S	" "
	18	1030	...	...	...	70	5.50	1100	74	Moderate	WNW	Clear, cool
	19	0930	...	...	...	63	5.50	0845	59	Light	NW	" "
	20	1800	...	...	...	62	5.50	1200	71	"	NW	Rain

1/ Water temperatures taken at station just above weir.
2/ Water gauge readings are in inches and represent absolute depth in midstream just below weir.
3/ Wind records supplemented by records of Mr. G. W. Hanson, U.S.C.G., 40 Mile Point Light Station, Lake Huron.

APPENDIX C

Table 2. Water temperatures in Hammond Bay and in the mouth of Carp Creek: April 25–June 27, 1947.

Date 1947	Mouth of Carp Creek[1]		Hammond Bay[2]	
	Time	Water temperature (Degrees F.)	Time	Water temperature (Degrees F.)
April 25	...	...	1600	42.5
May 5	1100	48.0	1115	48.0
May 14	1200	48.0	1130	48.0
May 19	1130	63.0	1135	54.0
May 22	1015	53.0	1020	52.0
May 28	1700	50.0	1705	49.0
May 30	1100	46.0	1110	48.0
June 4	1615	59.0	1630	51.0
June 11	1120	68.0	1130	52.0
June 19	1100	66.0	1050	62.0
June 27	1030	72.0	1035	60.0

[1] Temperature station where creek water enters zone of wave action.

[2] Temperatures taken six inches below surface outside the zone of wave action. Stations variable but usually 300 to 500 feet north or south of creek mouth and always beyond the possible influence of the discharge from Carp Creek.

Table 3. Number and average length and weight by sexes and total sea lampreys taken in the Carp Creek weir by dates and by cumulative periods in 1947.

Date 1947	Males				Females				Number taken with no data recorded	Total ♂♂ and ♀♀ taken
	Number taken	Average length in inches	Average length in millimeters	Average weight in grams	Number taken	Average length in inches	Average length in millimeters	Average weight in grams		
April 22	0	...	...	...	0	...	...	...	1	1
23	0	...	...	...	0	...	...	...	0	0
24	1	17.6	447	202	1	18.5	470	285	1	3
25	3	17.6	447	182	4	18.1	460	165	0	7
April 22-25	4	17.6	447	187	5	18.2	462	189	2	11
April 26	0	...	...	...	0	...	...	...	0	0
27	3	17.3	439	160	4	17.7	450	191	0	7
28	2	17.3	439	171	2	17.5	445	184	0	4
29	0	...	...	...	2	17.5	445	168	0	2
30	6	17.1	434	175	3	17.0	432	173	0	9
April 26-30	11	17.2	437	170	11	17.4	442	180	0	22
May 1	2	17.7	450	195	1	17.3	439	155	0	3
2	0	...	...	...	0	...	...	...	0	0
3	15	18.0	457	178	6	18.5	470	206	0	21
4	12	17.6	447	179	8	18.2	462	187	0	20
5	36	18.1	460	194	12	18.5	470	208	0	48
May 1-5	65	17.9	455	187	27	18.3	465	199	0	92
May 6	12	17.4	442	153	4	17.7	450	172	0	16
7	12	17.6	447	163	5	17.8	452	179	0	17
8	5	17.4	442	158	2	18.5	470	215	0	7
9	1	20.3	516	239	0	...	...	...	0	1
10	0	...	...	...	0	...	...	...	0	0
May 6-10	30	17.6	447	161	11	17.9	455	183	0	41
May 11	6	18.6	472	226	0	...	...	...	0	6
12	5	17.3	439	181	6	17.8	452	194	0	11
13	11	16.9	429	180	7	16.9	429	189	0	18
14	7	18.2	462	191	3	18.3	465	208	0	10
15	6	17.6	447	179	5	16.2	411	133	2	13
May 11-15	35	17.6	447	190	21	17.2	437	180	2	58
May 16	2	16.3	414	121	5	16.9	429	183	3	10
17	33	17.6	447	186	26	18.0	457	210	0	59
18	9	17.8	452	175	9	17.0	432	181	0	18
19	55	17.7	450	192	37	18.1	460	211	0	92
20	57	17.6	447	185	31	18.1	460	198	5	93
May 16-20	156	17.6	447	186	108	17.9	455	203	8	272
May 21	38	17.6	447	190	26	17.8	452	208	0	64
22	28	17.5	445	173	10	17.6	447	193	0	38
23	32	17.8	452	184	14	17.5	445	177	0	46
24	40	17.7	450	188	26	17.0	432	177	5	71
25	40	17.5	445	179	13	17.4	442	185	0	53
May 21-25	178	17.6	447	183	89	17.5	445	189	5	272
May 26	33	18.0	457	197	13	17.6	447	182	0	46
27	30	17.3	439	177	11	17.3	439	181	0	41
28	12	17.6	447	168	10	18.5	470	196	0	22
29	4	18.9	480	206	2	17.0	432	172	0	6
30	0	...	...	...	1	17.6	447	198	0	1
May 26-30	79	17.7	450	186	37	17.7	450	186	0	116
May 31	1	18.6	472	240	0	...	...	...	0	1
June 1	(Weir inoperative)									...
2	12	17.2	437	173	7	18.0	457	198	0	19
3	11	17.4	442	182	12	17.3	439	197	0	23
4	15	16.6	422	171	9	16.9	429	177	0	24
5	18	17.7	450	178	13	18.0	457	210	0	31
May 31-June 5	57	17.3	439	177	41	17.6	447	197	0	98

Continued next page

Date 1947	Males: Number taken	Males: Average length in inches	Males: Average length in millimeters	Males: Average weight in grams	Females: Number taken	Females: Average length in inches	Females: Average length in millimeters	Females: Average weight in grams	Number taken with no data recorded	Total ♂♂ and ♀♀ taken
June 6	27	17.5	445	195	16	17.2	437	189	0	43
7	27	16.9	429	176	24	17.5	445	193	0	51
8	31	16.7	424	172	21	17.1	434	178	0	52
9	43	17.2	437	183	39	17.0	432	178	0	82
10	28	17.5	445	200	11	17.4	442	186	0	39
June 6-10	156	17.2	437	185	111	17.2	437	184	0	267
June 11	22	17.0	432	188	17	16.9	429	191	0	39
12	9	17.7	450	195	6	17.3	439	188	0	15
13	6	18.3	465	215	1	16.0	406	150	0	7
14	12	16.8	427	153	7	16.8	427	147	0	19
15	9	17.0	432	162	10	16.9	429	160	0	19
June 11-15	58	17.2	437	180	41	16.9	429	172	0	99
June 16	47	16.9	429	175	32	16.9	429	172	0	79
17	11	17.1	434	159	6	16.9	429	171	0	17
18	12	16.5	419	155	15	16.3	414	157	0	27
19	11	16.4	417	167	6	15.9	404	158	0	17
20	7	17.3	439	190	3	17.4	442	195	0	10
June 16-20	88	16.8	427	171	62	16.8	427	168	0	150
June 21	4	17.7	450	201	5	17.6	447	188	0	9
22	3	16.8	427	168	2	16.2	411	154	0	5
23	4	17.6	447	196	2	18.3	465	209	0	6
24	8	17.7	450	188	2	16.4	417	202	0	10
25	3	17.3	439	175	2	16.6	422	148	0	5
June 21-25	22	17.5	445	187	13	17.1	434	182	0	35
June 26	1	18.9	480	264	4	16.6	422	166	0	5
27	4	16.5	419	148	2	15.3	389	115	0	6
28	4	17.1	434	150	0	...	...	...	0	4
29	8	16.8	427	147	5	16.2	411	163	0	13
30	8	17.3	439	181	3	17.0	432	148	0	11
June 26-30	25	17.0	432	163	14	16.4	417	154	0	39
July 1	12	17.5	445	181	2	16.1	409	153	0	14
2	4	17.2	437	177	2	17.3	439	179	0	6
3	3	16.2	412	164	2	18.0	457	259	0	5
4	0	...	...	...	2	15.3	389	116	0	2
5	3	16.0	406	143	1	14.8	376	118	0	4
July 1-5	22	17.1	434	173	9	16.4	417	170	0	31
July 6	1	15.6	396	142	1	15.6	396	142	0	2
7	3	16.7	424	151	0	...	...	...	0	3
8	2	17.2	437	170	2	19.2	488	255	0	4
9	1	18.9	480	260	0	...	...	...	0	1
10	1	16.8	427	196	0	...	...	...	0	1
July 6-10	8	17.0	432	174	3	17.9	455	217	0	11
July 11	0	...	...	...	0	...	...	...	0	0
12	2	17.8	452	205	0	...	...	...	0	2
13	1	17.0	432	...	0	...	...	...	0	1
			(No sea lampreys entered the trap after July 13)							
July 11-13	3	17.5	445	(2)205	0	...	...	...	0	3
Totals and grand averages	997	17.4	442	181.6	603	17.4	442	186.6	17	1,617

Table 4. Daily minimum, maximum, and mean water temperatures and water gauge readings for Carp Creek with air temperatures and wind and weather records for the locality: April 7-July 15, 1948.[1]

Date 1948		Time	Water temperature (Degrees F.)			Water gauge[2]	Air temperature[3] (Degrees F.)	Wind		Weather
			Min.	Mean	Max.			Strength	Direction and shift	
April	7	0930	38	38.5	39	31.00	39	Light	NE	Clear, cold
	8	0830	...	...	...	38.00	...	"	SW	Rain
	9	0620	32	35.0	38	39.00	22	Moderate	NW	Snow, freezing
	10	0900	...	...	...	40.00	33	Strong	NW	Overcast, cold
	11	0930	36	38.0	40	(Flood	48	...	S	" "
	12	0850	38	40.5	43	stage)	40	Light	W	Clear, warmer
	13	0900	39	40.5	42	"	40	"	NNE	Clear, cool
	14	0905	38	40.0	42	"	40	"	ESE	" "
	15	0835	41	44.5	48	"	46	"	N	" "
	16	0910	44	46.0	48	"	40	Moderate	NW	Rain
	17	0915	39	40.5	42	"	34	Strong	S	Clear, cold
	18	1000	39	41.0	43	"	37	Moderate	S	Rain, cold
	19	0925	42	43.0	44	"	41	Light	NW	Overcast, fog
	20	0900	43	45.0	47	"	40	"	N	" "
	21	0920	39	40.5	42	"	40	"	N	Clear, cool
	22	0855	42	46.5	51	"	56	Moderate	S	Clear, warmer
	23	0935	48	49.0	50	"	41	Light	SSW to SE	Overcast
	24	0920	48	49.0	50	22.00	41	"	N to E	Rain
	25	0935	47	48.0	49	22.50	43	Moderate	E	Fog, clearing
	26	0930	49	51.5	54	22.00	48	Light	E	Clear, warmer
	27	0925	52	53.0	54	23.00	42	Moderate	NE to E	Rain, fog
	28	1005	48	50.0	52	24.00	53	Light	N	Clear, warmer
	29	1025	52	54.0	56	23.00	45	"	ENE	Clear
	30	0900	50	53.5	57	22.00	50	Moderate	N to NNE	"
May	1	0900	46	54.0	62	21.00	42	"	E	Clear, cooler
	2	0820	51	56.0	61	20.00	43	Light	N to NE	Clear, cool
	3	0940	50	55.0	60	19.50	46	"	NE	" "
	4	0840	53	57.0	61	19.00	46	"	NE to E	Overcast, cool
	5	0915	49	51.5	54	18.00	50	"	E	Clear, warmer
	6	0920	52	56.5	61	18.50	51	"	E	Rain
	7	0925	48	52.5	57	19.00	37	Moderate	N	Overcast, cold
	8	0855	40	44.5	49	19.50	37	Strong	N	Clear, cold
	9	0930	40	46.0	52	19.50	41	Moderate	N	Overcast, cold
	10	0855	43	46.0	49	19.00	42	"	NE	Clear, cool
	11	0920	45	50.0	55	17.50	44	Light	SE	Overcast
	12	0920	47	49.0	51	17.00	48	"	N	Clear
	13	0915	49	54.0	59	16.50	51	"	NE	Clear, warmer
	14	0930	54	58.0	62	16.50	63	"	N to NE	Clear, warm
	15	0910	55	60.5	66	16.00	51	"	SE	Overcast, cooler
	16	0945	52	56.0	60	17.00	48	...	(None)	Overcast, fog
	17	0950	51	54.0	57	17.00	56	Light	N	Clear, cool
	18	0930	53	59.5	66	17.00	55	"	E	" "
	19	0925	52	58.0	64	16.50	48	"	NE	" "
	20	0855	54	59.0	64	16.25	68	"	SSE	Clear, warm
	21	1010	54	60.5	67	15.75	51	Strong	NW	Partly overcast
	22	0950	48	54.0	60	15.50	49	"	S to SE	Overcast
	23	0830	49	53.5	58	15.25	45	Moderate	NW	Overcast, cold
	24	0845	50	55.5	61	15.00	53	Light	NW	Clear, Haze
	25	0845	50	54.0	58	14.50	60	"	NE	Clear
	26	0850	51	57.0	63	14.25	65	"	S to SE	"
	27	0820	55	62.0	69	14.00	68	"	S	Clear, hot
	28	0840	60	65.5	71	13.75	55	"	NW	Overcast, rain
	29	0840	54	60.0	66	13.50	49	"	N	Clear
	30	0945	55	60.0	65	13.25	58	Moderate	NE	"
	31	0835	58	63.0	68	13.00	64	Strong	NE	"

Continued next page

Date 1948		Time	Water temperature (Degrees F.)[1] Min.	Mean	Max.	Water gauge[2]	Air temperature[3] (Degrees F.)	Wind Strength	Wind Direction and shift	Weather
June	1	0905	60	65.0	70	13.00	71	Light	S to SE	Clear, hot
	2	0930	63	68.0	73	12.50	74	"	ESE	" "
	3	0915	63	68.0	73	12.00	70	"	NE	" "
	4	0905	62	67.5	73	11.50	70	"	NW	Overcast
	5	0920	56	61.0	66	11.25	63	"	N to NE	Clear
	6	0900	54	60.5	67	11.25	55	"	E	"
	7	0930	55	60.5	66	11.50	65	"	S	Partly overcast
	8	1040	55	59.5	64	11.25	60	"	N	Overcast
	9	0950	58	62.0	66	11.00	65	"	N	Heavy smoke haze
	10	0920	56	61.5	67	11.00	66	"	SW	Overcast, hot
	11	0905	57	61.0	65	11.00	58	"	NNW	Overcast
	12	0910	54	61.0	68	11.00	63	"	E	"
	13	0900	54	59.0	64	11.00	59	"	W	Clear, cooler
	14	0905	53	61.0	69	11.00	73	Moderate	S	Clear
	15	1115	52	61.5	71	10.75	65	Light	NNE	"
	16	0915	51	59.5	68	10.50	61	"	S to SE	"
	17	0930	54	61.0	68	10.00	63	"	N	"
	18	0930	52	58.5	65	10.00	56	"	NE	Overcast, cool
	19	0955	54	58.0	62	10.00	...	"	N	" "
	20	1010	52	57.5	63	10.00	67	Moderate	SW	Clear
	21	0900	51	61.5	72	9.75	64	Light	NE	Overcast
	22	0915	56	58.5	61	9.75	60	"	E	Overcast, cool
	23	1045	54	58.0	62	10.00	80	"	S	Overcast, hot
	24	0945	60	66.5	73	10.00	74	"	SW	Overcast
	25	1030	62	67.5	73	10.00	61	"	W	Overcast, rain
	26	0835	54	61.0	68	10.00	59	"	E	Clear, cool
	27	1155	55	61.0	67	10.00	74	"	NE	Overcast, hot
	28	0850	58	64.0	70	10.00	61	(None)		Rain, fog
	29	0910	58	60.5	63	10.25	65	(None)		Overcast, hot
	30	0850	58	63.5	69	10.00	67	Light	NW	Overcast
July	1	0925	55	62.0	69	9.75	63	"	NE	Clear
	2	1010	56	63.5	71	9.75	75	"	SSE	Overcast
	3	0915	56	61.5	67	9.75	62	"	E	"
	4	0920	59	64.5	70	9.75	84	"	S	Clear, hot
	5	1225	62	70.5	79	9.75	89	"	SW	" "
	6	1220	63	72.0	81	9.75	73	"	NNE	Overcast, hot
	7	1340	58	67.0	76	9.75	78	(None)		Clear, hot
	8	1525	57	67.0	77	9.75	...	Light	SE	" "
	9	1410	59	66.5	74	9.75	80	"	N	" "
	10	1435	60	70.0	80	9.50	80	"	N	" "
	11	1615	62	70.5	79	9.50	77	"	NE	" "
	12	1055	62	68.5	75	9.50	81	(None)		" "
	13	1705	64	71.0	78	9.50	77	(None)		" "
	14	1645	61	69.0	77	9.50	77	(None)		" "
	15	1550	57	66.5	76	9.50	75	Light	NE	" "

[1] Water temperatures taken at station just above weir.
[2] Water gauge readings are in inches and represent absolute depth in midstream just below weir. Readings are accurate down to 10-inch level. Below that point, level is influenced by impounding action of clay and gravel ridge in stream bed below gauge.
[3] Air temperature taken with pocket thermometer at time given for water temperature readings.

Table 5. Water temperatures in Hammond Bay in the vicinity of the mouth of Carp Creek: April 9–July 6, 1948.[1]

Date (1948)	Time	Water temp. (Degrees F.)	Date	Time	Water temp. (Degrees F.)
April 9	0635	32.0[2]	May 25	0930	51.0
13	0930	40.0	28	0920	55.0
22	1055	42.0	31	0910	57.0
25	1100	46.0	June 3	1010	60.0
28	1100	47.0	6	0930	59.0
May 1	1000	44.0	12	0930	60.0
4	0945	45.0	15	1130	62.0
7	1010	44.0	18	1000	60.5
10	0930	44.0	21	0915	59.0
13	1220	52.0	27	1230	64.0
16	1010	50.0	30	0915	57.0
19	1000	51.0	July 3	0935	57.0
22	1020	50.0	6	1240	63.0

[1] Temperatures taken 6 inches below surface outside the zone of wave action. Stations variable but usually 300 to 500 feet north or south of creek mouth and always beyond the possible influence of the discharge from Carp Creek.

[2] Last of flow ice disappeared from Hammond Bay on this date.

Table 6. Number and average length by sexes and total sea lampreys taken in the Carp Creek weir by dates and by cumulative periods in 1948.

