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THE POPULATION OF SEA LAMPREY LARVAE IN EAST BAY, ALGER COUNTY, MICHIGAN

By

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Larvicides have proven their effectiveness by virtually eradicating ammocoetes[1] of the sea lamprey (Petromyzon marinus) in streams tributary to Lake Superior.[2] It has been demonstrated, however, that ammocoetes also occur in the Great Lakes or in tributary inland lakes, where larvicide treatment by present methods would be prohibitively expensive. Hansen and Hayne (in press) estimated that the population of ammocoetes in a small bay in Big Bay de Noc, Delta County, exceeded 30,000; Stauffer and Hansen[3] found larvae at four other areas in Lake Michigan in 1957; Thomas (1960) collected ammocoetes in Lake Superior; and we (unpublished) have collected larvae in Huron Bay (Lake Superior), and in Au Train Lake (a tributary of Lake Superior). It thus appears that ammocoete populations are not uncommon in the Great Lakes, and that their presence may retard the sea lamprey control program, even though these lentic populations are presumably derived from tributary streams (Hansen and Hayne, in press).

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[1] "Ammocoete" and "larva" refer to the sea lamprey, unless stated otherwise.

[2] Programs and Progress, 1959. Mimeographed report of Great Lakes Fisheries Investigations, Bureau of Commercial Fisheries, Fish and Wildlife Service, U. S. Dept. of Interior.

[3] 1958. A preliminary report on the migration of sea lamprey ammocoetes in Michigan. Mich. Dept. Cons., Inst. Fish. Res. Report No. 1535 (unpublished).

The present study was undertaken in 1960 to provide additional information on the magnitude and characteristics of populations of ammocoetes in lentic environments. The population of ammocoetes in East Bay, Alger County (Fig. 1) that was selected for study, was of especial interest because the Sucker River (a tributary of East Bay and the presumed source of the bay population) had been successfully treated with larvicide in 1959.

East Bay and the Sucker River are located about 75 miles west of Sault Ste. Marie, Michigan. The bay is a 78-acre lake, connected by 1/3-mile-long East Bay Channel to West Bay, which in turn opens on Lake Superior. East Bay has a maximum depth of 46 feet and a predominantly sand bottom to depths of 20 feet; at greater depths, the bottom is mostly organic silt. In general, the shoreline is barren and wind-swept, and the shoal area has only small amounts of emergent and floating vegetation. There was apparently no thermal stratification of the lake during the summer of 1960. The predominant fishes in the lake, in addition to larvae of the sea lamprey and American brook lamprey (*Lampetra lamottei*), were yellow perch (*Perca flavescens*), northern pike (*Esox lucius*), rainbow trout (*Salmo gairdneri*), white sucker (*Catostomus commersoni*), and Johnny darter (*Etheostoma nigrum*).

The Sucker River supported a moderate population of brook trout (*Salvelinus fontinalis*) and rainbow trout, and was one of the three largest producers of sea lampreys among Michigan tributaries of Lake Superior (Stauffer and Hansen, 1958). The stream divides into two channels near the mouth and enters East Bay (summer discharge about 30 c.f.s.) on the south side; a third, smaller, intermittent channel enters the bay in the southeast corner during the spring runoff (Fig. 1).

Figure 1.--East Bay, showing strata (I-XIII), and the number of ammocoetes collected per square foot at different sampling stations.

