A BENTHOLOGICAL INVESTIGATION OF LAKE MICHIGAN

THESIS FOR THE DEGREE OF M. S.
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JAMES WILLIAM MERNA

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A BENTHOLOGICAL INVESTIGATION OF LAKE MICHIGAN

By

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A THESIS

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ABSTRACT

The bottom fauna of Lake Michigan is typically an oligotrophic population, and is dominated, both numerically and volumetrically, by the amphipod Pontoporeia affinis. Thirty-one forms of benthic organisms were identified. The numerically dominant organisms included Oligochaeta, Gastropoda, Pelecypoda and Diptera larvae in addition to P. affinis. Of lesser importance in the fauna were several species of insect larvae; the amphipod Gammarus sp. and the isopod Lirceus lineatus (Say).

A distinct shallow-water fauna was collected in several shallow shoal areas. This habitat was evident in the shoal area east of Beaver Island, where Gammarus sp., isopods, insect larvae and leeches were abundant.

There was a distinct decline in the number of species and abundance of all organisms from a depth of 25 to 40 fathoms. Several of the typical shallow-water forms were absent from all samples collected at depths of 40 fathoms or more.

P. affinis comprised an average of 70 percent of the volume of all samples. This amphipod was dominant numerically at all depths sampled from 5 to 100 fathoms.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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INTRODUCTION

This project constituted a benthological investigation of the profundal bottom fauna of Lake Michigan. It was conducted in cooperation with the United States Bureau of Commercial Fisheries as one phase of their extensive investigation of the Great Lakes.

In recent years the Great Lakes have become of paramount interest to the aquatic biologist. These lakes have been major contributors to the commercial fishery of the United States. The present extensive interest in the Great Lakes is primarily a result of the invasion of the sea lamprey (*Petromyzon marinus*) and its destruction of the lake trout (*Salvelinus namaycush*) and certain other commercial species of fish. It is now evident that the Great Lakes present a dynamic ecosystem with ever-changing species composition and productivity. In order to evaluate these transitions it is important that we understand the factors influencing and accompanying the changes. Among such factors is the benthic fauna which constitutes a potential food source for the fish population.

The available literature contains very little information relative to the benthic fauna of the Great Lakes. Due to the magnitude of the Great Lakes, and the inefficiency of sampling methods on large bodies of water, it is not difficult to understand why this work has not been undertaken sooner. The lack of suitable craft, trained crews and operating expenses inhibited early investigators of the Great Lakes. Eggleton (1935,1936) was one of the few biologists to

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to attempt a study of the benthos of Lake Michigan.

It was not until the U. S. Bureau of Commercial Fisheries put its boat, the Cisco, into operation in 1951 with a trained crew of biologists that extensive benthological samples of Lake Michigan could be obtained. Dredging operations were conducted in Lake Michigan during the summers of 1951, 1952, 1954 and 1955, and it is from this work that the data for this project have been taken.

The majority of the samples in this survey were collected with an orange-peel dredge. This dredge is frequently used in benthological sampling. It offers several advantages over both the Ekman and Petersen dredges, especially in deep-water areas. The Ekman dredge lacks sufficient weight for deep-water sampling, and does not function properly in sand. The U. S. Bureau of Commercial Fisheries has used the orange-peel dredge extensively in the Great Lakes, as it is the only dredge that operates in hard clay or gravel. This is particularly true in Lake Superior where the Petersen dredge is often ineffective.

Quantitative benthological investigations require a sample from a known area. No previous attempts to determine the sampling area of the orange-peel dredge in various bottom types are known. Henson (1954) has made a comparison of the sampling abilities of the orange-peel and Ekman dredges. He accepts the circular cross-section of 11.5 inches as representing the sampling area of the orange-peel dredge. This is equivalent to 0.72 square foot. The use of this figure presumes a full sample, and would not be accurate where the penetration was limited by a hard substratum. Henson concluded that the orange-peel dredge samples with a lower variance than does the Ekman dredge. He credited this advantage to a more uniform penetration in a mud bottom.

The area sampled by an orange-peel dredge is determined by the depth of penetration of the blades into the substratum. It varies greatly with the bottom type.

An attempt has been made to correlate the sampling area of the dredge with the volume of bottom material collected at various depths of penetration of the blades. The volume of the sample varied directly with the area covered by the dredge. It is believed that a plot of this relationship will serve as a practical method for determining the sample area from any measured volume of bottom material.

A series of samples was taken in the laboratory from a container of sand. The depth of sand was adjusted by one inch intervals from one to six inches inclusive. A measurement was made of the area sampled and the volume of sand collected in each sample.

The surface area sampled by the dredge was determined by placing dry beans on the surface of the sand in a one inch square grid pattern. The beans were alined on the sand by using a plywood board with holes bored at every inch to form the grid. The board was then removed and the beans were pushed down until they were flush with the surface of the sand. This was believed to present the most accurate sampling situation as it prevented them from being pushed to the side when they otherwise would have been collected in the sample. A grab was then made with the dredge and the number of beans taken was accepted as the actual area sampled. The volume of sand collected was then measured to the nearest 0.25 quart. It is believed that this measurement would not be impractical under field conditions. The entire sampling procedure was repeated six times at each succeeding one inch depth interval (Table 1). The sand was kept wet throughout the experiments.

The use of this method for determining sampling area necessitates a dredge in good operating condition which will not allow the loss of bottom material as the sample is brought to the surface.

The orange-peel dredge covers the maximum obtainable sampling area at a penetration of five inches, although the volume of material collected increases at greater depths of penetration. A volume of bottom material which measures nine quarts or more can therefore be accepted as representing a sample area of 138 square inches (Table 1).

A plot of the data indicates a parabola for which the formula $Y = a + b_1 X + b_2 X^2$ gives a satisfactory fit where:

$a = 51.8294$

$b_1 = 19.537$

$b_2 = -1.1177$

In this formula, Y represents the unknown area of the sample, and X designates the measured volume of sand. The curve calculated from the data is shown in Figure 1, from which the area sampled can be determined from any measured volume of bottom material.

The dredge used in this work was a number 3 orange-peel with a closed diameter of 13 inches and a diameter of 15 inches when open. Since this work was performed after the samples were collected for this investigation, the area represented in the samples could not be determined. The method is being presented here in hopes that it will be of use in future benthological investigations employing the orange-peel dredge.