Date 1948	Males: Number taken	Males: Average length in inches	Males: Average length in millimeters	Females: Number taken	Females: Average length in inches	Females: Average length in millimeters	Number taken with no data recorded	Total ♂♂ and ♀♀ taken
April 7	0	...	...	0	...	...	0	0
8	0	...	...	0	...	...	0	0
9	(Weir inoperative)							
10	" "							
April 7-10	0	...	...	0	...	...	0	0
April 11	(Weir inoperative)							
12	" "							
13	" "							
14	0	...	...	0	...	...	0	0
15	3	17.6	447	1	19.6	498	0	4
April 11-15	3	17.6	447	1	19.6	498	0	4
April 16	1	15.1	384	0	...	...	0	1
17	0	...	...	0	...	...	4	4
18	2	19.8	503	0	...	...	0	2
19	0	...	...	0	...	...	0	0
20	0	...	...	0	...	...	0	0
April 16-20	3	18.3	465	0	...	...	4	7
April 21	0	...	...	0	...	...	0	0
22	0	...	...	0	...	...	0	0
23	1	20.3	516	1	15.2	386	0	2
24	13	17.7	450	6	17.8	452	0	19
25	7	18.2	462	2	16.9	429	0	9
April 21-25	21	18.0	457	9	17.3	439	0	30
April 26	5	17.2	437	4	17.8	452	0	9
27	9	17.2	437	5	18.2	462	0	14
28	17	17.3	439	12	18.0	457	0	29
29	46	17.0	432	20	17.5	445	0	66
30	85	16.7	424	50	16.9	429	0	135
April 26-30	162	16.9	429	91	17.3	439	0	253
May 1	50	17.2	437	22	16.4	417	0	72
2	36	17.0	432	21	17.6	447	0	57
3	28	17.5	445	24	17.7	450	0	52
4	76	17.0	432	48	16.9	429	0	124
5	24	17.0	432	13	18.1	460	0	37
May 1-5	214	17.1	434	128	17.2	437	0	342
May 6	114	16.9	429	75	17.5	445	0	189
7	64	17.3	439	35	17.5	445	0	99
8	11	17.3	439	3	16.0	406	0	14
9	8	17.2	437	1	17.0	432	0	9
10	6	17.2	437	2	16.9	429	0	8
May 6-10	203	17.0	432	116	17.4	442	0	319
May 11	11	17.0	432	8	15.9	404	0	19
12	21	17.2	437	8	17.0	432	0	29
13	76	16.7	424	59	17.0	432	0	135
14	113	16.2	411	73	16.5	419	0	186
15	99	16.4	417	61	16.4	417	0	160
May 11-15	320	16.5	419	209	16.6	422	0	529
May 16	22	16.6	422	22	17.1	434	0	44
17	39	16.8	427	14	17.5	445	0	53
18	140	16.8	427	87	17.2	437	0	227
19	80	16.4	417	49	16.7	424	0	129
20	20	16.7	424	19	17.7	450	0	39
May 16-20	301	16.7	424	191	17.1	434	0	492
May 21	56	16.1	409	51	16.7	424	0	107
22	24	17.7	450	11	16.9	429	0	35
23	18	16.6	422	11	16.6	422	0	29
24	45	16.8	427	14	16.7	424	0	59
25	22	16.7	424	10	17.2	437	0	32
May 21-25	165	16.5	419	97	16.8	427	0	262

Continued next page

Appendix C, Table 6, continued

Date 1948	Males: Number taken	Males: Average length in inches	Males: Average length in millimeters	Females: Number taken	Females: Average length in inches	Females: Average length in millimeters	Number taken with no data recorded	Total ♂♂ and ♀♀ taken
May 26	28	16.2	411	26	16.4	417	0	54
27	42	16.0	406	26	15.9	404	0	68
28	33	16.1	409	10	16.6	422	0	43
29	57	16.5	419	41	16.5	419	0	98
30	47	16.4	417	34	16.5	419	0	81
May 26-30	207	16.3	414	137	16.4	417	0	344
May 31	29	17.1	434	8	17.1	434	0	37
June 1	32	16.9	429	12	17.1	434	0	44
2	26	16.8	427	5	16.1	409	0	31
3	10	16.0	406	6	16.1	409	0	16
4	13	17.0	432	6	16.3	414	0	19
May 31-June 4	110	16.7	424	37	16.7	424	0	147
June 5	25	16.5	419	24	16.6	422	0	49
6	25	16.8	427	19	16.3	414	0	44
7	38	16.3	414	12	16.6	422	1	51
8	24	17.1	434	8	16.9	429	0	32
9	13	15.7	399	6	15.4	391	0	19
June 5-9	125	16.5	419	69	16.5	419	1	195
June 10	4	17.3	439	0	...	...	3	7
11	0	...	...	1	15.7	399	0	1
12	0	...	...	0	...	...	0	0
13	0	...	...	0	...	...	0	0
14	0	...	...	1	16.0	406	0	1
June 10-14	4	17.3	439	2	15.9	404	3	9
June 15	0	...	...	0	...	...	0	0
16	0	...	...	0	...	...	0	0
17	0	...	...	0	...	...	0	0
18	0	...	...	0	...	...	0	0
19	0	...	...	0	...	...	0	0
June 15-19	0	...	...	0	...	...	0	0
June 20	0	...	...	0	...	...	0	0
21	1	15.3	389	0	...	...	0	1
22	1	14.2	361	0	...	...	0	1
23	0	...	...	0	...	...	0	0
24	1	15.1	384	0	...	...	0	1
June 20-24	3	14.9	378	0	...	...	0	3
June 25	1	15.2	386	0	...	...	0	1
26	0	...	...	0	...	...	0	0
27	0	...	...	1	13.3	338	0	1
28	0	...	...	0	...	...	0	0
29	0	...	...	0	...	...	0	0
June 25-29	1	15.2	386	1	13.3	338	0	2
June 30	0	...	...	0	...	...	0	0
July 1	0	...	...	0	...	...	0	0
2	0	...	...	0	...	...	0	0
3	0	...	...	0	...	...	0	0
4	0	...	...	0	...	...	0	0
June 30-July 4[1]	0	...	...	0	...	...	0	0
July 5	0	...	...	0	...	...	0	0
6	0	...	...	1	15.6	396	0	1
7	0	...	...	0	...	...	0	0
8	0	...	...	0	...	...	0	0
9	0	...	...	0	...	...	0	0
July 5-9	0	...	...	1	15.6	396	0	1
July 10	0	...	...	0	...	...	0	0
11	0	...	...	0	...	...	0	0
12	0	...	...	0	...	...	0	0
13	0	...	...	0	...	...	0	0
14	0	...	...	0	...	...	0	0
15	0	...	...	0	...	...	0	0
July 10-15	0	...	...	0	...	...	0	0
Totals and grand averages	1,842	16.7	424	1,089	16.9	429	8	2,939

[1] Four specimens taken by fishermen below weir.

Table 7. Daily minimum, maximum, and mean water temperatures and water gauge readings for Carp Creek with air temperatures and wind and weather records for the locality: April 6–July 18, 1949.[1]

Date 1949		Time	Water temperature (Degrees F.) Min.	Mean	Max.	Water gauge[2]	Mean air temperature[3] (Degrees F.)	Wind Direction and shift	Weather
April	6	1200	38	40.0	42	25.00	45.0	NW	Partly overcast
	7	1030	37	39.5	42	24.50	42.0	N	Light snow, rain
	8	1330	36	38.5	41	24.00	37.0	N	Clear
	9	0830	37	39.5	42	23.00	39.0	NE	"
	10	0930	37	40.5	44	22.50	36.5	(None)	"
	11	0900	39	43.0	47	21.50	45.5	(None)	Clear, warmer
	12	0900	42	47.0	52	21.00	55.0	S	Clear, warm
	13	1000	45	50.5	56	20.50	47.5	S	Clear
	14	0900	47	53.0	59	20.75	46.0	N	Overcast, cooler
	15	0900	39	45.0	51	19.25	37.0	NE	Snow
	16	0900	32	40.5	49	19.00	33.0	NE	Clear, very cold
	17	0900	32	37.5	43	19.50	31.5	NE	Clear, cool
	18	0830	38	42.0	46	18.50	42.0	NE	Clear
	19	0830	41	45.5	50	18.00	37.0	NW	Clear, warmer
	20	0900	44	49.0	54	18.00	52.5	SW	Overcast
	21	0850	48	51.0	54	17.75	59.0	SW	Overcast, warm
	22	0830	50	54.0	58	17.50	47.0	(None)	Rain
	23	0900	41	47.0	53	18.00	47.5	SW	Overcast
	24	0900	42	47.0	52	18.00	36.5	N	Overcast, cool
	25	0900	40	45.5	51	18.50	36.5	W	Overcast, warm
	26	0900	44	47.0	50	19.00	51.5	(None)	Overcast, fog
	27	0915	48	52.5	57	19.00	46.0	NW	Clear, warm
	28	0900	47	53.0	59	19.50	42.0	N	Clear, cool
	29	0930	46	49.0	52	19.50	49.0	W	Overcast
	30	0800	52	56.0	60	19.00	58.0	N	Clear
May	1	0800	52	57.5	63	18.00	62.5	SW	Overcast, warm
	2	0800	58	60.0	62	18.00	58.5	NW	Overcast
	3	0815	52	55.0	58	17.50	54.0	SW	Clear, warm
	4	0900	54	59.5	65	17.00	73.0	(None)	Overcast, warm
	5	0915	63	67.5	72	18.00	61.0	NW	" "
	6	0830	63	68.0	73	18.50	64.5	W	Partly overcast
	7	0815	58	64.5	71	19.00	58.5	(None)	Clear, cooler
	8	0820	52	59.0	66	18.50	52.0	S	Clear, warm
	9	0830	56	61.0	66	17.50	56.0	(None)	Overcast
	10	0815	51	57.0	63	16.50	47.5	NE	Clear, cool
	11	0815	47	53.5	60	16.50	40.0	S	Overcast
	12	0820	46	51.0	56	15.75	46.0	(None)	Overcast, cool
	13	0815	45	52.0	59	15.50	56.5	E	Overcast, warm
	14	0830	52	59.5	67	15.25	58.0	N	Clear, cool
	15	0925	45	51.0	57	15.25	43.0	N	" "
	16	0900	44	50.5	57	15.00	53.0	(None)	Clear, warmer
	17	0930	50	56.5	63	14.50	58.5	N	Clear, cool
	18	0810	54	61.0	68	14.50	63.5	S	Overcast, warm
	19	0930	58	68.0	78	16.00	66.0	NW	Overcast, rain
	20	0820	53	56.5	60	16.75	46.5	NW	Clear, cool
	21	0930	51	56.0	61	17.50	45.0	NNW	" "
	22	0830	56	60.0	64	17.25	56.5	(None)	Overcast, oool
	23	0900	43	51.0	59	17.00	54.5	NW	Clear, warm
	24	0825	51	57.5	64	16.50	62.0	W	Overcast
	25	0915	41	49.0	57	15.75	45.5	SW	Overcast, cool
	26	0845	40	46.0	52	15.50	47.0	NW	" "
	27	0830	37	44.0	51	15.00	45.0	N	" "
	28	0825	38	45.5	53	14.00	43.0	N	Clear, oool
	29	0915	47	54.0	61	14.00	50.5	N	" "
	30	1300	50	57.0	64	13.75	55.0	W	Overcast, warm
	31	0820	56	61.5	67	13.75	52.5	E	Clear, warm

Continued next page

Date 1949	Time	Water temperature (Degrees F.) Min.	Mean	Max.	Water gauge[2]	Mean air temperature[3] (Degrees F.)	Wind Direction and shift	Weather
June 1	0820	58	62.5	67	13.75	60.0	(None)	Clear, warm
2	0845	60	64.0	68	13.50	69.0	SW	" "
3	0820	62	67.5	73	13.00	76.0	S	Clear, hot
4	0830	66	70.5	75	13.00	67.0	WNW	" "
5	0830	49	64.0	79	12.75	65.5	W to N	Clear, cool
6	0900	55	62.0	69	12.75	63.0	W	" "
7	0830	56	62.5	69	12.25	57.0	N	" "
8	0845	51	58.0	65	12.00	45.0	NNE	" "
9	0850	53	59.0	65	11.75	52.0	SE	" "
10	0900	56	61.0	66	11.50	61.5	SW	Clear, warm
11	0820	60	64.0	68	11.50	64.0	SW	" "
12	0905	62	68.5	75	11.00	77.0	SW	Clear, hot
13	0920	64	68.5	73	11.00	80.5	SW	Overcast, hot
14	0915	63	68.5	74	11.50	71.0	(None)	Rain
15	0840	63	64.5	66	12.50	63.5	(None)	"
16	0930	60	63.0	66	13.00	58.0	S	Overcast, cool
17	0820	62	63.0	64	13.00	61.0	(None)	Overcast, fog
18	0845	62	66.0	70	13.25	69.0	(None)	Clear, hot
19	0815	68	72.5	77	13.00	66.0	(None)	Overcast
20	0820	67	70.0	73	13.25	66.5	(None)	Rain
21	0820	67	70.0	73	13.50	74.5	NW	Overcast
22	0845	66	70.0	74	13.00	64.0	N to NE	Clear
23	0830	66	71.0	76	13.00	65.5	(None)	Light rain
24	0830	64	66.0	68	13.00	66.0	(None)	Rain
25	0900	64	67.5	71	14.50	72.5	SE	"
26	0900	66	68.5	71	18.00	72.0	NW	Clear
27	0900	68	73.0	78	19.00	70.0	NW	"
28	...	...	...	...	...	...	...	...
29	0815	71	75.5	80	...	70.5	SW	Clear, warm
30	0900	72	77.0	82	16.50	72.5	SE	Clear, hot
July 1	0820	70	76.0	82	15.50	72.5	E	" "
2	0920	76	79.0	82	15.00	72.0	(None)	" "
3	0830	76	79.5	83	14.50	74.5	SE	" "
4	0900	73	77.5	82	14.50	79.0	(None)	Rain
5	0850	72	75.0	78	13.75	73.0	...	Overcast, cooler
6	0845	72	73.0	74	13.75	74.0	N	" "
7	0815	66	71.0	76	12.75	69.0	E	Clear, warm
8	0915	64	69.0	74	12.50	70.5	W	" "
9	0810	64	69.5	74	12.25	70.5	(None)	Overcast
10	0900	64	67.0	70	12.00	65.0	N	Clear, cool
11	0845	60	67.0	74	11.75	60.5	(None)	Overcast
12	0800	62	67.5	73	11.75	67.5	W	Overcast, warm
13	0815	64	69.0	74	11.50	67.0	(None)	" "
14	0830	62	68.0	74	11.00	65.0	W	" "
15	0845	63	67.5	72	11.00	65.5	W	Overcast, cool
16	0820	62	67.5	73	10.75	67.0	SW	Clear, warm
17	0820	64	68.0	72	10.50	71.5	W	" "
18	0820	64	70.0	76	10.25	74.5	SW	" "

[1] Water temperatures taken at station just above weir.
[2] Water gauge readings are in inches and represent absolute depth in midstream just below weir.
[3] Air temperatures obtained at Ocqueoc River weir site about four miles from the Carp Creek weir.

APPENDIX C

Table 8. Water temperatures in Hammond Bay and in the mouth of Carp Creek: April 6-July 8, 1949.

Date 1949	Time	Water temperature (Degrees F.) Mouth of Carp Creek[1]	Hammond Bay[2]
April 6	1100	38	40
14	1515	50	45
16	1500	41	43
19	1615	53	50
24	1000	40	42
29	1000	51	47
May 4	1830	60	50
9	1500	62	52
14	0830	54	48
19	0930	58	46
24	0900	56	49
29	0915	53	50
June 3	0840	68	52
8	0910	53	54
13	0930	70	60
18	1400	70	61
25	0910	65	62
30	0910	74	68
July 3	0845	75	68
8	...	66	62

[1] Temperature station where creek enters zone of wave action.

[2] Temperatures taken six inches below surface outside the zone of wave action. Stations variable but usually 300 to 500 feet north or south of creek mouth and always beyond possible influence of the discharge from Carp Creek.

Table 9. Number and average length by sexes of samples taken on alternate days and total sea lampreys taken in the Carp Creek weir by dates and by cumulative periods in 1949.

	Males				Females				
Date 1949	Number taken	Number measured	Average length in inches	Average length in millimeters	Number taken	Number measured	Average length in inches	Average length in millimeters	Total ♂♂ and ♀♀ taken
April 6				(Weir inoperative)					
7				"	"				
8	0	...	...	...	0	...	...	...	0
9	0	...	...	...	1	...	...	...	1
10	2	2	16.0	406	0	...	...	...	2
April 6-10	2	2	16.0	406	1	...	...	...	3
April 11	1	...	...	...	0	...	...	...	1
12	4	4	16.2	412	1	1	(15.2)	(386)	5
13	3	...	...	...	2	...	...	...	5
14	7	7	17.7	450	5	5	18.8	478	12
15	9	...	...	...	2	...	...	...	11
April 11-15	24	11	17.2	437	10	6	18.2	462	34
April 16	0	...	...	...	0	...	...	...	0
17	0	...	...	...	0	...	...	...	0
18	4	4	16.6	422	4	4	19.2	488	8
19	4	...	...	...	0	...	...	...	4
20	9	9	16.5	419	5	5	17.4	442	14
April 16-20	17	13	16.5	419	9	9	18.2	462	26
April 21	23	...	...	...	9	...	...	...	32
22	20	20	17.4	442	10	10	18.3	465	30
23	8	...	...	...	1	...	...	...	9
24	8	8	17.4	442	6	6	18.8	478	14
25	16	...	...	...	6	...	...	...	22
April 21-25	75	28	17.4	442	32	16	18.5	470	107
April 26	11	11	17.9	455	7	7	19.2	488	18
27	19	...	...	...	11	...	...	...	30
28	57	57	17.3	439	20	20	18.2	462	77
29	45	...	...	...	17	...	...	...	62
30	86	86	17.1	434	38	38	17.7	450	124
April 26-30	218	154	17.2	437	93	65	18.0	457	311
May 1	59	...	...	...	19	...	...	...	78
2	90	82	17.3	439	51	45	17.7	450	141
3	55	...	...	...	34	...	...	...	89
4	69	68	16.9	429	22	21	17.9	455	91
5	48	...	...	...	9	...	...	...	57
May 1-5	321	150	17.1	434	135	66	17.8	452	456
May 6	6	...	...	...	8	2	18.8	478	14
7	98	...	...	...	43	...	...	...	141
8	49	33	17.5	445	23	19	17.9	455	72
9	22	...	...	...	4	...	...	...	26
10	25	25	17.3	439	13	13	17.6	447	38
May 6-10	200	58	17.3	439	91	34	17.9	455	291
May 11	18	...	...	...	4	...	...	...	22
12	9	9	16.8	427	5	5	17.3	439	14
13	24	...	...	...	11	...	...	...	35
14	36	36	16.5	419	21	21	17.4	442	57
15	31	...	...	...	21	...	...	...	52
May 11-15	118	45	16.6	422	62	26	17.4	442	180
May 16	28	28	17.1	434	13	13	16.8	427	41
17	78	...	...	...	33	...	...	...	111
18	81	60	16.5	419	46	40	17.0	432	127
19	74	...	...	...	38	...	...	...	112
20	51	51	16.7	424	28	28	17.3	439	79
May 16-20	312	139	16.7	424	158	81	17.1	434	470
May 21	15	...	...	...	15	...	...	...	30
22	32	32	16.5	419	22	22	17.3	439	54
23	41	...	...	...	24	...	...	...	65
24	67	67	16.5	419	44	44	17.0	432	111
25	41	...	...	...	19	...	...	...	60
May 16-25	196	99	16.5	419	124	66	17.1	434	320

Continued next page

Date 1949		Males: Number taken	Males: Number measured	Males: Average length in inches	Males: Average length in millimeters	Females: Number taken	Females: Number measured	Females: Average length in inches	Females: Average length in millimeters	Total ♂♂ and ♀♀ taken
May	26	16	16	17.4	442	14	14	16.9	429	30
	27	8	...	...	...	4	...	...	...	12
	28	5	5	15.8	401	2	2	17.1	434	7
	29	11	...	...	...	5	...	...	...	16
	30	18	9	16.6	422	8	8	16.9	429	26
May	26-30	58	30	16.9	429	33	24	16.9	429	91
May	31	19	...	...	...	10	...	...	...	29
June	1	31	31	16.3	414	13	13	16.8	427	44
	2	39	...	...	...	22	...	...	...	61
	3	17	17	16.2	412	15	15	17.7	450	32
	4	10	...	...	...	2	...	...	...	12
May 31-June 4		116	48	16.3	414	62	28	17.3	439	178
June	5	5	5	17.2	437	4	4	17.6	447	9
	6	5	...	...	...	3	...	...	...	8
	7	29	29	16.9	429	18	18	16.2	412	47
	8	20	...	...	...	4	...	...	...	24
	9	16	16	16.9	429	3	3	17.2	437	19
June	5-9	75	50	16.9	429	32	25	16.5	419	107
June	10	7	...	...	...	3	...	...	...	10
	11	10	10	16.3	414	1	1	(16.8)	(427)	11
	12	1	...	...	...	0	...	...	...	1
	13	3	3	16.4	417	2	1	(15.5)	(394)	5
	14	2	...	...	...	0	...	...	...	2
June	10-14	23	13	16.3	414	6	2	16.2	412	29
June	15	15	15	17.1	434	4	4	17.1	434	19
	16	10	...	...	...	9	...	...	...	19
	17	18	18	16.9	429	5	5	17.5	445	23
	18	17	...	...	...	4	...	...	...	21
	19	9	9	16.0	406	4	4	15.7	399	13
June	15-19	69	42	16.8	427	26	13	16.8	427	95
June	20	9	...	...	...	2	...	...	...	11
	21	5	5	16.3	414	0	...	...	...	5
	22	1	...	...	...	1	...	...	...	2
	23	4	4	16.4	417	1	1	(17.1)	(434)	5
	24	8	...	...	...	5	...	...	...	13
June	20-24	27	9	16.4	417	9	1	(17.1)	(434)	36
June	25	3	3	16.7	424	5	5	17.9	455	8
	26	5	...	...	...	0	...	...	...	5
	27	2	2	15.2	386	3	3	17.2	437	5
	28	1	...	...	...	0	...	...	...	1
	29	3	3	14.5	368	0	...	...	...	3
June	25-29	14	8	15.5	394	8	8	17.6	445	22
June	30	1	...	...	...	3	...	...	...	4
July	1	0	...	...	...	0	...	...	...	0
	2	0	...	...	...	0	...	...	...	0
	3	0	...	...	...	0	...	....	...	0
	4	0	...	...	...	0	...	...	...	0
June 30-July 4		1	...	...	...	3	...	...	...	4
July	5	0	...	...	...	2	2	17.1	434	2
	6	0	...	...	...	1	...	...	...	1
	7	0	...	...	...	0	...	...	...	0
	8	0	...	...	...	0	...	...	...	0
	9	0	...	...	...	0	...	...	...	0
July	5-9	0	...	...	...	3	2	17.1	434	3
(No lampreys taken: July 10 to 19)										
July	10-19	0	...	...	...	0	...	...	...	0
Totals and grand averages		1,866	899[1]	16.9	429	897	472[2]	17.4	442	2,763

1/ Samples obtained for length data constitute 48.2 percent of all males taken.
2/ Samples obtained for length data constitute 52.6 percent of all females taken.