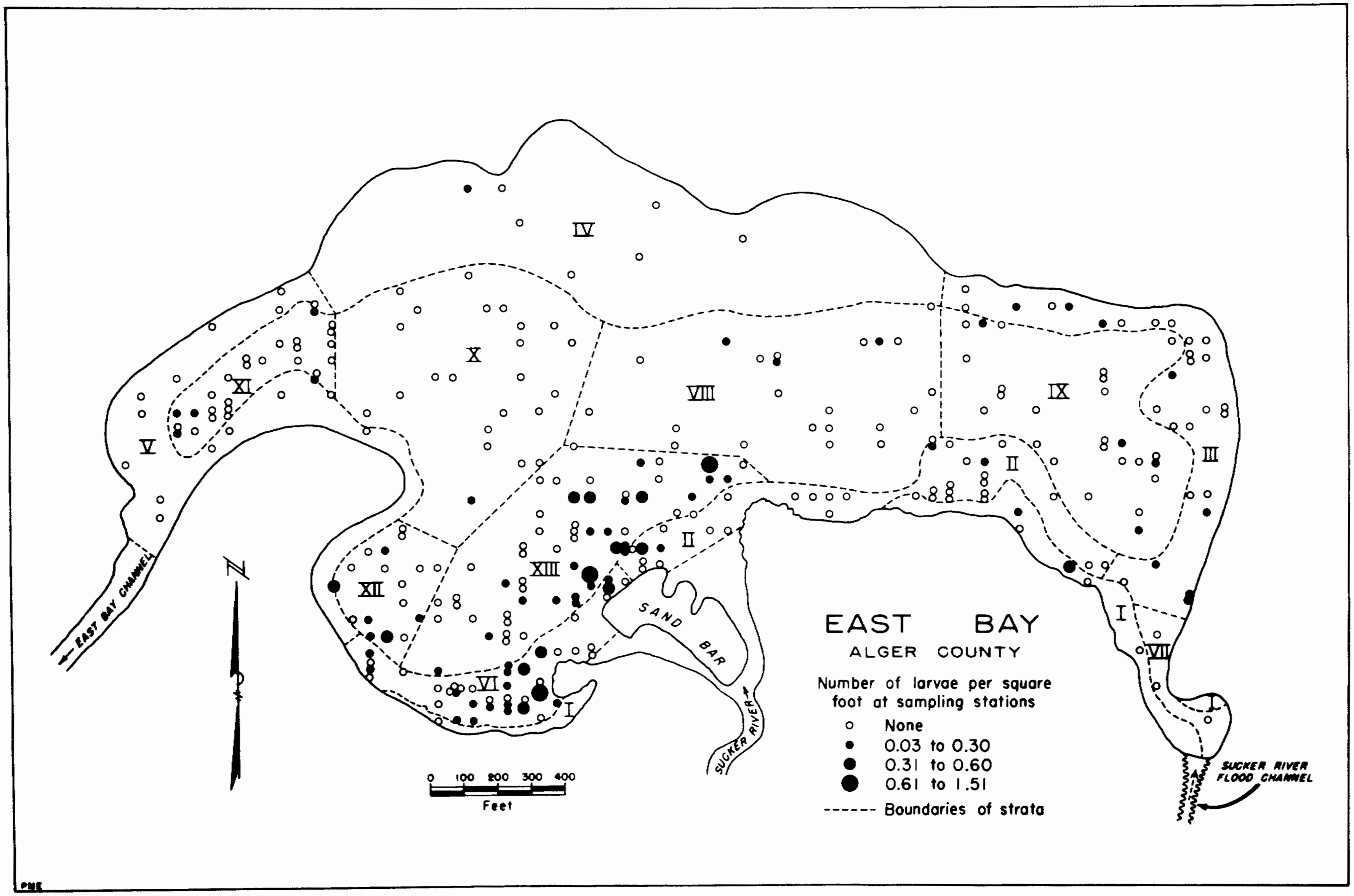
EAST BAY
ALGER COUNTY
Number of larvae per square foot at sampling stations
None
0.03 to 0.30
0.31 to 0.60
0.61 to 1.51
Boundaries of strata
SAND BAR
SUCKER RIVER
SUCKER RIVER FLOOD CHANNEL
EAST BAY CHANNEL
Feet
0 100 200 300 400
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII

Figure 1

In October, 1958, the Sucker River was treated with a larvicide by the U. S. Bureau of Commercial Fisheries, but a drop in temperature prevented a complete kill. The river was retreated in August, 1959 and no lampreys were found during post-treatment surveys in September, 1959.[2] In July, 1956, before the river had been treated, 5 hours of electrofishing along the shoreline of East Bay revealed that ammocoetes of the sea lamprey and the American brook lamprey were relatively abundant near the major mouths of the river and along the south shore toward East Bay Channel, but were comparatively rare along the southeast, east, and north shores. In May, 1960, after treatment of the river, collections were again made with a direct-current shocker along most of the shoreline of East Bay, to determine whether the ammocoete population was still present after larvicide treatment of the "parent" stream. The catch of ammocoetes per hour in 1960 was similar to the catch in 1956 (suggesting a substantial ammocoete population) so a detailed population study was undertaken from July 22 to September 1, 1960.