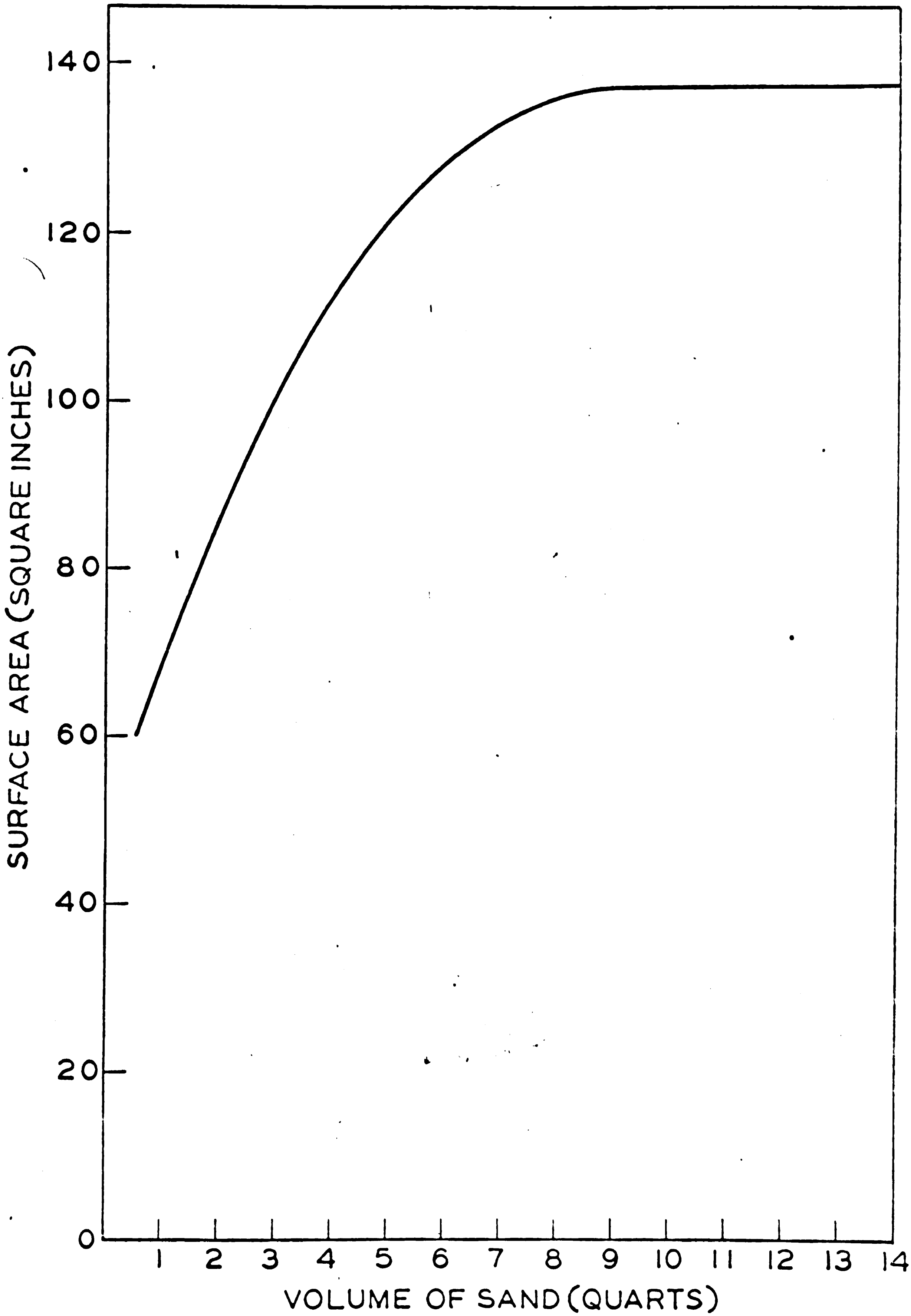
Table 1. Area sampled and volume of bottom material collected at various depths of penetration by a number 3 orange-peel dredge

Depth of penetration (inches)	Area sampled (sq.in.)	Volume of sand (quarts)
1	62	1.00
1	68	0.75
1	63	1.00
1	65	1.00
1	66	1.00
1	67	1.00
2	105	3.00
2	105	2.75
2	99	2.50
2	101	2.75
2	103	2.75
2	104	2.75
3	124	5.25
3	124	5.25
3	124	5.00
3	126	5.25
3	123	5.50
3	125	5.00
4	131	7.00
4	134	7.50
4	131	7.00
4	134	7.50
4	127	7.00
4	132	7.00
5	138	9.00
5	138	9.00
5	138	9.00
5	137	9.00
5	135	9.00
5	139	9.00

Table 1. (continued)

Depth of penetration (inches)	Area sampled (sq.in.)	Volume of sand (quarts)
6	137	11.00
6	138	11.00
6	138	10.00
6	139	11.00
6	137	11.00
6	138	10.50

Figure 1. The relationship between the volume of sand collected, and the surface area sampled by a number 3 orange-peel dredge.


SURFACE AREA (SQUARE INCHES)
0
20
40
60
80
100
120
140
1 2 3 4 5 6 7 8 9 10 11 12 13 14
VOLUME OF SAND (QUARTS)

METHODS

The routine operation of the Cisco consisted of a series of two-week cruises throughout the entire open water period of the year. Roman numerals used as prefixes to station numbers throughout the text and appendix indicate cruises of the Cisco. Cruises are numbered consecutively beginning with Roman numeral I for the first cruise of each year. The stations sampled had been predetermined to coincide with other investigations being conducted by the U. S. Bureau of Commercial Fisheries. Bottom samples were taken at both hydrographic and fishing stations.

All sampling in 1951 employed a light-weight Petersen dredge. Both light-and-heavy-weight Petersen dredges and a 6 inch Ekman dredge were used in 1952. The 1954 and 1955 samples were taken by an orange-peel dredge with the exception of a few dredgings made with the light-weight Petersen dredge in 1955. The orange-peel dredge used was a No.3 with a closed diameter of 13 inches. The Petersen dredges used sample a surface area of 0.79 square meter.

The most extensive sampling of Lake Michigan was conducted in 1954 and 1955, and consequently, these data are the basis for the majority of this report. Only the samples taken by the orange-peel dredge are used throughout this report in making a quantitative comparison of the organisms present. Tow net samples were taken at several stations in addition to the dredge samples. The procedure consisted of attaching a 25 cm. diameter plankton net to a bottom trawl during the routine trawling operation. No attempt was made

to obtain quantitative samples by this procedure, but they proved valuable in yielding several benthic forms which were not found in dredge samples. This was especially true in several shallow water areas from which very few dredge samples were collected. All forms taken in tow samples are included in the species list of organisms and are considered with respect to their qualitative distribution.