Table 10. Daily minimum, maximum, and mean water temperatures and water gauge readings for the Ocqueoc River with air temperatures for the locality: April 15–August 4, 1947.

Date 1947		Time	Water temperature (Degrees F.) Min.	Mean	Max.	At visit	Air temperature (Degrees F.)	Water gauge (in inches)
April	15	1630	...	...	...	...	...	41.50
	16	1000	...	...	...	38	36	...
		1600	38	38.0	38	38	47	37.50
	17	1000	38	38.5	39	38	40	...
		1600	38	38.0	38	38	41	33.25
	18	1000	37	38.0	39	39	41	...
		1600	39	39.0	39	39	40	30.00
	19	0945	38	38.5	39	39	...	...
		1600	38	38.5	39	39	40	27.00
	20	1700	39	39.5	40	40	45	25.00
	21	0920	39	39.5	40	40	38	...
		1600	40	40.0	40	40	39	23.00
	22	0830	40	40.0	40	40	41	...
		1600	40	40.5	41	41	42	21.50
	23	0900	40	41.0	42	41	46	...
		1600	40	40.5	41	41	58	21.00
	24	0900	40	40.5	41	41	50	...
		1600	41	41.5	42	41	54	24.50
	25	0900	40	40.5	41	40	42	...
		1600	42	43.0	44	44	51	25.00
	26	0900	41	42.5	44	44	42	...
		1600	44	45.0	46	46	46	24.00
	27	1600	43	44.5	46	46	...	24.75
	28	1600	44	45.5	47	47	60	23.50
	29	0930	46	46.5	47	47	68	22.00
		1630	47	48.0	49	49	66	21.75
	30	0845	47	48.5	50	48	52	...
		1600	...	...	...	...	...	23.75
May	1	0930	47	48.0	49	49	52	26.00
	2	1000	47	48.0	49	48	...	...
		1600	...	...	...	...	...	28.50
	3	0930	47	48.0	49	47	54	...
		1600	...	...	...	...	...	38.00
	4	0930	46	46.5	47	47	64	38.50
	5	0830	46	46.5	47	47	54	43.00
	6	1100	45	46.5	48	48	44	40.00
	7	1145	46	49.0	52	48	44	34.00
	8	1130	38	45.0	52	48	30	29.00
	9	1045	42	45.0	48	46	41	25.50
	10	1230	42	45.0	48	48	60	22.00
	11	0815	45	46.5	48	47	50	20.50
	12	0845	46	47.5	49	49	67	18.00
	13	0845	48	49.5	51	50	41	18.00
	14	0900	49	51.0	53	50	49	20.00
	15	0930	48	49.5	51	51	57	18.50
	16	0930	49	50.5	52	51	58	17.00
	17	0945	49	51.0	53	53	65	15.75
	18	1000	52	53.0	54	54	63	14.50
	19	0915	52	55.0	58	57	73	13.00
	20	0900	53	56.0	59	55	51	13.50
	21	0845	53	56.0	59	56	43	13.25
	22	0915	55	56.5	58	56	50	16.00
	23	0945	55	56.5	58	56	51	16.00
	24	0900	54	55.5	57	56	56	15.25
	25	0930	54	56.0	58	56	55	14.50
	26	1000	55	56.5	58	56	52	16.50
	27	0930	54	56.0	58	54	42	17.00
	28	1000	53	54.5	55	53	47	17.00
	29	1015	50	52.0	54	50	40	18.00
	30	0915	49	50.5	51	49	50	23.50
	31	0915	49	51.0	53	49	53	21.75

Continued next page

Date 1947		Time	Water temperature (Degrees F.) Min.	Mean	Max.	At visit	Air temperature (Degrees F.)	Water gauge (in inches)[2]
June	1	0845	49	50.5	52	51	55	18.75
	2	0945	50	51.5	53	52	47	16.00
	3	0900	50	51.5	53	50	46	14.00
	4	0900	52	54.5	57	55	60	12.25
	5	0900	54	56.0	58	56	70	11.25
	6	1000	56	58.0	60	57	66	10.50
	7	0915	57	59.5	62	59	54	9.75
	8	0900	57	59.5	62	62	58	9.25
	9	1215	60	62.0	64	64	72	8.25
	10	0900	61	64.0	67	66	80	8.00
	11	1130	65	68.5	72	68	58	8.00
	12	1015	64	66.0	68	66	56	7.25
	13	1045	64	66.0	68	64	52	6.50
	14	1015	61	62.5	64	63	56	8.25
	15	1115	61	62.0	63	60	53	8.00
	16	1030	61	61.0	61	60	56	9.00
	17	1145	58	60.0	62	62	59	8.00
	18	1145	60	62.0	64	62	62	7.25
	19	1030	60	62.0	64	64	64	6.50
	20	1115	62	65.0	68	66	68	6.00
	21	0930	62	65.0	68	65	66	5.25
	22	1145	65	67.5	70	69	74	5.00
	23	1015	67	69.0	71	69	78	4.75
	24	0930	67	69.0	71	67	62	4.00
	25	1400	65	68.0	71	70	74	4.50
	26	0900	68	70.0	72	68	64	4.00
	27	0915	64	68.5	73	72	78	3.00
	28	0930	72	73.0	74	72	74	4.75
	29	0930	70	72.5	75	72	70	5.00
	30	0945	68	70.5	73	70	66	4.50
July	1	0900	68	69.5	71	68	56	4.50
	2	1100	66	68.5	71	70	70	4.00
	3	1030	67	69.5	72	68	74	3.25
	4	1000	68	71.0	74	70	76	2.75
	5	0930	70	72.0	74	72	68	2.50
	6	0945	68	70.0	72	69	62	8.00
	7	1030	66	68.0	70	68	70	9.00
	8	0930	66	68.0	70	67	70	7.75
	9	1000	68	69.0	70	70	72	6.00
	10	1000	68	71.0	74	72	72	4.75
	11	1100	69	71.0	73	72	74	4.00
	12	1015	69	71.5	74	73	70	3.50
	13	1330	71	73.5	76	76	82	3.25
	14	...	...	...	...	...	...	...
	15	1145	70	73.5	77	70	70	4.50
	16	1000	69	71.0	73	70	72	4.50
	17	1145	70	73.0	76	75	82	4.00
	18	1100	72	75.0	78	76	74	3.75
	19	0845	69	73.0	77	69	59	3.50
	20	1200	68	70.5	73	71	71	3.25
	30	1530	66[3]	72.5	79[3]	77	84	3.50
August	4	0930	...	...	...	...	...	1.75

[1] Readings taken at station 100 feet below the outlet of Ocqueoc Lake.
[2] Depth in midstream directly opposite water gauge was approximately 24 inches greater than gauge readings listed.
[3] Minimum and maximum water temperatures for period July 21 to July 30 inclusive.

APPENDIX C

Table 11. Number and average length and weight by sexes and total sea lampreys taken in the Ocqueoc watershed in 1947

Date 1947	Location in watershed	Nature of specimens	Males: Number taken	Males: Average length in inches	Males: Average length in millimeters	Males: Average weight in grams	Females: Number taken	Females: Average length in inches	Females: Average length in millimeters	Females: Average weight in grams	Total ♂♂ and ♀♀ taken
May 14	Below Lower Falls	Migrants	3	16.8	427	159	3	19.1	485	2[illegible]8	6
17	" " "	"	3	17.8	452	218	2	17.3	439	202	5
26	" " "	"	...	...	...	...	1	(18.3)	(465)	(238)	1
May 29-June 1	Ocqueoc Lake	"	4	17.5	445	168	...	...	...	...	4
June 4	Below Lower Falls	Dead - unspawned	1	(16.3)	(414)	(118)	...	...	...	...	1
6	" " "	Migrants	9	15.4	391	187	1	(15.7)	(399)	(134)	10
June 7-10	Ocqueoc Lake	"	6	16.6	422	174	2	18.7	475	241	8
12	Below Lower Falls	"	37	16.2	412	151	44	16.8	427	177	81
14	" " "	"	17	17.0	432	149	18	16.3	414	149	35
June 14-16	Ocqueoc Lake	"	5	15.7	399	117	6	16.3	414	133	11
16	Lower Falls	"	114	16.1	409	152	97	16.2	412	158	211
17	" "	"	40	15.7	399	136	39	16.2	412	153	79
June 18-19	Ocqueoc Lake	"	13	15.7	399	128	14	16.5	419	149	27
20	Lower & Upper Falls	"	23	16.7	424	180	23	17.1	434	200	46
20	Lower River	Spawning or spent	11	15.6	396	180	4	17.4	442	240	15
June 20-21	Ocqueoc Lake	Migrants	4	17.2	437	181	1	(20.5)	(521)	(270)	5
21	Lower Falls	"	19	16.7	424	181	14	16.4	417	165	35
21	Lower River	Spawning or spent	14	16.0	406	182	16	15.4	391	161	30
22	Lower Falls	Migrants	2	15.7	399	134	2	17.9	455	192	4
24	Lower River	Spawning or spent	1	(16.6)	(422)	(208)	4	14.0	356	124	5
24	" "	Dead or dying	11	16.0	406	169	5	13.5	343	92	16
June 25-26	Ocqueoc Lake	Migrants	5	16.3	414	154	5	15.4	391	127	10
27	Lower River	Spawning or spent	6	16.1	409	195	...	...	...	...	6
28	" "	Dead or dying	4	16.5	419	202	5	14.5	368	129	9
29	" "	Spawning or spent	11	16.2	412	198	6	15.2	386	152	17
July 12-13	Ocqueoc Lake	Migrants	1	(14.7)	(373)	(103)	2	15.7	399	129	3
15	" "	"	...	...	...	...	1	(16.0)	(406)	(106)	1
Grand totals and averages			364	16.2	412	154[1]	315	16.3	414	165[2]	679

[1] Average based on migrant specimens only. Fifty-eight spawning, spent, dying or dead males not included.
[2] Average based on migrant specimens only. Forty spawning, spent, dying or dead females not included.

Table 12. Daily minimum, maximum, and mean water temperatures and water gauge readings for the Ocqueoc River with air temperatures for the locality: March 31-July 31, 1949.1/

Date 1947		Time	Water temperature (Degrees F.) Min.	Aver.	Max.	Water gauge2/	Mean air temperature (Degrees F.)
March	31	0930	34	36.0	38	15.00	40.0
April	1	1000	32	34.5	37	14.00	34.0
	2	0915	32	35.0	38	14.30	31.0
	3	1030	35	37.5	40	13.20	31.0
	4	0930	36	39.0	42	12.50	37.5
	5	1000	32	37.0	42	12.10	37.0
	6	0920	32	36.5	41	13.00	45.0
	7	0930	35	39.0	43	12.40	42.0
	8	1300	35	38.5	42	12.40	37.0
	9	0945	33	38.5	44	12.00	39.0
	10	0900	33	39.0	45	11.20	36.5
	11	0820	38	43.0	48	11.00	45.5
	12	0815	36	41.5	47	11.20	55.0
	13	0815	44	47.5	51	10.60	47.5
	14	0830	43	46.5	50	10.60	46.0
	15	0830	39	44.0	49	10.60	37.0
	16	0930	33	38.0	43	10.50	33.0
	17	0930	32	38.5	45	11.00	31.5
	18	0930	38	41.0	44	11.00	42.0
	19	0930	42	43.0	44	11.50	37.0
	20	1030	39	44.5	50	11.50	52.5
	21	1030	44	46.5	49	...	59.0
	22	1000	42	50.0	58	11.00	47.0
	23	0815	41	47.0	53	11.40	47.5
	24	0815	44	47.5	51	11.00	36.5
	25	0815	41	46.0	51	11.20	36.5
	26	0815	42	47.0	52	11.40	51.5
	27	0815	41	46.0	51	14.00	46.0
	28	0815	46	49.0	52	13.00	42.0
	29	0815	43	47.0	51	13.00	49.0
	30	1000	48	51.0	54	11.00	58.0
May	1	1000	52	54.5	57	10.50	62.5
	2	0930	52	55.0	58	11.00	58.5
	3	1030	53	54.5	56	11.00	54.0
	4	0945	53	57.0	61	10.50	73.0
	5	1015	56	62.0	68	10.50	61.0
	6	1015	...	64.0	...	11.00	64.5
	7	1030	57	61.5	66	10.00	58.5
	8	0915	47	54.5	62	11.00	52.0
	9	0900	52	59.0	66	10.10	56.0
	10	0900	54	58.5	63	9.40	47.5
	11	0915	44	53.5	63	10.10	40.0
	12	0900	46	52.0	58	9.60	46.0
	13	0930	43	53.0	63	10.00	56.5
	14	1000	47	53.0	59	10.50	58.0
	15	1000	46	53.5	61	10.50	43.0
	16	0930	46	54.0	62	10.50	53.0
	17	1030	54	58.5	63	10.25	58.5
	18	1015	54	58.0	62	10.00	63.5
	19	1030	50	58.0	66	11.00	66.0
	20	1015	49	55.0	61	14.00	46.5
	21	1000	48	53.0	58	13.50	45.0
	22	0915	52	57.5	63	12.50	56.5
	23	0930	40	50.0	60	12.50	54.5
	24	0915	51	57.0	63	12.00	62.0
	25	1000	49	54.5	60	11.50	45.5
	26	0915	49	53.5	58	11.00	47.0
	27	0900	45	51.0	57	11.00	45.0
	28	1000	48	54.0	60	11.00	43.0
	29	1100	51	54.5	58	10.50	50.5
	30	1000	52	56.5	61	10.50	55.0
	31	1000	53	57.5	62	10.00	52.5

Continued next page

Date 1947		Time	Water temperature (Degrees F.) Min.	Aver.	Max.	Water gauge[2]	Mean air temperature (Degrees F.)
June	1	0900	55	60.0	65	9.50	60.0
	2	0945	57	62.5	68	9.50	69.0
	3	0930	60	65.0	70	9.50	76.0
	4	0900	58	65.5	73	9.00	67.0
	5	0900	62	68.0	74	8.75	65.5
	6	0830	57	64.5	72	9.00	63.0
	7	0900	59	65.0	71	8.50	57.0
	8	0930	56	62.0	68	8.00	45.0
	9	0915	58	63.5	69	7.50	52.0
	10	0945	59	64.5	70	7.00	61.5
	11	0930	62	67.0	72	7.25	64.0
	12	0940	62	68.5	75	7.25	77.0
	13	1010	67	71.0	75	6.25	80.5
	14	0940	68	71.5	75	8.50	71.0
	15	0920	68	70.0	72	10.50	63.5
	16	0830	66	68.0	70	9.75	58.0
	17	0900	65	66.5	68	9.75	61.0
	18	0910	65	68.0	71	9.75	69.0
	19	0900	55	65.5	76	9.25	66.0
	20	0930	66	70.0	74	8.25	66.5
	21	0930	68	72.0	76	8.25	74.5
	22	0925	65	70.0	75	10.25	64.0
	23	0915	66	71.0	76	9.75	65.5
	24	0915	67	68.5	70	9.75	66.0
	25	1000	67	70.5	74	11.00	72.5
	26	0930	68	70.0	72	16.00	72.0
	27	1000	66	70.0	74	13.75	70.0
	28	...	...	...	...	...	...
	29	0915	69	72.5	76	11.50	70.5
	30	1015	69	73.0	77	10.00	72.5
July	1	0900	70	75.0	80	10.00	72.5
	2	1000	73	80.0	87	10.00	72.0
	3	0915	73	78.5	84	10.00	74.5
	4	0915	73	77.5	82	11.00	79.0
	5	0930	68	75.0	82	11.25	73.0
	6	0945	70	71.0	72	9.00	74.0
	7	0845	65	70.5	76	8.50	69.0
	8	1000	66	71.5	77	9.00	70.5
	9	0830	67	72.5	78	9.50	70.5
	10	0820	64	65.5	67	10.00	65.0
	11	0915	63	69.5	76	9.25	60.5
	12	1030	64	70.0	76	9.25	67.5
	13	0900	66	71.0	76	9.00	67.0
	14	0915	65	71.0	77	9.25	65.0
	15	0915	67	71.5	76	10.75	65.5
	16	0900	67	71.5	76	9.00	67.0
	17	0900	66	72.0	78	9.00	71.5
	18	0930	69	74.0	79	10.00	74.5
	19	0815	68	74.5	81	8.50	79.0
	20	0900	68	74.0	80	8.00	68.0
	21	0830	67	72.0	77	9.75	61.5
	22	0900	66	71.0	76	8.00	74.5
	23	0830	63	70.0	77	9.50	74.5
	24	0830	64	71.0	78	8.00	67.0
	25	0900	66	71.0	76	10.00	75.5
	26	0915	69	74.0	79	8.00	77.5
	27	0830	74	78.0	82	8.50	82.0
	28	0825	73	78.0	83	9.50	80.0
	29	0820	72	78.5	85	9.75	79.5
	30	0820	72	78.0	84	9.50	73.0
	31	0820	67	71.0	75	9.50	72.0

1/ All temperature data obtained at station on weir structure.
2/ Water gauge readings are in inches and represent absolute depth of water passing over the deck of the weir.

Table 13. Number and average length by sexes of samples taken on alternate days and total sea lampreys taken in the Ocqueoc River by dates and by cumulative periods in 1949.