Methods

An orange-peel dredge was used to estimate the ammocoete population of East Bay by the area-density method (Rounsefell and Everhart, 1953). A physical survey of the lake was made in June, 1960, to facilitate the random sampling required for the population estimate. Depths and bottom types were determined and recorded on a shore outline map drafted from an aerial photograph.

Selection of stations.--For the population estimates, East Bay was divided according to bottom type and depth into two areas. Further subdivisions into a total of 13 strata (Fig. 1) were based on the expected concentration of ammocoetes as estimated by the preliminary sampling, and on the distance from the mouth of the Sucker River (ammocoete concentration was expected to be greater near the stream mouth). The one exception was Stratum I, which arbitrarily included all areas with emergent vegetation, regardless of the location in the bay or the estimated abundance of ammocoetes. (Emergent vegetation was restricted to water depths of less than 3 feet.)

To establish station locations in each stratum, grid lines were drawn at 50-foot intervals on the map of the bay. Within each stratum, each grid-line intersection was numbered and became a possible sampling station, subject to random selection. To assure random sampling in time among strata, the order in which collection stations in the bay were sampled was determined at random.

The number of stations to be sampled in each stratum was adjusted so that the strata with the higher populations were sampled more frequently than strata with lower populations. For the first complete series of samples (25 lifts of an orange-peel dredge at each of 101 stations), the number of stations in each stratum was based on the anticipated abundance of ammocoetes as indicated by the earlier electrofishing in the bay, on the distance of the stratum from the mouth of the Sucker River, and on the area of the stratum. During the second round of sampling (15 lifts with an orange-peel dredge at each of 195 stations; and 7 stations with a metal enclosure, as described below), the number of stations in each stratum was determined on the basis of the size of the ammocoete population suggested by the first round of sampling.

To facilitate location of each sampling station in the bay (after random selection of the grid point), markers were placed along the shoreline at intervals of 150 to 250 feet, and 14 buoys were anchored in the bay. All markers and buoys were then plotted on the map. To locate the first 143 stations, distances from known points (shore markers and buoys) to the sampling stations were estimated; this method may have introduced some error, in the location of sampling sites within intended strata, for stations within 200 feet of shore where depth and bottom type changed rapidly in relation to distance from the shore. At subsequent stations the distances from shore to all stations within 200 feet of the shore were measured with a floating line to remove this possible bias. Distances to stations more than 200 feet from shore were estimated; here depth and bottom type were relatively uniform and it was unlikely that error in location of sites would affect the accuracy of the population estimate. For all stations, the direction of both estimated and measured distances to the station was determined by "lining up" with markers and buoys of known location.

Sampling procedure.--In Strata II-XIII, 15 or 25 lifts were taken at each station with an orange-peel dredge that was operated with a boom and winch from a 16-foot trapnet boat; care was taken to avoid superimposed lifts. The dredged material was emptied into a 28- by 60-inch screen box, 10 inches deep, of 1/8-inch wire mesh. The fine sediments were washed out by a water-sprinkler system supplied by a 2,000-gallon-per-hour centrifugal pump. Ammocoetes, debris and coarse particles were retained by the screen. The screened material was carefully examined before it was discarded. All ammocoetes were preserved in 10-percent formalin and later identified and measured.

The dredge sampled varying areas of the bottom in each lift, depending upon bottom type. In organic silt (81 stations), where the dredge penetrated deepest, the area sampled was judged to be 0.92 square foot (the maximum capacity of the dredge). In hard sand bottom (90 stations), the dredge was calibrated[4] and the average area sampled by one lift was found to be 0.76 ±0.004 square foot. In heterogeneous bottom types (125 stations), the estimate of bottom area sampled was derived by interpolation between the above values for silt and sand. Not infrequently, the jaws of the dredge were prevented from closing by sticks or other objects. Lifts, in which the jaws did not close and in which little bottom material was retained, were not used in the population estimate.