The bottom type was recorded for all dredge samples at the time they were collected. The material was recorded as being sand, gravel, clay, silt, or mixtures of any or all of these. No attempt was made to make a quantitative analysis of the percentage of any of these materials.

Samples were washed through a 30 mesh screen when collected, and any remaining bottom material, along with the organisms present, was stored in a 10 percent formalin solution. The material was kept in this condition until it could be handled at a later date in the laboratory.

A floatation method using a saturated sugar solution was used to sort the organisms. The sample was first emptied into a 1/20 mm. mesh sieve and washed with tap water until all traces of formaldehyde were removed. The material was then placed in a shallow enamel pan and covered with a saturated sugar solution. The floating organisms were removed from the surface with a fine mesh scoop. The majority of the organisms floated for several minutes until, due to osmosis, their density approached that of the solution. The sample was then placed in water and the non-floating organisms were hand picked. After standing in water for several minutes, the density of the organisms readjusted so that they could again be floated if any remained in the sample material. If a small amount of bottom material was present the second floatation was found to be unnecessary. After sorting, the organisms were preserved in a solution of 70 percent alcohol and 5 percent glycerine.

A review of the literature revealed a conspicuous lack of uniformity in methods of quantitatively measuring benthological samples. Volumetric measurements were chosen over the wet weight method primarily because of the greater speed and ease of operation. All samples were allowed to drain to a constant state of dryness before measuring the total volume. Ball (1948) found that the volume of organisms could be converted to live weight by a conversion factor of 0.98, which he considered to be not significantly different from unity. Conversions made on this basis would be within the accuracy of the methods employed.

Due to the variations in size of individual organisms, a volumetric measurement often is not indicative of the number of specimens in a sample. For this reason a total count was made of all the organisms present. Individuals of Pontoporeia affinis were divided into four size groups before counting, for the purpose of showing variations in size distribution. The sizes which proved to be most satisfactory were: less than 3 mm.; 3 - 5 mm.; 5 - 7 mm. and greater than 7 mm. The maximum length attained was approximately 10 mm. The average volume of the individual P. affinis in each group was determined by measuring a known number of each size. The volume of P. affinis in each size group was then calculated mathematically for all samples. The sum of the volumes of the four sizes was accepted as the total sample volume of P. affinis. The measurements from which the average

volumes were calculated are shown in Table 2. The accuracy of this method was checked by comparing the calculated volume with the measured volume of four samples (Table 3). These were samples which had been previously measured and were found to contain no organisms other than P. affinis.

Table 2. Data used to determine the volume of individual *Pontoporeia affinis* in each of four size groups from Lake Michigan

Size group	No. of organisms	Volume (ml.)	Ave. vol. per organism (ml.)
Less than 3 mm.	500	0.25	0.00050
	500	0.22	0.00044
			0.00047
3-5 mm.	78	0.25	0.0029
	1003	0.74	0.00074
	300	0.50	0.0016
	300	0.50	0.0016
			0.0017
5-7 mm.	340	1.53	0.0045
	324	1.65	0.0051
			0.0048
Greater than 7 mm.	65	0.63	0.0098
	68	0.70	0.0102
	51	0.48	0.0094
			0.0098

Table 3. Comparison of calculated volume and measured volume of <u>Pontoporeia affinis</u> taken from Lake Michigan

No. in each size group				Total no.	Measured vol. (ml.)	Calculated vol. (ml.)
Less than 3 mm.	3-5 mm.	5-7 mm.	Greater than 7 mm.			
1	47	83	18	149	0.75	0.71
6	7	12	12	37	0.14	0.19
1	3	22	9	35	0.17	0.20
13	160	116	14	303	1.08	1.05

SAMPLING STATIONS

The data from Lake Michigan for the years 1954 and 1955 represent 203 dredge samples taken from 40 stations and 13 tow samples from 5 stations (Figure 2). The stations had been predetermined by the U. S. Bureau of Commercial Fisheries for the purpose of fishery and limnological investigations. Several of these stations covered a considerable area as is evident by the diversity of the depth and bottom type within stations (Table 4). These were fishing stations where bottom samples were collected in conjunction with the routine trawling operations of the Cisco. Fishing stations consisted of an area where trawling was conducted at 15, 25 and 50 fathoms. The size of the area was determined by the slope of the lake bottom and was only large enough to include water from 15 to 50 fathoms in depth. A bottom sample was taken prior to each trawl. These samples indicated the suitability of the bottom for trawling as well as serving as the basis for this benthological investigation. The fishing stations in 1954 included 51a, 52a, 53a, 55a, 59c and 61a. In 1955 trawling was conducted at stations 71c. 72d, 75d and 76e. All other stations were hydrographic stations. These were established by degrees of longitude and latitude, and an attempt was made to return to the exact location at each succeeding cruise. Despite the modern methods of navigation, there was always variation in location each time a station was visited. For this reason the depth and bottom type varied within stations when samples were taken on several cruises. Due to this discrepancy, no quantitative comparisons have been made within stations. All stations were located by the use of a compass and radar.

Figure 2. Location of stations where bottom samples were collected in Lake Michigan in the years 1954 and 1955