Date 1949		Males: Number taken	Males: Number measured	Males: Average length in inches	Males: Average length in millimeters	Females: Number taken	Females: Number measured	Females: Average length in inches	Females: Average length in millimeters	Total ♂♂ and ♀♀ taken
March 31-April 25 (Weir operation continuous - no lampreys taken)										
April	26	0	...	...	...	0	...	...	...	0
	27	0	...	...	...	0	...	...	...	0
	28	16	16	19.0	483	5	5	19.2	488	21
	29	21	...	...	...	11	...	...	...	32
	30	145	145	17.5	445	74	74	17.9	455	219
April	26-30	182	161	17.7	450	90	79	18.0	457	272
May	1	145	...	...	...	61	...	...	...	206
	2	664	133	17.3	439	234	69	17.4	442	898
	3	425	...	...	...	207	...	...	...	632
	4	1,693	61	17.2	437	783	39	17.5	445	2 476
	5	1,262	...	...	...	536	...	...	...	1,798
	6	1,365	71	16.8	427	636	29	17.0	432	2,001
	7	591	...	...	...	272	...	...	...	863
	8	361	70	18.3	465	168	30	18.0	457	529
	9	343	...	...	...	163	...	...	...	506
	10	413	132	17.6	447	182	68	17.8	452	595
May	1-10	7,262	467	17.4	442	3,242	235	17.6	447	10,504
May	11	185	...	...	...	61	...	...	...	246
	12	52	52	17.7	450	22	22	18.1	460	74
	13	119	...	...	...	57	...	...	...	176
	14	104	104	17.4	442	54	54	17.5	445	158
	15	110	...	...	...	46	...	...	...	156
	16	101	68	17.7	450	46	34	18.2	462	147
	17	342	...	...	...	177	...	...	...	519
	18	436	65	17.2	437	208	35	17.3	439	644
	19	1,206	...	...	...	578	...	...	...	1,784
	20	270	67	16.9	429	131	32	17.2	437	401
May	11-20	2,925	356	17.4	442	1,380	177	17.7	450	4,305
May	21	235	...	...	...	109	...	...	...	344
	22	293	139	16.6	422	171	69	17.1	434	464
	23	195	...	...	...	82	...	...	...	277
	24	424	139	16.9	429	199	63	17.4	442	623
	25	561	...	...	...	217	...	...	...	778
	26	254	139	17.5	445	75	44	17.8	452	329
	27	160	...	...	...	58	...	...	...	218
	28	46	45	17.8	452	15	15	18.4	467	61
	29	131	...	...	...	34	...	...	...	165
	30	325	142	17.1	434	144	63	17.5	445	469
May	21-30	2,624	604	17.1	434	1,104	254	17.5	445	3,728
May	31	512	...	...	...	232	...	...	...	744
June	1	639	149	16.6	422	307	69	16.9	429	946
	2	633	...	...	...	362	...	...	...	995
	3	192	137	16.3	414	105	75	16.5	419	297
	4	89	...	...	...	49	...	...	...	138
	5	209	106	16.9	429	123	58	16.9	429	332
	6	171	...	...	...	81	...	...	...	252
	7	255	83	16.8	427	130	52	17.1	434	385
	8	170	...	...	...	102	...	...	...	272
	9	77	77	16.8	427	48	48	17.0	432	125
May 31-June 9		2,947	552	16.6	422	1,539	302	16.8	427	4,486
June	10	27	...	...	...	26	...	...	...	53
	11	40	40	17.1	434	19	19	16.8	427	59
	12	37	...	...	...	25	...	...	...	62
	13	22	22	17.1	434	15	14	16.8	427	37
	14	26	...	...	...	18	...	...	...	44
	15	93	92	16.6	422	46	46	16.4	417	139
	16	87	...	...	...	39	...	...	...	126
	17	81	79	17.1	434	38	38	16.7	424	119
	18	48	...	...	...	32	...	...	...	80
	19	62	62	16.6	422	30	30	16.7	424	92
June	10-19	523	295	16.8	427	288	147	16.6	422	811

Continued next page

Date 1949	Males: Number taken	Males: Number measured	Males: Average length in inches	Males: Average length in millimeters	Females: Number taken	Females: Number measured	Females: Average length in inches	Females: Average length in millimeters	Total ♂♂ and ♀♀ taken
June 20	52	...	...	...	20	...	...	...	72
21	33	33	16.6	422	21	21	16.4	417	54
22	48	...	...	...	45	...	...	...	93
23	38	38	17.1	434	19	19	16.3	414	57
24	24	...	...	...	17	...	...	...	41
25	10	10	16.8	427	6	6	15.6	396	16
26	11	...	...	...	5	...	...	...	16
27	10	10	17.2	437	7	7	15.5	394	17
28	14	...	...	...	9	...	...	...	23
29	14	14	15.6	396	3	3	15.2	386	17
June 20-29	254	105	16.7	424	152	56	16.1	409	406
June 30	16	...	...	...	12	...	...	...	28
July 1	11	11	15.2	386	4	3	15.0	381	15
2	4	...	...	...	3	...	...	...	7
3	4	4	15.8	401	0	...	...	...	4
4	0	...	...	...	0	...	...	...	0
5	2	2	16.4	417	4	4	16.6	422	6
6	2	...	...	...	0	...	...	...	2
7	2	2	16.3	414	0	...	...	...	2
8	0	...	...	...	1	...	...	...	1
9	1	1	(15.8)	(401)	1	1	(15.0)	(381)	2
June 30-July 9	42	20	15.6	396	25	8	15.8	401	67
July 10	1	...	...	...	1	...	...	...	2
11	8	8	16.0	406	3	3	13.8	351	11
12	6	...	...	...	8	...	...	...	14
13	0	...	...	...	1	1	(15.5)	(394)	1
14	6	...	...	...	4	...	...	...	10
15	0	...	...	...	0	...	...	...	0
16	0	...	...	...	0	...	...	...	0
17	0	...	...	...	0	...	...	...	0
18	0	...	...	...	0	...	...	...	0
19	0	...	...	...	0	...	...	...	0
July 10-19	21	8	16.0	406	17	4	14.2	361	38
July 20	0	...	...	...	0	...	...	...	0
21	1	...	...	...	2	...	...	...	3
22	0	...	...	...	1	...	...	...	1
23	0	...	...	...	0	...	...	...	0
24	1	...	...	...	0	...	...	...	1
25	3	...	...	...	0	...	...	...	3
26	1	...	...	...	0	...	...	...	1
27	0	...	...	...	0	...	...	...	0
28	0	...	...	...	0	...	...	...	0
29	0	...	...	...	0	...	...	...	0
July 20-29	6	0	...	...	3	0	...	...	9
July 30	0	...	...	...	1	...	...	...	1
August 1	1	...	...	...	1	...	...	...	2
6	0	...	...	...	1	...	...	...	1
11	1	...	...	...	0	...	...	...	1
19	0	...	...	...	1	...	...	...	1
22	1	...	...	...	0	...	...	...	1
24	1	...	...	...	0	...	...	...	1
30	1	...	...	...	0	...	...	...	1
31	1	...	...	...	0	...	...	...	1
Sept. 2	1	...	...	...	0	...	...	...	1
7	1	...	...	...	0	...	...	...	1
10	0	...	...	...	1	...	...	...	1
11	1	...	...	...	0	...	...	...	1
21	1	...	...	...	0	...	...	...	1
23	1	...	...	...	0	...	...	...	1
24	1	...	...	...	0	...	...	...	1
July 30-Sept. 30	12	...	...	...	5	...	...	...	17
Totals and grand averages	16,798	2,568[1]	17.0	432	7,845	1,262[1]	17.2	437	24,643

[1] Samples obtained for length data constitute 15.6 percent of all sea lampreys taken.

APPENDIX D

Table 1. Numbers and kinds of fish other than sea lampreys taken in the Carp Creek weir summarized by semi-monthly periods: April 25-July 15, 1947.
(upstream migrants)

Species[1]	April 25-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	Total number of each species taken
Rainbow trout	7	3	1	5	1	0	17
Brook trout	0	0	1	0	0	0	1
Brown trout	0	0	1	0	0	0	1
Northern pike	3	2	0	0	0	0	5
Rock bass	2	2	14	49	31	6	104
Smelt	471	56	11	0	0	0	538
White suckers	8	26	1,391	1,825	122	176	3,548
Redhorse suckers	5	0	143	4	0	0	152
Black bullheads	0	2	25	37	17	8	89
Lake chubs	119	1,539	1,988	493	8	0	4,147
Great Lakes longnose dace	0	200	448	151	5	0	804
Common shiners	5	16	60	27	20	10	138
Creek chubs	0	0	1	0	0	0	1
Hornyhead chubs	0	3	1	0	0	0	4
Finescale dace	0	6	23	0	0	0	29
Horned dace	0	0	1	0	0	0	1
Muddlers	0	0	1	0	0	0	1
Mudminnows	0	1	0	0	0	0	1
Johnny darters	0	0	1	0	1	0	2
Silver lampreys	0	0	1	1	0	0	2
Grand total							9,585

[1] Also taken during the weir operation were one painted turtle (Chrysemys picta), two snapping turtles (Chelydra serpentina), and one water snake (Natrix s. sipedon).

APPENDIX D

Table 2. Numbers and kinds of fish other than sea lampreys taken in the Carp Creek weir summarized by semi-monthly periods: April 7-July 15, 1948.
(upstream migrants)

Species[1]	Numbers of fish taken in semi-monthly periods							Total number of each species taken
	April		May		June		July	
	7-15	16-30	1-15	16-31	1-15	16-30	1-15	
Rainbow trout	0	9	1	0	0	0	0	10
Brook trout	0	0	1	0	0	0	0	1
Rock bass	0	2	10	64	20	0	0	96
Smelt	0	17,405	462	14	0	0	0	17,881
White suckers	1	778	871	859	320	0	0	2,829
Redhorse suckers	0	12	6	1	0	0	0	19
Black bullheads	0	1	3	12	1	0	0	17
Lake chubs	0	299	2,727	4,197	55	3	0	7,281
Great Lakes longnose dace	0	3,042	2,257	356	116	25	2	5,798
Common shiners	0	163	105	249	50	14	0	581
Creek chubs	0	0	17	1	0	0	0	18
Hornyhead chubs	0	15	9	1	0	0	0	25
Finescale dace	0	5	16	8	0	3	0	32
Sticklebacks	0	11	7	1	0	8	2	29
Muddlers	0	6	4	12	5	2	0	29
Johnny darters	0	0	0	0	0	1	1	2
Unidentified	0	0	0	1	0	0	0	1
Silver lampreys	0	1	2	3	1	0	0	7
Grand total								34,656

[1] Also taken during the weir operation were one painted turtle (Chrysemys picta) and one water snake (Natrix s. sipedon).

APPENDIX D

Table 3. Numbers and kinds of fish other than sea lampreys taken in the Carp Creek weir summarized by semi-monthly periods: April 6-July 18, 1949. (upstream migrants)

Species[1]	April 6-15	April 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-18	Total number of each species taken
Rainbow trout	0	3	2	0	1	0	0	6
Brook trout	0	1	1	1	0	2	0	5
Brown trout	0	0	2	0	0	0	0	2
Northern pike	1	0	0	0	0	0	0	1
Smallmouth bass	0	0	0	0	0	2	0	2
Rock bass	0	0	7	19	11	6	2	45
Yellow perch	2	4	1	1	0	0	0	8
Smelt	275	10,386	62	0	0	0	0	10,723
White suckers	0	90	606	766	71	277	0	1,810
Redhorse suckers	0	1	0	0	0	0	0	1
Black bullheads	0	0	1	4	12	18	6	41
Lake chubs	2	131	219	475	32	1	0	860
Great Lakes longnose dace	534	8,287	6,435	302	79	57	0	15,694
Common shiners	21	37	167	146	78	44	19	512
Creek chubs	2	1	1	1	0	0	0	5
Sticklebacks	1	5	0	0	0	0	0	6
Muddlers	18	42	16	18	8	0	0	102
Unidentified	4	9	16	1	0	3	0	33
Grand total								29,856

[1] Also taken during the weir operation were two painted turtles (*Chrysemys picta*) and five snapping turtles (*Chelydra serpentina*).

APPENDIX D

Table 4. Numbers and kinds of fish other than sea lampreys taken in the Ocqueoc River weir summarized by semi-monthly periods: April 1-July 15, 1949. (upstream migrants)

Species	Numbers of fish taken in semi-monthly periods							Total number of each species taken
	April		May		June		July	
	1-15	16-30	1-15	16-31	1-15	16-30	1-15	
Rainbow trout	0	37	39	16	10	1	1	104
Brook trout	1	0	2	1	2	0	0	6
Northern pike	1	0	2	1	0	0	0	4
Smallmouth bass	0	0	10	36	39	14	3	102
Rock bass	0	0	3	6	19	6	4	38
Bluegill sunfish	0	0	0	0	0	0	6	6
Yellow perch	0	1	13	13	2	0	0	29
Smelt	0	72	0	0	0	0	0	72
White suckers	13	406	1,305	753	69	3	0	2,549
Redhorse suckers	0	282	324	0	0	2	0	608
Black bullheads	0	0	0	1	25	36	81	143
Bowfin	0	0	0	0	0	0	1	1
Lake chubs	0	2	11	13	2	1	0	29
Great Lakes longnose dace	0	61	4,202	757	747	158	1	5,926
Common shiners	0	0	69	63	61	13	2	208
Log perch	0	0	6	9	11	4	0	30
Unidentified	0	0	3	0	6	0	1	10
Grand total								9,865

APPENDIX D

Table 5. Numbers and kinds of fish other than sea lampreys taken in the Ocqueoc River weir summarized by semi-monthly periods: April 1-July 15, 1949.
(downstream migrants)

Species	Numbers of fish taken in semi-monthly periods							Total number of each species taken
	April		May		June		July	
	1-15	16-30	1-15	16-31	1-15	16-30	1-15	
Rainbow trout	0	4	7	14	1	3	1	30
Northern pike	17	4	0	0	0	0	0	21
Smallmouth bass	1	2	0	5	16	19	3	46
Largemouth bass	0	0	1	0	0	0	0	1
Rock bass	1	11	26	20	19	4	2	83
Bluegill sunfish	0	5	0	0	0	0	1	6
Yellow perch	7	34	966	602	54	6	2	1,671
Smelt	1	2	0	0	0	0	0	3
White suckers	1	12	74	98	205	416	126	932
Redhorse suckers	0	26	96	133	27	11	7	300
Black bullheads	1	1	2	0	1	1	3	9
Sea eel	0	0	0	1	0	0	0	1
Lake chubs	3	3	3	1	0	0	0	10
Great Lakes longnose dace	0	0	9	1	9	0	0	19
Common shiner	0	1	34	7	2	1	0	45
Log perch	0	0	0	1	0	0	0	1
Unidentified	0	0	0	12	8	0	0	20
Grand total								3,198

APPENDIX B

Table 1. Length-frequency table for sea lampreys collected in Carp Creek, Presque Isle County, in 1947, 1948, and 1949. (Data presented by 0.2-inch size groups).

Midpoint of length group (inches)	1947 Run			1948 Run			1949 Run		
	Males	Females	Sexes combined	Males	Females	Sexes combined	Males	Females	Sexes combined
11.0	...	...	...	1	...	1	...	...	...
.2	...	...	...	1	...	1	...	...	...
.4	...	...	...	...	...	...	...	...	...
.6	...	...	...	...	...	...	...	...	...
.8	...	...	...	1	...	1	...	...	...
12.0	...	1	1	...	1	1	...	...	...
.2	...	...	...	2	...	2	...	...	...
.4	...	...	...	...	...	...	...	...	...
.6	...	1	1	1	2	3	1	...	1
.8	...	...	...	4	1	5	...	...	...
13.0	1	...	1	9	1	10	2	1	3
.2	3	...	3	3	...	3	1	1	2
.4	2	1	3	8	3	11	3	...	3
.6	...	2	2	11	5	16	3	1	4
.8	1	3	4	19	5	24	4	1	5
14.0	6	1	7	17	6	23	4	1	5
.2	4	2	6	13	13	26	8	1	9
.4	5	4	9	26	14	40	9	4	13
.6	9	6	15	24	21	45	23	3	26
.8	8	7	15	37	18	55	22	2	24
15.0	16	10	26	59	40	99	28	6	34
.2	16	12	28	57	22	79	23	8	31
.4	22	8	30	60	41	101	31	12	43
.6	27	22	49	75	40	115	42	19	61
.8	35	18	53	117	55	172	28	12	40
16.0	32	20	52	115	78	193	50	15	65
.2	29	26	55	55	30	85	41	25	66
.4	50	28	78	95	58	153	45	21	66
.6	36	31	67	94	48	142	58	30	88
.8	45	22	67	103	51	154	38	15	53
17.0	75	42	117	103	62	165	61	27	88
.2	52	26	78	69	38	107	44	19	63
.4	40	26	66	91	53	144	29	27	56
.6	68	27	95	81	46	127	50	27	77
.8	43	30	73	78	42	120	38	14	52
18.0	47	20	67	85	43	128	33	27	60
.2	28	25	53	39	21	60	24	16	40
.4	43	22	65	63	44	107	27	12	39
.6	45	23	68	37	34	71	25	10	35
.8	39	29	68	31	32	63	21	17	38
19.0	28	17	45	32	24	56	22	30	52
.2	27	17	44	23	12	35	15	11	26
.4	20	13	33	22	16	38	10	11	21
.6	20	15	35	18	15	33	8	12	20
.8	19	9	28	19	18	37	10	9	19
20.0	10	7	17	11	16	27	8	7	15
.2	13	4	17	7	3	10	4	3	7
.4	11	7	18	5	5	10	1	7	8
.6	6	6	12	4	2	6	6	4	10
.8	4	3	7	6	...	6	6	2	8
21.0	...	3	3	4	3	7	4	2	6
.2	1	...	1	3	1	4	1	1	2
.4	2	1	3	1	1	2	...	...	...
.6	3	2	5	...	2	2	...	...	...
.8	2	...	2	1	1	2	2	...	2
22.0	1	1	2	...	...	...	...	...	...
.2	2	1	3	...	...	...	...	...	...
.4	1	1	2	...	2	2	1	...	1
.6	...	1	1	...	...	...	...	...	...
.8	...	...	...	...	...	...	...	...	...
23.0	...	...	...	...	...	...	...	...	...
.2	...	...	...	...	...	...	...	...	...
.4	...	...	...	1	...	1	...	...	...
.6	...	...	...	...	...	...	...	...	...
Totals	997	603	1,600	1,841	1,089	2,930	914[1]	473[2]	1,387
Mean length	17.4	17.4	17.4	16.7	16.9	16.8	16.9	17.4	17.1
Standard deviation	±1.52	±1.60	±1.55	±1.53	±1.57	±1.55	±1.53	±1.51	±1.55

[1] Includes 15 specimens taken at random on other than regular sampling dates. Total specimens measured constitute 49.0 percent of all males taken.
[2] Includes 1 specimen taken at random on other than regular sampling dates. Total specimens measured constitute 52.7 percent of all females taken.

APPENDIX E

Table 2. Length-frequency table for sea lampreys collected in the Ocqueoc River, Presque Isle County, in 1947 and 1949. (Data presented by 0.2-inch size groups).

Midpoint of length group (inches)	1947 Run			1949 Run		
	Males	Females	Sexes combined	Males	Females	Sexes combined
11.0	...	...	...	...	...	...
.2	...	...	...	...	...	...
.4	...	...	...	...	1	1
.6	...	...	...	...	...	...
.8	...	...	...	...	...	...
12.0	...	1	1	1	...	1
.2	...	...	...	4	...	4
.4	...	...	...	...	...	...
.6	1	1	2	3	5	8
.8	...	...	...	3	...	3
13.0	...	2	2	6	2	8
.2	3	6	9	7	1	8
.4	1	1	2	10	1	11
.6	2	1	3	12	1	13
.8	5	2	7	18	9	27
14.0	3	2	5	28	10	38
.2	9	4	13	24	12	36
.4	12	9	21	34	11	45
.6	12	7	19	37	29	66
.8	13	18	31	40	21	61
15.0	16	8	24	78	34	112
.2	19	18	37	83	34	117
.4	16	12	28	71	30	101
.6	21	20	41	100	50	150
.8	21	12	33	100	55	155
16.0	21	26	47	132	48	130
.2	21	10	31	90	43	133
.4	19	17	36	92	54	146
.6	21	15	36	139	57	196
.8	19	16	35	105	51	156
17.0	13	10	23	134	64	198
.2	20	15	35	100	50	150
.4	15	14	29	111	60	171
.6	5	9	14	120	57	177
.8	16	10	26	102	54	156
18.0	9	8	17	111	63	174
.2	10	7	17	81	43	124
.4	6	6	12	73	40	113
.6	3	4	7	96	38	134
.8	4	4	8	68	34	102
19.0	6	6	12	76	43	119
.2	1	3	4	54	21	75
.4	1	4	5	36	36	72
.6	...	1	1	53	28	81
.8	...	3	3	29	18	47
20.0	...	1	1	37	22	59
.2	...	...	...	29	11	40
.4	...	...	...	17	8	25
.6	...	1	1	13	13	26
.8	...	...	...	6	8	14
21.0	...	...	...	8	4	12
.2	...	1	1	11	4	15
.4	...	...	...	5	1	6
.6	...	...	...	4	3	7
.8	...	...	...	2	3	5
22.0	...	...	...	3	1	4
.2	...	...	...	1	...	1
.4	...	...	...	...	...	...
.6	...	...	...	...	1	1
.8	...	...	...	...	...	...
23.0	...	...	...	...	...	...
Totals	364	315	679	2,597 [1]	1,287 [2]	3,884
Mean length	16.2	16.3	...	17.0	17.2	17.1
Standard deviation	...	...	...	±1.68	±1.67	±1.69

[1] Includes 29 male sea lampreys not shown in Table 13, Appendix C.
[2] Includes 25 female sea lampreys not shown in Table 13, Appendix C.

APPENDIX E

Table 3. Weight-frequency table for 1,599 sea lampreys collected in the Carp Creek weir, Presque Isle County, in 1947.

Weight group (10-gram intervals)	Males	Females	Sexes combined
50 - 59	1	...	1
60 - 69	...	1	1
70 - 79	1	1	2
80 - 89	5	4	9
90 - 99	10	7	17
100 - 109	22	12	34
110 - 119	32	18	50
120 - 129	40	23	63
130 - 139	71	47	118
140 - 149	79	40	119
150 - 159	98	59	157
160 - 169	101	48	149
170 - 179	87	46	133
180 - 189	85	42	127
190 - 199	60	39	99
200 - 209	55	28	83
210 - 219	42	37	79
220 - 229	42	33	75
230 - 239	38	26	64
240 - 249	31	20	51
250 - 259	27	12	39
260 - 269	16	11	27
270 - 279	10	14	24
280 - 289	10	8	18
290 - 299	9	7	16
300 - 309	10	5	15
310 - 319	3	7	10
320 - 329	3	3	6
330 - 339	1	1	2
340 - 349	2	1	3
350 - 359	1	...	1
360 - 369	1	...	1
370 - 379	1	1	2
380 - 389	1	...	1
390 - 399	...	...	...
400 - 409	1	1	2
410 - 419	...	...	...
420 - 429	...	...	...
430 - 439	...	1	1
Totals	996	603	1,599

Table 4. Length-weight relationship of migrating sea lampreys taken in Carp Creek and the Ocqueoc River, Presque Isle County, in 1947.