In Stratum I, where emergent vegetation was present, the dredge would not penetrate the heavy root mat. To sample this stratum, a 55-gallon steel barrel from which both ends had been removed was used. Blades were attached to the bottom rim of the barrel to cut through the roots, and a 10-foot steel pipe was attached across the top to use as a lever to rotate the barrel and thus facilitate penetration of the lower edge into the bottom. In

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[4] One dredge lift was taken at each of ten areas in sand bottom where 1/4-inch ball bearings had been placed in a 2-inch grid pattern covering 9 square feet. The average area sampled was determined from the average number of bearings (each of which represented an area of 4 square inches) picked up.

sampling, the enclosure was placed over a randomly selected sampling site and slowly rotated until the lower edge had penetrated 8 to 12 inches into the substrate. Vegetation, roots and other debris were first removed and examined for ammocoetes. Then a lamprey larvicide, the sodium salt of 3-trifluormethyl-4-nitrophenol, was introduced at a concentration of 40 to 60 ppm. After a waiting period of 1 to 2 hours, a scap net was passed repeatedly through the water in the enclosure to recover any ammocoetes that were present. The water was then pumped from the enclosure into a screened box and the substrate was examined for ammocoetes to a depth of about 2 inches. (No larvae were found in the substrate in any of the samples, however.) The area sampled by the enclosure was 2.64 square feet. Three enclosure samples were taken at each station, representing a total area of 7.92 square feet.

Estimation of population.--The estimated number of sea lamprey ammocoetes in each stratum was the product of the mean number of ammocoetes collected per square foot (mean number per station divided by mean station area), and the total area of the stratum, in square feet. The total estimated population was found by summing the estimates for the different strata. A variance for the ratio estimate was calculated by methods given by Cochran (1953).

Most of the sampling on East Bay was done with the orange-peel dredge. Hansen and Hayne (in press) compared dredge collections in Ogontz Bay and River with collections made there with a metal enclosure (which presumably caught all larvae), and found that the dredge collected only about one-third of the ammocoetes of the sea lamprey and American brook lamprey present in a given area. Thus estimates based on orange-peel dredge samples were judged to be far too low for East Bay.

Reasons why the orange-peel dredge does not capture all lampreys within the area covered by the open dredge include the following: (1) The dredge does not close completely on a bottom containing detritus; this bottom type is a preferred habitat for lampreys (see below). (2) Jaws of the dredge, as they close, slice into the substrate at an angle, thus reducing the area which is sampled effectively. A correction factor for this bias was determined for sand bottom by calibration but was assumed to be nil for silt bottom (possibly an erroneous assumption). (3) There may be some escapement through an opening (used for cleaning) at the top of the dredge. (4) Some lampreys may escape from the area to be dredged during the short interval of time between the placement of the dredge and the closure of the jaws.

Population estimate

A total of 214 ammocoetes were taken from the 303 randomly selected dredging and enclosure stations. The estimated population of sea lamprey larvae in East Bay was 96, 300 ±20, 500 of which 47, 400 ±8, 500 were from strata in water depths of more than 20 feet (Table 1). The percentage of the population that was metamorphosing was apparently small, since only a single transforming specimen was taken during the sampling. The relatively small average length (3.6 inches, S.D. = 0.66) of the larvae collected also indicated that few were nearing metamorphosis. Applegate and Brynildson (1952) found that the average length of newly metamorphosed sea lampreys

Table 1.--Areas of strata, number of sampling stations, number of larvae collected, and estimated population of sea lamprey larvae in East Bay, Alger County, 1960

Stratum number	Areas of strata (acres)	Number of sta- tions	Number of larvae collected	Population estimates: Number of larvae	Population estimates: Standard error
Shallow water[1]					
I	2.50	7	4	7,900	5,900
II	3.69	32	11	4,400	2,900
III	4.88	28	13	6,700	2,500
IV	14.20	7	3	16,500	16,600
V	5.44	13	0	-	-
VI	2.50	40	66	13,400	4,500
VII	0.86	3	0	-	-
Total	34.07	130	97	48,900	18,600
Deep water[1]					
VIII	10.76	22	3	3,600	2,000
IX	7.50	25	4	3,000	1,400
X	9.39	24	1	900	900
XI	2.13	28	12	2,600	1,300
XII	2.08	17	13	4,300	2,000
XIII	7.37	57	84	33,000	7,800
Total	39.23	173	107	47,400	8,500
Grand total	73.30	303	214	96,300	20,500

[1] Shallow water = 0-20 feet; deep water, 20-46 feet.

migrating downstream in the Carp Lake River, Michigan, was 5.7 inches (S.D. = 0.42) in 1948-1949 and 5.7 inches (S.D. = 0.46) in 1949-1950. Few ammocoetes in East Bay were near this size.