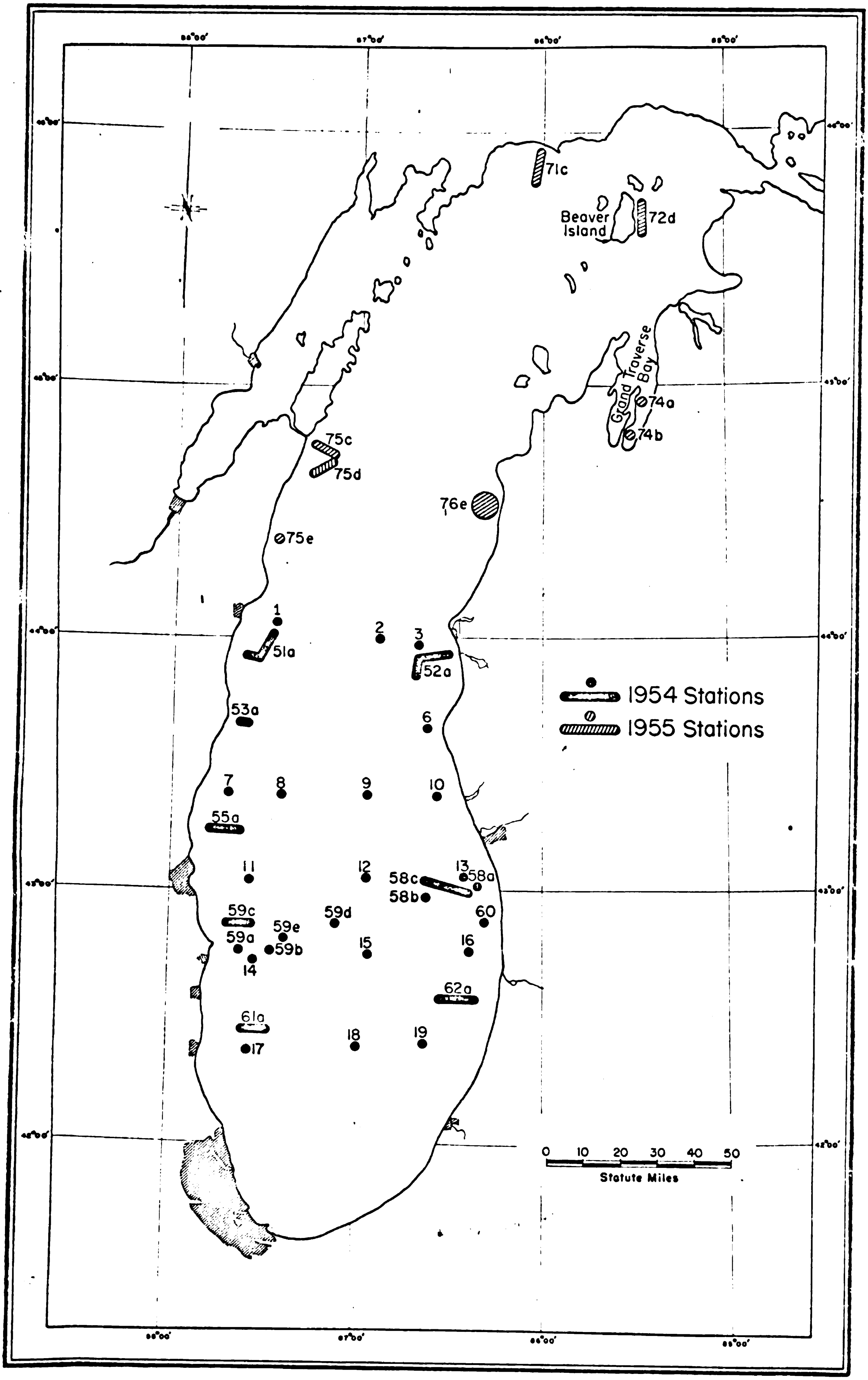

71c
Beaver Island
72d
Grand Traverse Bay
74a
74b
75c
75d
76e
75e
1
2
3
51a
52a
53a
6
1954 Stations
1955 Stations
7
8
9
10
55a
11
12
13
58a
58c
58b
59c
59d
60
59e
59a
59b
15
16
14
62a
61a
18
19
17
0 10 20 30 40 50
Statute Miles

Table 4. Depth, bottom types and number of samples collected at the Lake Michigan sampling stations in 1954 and 1955

1954

Station number	Depth (fathoms)	Bottom type	Number of samples
1	40	Sand, clay	3
2	80	Sand : sand, clay	3
3	40	Sand, clay	3
6	40	Silt	1
7	35	Sand	1
8	58	Clay, silt	1
9	60	Clay, sand, gravel	1
10	40	Silt	1
11	40	Clay, sand, silt	10
12	50	Clay, sand : clay, silt Clay, gravel Clay, sand, silt, gravel	9
13	40	Sand, silt : silt	17
14	40	Sand, gravel, clay, silt Sand, clay : sand, silt, clay	8
15	85 87	Silt Silt	2 2
16	35 40	Silt Silt	2 2
17	40	Clay, silt : clay, sand, silt	2
19	40	Silt	3
51a	20 32 42 45	Sand Sand, clay Sand, clay Clay	1 1 1 1

Table 4. (continued)

1954

Station number	Depth (fathoms)	Bottom type	Number of samples
52a	15	Sand	2
	19	Sand	1
	30	Sand,clay	2
	32	Sand,clay,silt	2
	41	Sand,clay	1
	71	Sand,silt,clay	1
53a	15	Sand	1
	27	Sand	1
55a	15	Sand,clay	3
	25	Sand,silt : clay,sand	3
	41	Sand,clay,gravel	2
	50	Silt	2
58a	25	Clay,silt : sand,silt	4
	27	Sand : silt	4
58b	48	Clay,sand	1
	49	Clay,sand	2
	50	Clay,sand,silt	1
	51	Clay,sand,silt	1
58c	8	Sand	4
	13	Sand	4
	15	Sand,silt,clay	2
	18	Sand	4
	20	Sand,clay	2
	23	Sand,silt	2
59a	25	Sand : sand,gravel,silt	5
59b	52	Clay,sand : Clay,sand,silt	6
59c	15	Sand,clay : sand	2
	30	Sand,silt,clay	4
	40	Clay,gravel	3
	50	Clay,sand,silt,gravel	4
59d	70	Clay,silt	1

Table 4. (continued)

1954

Station number	Depth (fathoms)	Bottom type	Number of samples
59e		Clay,silt,gravel	1
60		Silt	1
61a	15	Sand	1
	25	Sand,silt	1
	50	Clay,silt	1
62a	15	Sand,silt	2
	25	Sand,silt	2
	41	Silt	2

1955

Station number	Depth (fathoms)	Bottom type	Number of samples
71c	5	Sand	3
	15	Sand,clay	3
	25	Sand,silt	3
	50	Sand,silt	3
72d	10	Sand,silt,algae	2
	14	Sand,silt,gravel	1
	25	Sand,silt,gravel	1
	50	Sand,silt	1
74a	11	Sand,silt,algae	1
	26	Sand,silt	1
74b	65	Sand,silt	1
75c	15	Sand,gravel,clay	1
	25	Sand	1
	50	Sand,clay	1
75d	30	Sand	2
	50	Sand,gravel,silt	1

Table 4. (continued)

1955

Station number	Depth (fathoms)	Bottom type	Number of samples
75e	15	Clay,sand : sand,silt	2
76e	15	Sand	3
	25	Clay,sand : sand,silt	2
	50	Sand,clay : sand,silt	3

QUALITATIVE DISTRIBUTION

All organisms were classified as far as the preserved condition of the specimens allowed. The identification of the Hirudinea almost demands the use of fresh specimens. For this reason the leeches could not be identified, although several forms were present. A list of the organisms identified is presented in Table 5. These organisms are predominantly deep-water forms, since samples were not taken from less than five fathoms. Only 45 samples were collected from less than 15 fathoms.