Total length in inches (by 0.2-inch length groups)	Males			Females		
	Number of specimens	Average weight Grams	Average weight Ounces	Number of specimens	Average weight Grams	Average weight Ounces
12.0	...	...	...	1	75	2.6
.2	...	...	...	...	...	...
.4	...	...	...	...	...	...
.6	...	...	...	2	66	2.3
.8	...	...	...	...	...	...
13.0	1	85	3.0	...	...	...
.2	5	90	3.2	3	100	3.5
.4	2	78	2.8	1	81	2.9
.6	2	88	3.1	2	130	4.6
.8	6	100	3.5	5	93	3.3
14.0	7	103	3.6	3	93	3.2
.2	12	99	3.3	5	123	4.3
.4	17	105	3.7	12	110	3.9
.6	18	121	4.3	11	114	4.0
.8	21	117	4.1	18	117	4.1
15.0	28	124	4.4	18	128	4.5
.2	32	121	4.3	23	123	4.3
.4	34	137	4.8	19	128	4.5
.6	45	132	4.7	37	133	4.6
.8	55	139	4.9	30	137	4.8
16.0	50	143	4.9	45	153	5.4
.2	47	145	5.1	36	150	5.3
.4	67	153	5.4	42	155	5.5
.6	50	162	5.7	46	157	5.6
.8	63	163	5.7	38	163	5.7
17.0	83	162	5.7	52	173	6.1
.2	70	171	6.0	41	177	6.2
.4	52	174	6.1	38	181	6.4
.6	73	182	6.4	36	184	6.5
.8	55	191	6.7	39	191	6.7
18.0	54	187	6.6	27	197	6.9
.2	37	198	7.0	31	209	7.4
.4	48	206	7.3	28	222	7.8
.6	48	219	7.7	27	225	7.9
.8	43	213	7.5	33	221	7.8
19.0	34	226	8.0	23	229	8.1
.2	28	237	8.4	20	243	8.5
.4	21	240	8.4	17	263	9.3
.6	20	250	8.8	16	252	8.9
.8	19	252	8.9	12	264	9.3
20.0	10	256	9.0	8	266	9.4
.2	13	271	9.6	4	266	9.4
.4	11	264	9.3	8	278	9.8
.6	6	277	9.8	7	274	9.7
.8	4	295	10.4	3	251	8.8
21.0	...	...	...	3	330	11.6
.2	1	284	10.0	1	316	11.2
.4	2	300	10.6	...	...	...
.6	3	350	12.3	2	361	12.7
.8	2	320	11.3	...	...	...
22.0	1	400	14.1	1	374	13.2
.2	2	359	12.7	1	254	8.9
.4	1	385	13.6	1	318	11.2
.6	...	...	...	1	436	15.4
.8	...	...	...	...	...	...
23.0	...	...	...	...	...	...
Totals	1,303	...	...	877	...	...

APPENDIX F

Table 1. Egg production of 10 female sea lampreys as determined by numerical counts, compared with values as determined volumetrically and gravimetrically from sample sections of the ovaries

Specimen data										
(1) Specimen number	#60	#58	#57	#70	#44	#73	#56	#23	#66	#63
(2) Place of capture	Ocqueoc River	Carp Creek	Carp Creek	Carp Creek	Carp Creek	Carp Creek	Carp Creek	Carp Creek	Cheboygan River	Ocqueoc River
(3) Date	6/16/47	6/15/47	6/15/47	6/26/47	6/11/47	7/2/47	6/15/47	5/25/47	6/26/47	6/20/47
(4) Total length in inches	12.6	14.2	14.9	15.0	16.3	17.0	17.1	17.5	18.0	21.1
(5) Total length in millimeters	320	361	378	381	414	432	434	445	457	536
(6) Weight in grams	70	100	137	128	182	178	165	168	236	316
(7) Total eggs by numerical count	23,986	21,000	48,694	66,537	53,012	67,604	59,185	55,486	69,736	107,138
(8) Total eggs in sample section, by actual count	1,343	1,962	9,372	8,594	8,929	6,951	3,470	3,684	6,686	5,703
(9) Total volume of ovary (cc.)	12.5	13.6	34.8	37.6	37.9	55.5	46.7	28.2	66.3	76.9
(10) Volume of sample section (cc.)	0.7	1.3	6.6	4.4	6.0	5.2	2.7	2.0	6.0	3.9
(11) Calculated number of eggs	23,982	20,526	49,416	73,440	56,402	74,189	60,018	51,944	73,880	112,451
(12) Percentage error	0.0	-2.3	+1.5	+10.4	+6.4	+9.7	+1.4	-6.4	+5.9	+5.0
(13) Total weight of ovary (grams)	13.50	13.93	32.49	34.86	36.30	51.55	45.97	28.81	65.18	73.44
(14) Weight of sample section (grams)	0.68	1.30	5.70	4.56	5.93	5.15	2.72	1.97	6.11	3.86
(15) Calculated number of eggs	26,662	21,024	53,420	65,699	54,658	69,577	58,646	53,876	71,325	108,505
(16) Percentage error	+11.1	0.0	+9.7	-1.3	+3.1	+2.9	-0.9	-2.9	+2.3	+1.3
(17) Egg production of specimen[1]	24,021	21,000	48,694	66,552	53,026	67,617	59,198	55,491	69,806	107,138

[1] Where these figures differ slightly from actual numerical counts listed on Line 7, it is due to addition of a small number of eggs not preserved, but counted, at time of collection.

Table 2. Data on size, weight and egg production for 70 sea lampreys with weights of ovaries and calculated number of eggs produced.

Specimen number	Total length (inches)	Total length (millimeters)	Total weight (grams)	Weight of ovary (grams)	Calculated egg production	Correction[2]	Total egg production
60	12.6	320	70	13.50	...	...	24,021[1]
61	12.6	320	61	11.88	31,162	44	31,206
28	13.4	340	81	11.31	41,959	37	41,996
37	13.7	348	101	13.90	36,372	16	36,388
59	13.9	353	90	20.65	46,387	51	46,438
58	14.2	361	100	13.93	...	...	21,000[1]
21	14.4	366	104	6.62	42,103	19	42,122
16	14.6	371	129	14.67	37,735	40	37,775
53	14.6	371	100	21.85	50,449	22	50,471
31	14.6	371	137	19.56	55,898	56	55,954
54	14.7	373	92	16.32	37,445	24	37,469
49	14.7	373	99	22.98	41,910	6	41,916
57	14.9	378	137	32.49	...	...	48,694[1]
13	15.0	381	122	15.75	46,622	8	46,630
70	15.0	381	128	34.86	...	...	66,552[1]
7	15.1	384	135	12.97	38,335	0	38,335
3	15.3	389	110	10.37	45,776	0	45,776
55	15.5	394	110	20.20	38,294	8	38,302
51	15.5	394	136	38.97	46,266	15	46,281
38	15.5	394	179	31.85	74,917	55	74,972
46	15.9	404	132	26.46	48,875	5	48,880
47	16.0	406	150	31.38	44,203	2	44,205
34	16.1	409	137	18.90	46,417	10	46,427
48	16.2	411	160	38.66	57,954	9	57,963
44	16.3	414	182	36.30	...	...	53,026[1]
15	16.4	417	142	16.98	61,023	0	61,023
1	16.7	424	149	16.43	57,519	20	57,539
52	16.8	427	158	43.65	69,236	1	69,237
22	16.9	429	143	20.55	43,784	24	43,808
26	17.0	432	170	19.65	43,976	34	44,010
19	17.0	432	151	22.52	65,953	18	65,971
73	17.0	432	178	51.55	...	...	67,617[1]
56	17.1	434	165	45.97	...	...	59,198[1]
4	17.2	437	134	13.40	48,183	17	48,200
36	17.2	437	246	36.17	52,569	2	52,571
14	17.2	437	165	23.10	59,663	11	59,674
18	17.2	437	175	21.93	61,970	2	61,972
2	17.2	437	222	22.97	80,440	0	80,440
9	17.3	439	155	13.70	58,423	0	58,423
69	17.3	439	176	33.82	69,657	51	69,708
27	17.3	439	198	31.38	82,373	16	82,389
23	17.5	445	168	28.81	...	...	55,491[1]
12	17.8	452	182	14.55	55,801	12	55,813
66	18.0	457	236	65.18	...	...	69,806[1]
68	18.0	457	216	40.41	73,688	0	73,688
35	18.0	457	253	40.28	84,330	34	84,364
41	18.0	457	228	49.52	91,373	21	91,394
40	18.1	460	216	48.61	77,425	0	77,425
65	18.2	462	222	65.45	83,261	72	83,333
5	18.4	467	179	14.72	47,670	48	47,718
50	18.4	467	198	47.02	60,912	3	60,915
20	18.5	470	236	45.54	80,135	8	80,143
11	18.6	472	183	13.52	61,821	37	61,858
32	18.6	472	251	40.32	77,898	9	77,907
6	19.0	483	202	26.92	53,147	0	53,147
42	19.0	483	186	30.04	60,675	25	60,700
8	19.0	483	226	35.82	73,501	0	73,501
67	19.0	483	283	77.95	86,829	15	86,844
39	19.2	488	277	54.45	77,481	5	77,486
30	19.4	493	303	58.53	79,934	14	79,948
29	19.6	498	285	49.02	73,101	10	73,111
45	19.6	498	262	35.55	91,414	18	91,432
33	19.7	500	231	32.78	82,299	21	82,320
24	19.7	500	285	56.67	97,263	25	97,288
10	19.8	503	240	26.31	76,830	6	76,836
17	20.2	513	328	48.31	93,881	16	93,897
43	20.3	516	296	56.72	87,118	12	87,130
25	20.5	521	221	37.00	76,223	12	76,235
62	20.5	521	270	59.55	94,515	11	94,526
63	21.1	536	316	73.44	...	...	107,138[1]

[1] Total number of eggs determined by numerical count (see Table 1, Appendix F).
[2] Number of eggs not preserved at time of collection.

Table 3. Number of unspawned eggs (developed and partially developed) in 40 spent and dead or dying sea lampreys and estimated percentage of potential egg production unspawned for each individual.

Specimen number	Date of collection (1947)	Total length (inches)	Total length (millimeters)	Weight (grams)	Unspawned eggs: Partially developed	Unspawned eggs: Developed	Potential egg production[1]	Estimated percentage unspawned
1	July 2	11.8	300	64	2,152	2,998	31,000	9.6
2	June 24	12.0	305	88	224	121	31,700	0.4
18	July 3	12.4	315	67	...	112	33,600	0.3
36	July 2	12.6	320	92	...	9,880	34,500	28.6
10	July 3	12.7	323	84	1,227	77	35,000	0.2
29	June 24	12.8	325	101	...	13,215	35,500	37.2
38	June 28	12.9	328	99	...	104	36,000	0.3
37	June 28	13.1	333	82	...	1,809	36,900	4.9
21	June 24	13.2	335	75	...	69	37,300	0.2
16	July 1	13.3	338	104	...	4,980	37,800	13.2
27	June 23	13.4	340	103	...	519	38,300	1.4
24	June 24	13.4	340	103	...	225	38,300	0.6
3	June 22	13.7	348	102	899	74	39,700	0.2
9	July 1	13.8	351	79	470	3,879	40,200	9.6
5	July 1	14.0	356	99	227	251	41,300	0.6
32	July 2	14.3	363	102	...	647	42,800	1.5
8	July 2	14.4	366	99	55	5	43,300	0.0
7	June 24	14.4	366	73	134	1,518	43,300	3.5
15	July 7	15.5	368	108	...	453	43,800	1.0
23	June 28	14.6	371	156	...	124	44,400	0.3
34	June 29	14.7	373	131	...	6,392	45,000	14.2
33	June 24	14.7	373	118	...	6,386	45,000	14.2
22	June 29	14.8	376	119	...	222	45,500	0.5
19	July 2	14.9	378	104	...	148	46,000	0.3
13	June 23	15.0	381	117	...	470	46,500	1.0
4	July 3	15.0	381	144	...	366	46,500	0.8
20	June 30	15.0	381	145	...	271	46,500	0.6
40	June 29	15.1	384	161	...	820	47,100	1.7
17	July 2	15.6	396	166	...	322	49,800	0.6
39	June 28	15.6	396	126	...	354	49,800	0.7
6	July 2	15.7	399	112	33	48	50,400	0.0
31	June 29	15.9	404	166	...	790	51,600	1.5
26	July 1	15.9	404	153	...	92	51,600	0.1
28	July 3	16.3	414	186	...	2,113	54,000	3.9
25	June 28	16.4	417	203	...	10,584	54,500	19.4
12	June 26	16.7	424	116	...	980	56,500	1.7
14	July 2	16.8	427	123	...	1,397	57,100	2.4
35	June 28	16.8	427	201	...	11,101	57,100	19.4
30	July 2	17.0	432	192	...	1,806	58,400	3.1
11	June 20	18.1	460	236	47	205	67,000	0.3

[1] Based on values obtained from curve projected in Figure 26.

APPENDIX G

Table 1. Summary of the physical characteristics of the Ocqueoc River, Presque Isle County, as determined at the stations indicated. (Data collected between June 21 and July 3, 1947; condition of stream: Approximately mean water level for the season.)

Zone	Station	Average width (in feet)	Average depth (in inches)	Mean channel velocity (f.p.s.)[1]	General character of flow	Bottom type (dominant type listed first)	Cover; character of watershed
1	1-A	(Estuary)		...	Sluggish	Sand	...
	1-B	47	20.0	1.9	Moderate	Clay, gravel, clamshells	Wooded
		(Ocqueoc Lake)					
	1-C	(Channel braided; partly underground)				Sand	Wooded
	1-D	34	22.0	2.3	Slow-Moderate	Sand and clay	Light second growth; pasture
	1-E	28	29.0	2.8	Slow-Moderate	Sand; some gravel bars	Pasture
	1-F	50	17.5	...	Slow-Moderate	Sand; many snags	Heavily wooded
	1-G	45	21.0	...	Slow-Moderate	Sand; many snags	Wooded; some pasture
	1-H	40	19.5	...	Slow-Moderate	Sand and silt	Wooded; mature hardwood
	1-I	38	21.0	2.4	Slow-Moderate	Sand and clay	Wooded
	1-J	37	24.5	2.0	Moderate	Sand	Wooded
	1-K	38	18.0	2.6	Moderate	Sand	Wooded
	1-L	27	20.0	3.5	Moderate-Rapid	Sand; some gravel	Lightly wooded
	1-M	32	15.0	2.5	Moderate	Gravel and sand	Lightly wooded
2	2-A	25	11.5	2.8	Moderate	Gravel and rubble	Wooded
	2-B	...	...	...	Moderate	Rubble and gravel	Wooded
	2-C	...	...	...	Moderate	Rubble, rock, gravel	Wooded
	2-D	40	7.5	3.0	Moderate	Gravel, rubble	Wooded; some pasture
	2-E	...	...	...	Moderate	Gravel, rubble	Wooded; pasture
	2-F	23	10.0	2.5	Moderate	Sand, occasional rubble	Pasture, marsh
	2-G	18	8.0	...	Slow-Moderate	Sand; gravel; rubble	Suburban area
	2-H	30	5.0	...	Slow-Moderate	Gravel; small rubble	Partly wooded
	2-I	50	12.0	3.1	Slow-Moderate	Gravel; small rubble	Heavily wooded
3	3-A	4	4.0	...	Sluggish	Sand and silt	Scrub brush
	3-B	(Intermittent—not flowing)					
	3-C	12	24.0	...	Sluggish	Muck	Marsh
	3-D	30-45	1.0-4.0	...	Sluggish	Muck, silt	Marsh
	3-E	28	30.0	...	Sluggish	Muck, silt	Marsh
	3-F	20	24.0	...	Sluggish	Muck, silt	Marsh
	3-G	2	6.0	...	Sluggish	Muck	Swamp
	3-H	25	18.0	...	Sluggish	Muck	Swamp
	3-I	4	12.0	...	Sluggish	Muck	Swamp
	3-J	3	8.0	...	Sluggish	Muck	Swamp

[1] Surface velocity X factor of 1.33.

APPENDIX G

Table 2. Summary of water analyses made in the Ocqueoc River, Presque Isle County, in 1947. (Depth of water samples: 3 to 6 inches below surface; water color for all stations: light brown; no turbidity.)

Zone	Station	Date 1947	Time	Temperature (Degrees F.) Air	Water	Sky	Wind	Oxygen (p.p.m.)	Carbon dioxide	ph-th	M.O.
1	1-B	6/27	5:45 PM	73	73	Partly overcast	SW, light	7.8	0.0	3.0	134
1	1-E	7/2	1:00 PM	71	66	Clear	NE, light	8.0	0.0	4.0	127
1	1-M	6/28	5:00 PM	74	81	Clear	SW, light	7.1	0.0	4.5	110
2	2-D	6/30	2:00 PM	75	78	Clear	SW, very light	7.2	0.0	2.0	115
2	2-G	6/30	3:00 PM	78	82	Clear	SW, very light	8.5	0.0	2.5	107
2	2-I	6/30	4:00 PM	79	77	Clear	SW, very light	7.4	0.0	1.0	106
1 (Little Ocqueoc River)	5-A	7/2	3:00 PM	67	62	Clear	NE, light	5.5	0.0	1.0	118

Table 3. Daily minimum, maximum, and mean water temperatures, air temperatures, water gauge readings, and weather records for the Ocqueoc River: April 11–August 20, 1948.[1]

Date 1948		Time	Water temperature (Degrees F.) Min.	Mean	Max.	At visit	Air temperature (Degrees F.)	Water gauge (in inches)[2]	Wind direction	Weather
April	11	1530	40	40.0	40	40	46	36.5	Calm	Light overcast
	12	1830	39	40.0	41	40	44	37.5	Calm	High cirrus
	13	1800	39	39.5	40	40	44	34.0	Calm	" "
	14	2000	40	41.5	43	43	44	30.0	E	Clear
	15	2000	43	45.5	48	48	53	28.0	S	Overcast
	16	1715	43	45.0	47	44	43	27.5	NW	Clear
	17	1530	44	46.0	48	47	48	26.5	Calm	"
	18	1700	44	46.0	48	44	47	26.0	Calm	Rain
	19	1720	44	45.0	46	44	42	30.5	Calm	Light overcast
	20	...	...	...	...	...	...	...	...	...
	21	1200	44	45.0	46	45	46	30.0	Calm	Clear
	22	1330	45	46.0	47	46	56	28.0	S	"
	23	1330	46	48.0	50	50	63	26.0	S	Overcast, warm
	24	1530	49	50.0	51	50	55	26.0	S	Overcast
	25	1300	48	49.5	51	51	65	26.0	NE	Light overcast, warm
	26	1200	50	52.5	55	54	52	25.0	NE	Overcast
	27	1045	53	54.5	56	56	49	28.5	N	"
	28	1215	54	55.5	57	55	54	33.5	SE	Clear
	29	1235	53	54.5	56	56	51	32.5	ENE	"
	30	1155	54	55.5	57	55	59	29.5	NW	"
May	1	1230	52	55.0	58	56	55	27.0	E	"
	2	1000	54	56.0	58	56	48	25.5	ENE	"
	3	1155	54	56.0	58	56	48	24.0	NE	"
	4	1130	55	56.0	57	56	56	23.0	E	Overcast
	5	1115	54	55.5	57	55	60	21.5	E	Clear
	6	1215	54	56.0	58	56	54	21.5	NW	Rain
	7	1200	52	54.5	57	53	38	23.5	NW	Cloudy, cold
	8	0945	50	52.0	54	50	37	23.5	N	Clear
	9	1015	49	51.5	52	50	40	22.5	N	Cloudy
	10	1045	48	50.0	52	50	43	21.5	E	Clear
	11	1050	49	50.5	52	50	40	21.0	NE	Overcast
	12	1055	48	50.0	52	50	52	20.5	NE	Clear
	13	1130	49	51.0	53	51	57	20.0	E	Clear
	14	1220	50	52.5	55	53	68	19.0	NE	"
	15	1140	51	54.0	57	57	67	18.5	NE	Overcast
	16	1100	53	55.0	57	55	49	20.5	E	"
	17	1140	53	55.0	57	55	68	21.0	NNW	Clear
	18	1215	52	54.5	57	56	53	20.5	ENE	"
	19	1130	54	56.0	58	57	61	19.5	E	Slight overcast
	20	0955	55	57.5	60	59	69	18.5	WNW	Cloudy, rain squalls
	21	1140	56	59.0	62	56	52	18.0	NW	Clear
	22	1110	53	55.0	57	56	55	17.0	NW	Cloudy
	23	1005	54	56.0	58	56	50	16.5	N	Clear
	24	1045	53	55.0	57	56	56	16.5	NW	Overcast
	25	1100	53	56.0	59	59	63	16.0	NW	Clear
	26	1010	54	57.0	60	59	70	15.25	SW	"
	27	1000	58	60.0	62	61	72	15.0	NW	"
	28	1100	61	62.5	64	62	55	14.0	NW	Rain (AM)
	29	1020	58	60.0	62	62	57	14.0	NE	Clear
	30	1110	57	60.0	63	63	65	13.5	NW	"
	31	0945	59	61.5	64	63	66	13.0	NW	"
June	1	1035	60	62.5	65	66	74	13.0	WNW	"
	2	1045	62	64.0	66	67	70	12.5	SW	Clear, haze
	3	1100	64	67.5	71	71	75	12.5	NE	Clear
	4	1245	66	68.5	71	69	65	12.5	NE	Rain
	5	1105	61	65.0	69	65	56	13.0	SE	Clear
	6	1045	63	65.0	67	67	66	13.0	N	"
	7	1130	64	65.5	67	67	70	12.5	NE	Overcast
	8	1135	63	65.0	67	64	63	11.5	NE	Haze, smoke
	9	1100	62	63.5	65	62	70	12.75	NE	" "
	10	1120	63	65.0	67	66	68	12.5	SW	Overcast
	11	1130	63	65.0	67	65	63	12.5	NE	Clear
	12	1115	63	65.5	68	66	64	12.0	W	Cloudy
	13	0930	63	66.0	69	66	62	12.0	W	Clear
	14	1115	64	66.5	69	67	74	11.75	SW	"
	15	1145	63	66.5	70	65	63	11.5	NE	"
	16	1140	62	65.0	68	64	65	11.5	SW	"
	17	1055	62	65.0	68	65	66	11.25	NNE	"
	18	1055	62	64.5	67	65	57	11.25	NW	Overcast, rain
	19	1130	62	63.5	65	64	59	11.75	NE	Overcast
	20	1100	62	64.0	66	65	69	12.0	SW	Clear
	21	1040	64	66.0	68	66	67	11.75	SE	Overcast
	22	0945	64	65.5	67	66	63	11.75	NE	Rain
	23	1235	62	65.0	68	68	79	14.0	SW	Clear
	24	1030	67	69.0	71	69	73	15.25	SW	"
	25	1100	66	68.5	71	67	62	14.0	W	Overcast
	26	1020	65	68.5	72	67	68	13.25	SE	"
	27	1315	62	65.5	69	68	72	12.75	NE	Light overcast
	28	1000	66	68.5	71	68	60	12.5	E	Overcast
	29	1050	66	68.0	70	70	70	14.0	NW	Clear
	30	0940	68	70.0	72	70	66	14.75	NW	Overcast