A total of 121 American brook lamprey ammocoetes (average length, 4.6 inches; range, 2.0-6.0) were also collected at the dredging stations. The population of American brook lamprey larvae was estimated as 72,500 ±13,700, of which 30,900 ±6,200 were in deep water. Although American brook lampreys apparently outnumbered the sea lampreys in the Sucker River by about 3 to 1 during 1955-1956 (based on 18 collections with an electric shocker), they were less numerous than sea lampreys in the bay in 1960.

Density of ammocoetes

As an average for the entire bay, the estimated density[5] of ammocoetes was 0.030 per square foot; among strata, the density varied from nil to 0.123 per square foot. Density was closely associated with the distance from the presumed sources of larvae (the three mouths of the river) and also seemed to be associated with bottom type and/or depth. The last two factors were so closely interrelated, however, that separate effects were difficult to differentiate.

Figure 1 shows that the density of ammocoetes per square foot was closely associated with distance from the stream mouths. The average density of ammocoetes at stations within 400 feet of stream mouths was

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[5] The densities given in this section have not been adjusted by the correction factor of 3.2.

0.108 per square foot as compared to an average density of 0.023 at stations 400 to 1,600 feet away.

The collecting stations were divided into three groups, on the basis of the two main bottom sediments present (silt and sand), as follows (number of stations in parentheses): silt, with less than 20 percent sand (106); silty sand, with at least 20 percent sand and 20 percent silt (49); and sand, with less than 20 percent silt (148). The density of larvae was highest in silty sand and higher in silt than in sand; the differences among the three groups were significant (chi-square = 11.26). Judging from many collections in streams, it was suspected, however, that detritus (which occurred in varying amounts in all three soil types) may have contributed to the differences. To further determine the possible effect of detritus, each of the three main groups (silt, silty sand, sand) were divided into two subgroups--one with 2 percent or more detritus and one with no detritus (i.e., less than 2 percent). In silt and in sand, larvae occurred at significantly larger numbers of stations with detritus than at stations with none (chi-square = 7.90 and 12.52, respectively), but no difference was observed between the two subgroups in silty sand. There was no significant difference in occurrence of ammocoetes among the three subgroups of stations with detritus, or among the three subgroups without it; therefore, all stations without detritus were combined, as were all stations with detritus. Overall, ammocoetes occurred more frequently at 108 stations with detritus than at 195 stations without it (chi-square = 27.40). On the basis of this high chi-square value, and general observations while collecting ammocoetes in many Michigan streams, we believe that a substrate containing detritus is a preferred habitat for ammocoetes.

The average density of larvae at the collecting stations in relation to depth of collection is shown in Figure 2. In 5-foot depth intervals, the average density of larvae per square foot ranged from 0.002 (41-46 feet in depth) to 0.144 (11-15 feet).

Length of ammocoetes

Hansen and Hayne (in press) showed that there was no difference in length between larvae (all species) collected with enclosures and those collected with the orange-peel dredge. Furthermore, in East Bay the average lengths of ammocoetes collected (within the 5-foot contour) with a direct-current shocker and with an orange-peel dredge were not significantly different. Thus, in the present study, we assume that the dredge was not selective for different sizes of ammocoetes.

The average length of the 214 ammocoetes collected by dredging and enclosures was 3.6 ±0.14 inches. For each stratum, the estimated number of larvae in each 0.1-inch size group was calculated from the lengths of ammocoetes collected and the population estimate. The totals from all strata were then summed to obtain the length-frequency distribution of the population in the entire bay (Fig. 3). The length-frequency distribution of the population approximated a normal curve, with three outstanding variations at 1.8, 2.8 and 4.2 inches. These abnormmally high points in the

Figure 2.--The density of sea lamprey larvae in relation to depth, East Bay, Michigan, 1960. Dots represent the number collected per square foot at each station. Encircled numbers are numbers of stations at which no sea lampreys were collected. The curve represents average density in relation to depth of water.