Turbellaria

Planarians were present in very limited numbers. Not more than one was found in any sample. These were present from 15 to 40 fathoms, although only one individual was found at a depth exceeding 20 fathoms. Rawson (1953) found planarians to be restricted to depths less than eight meters in Great Slave Lake. Apparently a sand bottom was the preferred habitat of the planaria, although the specimen from 40 fathoms was taken from a mixture of sand, silt and clay. The scarcity of this organism is evident from the fact that Eggleton (1935,1936) did not take a single specimen in his collections from Lake Michigan.

Hirudinea

Hirudinea were well represented throughout Lake Michigan at stations with depths less than 40 fathoms. The greatest numbers

Table 5. Benthic organisms identified from Lake Michigan

Platyhelminthes

Turbellaria

Planarian

Annelida

Hirudinea

Oligochaeta

Limnodrilus udekemianus
Peloscolex sp.
Sparganophilus sp.

Arthropoda

Amphipoda

Pontoporeia affinis Lindstrom
Gammarus sp.

Mysidacea

Mysis relicta Loven

Isopoda

Lirceus lineatus Say

Trichoptera

Lepidostomatidae

Lepidostoma sp.

Molannidae

Molanna sp.

Table 5. (continued)

Odonata

Zygoptera

Ephemeroptera

Hexagenia sp.

Diptera

Chironomidae (= Tendipedidae)

Chironominae

Chironomus plumosus

Cryptochironomus sp.

Polypedilum sp.

Pseudochironomus sp.

Calopsectra sp.

Pelopiinae (= Tanypodinae)

Pentaneura sp.

Hydrobaeninae (= Orthocladiinae)

Brillia sp.

Cricotopus sp.

Spaniotoma sp.

Mollusca

Gastropoda

Gyraulus sp.

Valvata sp.

Campeloma sp.

Table 5. (continued)

Gastropoda (continued)
Amnicola sp.
Goniobasis sp.
Lymnea sp.
Pelecypoda
Sphaerium sp.
Pisidium sp.

of leeches were found in the tow samples from 6 to 15 fathoms. The number of dredge samples available from this depth range was insufficient to show the distribution of these organisms. More Hirudinea were taken from station 71c than from any other station. Two orange-peel dredge samples taken at this station in June and September, 1955 each contained four leeches. Both samples were taken at 15 fathoms, where the bottom material consisted of a mixture of sand, silt and clay. No more than one leech per sample was ever taken from any other station. Tow samples taken from station 71c in September, 1955 indicated an abundance of these organisms at 15 fathoms. Both tow and dredge samples taken at different depths within the same station area failed to yield as many. Samples taken at a depth of five fathoms within station 71c were from a sand bottom. At 25 and 50 fathoms the bottom type was similar to that at 15 fathoms. The reason for the apparent concentration of leeches at 15 fathoms within this area is unknown.

The only other station which showed an abundance of Hirudinea was 72d in the shallow-water area east of Beaver Island. Leeches were found in tow samples at 5, 15 and 25 fathoms in September, 1955. Since the area covered by the tow samples was unknown, the relative abundance of Hirudinea could not be determined. Only one of 17 orange-peel dredge samples from station 72d contained leeches. The dredge samples were collected in depths from 10 to 50 fathoms. The bottom material consisted of sand, silt and gravel.

Oligochaetes

The contribution of the oligochaetes to the profundal biomass of

Lake Michigan is exceeded only by Pontoporeia affinis. Three species were found: Limnodrilus eudekemianus, Peloscolex sp. and Sparganophilus sp. At least one of these species was present in over 80 percent of all dredge samples.

Sparganophilus sp. was limited in numbers and distribution. It was restricted to shallow-water areas of less than ten fathoms, and no more than two specimens were present in any one orange-peel dredge sample. Only five Sparganophilus sp. were recorded from all of the Lake Michigan samples. They were all taken from the shallow-water area east of Beaver Island at station 72d. The bottom type varied from a mixture of sand, gravel and rubble, to an aggregate of sand, silt and algae. The seemingly restricted distribution of this species was presumed to be due to the small number of shallow water samples available from other areas. A total of seven orange-peel dredge samples from less than ten fathoms were taken from stations other than 72d.

Peloscolex sp. was limited in numbers, but exhibited a wide range of distribution. Specimens were taken at all depths from 15 to 85 fathoms. The incidence of occurrence was the highest in samples from 15 to 40 fathoms. At this depth range Peloscolex sp. was present in 20 percent of the samples. At depths exceeding 40 fathoms they were found in less than five percent of the samples. This genus was not collected at less than 15 fathoms, which may have been due to the small number of shallow water samples.

Peloscolex sp, showed no apparent specificity as to preferred bottom type. Specimens were taken from pure sand and various mixtures of sand, clay, silt and gravel.

The numbers of *Peloscolex* sp. were small in relation to the total number of oligochaetes in the samples. The highest number found in any sample was ten, and this represented only five percent of the total number of oligochaetes in the sample. In only one sample was this genus the sole representative of the aquatic worms. This was a sample taken at 50 fathoms at station 12. This may have resulted from sampling variation, as other dredgings from this station contained both *Peloscolex* sp. and *Limnodrilus udekemianus*.

Limnodrilus udekemianus was more abundant than other forms of oligochaetes in Lake Michigan. It exceeded other species in both numbers and range of distribution. *L. udekemianus* was found in 98 percent of the samples which contained oligochaetes . It was collected at depths from 5 to 85 fathoms, with no apparent difference in incidence of occurrence at any depth. Specimens were present in all samples between 70 and 85 fathoms. This is the maximum depth that was well represented by the dredge samples. Only one sample was taken at more than 100 fathoms. *L. udekemianus* was absent in this sample. However, this could not be considered significant.

No bottom type preference was evident from the distribution of *L. udekemianus*. Individuals were present in samples from all recorded sediment varieties.

Teter (1960) recorded only two forms of oligochaetes from Lake Huron: *Miadium* sp. and *Limnodrilus claparedeianus*, both of which occurred to depths of 119 meters.