Continued next page

Date 1948		Time	Water temperature (Degrees F.) Min.	Mean	Max.	At visit	Air temperature (Degrees F.)	Water gauge (in inches)[2]	Wind direction	Weather
July	1	1415	65	68.5	72	69	66	14.5	W	Clear
	2	1120	67	69.0	71	68	73	14.25	SW	Overcast
	3	1200	67	68.5	70	68	78	14.25	E	Clear
	4	1050	66	70.0	74	73	83	14.0	SW	"
	5	1015	69	72.0	75	75	80	13.5	SW	"
	6	1030	70	74.5	79	71	69	13.25	NW	Overcast
	7	1030	68	70.0	72	70	71	13.0	SE	Clear
	8	1030	69	71.5	74	72	75	12.75	SW	"
	9	0955	71	73.5	76	72	78	12.25	SW	Overcast
	10	1045	72	74.0	76	75	85	12.0	NW	Clear
	11	1115	73	75.5	78	75	82	11.75	ESE	"
	12	1300	73	75.5	78	76	83	11.5	SE	"
	13	1635	73	75.5	78	75	81	11.25	SE	"
	14	1315	72	74.5	77	74	79	11.0	SE	"
	15	1640	70	73.5	77	75	77	10.5	NE	"
	16	1745	61	68.5	76	75	68	10.5	...	Cloudy
	17	1015	71	73.5	76	72	75	10.5	NW	Rain
	18	1145	71	74.0	77	74	72	10.75	NW	Clear
	19	1300	69	72.0	75	74	53-76	10.5	NE	"
	20	1100	70	73.0	76	76	59-79	10.5	SW	"
	21	1235	69	72.5	76	72	52-86	10.25	NE	Rain
	22	1100	69	71.0	73	72	62-73	10.0	NE	Rain
	23	1030	67	69.5	72	69	56-71	10.75	NW	Rain
	24	1745	65	68.0	71	70	53-76	10.5	NW	Clear
	25									
	26[3]	1015	66	68.5	71	71	51-77	11.25	NW	"
	27	0945	68	70.5	73	71	61-83	11.0	SW	Overcast
	28	0925	69	71.5	74	71	54-78	10.75	W	Clear
	29	1000	70	72.5	75	72	57-82	10.5	SW	"
	30	1030	71	73.0	75	73	70-83	11.0	SW	"
	31									
August	1[3]	1125	70	73.0	76	72	55-77	10.5	W	"
	2	1300	69	71.0	73	71	57-73	10.25	SE	"
	3	1420	69	71.0	73	71	55-77	10.0	E	"
	4	1920	68	70.5	73	72	51-72	10.0	W	"
	5	1050	68	70.0	72	70	47-68	10.0	W	"
	6									
	7[3]	0900	68	70.0	72	70	47-74	9.75	(None)	"
	8									
	9[3]	1100	68	70.0	72	70	47-76	9.75	NNE	"
	10									Rain
	11[3]	1530	67	69.5	72	72	52-80	11.0	W	Clear
	12	1100	68	70.0	72	69	61-81	11.5	SSW	Rain
	13	1145	66	68.0	70	67	59-70	11.0	NW	Overcast
	14	1135	66	67.0	68	68	50-72	10.5	NW	Clear
	15	1235	66	68.0	70	69	54-78	10.25	NE	"
	16	1000	69	70.0	71	71	54-77	10.0	SE	"
	17	1015	69	71.0	73	71	59-82	10.25	ENE	"
	18	1000	69	70.5	72	71	61-74	10.5	W	Overcast
	19	0930	68	70.0	72	70	52-75	10.5	SE	Clear
	20	0940	68	70.0	72	71	56-78	10.5	(None)	"

[1] Readings taken at Station 1-B, 100 feet below the outlet of Ocqueoc Lake.
[2] Depth in midstream directly opposite water gauge is approximately 24 inches greater than gauge readings.
[3] All readings for 48-hour period.

Table 4. Proportions of monogamous, polygamous, and promiscuous spawning among sea lampreys in the Ocqueoc River on various dates in 1948. (Numbers of nests upon which working or spent sea lampreys were found and the number of casual sea lampreys noted in the spawning areas on these dates are also indicated)[1]

Date of observations (1948)	Total number of nests observed with ♂♂ and/or ♀♀ on them	Number of nests in which following spawning combinations noted											Number of nests under construction		Number of nests in which there were:		Number of casual lampreys in spawning area
		1♂+1♀	1♂+2♀♀	1♂+3♀♀	1♂+4♀♀	1♂+5♀♀	2♂♂+1♀	2♂♂+2♀♀	2♂♂+3♀♀	2♂♂+7♀♀	3♂♂+2♀♀	4♂♂+2♀♀	By ♂♂	By ♀♀	Spent ♂♂	Spent ♀♀	
May 29	72	28	2	...	...	...	...	...	...	...	...	...	17	2	23	...	3
June 2	220	74	5	1	...	...	9	...	...	...	2	1	56	7	65	25	12
June 6	222	55	12	2	1	1	7	...	...	1	...	...	50	11	81	15	12
June 13[2]	22	6	...	...	...	...	...	...	...	...	...	...	5	1	10	...	...
June 14	301	77	15	3	...	...	1	1	1	...	...	...	79	4	89	13	18
June 20[3]	10	4	...	...	...	...	...	...	...	...	...	...	2	...	2	2	1
June 23[3]	7	3	2	...	...	...	...	...	...	...	...	...	2	...	...	...	1
June 25	63	8	...	...	...	...	1	...	...	...	...	...	4	3	36	11	4
June 26–July 5[4]	26	6	3	...	...	...	...	...	...	...	...	...	...	...	14	3	1
July 6[5]	3	...	1	...	...	...	...	...	...	...	...	...	2	...	...	...	1
July 8[5]	5	...	2	...	1	...	...	...	...	...	...	...	...	...	2	...	...
July 10[5]	2	...	1	...	...	...	...	...	...	...	...	...	...	...	1	...	...
July 12[5]	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Totals		261	44	6	2	1	18	1	1	1	2	1	217	28	324	69	53
Percent of total spawning combinations observed		(77.2)	(13.0)	(1.8)	(0.6)	(0.3)	(5.3)	(0.3)	(0.3)	(0.3)	(0.6)	(0.3)	...	...	...	...	...

[1] Counts represent activity of all live sea lampreys present in area of river examined on given date. Unless otherwise noted data obtained in area between Stations 1L and 1M (Zone 1).
[2] Stations 1F and 2I.
[3] Stations 1B and 1E.
[4] Station 1B and Stations 1L to 1M.
[5] Station 1B.

Table 5. Depths, dimensions, and materials used in the construction of sea lamprey nests in the Ocqueoc River (Stations 1L to 1M). (All depths and dimensions in inches. Bottom type symbols: "P" - pea gravel, 3/16" to 3/8" in diameter; "M" - marble gravel, 1/2" to 1" in diameter; "E" - egg gravel, 1 and 1/4" to 2 and 1/2" in diameter; "R" - rubble; "S" - sand. All bottom types listed in order of dominance.)

Depth to center of nest	Dimensions of nest	Downstream rim of nest: Depth to summit	Downstream rim of nest: Materials	Upstream rim of nest: Depth to summit	Upstream rim of nest: Materials	Bottom type—floor of nest	Remarks on location of nest
		(Transverse bar - 3 x 27 feet)					
12.5	27.0 x 35.0	4.0	P, M, E	1/	R	P, R, S	Forward slope of bar
12.5	13.0	7.5	P, M, E	1/	R	P, R, S	" " " "
11.0	23.0	4.0	P, M, E	1/	R	P, R	" " " "
11.5	25.0	4.5	P, M, E	1/	R, S	P	" " " "
12.0	26.0	7.0	P, E	8.5	P, E	P	Reverse slope of bar
10.0	21.0	6.5	P, M	1/	R, P	P, R	Forward slope of bar
17.0	36.0	10.0	P, M	13.5	P, M	P, S	At bank
		(Transverse bar)					
14.5	22.0	8.0	P, M, E	12.5	P, R	P, R	Forward slope of bar
12.5	30.0	6.0	P, M	1/	M, R	S, R	Reverse slope of bar
12.0	17.0	5.0	Large rock, P, M	9.0	S, M	S, P	Forward slope of bar
10.0	16.0	6.0	P, M	8.0	S, M	P	" " " "
10.0	22.0	4.5	P, M, S	8.0	P, M	P	Crest of bar
12.0	28.0	5.0	M, E	1/	P, R	P, R	Forward slope of bar
9.0	18.0 x 23.0	3.0	P, M, E	7.5	S, M, R	P	" " " "
9.0	15.0	4.5	P, M	6.0	S, M	P, S	" " " "
10.0	14.0	4.5	P, M	1/	S	P, S	" " " "
		(Quieter water between bars)					
8.5	20.0	4.5	P, M, E, R	6.0	M, R	P, S, R	Profile of bottom level
		(Transverse bar)					
10.0	19.0	3.0	M, E, R	1/	M, R	P	Forward slope of bar
8.0	22.0	2.5	M, E	5.0	M, E, R	P, M	Crest of bar
10.0	14.0	4.0	P, M, E	9.5	M, R	P, S	Forward slope of bar
10.0	14.0	3.5	P, M, E	1/	M, E	P, S, R	" " " "
10.5	19.0	3.0	P, M, E	8.5	M, E	P, M	" " " "
10.0	19.0	3.0	P, M, E	8.5	M, E	P, M	" " " "
13.0	28.0	5.5	M, E	7.0	M, E, S	P	" " " "
14.0	25.0	7.5	P, M, E	1/	S, R	P, S	" " " "
12.0	23.0	5.5	M, E	9.5	P, M	P, M	Crest of bar
15.0	23.0	8.5	P	12.5	M, S	P	Forward slope of bar
13.5	16.0	9.0	P, R, M	12.5	M, S	S, P	" " " "
13.5	15.5	9.0	P, R, M	12.5	M, S	S, P	" " " "
16.5	29.0	9.5	P, M	12.0	M, S	P	" " " "
18.0	22.0 x 29.0	9.0	P, M	15.5	P, S	P, S	" " " "
17.0	30.0	10.0	P, M	1/	S	P, M, S	Under overhanging bank
		(Gravel bed—quieter water between two riffle areas)					
13.0	25.0	7.0	M, E	10.0	M, E	P	...
15.0	22.0	9.0	M, E	12.0	M, E	P, S	...
13.0	24.0	7.5	M, E	9.5	M, E	P, S	...
14.0	22.0 x 26.0	6.0	M	13.0	M, E	P, S	Under overhanging bank
15.0	19.0	11.0	P, M	13.0	M, E	P	...
18.0	27.0	11.0	P, M	15.5	P, M	P	...
19.0	28.0	13.0	M, E	1/	P	P	...
24.0	25.0	17.0	Snag, E	1/	P, R	P, R	...
		(Broad transverse bar)					
11.5	16.0	5.0	E, M	1/	E, R	P, R	Forward slope of bar
13.0	18.0 x 24.0	4.5	E	11.5	E, R	P, R	" " " "
14.5	17.0 x 23.0	5.5	E	13.0	M, E, R	P, R	" " " "
16.0	18.0 x 22.0	6.5	E	15.0	P, M, R	P, R	" " " "
14.5	19.0	7.0	E, M	1/	P, R	P, R	" " " "
12.0	21.0 x 25.0	5.0	M, E	10.5	M, E, R	P, R	" " " "
Average 13.0	22.1 2/	6.6	...	10.5	...	...	...

1/ Upstream rim of nest poorly defined or not elaborated during nest construction. Materials listed are bottom type immediately upstream from nest proper.
2/ Mean diameter of asymmetrical nests included in average.

Table 5. Depths, dimensions, and materials used in the construction of sea lamprey nests in the Ocqueoc River (Stations 1K to 1L). (All depths and dimensions in inches. Bottom type symbols: "P" - pea gravel; 3/16" to 3/8" in diameter; "M" - marble gravel, 1/2" to 1" in diameter; "E" - egg gravel, 1 and 1/4" to 2 and 1/2" in diameter; "R" - rubble; "S" - sand. All bottom types listed in order of dominance.)

Depth to center of nest	Dimensions of nest	Downstream rim of nest: Depth to summit	Downstream rim of nest: Materials	Upstream rim of nest: Depth to summit	Upstream rim of nest: Materials	Bottom type—floor of nest	Remarks on location of nest
24.0	31.0 x 48.0	...	M, E	[1]	S	S, P	
22.0	17.0	...	P, M	[1]	S	S	
24.0	17.0	...	M, E	[1]	S	S	Located on small scattered patches of gravel on predominantly sandy stream bed
24.0	19.0	...	M, E	[1]	S	S	
23.5	20.0 x 27.0	11.0	M, E, P	[1]	S	S, P	
14.0	11.0	...	P	[1]	P	S, P	
11.0	37.0	4.0	M, E, P	[1]	S, P	S, P	Gravel riffle behind old log deflector
15.0	13.0	6.0	M, E, P	[1]	M, E, P	S, P	
12.0	15.0	5.0	M, E, P	[1]	M, P, S	S, P	
15.0	25.0	6.5	M, E	13.0	P	Clay, P	...
23.0	36.0 x 40.0	14.0	E, S	[1]	P, S	P, S	...
27.0	25.0 x 28.0	18.0	P, M	[1]	S	P, M, S	Midstream
28.0	17.0	22.0	M, E, P	[1]	M, S	P, S	
25.5	15.0	20.0	M, E, P	[1]	M, S	P	Scattered gravel pockets in midstream
28.0	13.0 x 30.0	22.0	Old log, M	[1]	M, S	P, M	
32.0	24.0 x 36.0	22.0	M, S	[1]	Clay	P, M	Waterlogged sticks in nest
19.0	24.0 x 26.0	13.0	M, E	[1]	Old deadfall	S, P	Midstream
22.0	21.0 x 20.0	13.0	M, E	[1]	S	P, M	Forward slope of bar
20.5	16.0	12.0	M, E	[1]	S	P, M	" " " "
19.5	26.0	14.0	M, E	14.0	M, E	P, M	Crest of bar
22.0	20.0	16.0	M, E	[1]	S	P	Forward slope of bar
18.0	16.0 x 21.0	12.0	M, E	17.0	M, R	S	" " " "
11.5	16.0 x 19.0	3.0	P, M, E	10.5	P	P, S	" " " "
14.5	16.0	9.0	E	11.0	E, M	P	Crest of bar
19.0	19.0 x 23.0	11.5	P, M, E	[1]	S	P, S	Forward slope of bar
24.0	18.0 x 21.0	15.5	E, R	[1]	S, R	P, R	" " " "
29.0	18.0	25.0	P, M, E	25.5	P, M, E	P	Reverse slope of bar
23.5	23.0	18.5	P, M, E	21.0	M, E	P, S	Forward slope of bar
22.0	19.0 x 26.0	14.0	M, E	19.0	M, E, R	P	" " " "
20.0	21.5	11.0	P, M, E	[1]	S	P	" " " "
16.0	16.0	8.0	M, E	[1]	S	P	" " " "
14.0	14.0	4.0	M, E	[1]	S	P	" " " "
12.5	14.0	4.0	M, E	[1]	S	P	" " " "
12.0	14.0	3.5	M, E	[1]	S	P	" " " "
Average 20.2	21.0[2]	12.3	...	...	...	...	...

[1] Upstream rim of nest poorly defined or not elaborated during nest construction. Materials listed are bottom type immediately upstream from nest proper.
[2] Mean diameter of asymmetrical nests included in average.

Table 7. Depths dimensions, and materials used in the construction of sea lamprey nests in the Little Ocqueoc River (Station 5B). (All depths and dimensions in inches. Bottom type symbols: "P" - pea gravel, 3/16" to 3/8" in diameter; "M" - marble gravel, 1/2" to 1" in diameter; "E" - egg gravel 1 and 1/4" to 2 and 1/2" in diameter; "R" - rubble; "S" - sand. All bottom types listed in order of dominance.)

Depth to center of nest	Dimensions of nest	Downstream rim of nest: Depth to summit	Downstream rim of nest: Materials	Upstream rim of nest: Depth to summit	Upstream rim of nest: Materials	Bottom type—floor of nest	Remarks on location of nest
7.5	20.0	2.0	M, E	4.0	M, E, R	P, R	Forward slope of bar
6.0	16.0	0.8	M, E	1.0	M, E, R	P	" " " "
7.5	10.0	5.0	E, R	4.0	E, R	P	Intermediate between bars
8.5	17.0	4.0	M, E	7.0	M, E	P	Midstream
9.0	10.0	5.0	E, R	6.0	M	P, R	"
10.5	17.5	11.5	R, P, E	8.0	M, E, R	P, R	"
10.0	17.0 x 23.0	5.5	P, E	8.0	P, S, R	P, M	Under roof of logs and cedar bows
9.0	16.0	4.5	M, large rock	4.5	M, E	P	Midstream
6.0	18.0 x 20.0	2.0	M, E	[1]	M, E	P	Close to bank
11.0	19.0 x 20.0	3.5	M, E	9.0	S, P, M	P, S	Midstream
6.0	14.0	3.0	P, M, E	4.0	M, R	P, S	Forward slope of bar
7.5	13.0 x 14.0	2.5	P, M, E	3.0	M, E	P, S	" " " "
8.5	23.0	2.0	P, M, E	[1]	E, R	P, R	Midstream
8.5	13.0 x 21.0	2.0	M, E	[1]	P, R	P	"
10.0	22.0	3.0	M, E	6.0	P, E, R	P, R	"
10.5	14.0	5.5	E, large rock	8.0	P, R	P, R	Forward slope of bar
10.0	24.0	2.5	M, E	[1]	M, E	P, R	" " " "
7.0	13.0	2.0	M, E	[1]	M, E	P, S	Under snags near bank
7.0	17.0	2.0	P, M, E	3.5	P, M	P	Midstream
7.5	23.0	1.5	P, M, E	4.5	P, M	P	"
9.5	21.0	3.5	M, E	[1]	M, E	P, R	Forward slope of bar
8.5	12.0	6.0	P, M, R	7.0	M, R	P, M, E	" " " "
10.0	22.0 x 24.0	2.5	P, M, E	[1]	M, E	P, M	" " " "
9.0	22.0	4.5	E, R, M	5.5	R	P, R	Midstream
7.0	18.0	3.5	E, R	4.5	R	P, R	"
9.0	16.0	4.0	P, M	7.0	P, R	P, S	Close to bank
15.0	20.0	3.5	M, E	11.0	E, R	P	Midstream
9.0	14.0	2.0	M, E	[1]	E, R	P	Close to bank
11.0	14.0	7.5	P, M	[1]	P, M	P	Midstream
12.5	25.0	6.0	E, M, S	10.0	M, E	P	"
13.5	19.0	7.0	Large rock, P, M	9.0	P, M, R	P, R	"
Average 9.0	17.7[2]	3.6	...	6.1	...	...	...