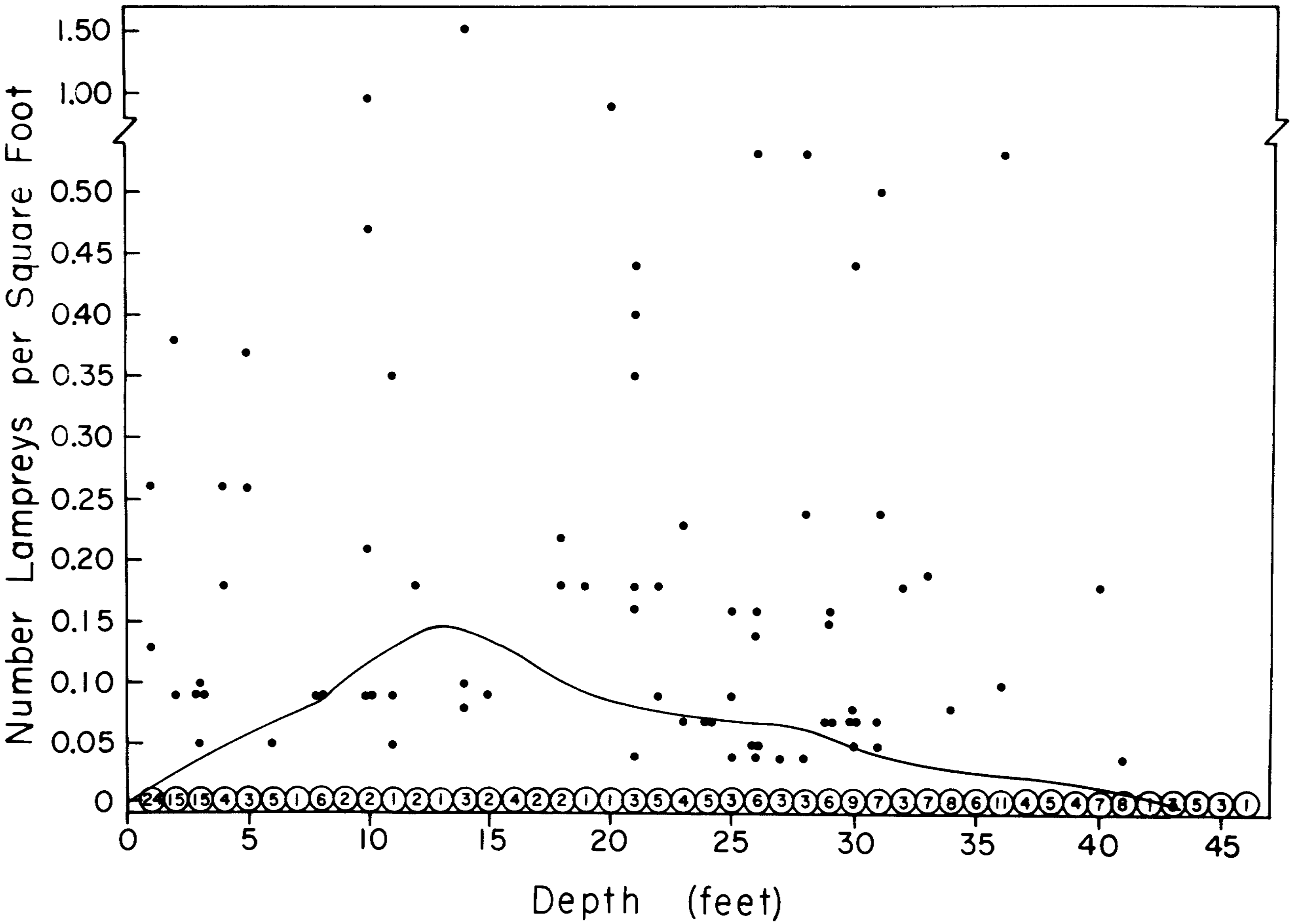
Number Lampreys per Square Foot
1.50
1.00
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
5
10
15
20
25
30
35
40
45
Depth (feet)

Figure 2

Figure 3.--Estimated length-frequency distribution of larval sea lampreys in East Bay, 1960.