Amphipoda

The amphipod, Pontoporeia affinis Lindstrom was by far the most abundant organism in the profundal biomass of Lake Michigan. Eggleton (1936) described this amphipod as being Pontoporeia hoyi, and at that time several species were believed to exist. The present belief is that all fresh water forms of Pontoporeia are identical to P. affinis (Larkin, 1948). P. affinis was the dominant organism in samples from all stations, and comprised an average of 70 percent of the volume of all samples. Fifty-two percent of the total volume of all organisms at five fathoms was due to P. affinis. This was the minimum depth sampled in this survey. The maximun depth of 100 fathoms was represented by only one sample, in which P. affinis was the only organism present. This sample was from the east arm of Grand Traverse Bay. At intermediate depths, regardless of bottom type, this amphipod was more abundant than all other organisms. Eggleton (1947) credited P. affinis as contributing 64 percent of the numerical composition of the Lake Michigan bottom fauna. This is similar to the abundance described by the workers in other large oligotrophic lakes. Rawson (1947,1953) found that this species comprised 61 percent of the total number of benthic organisms taken from Lake Athabaska and 62 percent of the Great Slave Lake bottom fauna. Chironomid larvae were more abundant in Lake Nipigon, where P. affinis made up only 34 percent of the benthic population (Adamston,1924). The numerical percentage in Lake Winnipeg was 64 percent P. affinis (Bajkov,1930).

Gammarus sp. in Lake Michigan was restricted to the shallow-water shoal areas. This genus was found only in tow samples from station 72d east of Beaver Island. Seventeen orange-peel dredge samples from the same station failed to yield *Gammarus* sp. The dredge samples were taken at 10, 14, 25 and 50 fathoms.

Gammarus sp. was collected in the tow samples at 8 and 12 fathoms. At eight fathoms it was the only amphipod present. However, at 12 fathoms both *Gammarus* and *Pontoporeia affinis* occurred in the same sample. This was the only instance in this survey where these two amphipods were collected in the same sample. This is considered to be an exceptional depth for the occurrence of *Gammarus* sp.. Rawson (1953) found them restricted to a depth of ten meters in Great Slave Lake. Eggleton (1935,1936) did not record this organism from Lake Michigan. This was perhaps due to the small number of shallow-water samples he collected.

Mysidacea

Mysis relicta Loven was frequently taken in dredge samples, and was quite numerous in tow samples. This species is more pelagic than benthic in its habits: consequently, dredge samples do not give a representative distribution. Beeton (1959) found mysids only in the bottom two meters of water during the day. In the evening, however, he observed mass migrations to the upper strata of water. These diurnal migrations were stimulated by decreasing light intensity. Since *M. relicta* are not true bottom organisms they are not being considered in this report. Information of the life history and behavior of this organism have been presented by

Larkin (1948) and Beeton (1958,1959).

Isopoda

Lirceus lineatus is a typical shallow water organism restricted to shallow shoal areas. It was numerous in tow samples from stations 72d and 71c. It was also taken infrequently in dredge samples from the same stations. Isopods were not present in samples from any other location, although a total of ten stations were sampled at 15 fathoms or less. This species was recorded at a maximum depth of 15 fathoms from both stations. The bottom type varied from a mixture of sand and clay to sand, silt and gravel.

L. lineatus inhabits the shallow-water sand banks of the Straits of Mackinac region where Henson (1958) has conducted an extensive sampling program. *L. lineatus* occurs in Lake Huron at depths of 5.5 to 25 meters (Teter,1960).

Trichoptera

Two genera of caddis-fly larvae were identified. These were *Lepidostoma* sp. of the family Lepidostomatidae, and the genus *Molanna* sp., representative of the family Molannidae. The latter is the same genus reported by Henson (1958) in the Straits of Mackinac region.

Neither genus was ever taken from a depth exceeding 25 fathoms. The greatest abundance of both genera was recorded from the tow samples from station 72d. This is the shoal area east of Beaver

Island, which has previously been shown to support a typical shallow-water fauna. The shallow-water fauna is probably influenced by a higher water temperature. On July 19, 1955 samples were taken from station 72d at 8.5, 14, 26.5 and 50 fathoms. The temperature was 60 degrees at 8.5 fathoms and 43 degrees at 14 fathoms. At 26.5 and 50 fathoms the water temperature was 40 degrees. The upper limit of the thermocline was at five fathoms, and the suface temperature was 71 degrees. The same two genera were seen infrequently in dredge samples from stations 58a and 71c, taken at 15 and 25 fathoms respectively.

The cases of several other larval forms were collected, but never with the larvae intact. These discarded cases were often abundant in areas of accumulated mollusc shells deposited by wave action. Larval cases collected in these areas did not represent the natural habitat of the Trichoptera, as they had been relocated by wave action.

Rawson (1953) reported 49 species of Trichoptera from Great Slave Lake, where the majority of the larvae were collected at depths of one to ten meters. The maximum depth at which he found larvae was 13 meters. Only empty cases were found at greater depths.

Odonata

Only one Odonata larva was found from all of the samples, but because of poor condition it could not be identified. The one representative of the order was a damselfly larva taken from station 58a at a depth of 25 fathoms.

Ephemeroptera

Hexagenia sp. was restricted to the tow samples from the shoal areas of Beaver Island. These mayfly larvae were present in tow samples from 8, 12 and 15 fathoms.

Henson (1958) reported the presence of Hexagenia sp. in the shallow-water areas of northern Lake Huron near the Straits of Mackinac. In the same area he also found Ephemera sp., a genus which was not present in the Lake Michigan samples.

Rawson (1935) reported the same two genera to be restricted to depths of less than four meters in Great Slave Lake.

Diptera

Nine genera of chironomid larvae were identified from the Lake Michigan samples. Although limited in numbers, they were widely distributed at depths of 40 fathoms or less. Chironomid larvae were present in 58 percent of all samples from less than 40 fathoms. At greater depths they were represented in 16 percent of all samples.

The samples containing chironomids had an average of five larvae, however, 75 percent of the samples contained fewer than six individuals. They ranged in numbers from 1 to 31 larvae per sample.

Chironomus plumosus and Calopsectra sp. were the only species limited to shallow water. C. plumosus was recorded only at stations 72d, 71c and 58c. All records of this species were from orange-peel dredge samples taken at ten fathoms or less. At stations 71c and 58c C. plumosus inhabited a pure sand bottom. The bottom type was similar at station 72d except for the addition of a small amount of gravel.