[1] Upstream rim of nest poorly defined or not elaborated during nest construction. Materials listed are bottom type immediately upstream from nest proper.

[2] Mean diameter of asymmetrical nests included in average.

APPENDIX G

Table 3. Depths, dimensions, and materials used in the construction of sea lamprey nests in the Ocqueoc River (Station 2B). (All depths and dimensions in inches. Bottom type symbols: "P" - pea gravel, 3/16" to 3/8" in diameter; "M" - marble gravel, 1/2" to 1" in diameter; "E" - egg gravel, 1 and 1/4" to 2 and 1/2" in diameter; "R" - rubble; "S" - sand. All bottom types listed in order of dominance.)

Depth to center of nest	Dimensions of nest	Downstream rim of nest: Depth to summit	Downstream rim of nest: Materials	Upstream rim of nest: Depth to summit	Upstream rim of nest: Materials	Bottom type—floor of nest	Remarks on location of nest
11.0	16.0	7.5	P, E, R	8.0	P, R	P	Midstream
11.5	21.0	7.0	P, E, R	8.0	P, R	P	"
10.5	18.0	6.5	P, M	6.0	P, M, R	P	"
13.5	18.0	10.0	P, M	10.0	P, R	P	"
13.0	18.0	6.0	P, M	10.5	P, M, R	P, M	"
11.5	20.0	8.5	P, M	9.0	P, M	P, R	"
11.5	17.0	5.0	P, M	9.0	P, M, R	P	Three feet from bank
10.5	19.0	5.0	M, E, R	8.0	P, R	P	Midstream
13.0	20.0	7.5	M	10.0	P, M, R	P	Six feet from bank
11.5	26.0	6.0	P, M, R	8.0	P, M, E	P	" " " "
9.5	21.0	4.5	P, E	[1]	P, R	P	Two feet from bank; overhung by bushes
10.0	17.0	5.0	P, M, E	6.5	P, M	P, R	Midstream
9.5	10.0 x 16.0	6.0	P, M, E	7.5	P, M, E	P	"
9.0	18.0	4.5	P, M	6.0	P, M	P	Fifteen feet from bank
12.0	17.0 x 21.0	6.0	P, M, E	[1]	P, M	P	Two and one-half feet from bank
9.0	22.0	3.0	P, E	6.0	P, M, E	P	At current split at head of small island
11.0	20.0	6.0	P, M, E	[1]	P, M, R	P	Side channel
11.0	19.0	6.0	P, M	8.5	P, M	P	Midstream
8.0	21.0	2.0	P, M	4.5	P, M	P	
13.0	22.0 x 25.0	5.5	P, M	[1]	P	P	
11.5	17.0	6.5	P, M	8.5	P, M	P	Scattered across stream bed
11.0	11.0 x 16.0	6.5	P, M	[1]	P, R	P	
12.0	15.0	6.5	P, M	[1]	P, M, R	P, R	
9.5	13.0	5.5	P, M	7.0	P, R, M	P, R	
10.0	23.0 x 27.0	3.5	P, M	[1]	P, M, R	P	Three feet from bank; against and alongside of log
Average 10.9	18.8[2]	5.8	...	7.8	...	...	...

[1] Upstream rim of nest poorly defined or not elaborated during nest construction; materials listed are bottom type immediately upstream from nest proper.

[2] Mean diameter of asymmetrical nests included in average.

APPENDIX C

Table 9. Characteristics of sea lamprey spawning grounds (including those of the Ocqueoc watershed).

		Color and turbidity						Stream bottom type					Current			Average width of stream (or range in width)	Depth	Temperature at time of observations
Stream	County	White	Light brown	Brown	Clear	Turbid	Heavily silted	Mud	Sand	Gravel	Rubble	Rocky	Sluggish	Moderate	Rapid	(feet)	(inches)	(degrees F.)
Region 1																		
Furlong Creek	Mackinaw	...	...	X	X	...	...	...	X	X	...	...	...	X	...	9	4 to 6	63
Sucker Creek	Mackinaw	...	...	...	X	...	...	...	...	X	...	...	...	X	...	10	6 to 12	73
Brevoort River	Mackinaw	...	...	...	X	...	...	...	X	X	X	X	...	X	...	35	... to 30	70
Carp River	Mackinaw	...	...	X	...	X	...	...	X	X	X	...	...	...	X	45	... to 36	68
Black River	Mackinaw	...	...	X	...	X	...	...	X	X	X	X	...	...	X	20	... to 36	...
Trout Brook	Chippewa	...	...	...	X	...	...	...	X	X	...	...	...	X	...	10	... to 30	66
Region 2																		
Mud Creek	Cheboygan	...	...	X	X	...	...	X	X	X	...	...	...	X	...	5 to 20	0 to 24	71
Loeb Creek	Charlevoix	X	...	...	X	...	...	X	X	X	...	...	...	X	...	10 to 20	12 to 24	66
Porter Creek	Charlevoix	X	...	...	X	...	...	...	X	X	...	...	...	X	...	5 to 15	12 to 24	62
Horton Creek	Charlevoix	X	...	...	X	...	...	...	X	X	...	...	...	X	...	15 to 40	12 to 24	59
Carp River	Emmet	X	...	...	X	...	...	...	X	X	X	...	...	X	...	20 to 40	0 to 48	71
Trout Creek	Presque Isle	...	X	...	X	...	...	...	X	X	...	X	...	X	...	15	10 to 24	68
Little Ocqueoc R.	Presque Isle	X	...	...	X	...	...	...	X	X	X	...	...	X	...	10	2 to 16	60
Ocqueoc River	Presque Isle	...	...	X	X	...	...	...	X	X	X	X	X	X	X	15 to 50	4 to 60	42 to 78
Silver Creek	Presque Isle	X	...	...	X	...	...	...	X	X	...	...	...	X	...	3 to 5	3 to 8	59
Smith Creek	Iosco	...	...	...	X	...	...	...	X	X	...	...	...	X	X	5 to 15	0 to 36	44
Au Sable River	Iosco	...	...	...	X	...	...	X	X	X	...	...	...	X	...	20	24	...
E. Br., Au Gres R.	Iosco	...	X	...	X	...	...	...	X	X	...	...	...	X	X	20 to 40	24 to 60	51 to 52
Au Gres River	Iosco	...	X	...	...	...	...	...	X	X	...	...	X	X	...	30	0 to 24	50
Johnson Creek	Iosco	...	...	...	X	...	...	X	X	X	...	...	X	X	...	5 to 8	0 to 24	48
Cold Creek	Iosco	...	...	...	X	...	...	...	X	X	...	...	...	...	X	5	0 to 30	47
Hope Creek	Iosco	...	X	...	...	...	...	...	X	X	...	...	...	X	X	4 to 15	0 to 36	49
Hale Creek	Iosco	...	X	...	...	...	...	X	X	X	...	...	...	X	X	5 to 20	... to 18	51
Little So. Br., Pere Marquette River	Lake	...	...	...	X	...	...	...	...	X	...	...	X	X	...	30	24	...
Baldwin Creek	Lake	...	X	...	X	...	...	...	...	X	X	X	...	X	...	30	12	62
Big Bear Creek	Manistee	X	...	...	X	...	...	...	X	X	X	...	...	X	...	15	12	52
Platte River	Benzie	X	...	...	X	...	...	...	X	X	X	...	...	X	...	50	24 to 48	...
No. Br., Lincoln R.	Mason	...	...	X	...	X	...	...	X	X	...	X	...	X	...	8	12	70
Stony Creek	Oceana	X	...	...	X	...	...	...	...	X	X	X	...	X	...	20	12	69
Region 3																		
Blue Creek	Berrien	...	...	...	X	...	...	...	...	X	...	...	...	X	...	5	12	53
Swan Creek	Allegan	...	X	...	...	...	...	...	...	X	...	...	...	...	X	15	18	58
Bear Creek	Allegan	X	...	...	X	...	...	...	X	X	...	...	...	X	...	5 to 8	4 to 12	...
Total streams observed:	32 (Frequency)	10[1]	7[1]	6[1]	25[2]	3[2]	0[2]	5	25	32	10	7	3	28	9	Range: 3 to 50	Range: 2 to 60	42 to 78

[1] No data for 9 streams.
[2] No data for 4 streams.

Table 10. Sexual maturity, color of liver, and intestinal and rectal diameters of 288 migrant and spawning male sea lampreys from Carp Creek, the Ocqueoc River, and Ocqueoc Lake, Presque Isle County.

Dates of collection (1947)	Migrant or spawning	Number of specimens	Average total length (in inches)	Number with gonads: Firm	Soft	Ripe	Color of liver (Number of specimens): Orange, Orange-yellow	Yellow, Yellow-green	Green	Diameter of intestine (in millimeters): Minimum	Average	Maximum	Diameter of rectum (in millimeters): Minimum	Average	Maximum
May 1-5	Migrant	25	17.7	25	...	...	21	...	...	6.5	8.0	10.5	4.5	6.1	8.0
								4	...	4.5	6.3	8.0	3.5	4.8	6.0
May 11-15	"	31	17.4	31	...	...	15	...	...	5.5	7.4	12.5	4.5	6.2	11.0
								12	...	4.5	6.0	8.0	4.0	5.0	7.0
									4	4.0	5.0	6.5	3.0	4.1	5.5
May 16-20	"	24	17.3	24	...	...	10	...	...	6.0	7.5	10.5	4.0	6.0	9.5
								10	...	4.5	5.5	7.0	3.5	4.5	6.0
									4	3.5	4.9	6.5	3.0	3.9	5.0
May 20-25	"	23	17.9	23	...	...	11	...	...	6.0	6.7	7.5	4.0	5.0	5.5
								4	...	5.0	5.1	5.5	4.0	4.5	5.0
									8	3.5	4.4	5.0	3.0	3.4	4.5
June 1-5	"	50	17.1	50	...	...	7	...	...	4.5	5.6	7.5	3.5	4.5	6.0
								17	...	5.0	5.5	6.0	3.5	4.5	5.0
									26	2.5	4.1	5.0	2.0	3.4	4.5
June 6-10	"	28	17.1	25	2	1	...	9	...	4.5	5.6	6.5	4.0	4.8	6.0
									19	2.0	3.3	5.0	1.5	2.7	4.5
June 11-15	"	39	16.7	38	1	...	1	...	...	...	(5.0)	...	...	(4.0)	...
								12	...	4.0	4.4	5.0	3.0	3.7	4.0
									26	1.5	2.9	5.0	1.5	2.5	4.0
June 16-20	"	30	16.0	29	1	...	...	15	...	3.0	4.0	5.0	2.0	3.3	4.0
									15	2.5	3.2	4.0	2.0	2.8	4.0
June 16-20	Spawning	11	15.6	...	...	11	...	...	11	1.5	2.0	2.5	1.0	1.6	2.0
June 21-25	Migrant	5	17.3	5	...	...	1	...	...	...	(5.0)	...	...	(4.0)	...
								3	...	4.0	4.1	4.5	3.0	3.7	4.0
									1	...	(2.0)	...	...	(2.5)	...
June 21-25	Spawning	7	16.5	...	...	7	...	...	7	2.0	2.1	2.5	1.0	1.8	2.0
June 26-30	Migrant	3	15.7	3	...	...	...	3	...	3.0	3.5	4.0	2.5	2.8	3.5
June 26-30	Spawning	11	16.2	...	...	11	...	...	11	1.5	2.1	2.5	1.0	1.7	2.0
July 10-15	Migrant	1	(14.7)	...	...	1	...	...	1	...	(2.0)	...	...	(2.0)	...
Total		288													

APPENDIX G

Table 11. Sexual maturity, color of liver, and intestinal and rectal diameters of 190 migrant and spawning female sea lampreys from Carp Creek, the Ocqueoc River, and Ocqueoc Lake, Presque Isle County.

Dates of collection (1947)	Migrant or spawning	Number of specimens	Average total length (in inches)	Number with gonads: Firm	Soft	Ripe	Color of liver (Number of specimens): Reddish-orange	Reddish-brown; Brown-green	Dark green	Diameter of intestine (in millimeters): Minimum	Average	Maximum	Diameter of rectum (in millimeters): Minimum	Average	Maximum
May 1-5	Migrant	14	18.2	14	...	...	2	...	...	9.5	10.8	12.0	8.0	9.0	10.0
								9	...	7.0	9.0	10.5	5.0	6.9	7.5
									3	7.0	7.0	7.2	4.5	5.3	6.0
May 11-15	"	21	17.3	14	7	...	1	...	...	...	(10.0)	...	...	(8.5)	...
								8	...	4.5	7.8	12.0	4.5	6.4	9.5
									12	3.5	4.8	6.0	2.0	3.9	5.5
May 16-20	"	12	17.8	12	...	...		3	...	5.0	6.3	7.5	3.5	4.2	4.5
									9	3.0	4.7	6.0	2.5	3.7	6.0
May 20-25	"	10	18.1	8	2	...		5	...	5.0	5.8	7.0	3.5	4.3	5.0
									5	3.5	4.8	6.5	3.0	3.6	4.5
June 1-5	"	28	17.3	28	...	...		5	...	4.5	5.4	6.0	4.0	4.3	5.0
									23	3.5	4.6	5.5	3.0	3.6	4.5
June 6-10	"	15	17.1	14	1	...		3	...	5.0	5.7	6.5	4.0	4.7	6.0
									12	2.5	3.6	5.0	2.0	3.0	4.0
June 11-15	"	32	16.7	18	13	1		3	...	4.0	4.5	5.0	3.5	3.8	4.0
									29	1.5	3.1	5.5	1.0	2.5	4.0
June 16-20	"	32	16.5	9	23	...		2	...	4.5	4.8	5.0	3.5	3.8	4.0
									30	1.5	3.1	5.0	1.0	2.5	4.0
June 16-20	Spawning	4	17.4	...	...	4		...	4	2.0	2.1	2.5	1.5	1.8	2.0
June 21-25	Migrant	3	14.7	...	1	2		...	3	2.5	3.0	3.5	2.0	2.7	3.0
June 21-25	Spawning	8	15.0	...	...	8		...	8	1.5	1.9	2.0	1.0	1.5	2.0
June 26-30	Migrant	2	16.5	...	1	1		...	2	3.0	3.0	3.0	2.5	2.5	2.5
June 26-30	Spawning	6	15.2	...	...	6		...	6	1.5	2.1	2.5	1.5	1.8	2.5
June 10-15	Migrant	3	15.8	1	...	2		1	...	...	(3.0)	...	...	(2.5)	...
									2	2.5	2.5	2.5	2.0	2.3	2.5
Total		190													

APPENDIX H

Table 1. Length-frequency table for larval lampreys collected in the Coqueoc River in August and October, 1947, and May, 1948.

Total length in millimeters (midpoint of 2 mm. size groups)	Number of larvae			Total length in millimeters (midpoint of 2 mm. size groups)	Number of larvae		
	August, 1947 collection	October, 1947 collection	May, 1948 collection		August, 1947 collection	October, 1947 collection	May, 1948 collection
11	10	...	...	91	22	18	11
13	86	...	...	93	25	21	20
15	187	...	...	95	26	20	16
17	170	...	...	97	19	22	17
19	53	3	...	99	20	18	19
21	3	35	...	101	27	40	19
23	...	56	...	103	23	27	16
25	...	31	3	105	25	26	21
27	...	48	10	107	20	22	16
29	...	8	31	109	19	20	14
31	1	3	37	111	19	16	15
33	...	...	31	113	9	16	17
35	5	...	27	115	21	12	18
37	9	...	17	117	8	13	10
39	24	6	7	119	9	11	22
41	43	13	4	121	8	9	14
43	45	15	4	123	4	5	11
45	51	30	4	125	2	5	11
47	36	33	17	127	6	5	8
49	22	40	15	129	2	3	9
51	18	32	33	131	3	6	5
53	12	38	33	133	3	7	6
55	16	22	30	135	2	5	5
57	7	20	21	137	1	4	1
59	10	16	20	139	1	4	4
61	20	12	19	141	5	3	2
63	13	12	32	143	3	4	3
65	14	12	26	145	1	6	3
67	14	14	35	147	1	4	3
69	17	12	27	149	...	1	5
71	16	7	28	151	1	...	3
73	13	18	29	153	...	1	3
75	16	11	24	155	...	...	...
77	9	8	26	157	...	1	2
79	16	13	16	159	...	...	1
81	16	8	18	161	...	...	...
83	16	17	14	163	...	1	...
85	18	13	15	165	...	...	1
87	19	10	24	167	...	...	1
89	24	21	9	169	...	...	...
				171	...	...	1
Totals					1,384	1,063	1,039

APPENDIX H

Table 2. Minimum, average, and maximum length of young-of-the-year sea lamprey ammocoetes collected at intervals during their first season of growth.

Date of collection (1948-49)	Number of specimens	Total length in millimeters [1]		
		Min.	Aver.	Max.
July 24	107	7.5	10.5	16.5
August 25	129	11.0	17.7	28.0
October 1	155	16.5	21.8	32.5
October 30	97	18.0	22.6	30.0
December 12	50	18.5	24.0	29.0
January 9	10	18.0	22.6	29.0
Total	548			

[1] At no time during the first season of growth does the size range of the young-of-the-year overlap that of the next oldest age group.

Table 1. Numbers and minimum, average, and maximum total lengths of newly-transformed sea lampreys migrating downstream in the Ocqueoc River during the winter of 1948-1949 with weather and water temperature and water level data for the period.