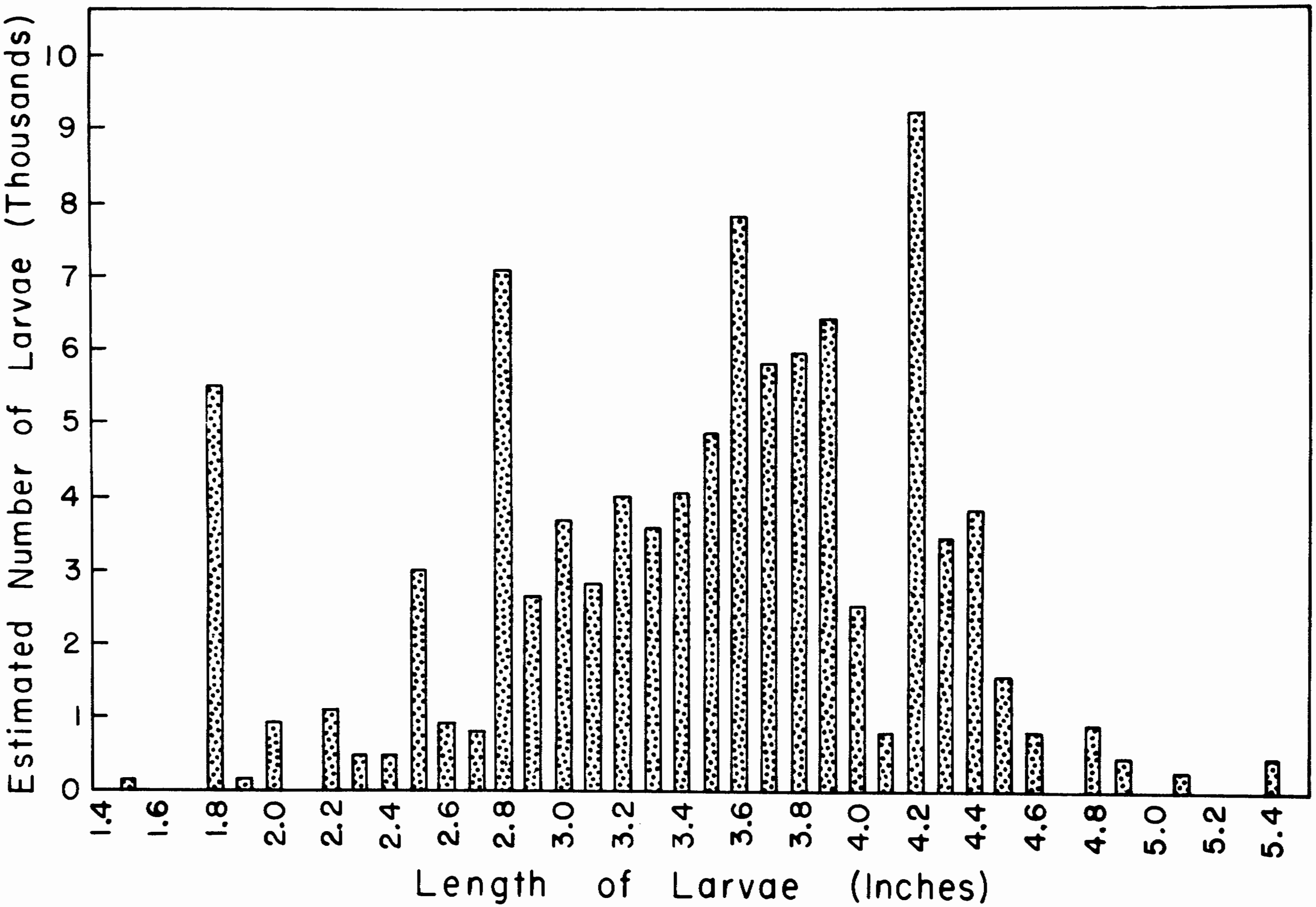
Estimated Number of Larvae (Thousands)
0
1
2
3
4
5
6
7
8
9
10
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
Length of Larvae (Inches)

Figure 3

distribution reflect disproportionally light sampling in Stratum IV in proportion to the population. The average size of the estimated population (3.4 inches) in the entire bay approximates that of the ammocoetes which were collected.

The length of ammocoetes was related to depth, but apparently not to distance from the mouth or to bottom type. Multiple regression analysis (Snedecor, 1956) was used to test the effect of depth, and distance from the mouth (independent variables) on the length of larvae (dependent variable). The multiple regression equation ($L = 3.275 \div 0.0172\,X - 0.00019\,Y$, where L = length of larvae in inches, X = depth of water in feet, and Y = distance from the mouths in feet) showed that the average length of larvae increased 0.017 inch with each foot of depth and decreased 0.019 inch with each 100-foot increase in distance from the mouths of the stream. The increase in length associated with depth was significant ($F = 16.35$) but the decrease in length associated with distance from the sources was not significant. An analysis of variance indicated that there was no difference among average sizes of ammocoetes collected in the six subgroups of bottom type mentioned in the preceding section (silt, silty sand, or sand; each considered with or without detritus).

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