The greatest number of C. plumosus present in any one sample was 20 individuals taken in one orange-peel dredge grab at station 71c. This sample was at five fathoms, the shallowest water sampled in this survey.

Calopsectra sp. was recorded only from stations 72d and 58c at ten fathoms. This genus was found in only two samples, each of which contained one individual. This was the most limited distribution of all the species taken in the survey.

With the exception of Spaniotoma sp., all other genera of Chironomidae were widely distributed at all depths less than 30 fathoms. Brillia sp., Pentaneura sp., Polypedilum sp., Pseudochironomus sp. and Cryptochironomus sp. have a wide range of distribution. Representatives of all of these genera were collected from 10 to 25 fathoms. Pseudochironomus sp. is the only one of these forms recorded from a depth of 40 fathoms. One specimen was taken from station 13 where the bottom was composed of sand and silt.

No bottom composition preference was evident as members of each genus were collected from all recorded sediment types.

Dredge samples exceeding 30 fathoms in depth were restricted to two genera of Chironomidae: Cricotopus sp. and Spaniotoma sp.. Cricotopus sp. was taken at 30 and 40 fathoms. Spaniotoma sp. was the only genus found at depths of 40 fathoms or more, and was the only chironomid restricted to deep water. It was never collected from depths of less than 30 fathoms nor more than 70 fathoms. Spaniotoma sp. was taken at all depths from 36 to 540 meters in Great Slave Lake (Rawson,1953).

Gastropoda

Six genera of snails were identified from the Lake Michigan samples. These were Gyraulus sp., Valvata sp., Campeloma sp., Amnicola sp., Goniobasis sp. and Lymnaea sp.. All forms were numerous in the shallow-water areas of stations 72d, 71c, 55a and 58c. Many deep-water stations showed evidence of drifting accumulations of Gastropoda shells. Only Gyraulus sp. and Goniobasis sp. were found alive at depths of 40 fathoms or more.

Pelecypoda

The Pelecypoda of Lake Michigan were represented by the genera Pisidium sp. and Sphaerium sp.. The small fingernail clams were abundant at all depths to 70 fathoms. However, it was often difficult to determine if their presence in samples represented their natural habitat or was the result of drifting. The bottom material of many samples consisted of little more than shell fragments of the fingernail clam. Teter (1960) listed Pisidium sp. and Sphaerium sp. as deep-water inhabitants of Lake Huron. Practically all of the live specimens dredged by Eggleton (1937) from Lake Michigan were of the genus Pisidium sp.. He found only scattered Sphaerium sp.. Henson (1958) also collected these same two genera from the straits area of Lake Huron.

QUANTITATIVE DISTRIBUTION

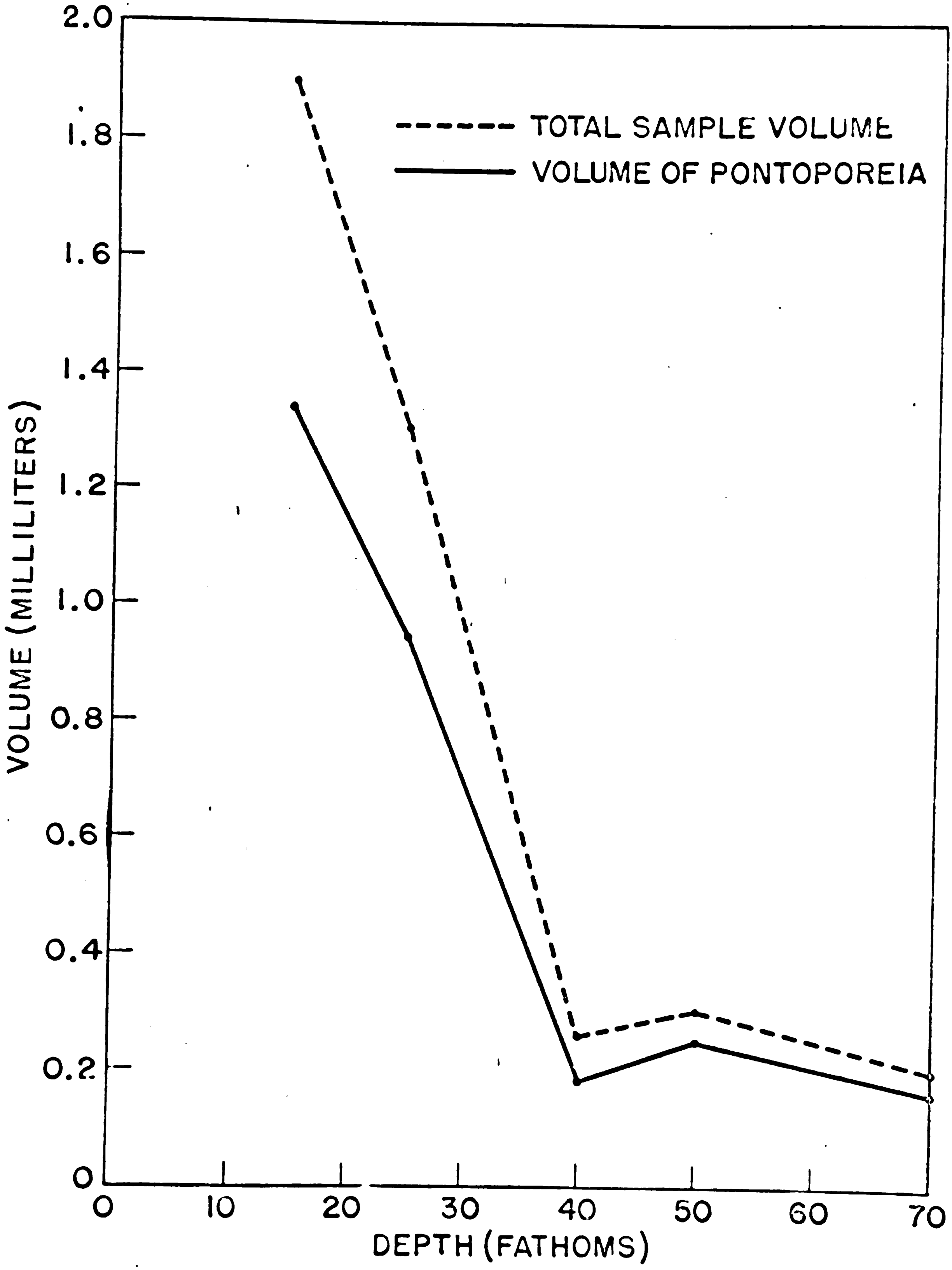
Volume of Organisms

The average volume of organisms per orange-peel dredge sample is shown in Figure 3. The volume ranged from 0.01 ml. to 3.5 ml. per orange-peel dredge sample. The greatest volume was taken at station 58c in 13 fathoms of water. The average volume of all samples was 0.79 ml. The plot of the volumes at 15 fathoms is actually the average of all samples from 5 to 15 fathoms, inclusive. The small number of samples taken at less than 15 fathoms indicated no significant difference in volume of organisms at depths ranging from 5 to 15 fathoms.