Date 1948-1949		Time	Mean water temperature (Degrees F.)	Water level (inches)	Weather	Sea lampreys (newly-transformed migrants) Number taken	Total length in mm. Min.	Aver.	Max.
Oct.	24	0930	...	7.7	Clear	0	...	...	...
	25	0930	...	7.6	"	0	...	...	...
	26	0945	...	8.0	"	0	...	...	...
	27	0945	...	8.0	"	0	...	...	...
	28	0940	...	8.1	"	0	...	...	...
	29	0945	...	7.7	"	0	...	...	...
	30	0910	...	8.1	Fog	0	...	...	...
	31	1030	...	8.0	Overcast	0	...	...	...
Nov.	1	1000	43.0	8.2	"	1	...	(131)	...
	2	0835	49.0	8.1	"	0	...	...	...
	3	0930	48.5	8.0	"	0	...	...	...
	4	1010	49.0	8.4	"	0	...	...	...
	5	1000	49.5	8.5	Rain	0	...	...	...
	6	1100	49.0	8.5	"	0	...	...	...
	7	1000	48.0	9.0	Overcast	0	...	...	...
	8	1010	46.5	8.6	Clear	1	...	...	...
	9	0935	44.5	8.4	"	1	...	(131)	...
	10	0940	44.0	8.4	Rain; snow	1	...	...	...
	11	0945	45.5	8.6	Rain	1	...	(132)	...
	12	0945	45.0	8.5	Clear	2	...	...	...
	13	0925	44.5	8.5	Rain	0	...	...	...
	14	1100	44.0	8.7	Snow	0	...	...	...
	15	...	...	...	Snow; rain	0	...	...	...
	16	0915[1]	41.0[1]	8.6	Clear	0	...	...	...
	17	1010	43.0	9.0	Cold rain	1	...	(140)	...
	18	1000	42.0	9.1	Overcast	0	...	...	...
	19	1015	41.0	9.2	"	1	...	(124)	...
	20	0930	41.5	9.2	Rain	2	...	...	...
	21	1100	41.0	9.2	Clear	7	123	145.6	178
	22	1110	41.0	9.3	Rain	21	...	...	...
	23	1100	41.5	9.2	Clear	98	119	134.2	163
	24	0930	41.5	9.2	"	64	...	...	...
	25	1700	...	9.2	Overcast	129	116	132.7[2]	165
	26	1045	42.0	9.2	Clear	109	...	...	...
	27	1030	42.0	9.2	Overcast	63	118	134.4	179
	28	1115	39.5	9.2	Snow	50	...	...	...
	29	1025	40.0	9.2	Clear	47	118	136.5	192
	30	1055	39.0	9.2	Overcast	69	...	...	...
Dec.	1	1015	38.0	9.2	Clear	49	120	135.0	172
	2	1100	37.5	9.0	"	16	...	...	...
	3	1020	37.5	9.0	"	15	123	135.1	146
	4	1045	37.0	9.0	"	24	...	...	...
	5	1100	37.5	9.0	"	20	116	133.9	157
	6	1110	37.5	9.1	Snow	27	...	...	...
	7	1120	38.5	9.1	Overcast	122	120	137.2	184
	8	1045	35.5	8.6	Snow	41	...	...	...
	9	1100	34.5	8.3	Snow	24	126	142.0	160
	10	1055	34.0	8.3	"	1	...	...	...
	11	0930	33.5	8.2	Clear	1	...	(138)	...
	12	1140	33.5	8.5	Rain	2	...	...	...
	13	0845	34.0	8.5	Overcast	2	137	142.0	147
	14	0915	33.5	8.5	"	0	...	...	...
	15	0945	33.5	8.6	Snow	0	...	...	...
	16	1030	34.0	8.6	Clear	3	...	...	...
	17	1045	34.0	8.6	Snow	0	...	...	...
	18	...	...	...	Overcast	0	...	...	...
	19	1050[1]	34.0[1]	8.6	Clear	3	139	142.0	145
	20	0855	34.0	8.6	"	1	...	...	...
	21	1100	33.5	8.6	Snow	4	133	145.5	159
	22	1100	34.5	8.6	Clear	6	...	...	...
	23	1100	33.5	8.6	"	6	117	134.2	148
	24	1115	33.0	8.6	"	0	...	...	...
	25	...	...	...	Overcast	0	...	...	...
	26	1130[1]	33.0[1]	8.6	Rain; snow	6	...	...	...
	27	1030	33.0	8.6	Overcast	1	...	(142)	...
	28	1100	33.0	8.6	"	11	...	...	...
	29	1020	33.5	8.7	Snow	4	126	146.0	171
	30	1020	33.0	8.6	Clear	3	...	...	...
	31	1045	34.0	8.6	"	1	...	(155)	...
Jan.	1	1015	...	8.6	"	4	...	...	...
	2	1130	...	8.6	"	1	...	(143)	...
	3	0855	...	8.6	"	0	...	...	...
	4	0945	...	8.6	Rain	0	...	...	...
	5	1020	35.0	8.6	Snow	4	...	...	...
	6	1115	33.0	9.2	Clear	1	...	(135)	...
	7	0950	32.0	9.0	"	3	...	...	...
	8	1100	33.0	9.0	"	2	129	135.5	142
	9	0950	33.0	9.1	"	0	...	...	...
	10	...	...	...	...	...	...	...	...
	11	1050[1]	32.5[1]	8.6	Overcast	0	...	...	...
	12	1045	33.0	8.6	Snow	0	...	...	...
	13	1100	33.0	9.0	"	0	...	...	...
	14	1030	33.5	9.0	"	0	...	...	...
	15	1130	33.0	8.7	Rain	0	...	...	...

Continued next page

Date 1948-1949	Time	Mean water temperature (Degrees F.)	Water level (inches)	Weather	Sea lampreys (newly-transformed migrants) Number taken	Total length in mm. Min.	Aver.	Max.
Jan. 16	1130	34.0	9.5	Rain	0	...	...	...
17	1030	34.0	10.0	Snow	11	...	...	...
18	1000	33.0	9.5	Overcast	6	126	144.7	168
19	0910	33.0	9.6	Snow	8	...	...	...
20	1130	33.0	9.6	Clear	2	150	155.5	161
21	1020	32.5	8.7	"	6	...	...	...
22	0845	32.5	9.0	Snow	9	115	128.8	148
23	1055	32.5	9.1	Clear	24	...	...	...
24	1130	33.0	9.5	Rain	8	121	137.6	163
25	1100	33.0	9.4	Snow	4	...	...	...
26	1030	32.5	9.3	Snow	1	...	(137)	...
27	1130	32.0	9.1	Overcast	9	...	...	...
28	1130	33.0	9.2	Snow	7	117	141.0	162
29	1030	32.5	9.0	Clear	3	...	...	...
30	1100	32.5	9.0	"	5	120	137.8	145
31	1110	32.5	9.3	"	3	...	...	...
Feb. 1	1030	33.0	9.3	Snow	7	121	133.0	147
2	1055	32.5	9.0	Clear	4	...	...	...
3	1030	33.0	9.0	"	1	...	(129)	...
4	1130	32.0	9.0	Snow	4	...	...	...
5	1100	32.5	9.0	Clear	2	117	123.5	130
6	1030	32.5	9.0	"	3	...	...	...
7	1100	32.5	9.1	Overcast	0	...	...	...
8	1100	33.0	9.1	Clear	0	...	...	...
9	1015	32.5	8.7	"	0	...	...	...
10	1015	32.5	8.6	Snow	0	...	...	...
11	1030	32.5	8.6	Clear	1	...	(142)	...
12	1030	33.0	8.6	"	2	...	...	...
13	1030	33.0	8.7	Snow	0	...	...	...
14	1030	33.0	8.7	Clear	0	...	...	...
15	1015	32.5	8.7	Snow	1	...	(133)	...
16	1000	33.0	8.4	Clear	2	...	...	...
17	1000	32.5	8.4	"	0	...	...	...
18	1000	32.0	8.4	"	4	...	...	...
19	0900	32.5	8.5	"	3	129	138.7	153
20	1030	32.5	8.7	"	2	...	...	...
21	1030	32.0	8.7	"	5	125	136.4	152
22	1000	32.0	8.7	"	1	...	...	...
23	0945	32.0	9.0	"	7	129	142.4	168
24	1000	33.0	9.1	Rain	4	...	...	...
25	1100	32.5	10.0	Snow	11	138	149.4	159
26	0935	32.5	10.0	Clear	1	...	...	...
27	1030	32.5	10.0	Snow	13	126	149.1	176
28	1000	32.5	10.0	Snow	28	...	...	...
Mar. 1	1030	33.0	10.1	Clear	6	114	133.5	172
2	0930	33.0	10.0	Snow	24	119	134.6	155
3	1100	32.5	10.1	Clear	19	118	141.9	167
4	1100	32.5	10.0	Rain	18	116	135.8	153
5	1100	32.5	9.6	Clear	7	131	142.0	164
6	1100	33.0	9.6	"	8	...	...	...
7	1130	33.0	10.3	"	8	110	140.6	166
8	1100	33.0	9.4	Overcast	9	...	...	...
9	1110	32.5	9.4	Snow	4	117	132.0	144
10	1045	33.0	9.2	Clear	3	...	...	...
11	0930	32.5	9.1	"	1	...	(127)	...
12	1000	32.5	9.6	"	0	...	...	...
13	1045	33.0	9.2	"	2	...	...	...
14	1015	32.5	9.1	Snow	1	...	...	...
15	1045	33.0	9.1	Clear	1	...	(129)	...
16	1045	33.0	9.0	Snow	1	...	...	...
17	1100	32.5	9.0	Overcast	1	...	...	...
18	1100	33.0	9.0	Clear	0	...	...	...
19	1500	32.0	9.0	"	3	121	133.3	141
20	1100	32.5	8.5	"	1	...	...	...
Grand total and grand average and range					1,404	110	136.4 3/	192

1/ Recording for 48-hour period.
2/ Range and average based on 93 specimens.
3/ Based on sample of 749 specimens.

Table 2. Numbers and minimum, average, and maximum total lengths of newly-transformed sea lampreys migrating downstream in the Carp Lake River during the winter of 1948-1949 with weather and water temperature and water level data for the period.

Date 1948-1949		Mean water temperature (Degrees F.)[1]	Water level (inches)[1]	Weather[1]	Sea lampreys (newly-transformed migrants) Number taken	Total length in mm. Min.	Aver.	Max.
Oct.	1	55.5	11.25	Clear	0	...	...	...
	2	56.0	10.00	Overcast	0	...	...	...
	3	53.5	9.50	Clear	0	...	...	...
	4	49.5	9.50	"	0	...	...	...
	5	49.0	9.75	Overcast	0	...	...	...
	6	49.0	9.75	"	0	...	...	...
	7	51.0	9.75	"	1	...	(127)	...
	8	52.5	10.00	Clear	0	...	...	...
	9	51.5	10.25	Overcast	0	...	...	...
	10	49.0	11.50	"	0	...	...	...
	11	47.5	11.75	"	0	...	...	...
	12	48.0	11.00	"	0	...	...	...
	13	48.0	11.00	"	0	...	...	...
	14	49.0	10.50	Clear	0	...	...	...
	15	48.0	10.50	"	0	...	...	...
	16	47.5	10.50	Overcast	0	...	...	...
	17	48.5	10.50	"	0	...	...	...
	18	44.0	10.50	Clear	0	...	...	...
	19	41.0	10.25	Overcast	0	...	...	...
	20	39.5	10.25	Clear	0	...	...	...
	21	39.0	10.00	"	1	...	(124)	...
	22	40.0	10.00	"	0	...	...	...
	23	40.0	10.00	Overcast	1	...	(128)	...
	24	43.0	10.00	Clear	0	...	...	. .
	25	41.0	10.50	"	0	...	...	...
	26	41.0	11.00	"	0	...	...	...
	27	43.5	11.50	"	0	...	...	...
	28	44.0	11.00	"	0	...	...	...
	29	45.0	10.50	"	0	...	...	...
	30	43.5	11.00	"	0	...	...	...
	31	45.0	11.00	Overcast	0	...	...	...
Nov.	1	47.0	10.50	"	0	...	...	...
	2	49.0	10.50	"	3	123	132.7	140
	3	50.0	10.50	"	6	...	...	...
	4	49.0	10.75	Rain	5	124	135.6	145
	5	50.0	11.00	"	5	...	...	...
	6	51.5	12.00	Overcast	2	135	139.5	144
	7	49.0	12.00	"	3	...	...	...
	8	45.5	11.75	Clear	0	...	...	...
	9	42.5	12.00	Rain	0	...	...	...
	10	44.5	12.50	"	4	128	141.3	148
	11	42.0	12.50	Overcast	16	...	...	...
	12	38.0	12.50	"	32	122	135.6	160
	13	38.5	12.75	Rain	3	...	...	...
	14	38.0	13.00	Snow	16	127	143.4	165
	15	37.0	12.75	Snow; rain	6	...	...	...
	16	38.5	12.50	Overcast	3	133	138.3	144
	17	37.0	13.00	Rain	121	...	...	...
	18	39.5	13.00	Overcast	120	117	135.2	168
	19	39.0	16.00	"	12	...	...	...
	20	38.0	16.00	Rain	216	121	143.0	172
	21	37.0	15.50	Overcast	3,467	...	...	...
	22	38.0	15.00	Rain	289	115	142.5	173
	23	39.0	14.75	Overcast	65	...	...	...
	24	37.5	14.50	"	68	126	144.2[2]	163
	25	37.0	14.50	"	0	...	...	...
	26	37.5	14.50	"	19	133	150.8	170
	27	39.5	14.50	"	19	...	...	...
	28	38.0	14.50	Snow	32	130	148.2	169
	29	36.0	14.50	Overcast	13	...	...	...
	30	36.5	14.50	"	23	129	145.6	163
Dec.	1	35.5	14.50	"	20	114	145.7	169
	2	34.0	14.50	"	12	131	143.3	157
	3	34.0	14.50	"	5	126	153.2	185
	4	35.0	14.50	Clear	14	134	145.8	163
	5	34.5	14.50	Overcast	9	...	...	...
	6	36.0	15.00	Snow	22	131	145.9	170
	7	34.0	15.00	Overcast	43	128	142.0	161
	8	32.5	14.00	Snow	12	119	151.0	174
	9	32.0	13.75	Overcast; snow	1	...	...	...
	10	32.5	13.75	Overcast	2	116	127.0	138
	11	32.0	13.75	"	4	...	...	...
	12	32.0	13.75	Rain	4	139	149.5	158
	13	32.5	14.00	Overcast	1	...	...	...
	14	32.0	14.00	"	1	...	(150)	...
	15	32.0	14.00	Snow	0	...	...	...

Continued next page

Date 1948-1949		Mean water temperature (Degrees F.)1/	Water level (inches)1/	Weather1/	Sea lampreys (newly-transformed migrants) Number taken	Total length in mm. Min.	Aver.	Max.
Mar.	1	32.0	32.00	Clear	16	...	...	...
	2	32.0	35.00	Snow	31	122	140.3	173
	3	32.0	30.00	Clear	11	...	...	...
	4	32.0	34.00	Overcast	4	132	140.8	151
	5	32.0	31.00	"	3	...	...	...
	6	32.0	29.00	Clear	22	123	143.8	187
	7	32.0	28.00	"	13	...	...	...
	8	32.0	28.00	Overcast	11	126	146.2	167
	9	32.0	27.00	Clear	3	...	...	...
	10	32.0	24.00	"	0	...	...	...
	11	32.0	21.00	Overcast	0	...	...	...
	12	32.0	20.00	Clear	2	128	137.0	146
	13	32.0	18.00	"	0	...	...	...
	14	32.0	17.00	"	0	...	...	...
	15	32.0	13.00	"	0	...	...	...
	16	32.0	14.00	Snow	0	...	...	...
	17	32.0	14.00	Overcast	0	...	...	...
	18	32.0	15.00	Clear	0	...	...	...
	19	32.0	14.00	Overcast	3	...	...	...
	20	32.0	14.00	Clear	2	155	161.0	167
	21	32.0	13.50	Overcast	0	...	...	...
	22	32.5	13.00	"	5	135	148.4	167
	23	33.5	13.00	"	701	...	...	...
	24	33.5	15.00	"	342	102	145.9	188
	25	33.5	17.00	"	348	...	...	...
(Trap inoperative during period March 26 to April 18 due to extreme flood conditions. Peak of downstream movement of sea lampreys observed during peak of flood: March 26-April 3. Samples obtained during inoperative period shown in right hand columns.)								
	26	34.0	20.00	Clear	(614)	118	143.5	180
	27	33.5	21.00	Overcast	...	...	...	...
	28	33.5	34.00	"	...	...	...	...
	29	33.0	35.00	"	...	...	...	...
	30	33.5	36.00	"	(167)	95	137.3	189
	31	33.5	34.00	"	(4)	...	...	...
Apr.	1	34.5	28.00	Clear	...	...	...	...
	2	35.5	27.00	"	(4)	...	...	...
	3	36.5	25.00	"	...	...	...	...
	4	37.5	23.00	"	...	...	...	...
	5	39.0	24.00	Overcast	...	...	...	...
	6	41.0	21.00	"	...	...	...	...
	7	42.0	20.50	"	...	...	...	...
	8	42.0	20.00	Clear	...	...	...	...
	9	41.0	20.00	"	...	...	...	...
	10	41.0	20.00	"	...	...	...	...
	11	42.0	19.00	"	(1)	...	(163)	...
	12	43.0	19.00	"	(1)	...	...	...
	13	47.5	19.00	"	...	...	...	...
	14	49.0	19.00	"	...	...	...	...
	15	44.0	18.00	"	...	...	...	...
	16	41.0	17.00	"	...	...	...	...
	17	41.0	17.00	"	...	...	...	...
	18	44.0	18.00	Overcast	(1)	...	...	...
	19	46.0	17.00	Clear	1	...	(141)	...
	20	46.5	16.00	Overcast	0	...	...	...
	21	48.0	16.00	"	0	...	...	...
	22	50.0	16.00	"	3	...	...	...
	23	48.5	17.00	"	3	139	144.7	156
	24	44.0	17.00	"	0	...	...	...
	25	46.0	17.00	Rain	0	...	...	...
	26	46.0	21.00	Overcast	0	...	...	...
	27	50.0	20.00	"	0	...	...	...
	28	53.0	19.00	Clear	0	...	...	...
	29	50.0	19.00	"	0	...	...	...
	30	55.0	18.00	"	0	...	...	...
Grand total and grand average and range					7,969	95	143.6 3/	189

1/ All readings and observations made at 0800 hours each day.
2/ Based on 37 specimens.
3/ Based on 2,462 specimens.

Date 1948-1949		Mean water temperature (Degrees F.)[1]	Water level (inches)[1]	Weather[1]	Sea lampreys (newly-transformed migrants) Number taken	Total length in mm. Min.	Aver.	Max.
Dec.	16	32.0	14.00	Overcast	0	...	...	...
	17	32.0	14.00	Snow	2	...	...	...
	18	32.0	14.00	Overcast	5	140	146.8	155
	19	32.0	14.00	"	1	...	...	...
	20	32.0	14.00	"	0	...	...	...
	21	32.0	14.00	Snow	2	...	...	...
	22	32.0	14.00	Overcast	4	135	140.3	154
	23	32.0	13.75	"	5	...	...	...
	24	32.0	13.75	"	2	145	155.0	165
	25	32.0	14.00	"	5	...	...	...
	26	32.0	14.00	Rain; snow	7	129	145.9	163
	27	32.0	14.00	Overcast	3	...	...	...
	28	32.0	14.00	"	3	135	147.3	156
	29	32.0	14.00	Snow	5	...	...	...
	30	32.0	13.75	Overcast	2	139	144.0	149
	31	32.0	13.75	"	5	...	...	...
Jan.	1	32.0	13.75	"	2	135	144.5	154
	2	32.0	13.75	"	1	...	...	...
	3	32.0	13.75	Snow	2	149	156.5	164
	4	32.0	13.75	"	3	...	...	...
	5	32.0	14.00	Overcast	0	...	...	...
	6	32.0	14.00	"	1	...	...	...
	7	32.5	17.75	"	2	129	134.5	140
	8	32.0	18.00	Clear	7	...	...	...
	9	32.0	18.00	"	1	...	(153)	...
	10	32.0	17.00	Overcast	1	...	...	...
	11	32.0	16.50	"	1	...	(166)	...
	12	32.0	16.00	Snow	0	...	...	...
	13	32.0	15.00	"	0	...	...	...
	14	32.0	15.00	"	0	...	...	...
	15	32.0	15.00	"	1	...	(142)	...
	16	32.0	20.00	"	0	...	...	...
	17	32.0	19.00	"	5	126	149.0	165
	18	32.0	18.50	Overcast	53	...	...	...
	19	32.0	18.00	Snow	34	128	152.0	167
	20	32.0	...	Overcast	65	...	...	...
	21	32.0	...	"	26	121	138.2	173
	22	32.0	...	Clear	30	...	...	...
	23	32.0	30.00	...	10	116	140.9	163
	24	32.0	28.00	Snow; rain	16	...	...	...
	25	32.0	26.00	Snow; sleet	14	132	147.0	166
	26	32.0	21.00	Snow	3	...	...	...
	27	32.0	21.00	Overcast	11	127	140.1	150
	28	32.0	19.50	Snow	7	...	...	...
	29	32.0	22.50	Clear	21	130	138.4	150
	30	32.0	23.00	"	12	...	...	...
	31	32.0	24.00	Overcast	7	119	134.4	148
Feb.	1	32.0	23.50	Snow	5	...	...	...
	2	32.0	25.00	Clear	4	127	131.3	134
	3	32.0	34.00	Overcast	7	...	...	...
	4	32.0	30.00	Snow	3	133	147.3	157
	5	32.0	28.00	Overcast	1	...	...	...
	6	32.0	26.00	Clear	0	...	...	...
	7	32.0	27.00	Overcast	4	...	...	...
	8	32.0	34.00	Clear	1	...	(133)	...
	9	32.0	28.00	Overcast	0	...	...	...
	10	32.0	26.00	"	2	132	142.0	152
	11	32.0	28.00	"	3	...	...	...
	12	32.0	29.00	Clear	1	...	(146)	...
	13	32.0	26.00	Snow	0	...	...	...
	14	32.0	26.00	Clear	0	...	...	...
	15	32.0	26.00	"	1	...	...	...
	16	32.0	29.00	Overcast	8	137	144.4	151
	17	32.0	22.00	Clear	2	...	...	...
	18	32.0	30.50	Clear	6	124	136.8	145
	19	32.0	29.00	"	18	...	...	...
	20	32.0	25.00	Overcast	1	...	(144)	...
	21	32.0	22.00	Clear	3	...	...	...
	22	32.0	24.00	Overcast	2	148	150.0	152
	23	32.0	23.00	"	1	...	...	...
	24	32.0	23.00	"	33	132	147.3	174
	25	32.0	36.00	Snow	303	...	...	...
	26	32.0	33.00	Overcast	129	124	145.5	182
	27	32.0	40.00	Snow	4	...	...	...
	28	32.0	32.00	"	2	135	137.5	140

Continued next page