The average volume per sample declined from a maximum of 1.9 ml. per sample at 15 fathoms to 1.27 ml. at 25 fathoms. From this point there was a sharp decline to 0.26 ml. per sample at 40 fathoms. The abundance then leveled off to an average of about 0.2 ml. per sample at 70 fathoms.

The plot of these data follows the general trend seen previously in the qualitative species distribution; that is, the wide break in both abundance and species distribution between 25 and 40 fathoms. Several species present in shallow water were absent from all samples over 40 fathoms. The drop in volume with increasing depth was due to a decrease in the total number of organisms rather than the loss of species representatives. A plot of the number of organisms per sample (Figure 4) is similar to the plot of total volumes. The average volume per sample at 40 fathoms is 13.7 percent of the volume

Figure 3. Relationship of depth to the volume of organisms per orange-peel dredge sample in Lake Michigan, 1954 and 1955



TOTAL SAMPLE VOLUME
VOLUME OF PONTOPOREIA
VOLUME (MILLILITERS)
DEPTH (FATHOMS)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70

at 15 fathoms. The total number of organisms per sample at 40 fathoms represents 15.3 percent of the number from 15 fathoms.

The volume of Pontoporeia affinis (Figure 3) follows the same trend as the total volume, declining from 1.35 ml. per sample at 15 fathoms to 0.94 ml. at 25 fathoms. This is followed by a sharp drop to 0.19 ml. at 40 fathoms. The slight increase in volume at 50 fathoms of both the total sample and P. affinis is presumed to be due to sampling variation. The greatest difference between total sample volume and volume of P. affinis is at 15 fathoms. Here the higher total sample volume reflects the presence of the shallow-water organisms.

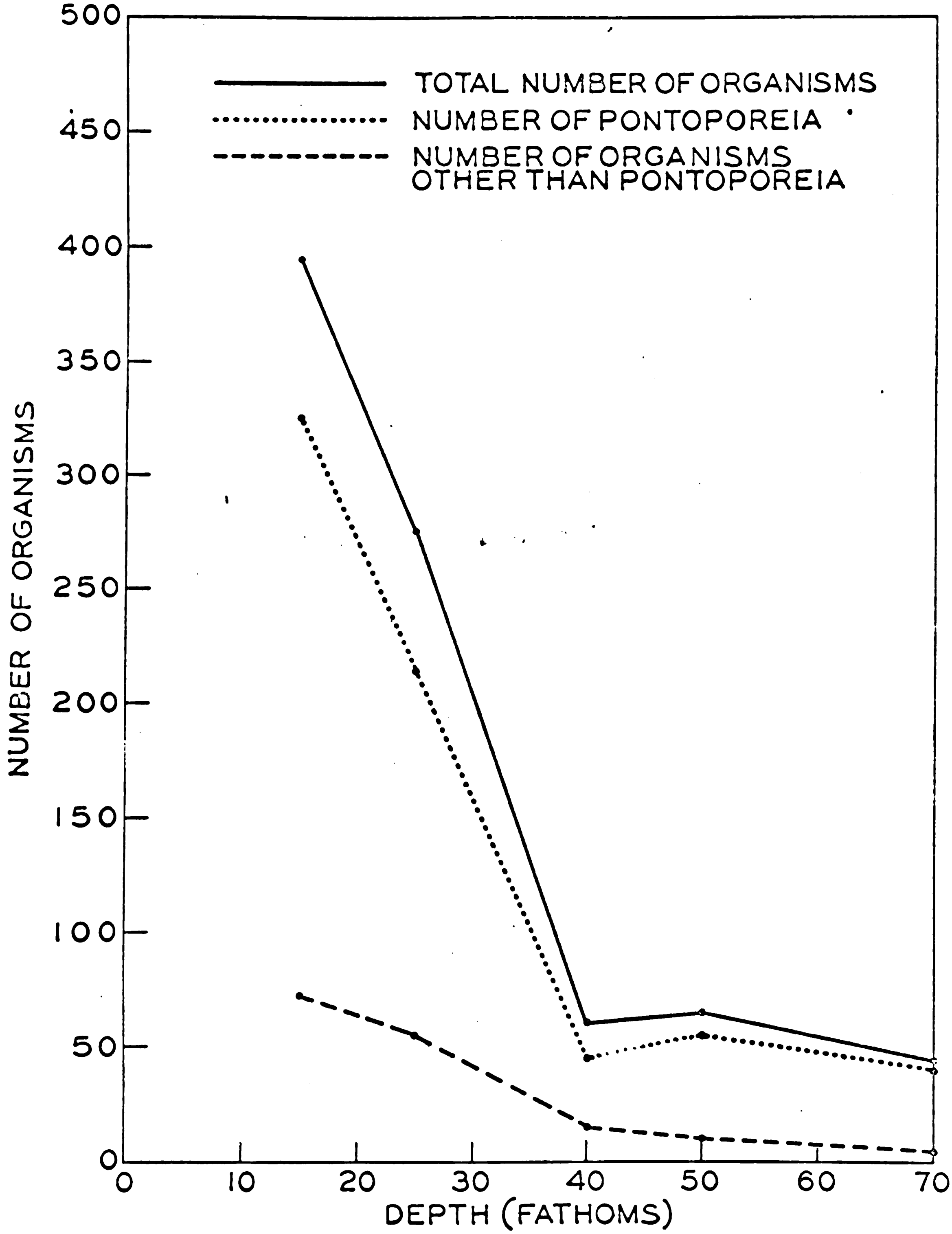
P. affinis comprised an average of 70 percent of the total volume of the samples. This is close to the 64 percent reported for Lake Michigan by Eggleton (1936). The percentage of the total volume of benthos, which was made up of P. affinis varied in Lake Michigan with the depth of water. The percentage declined from 73 percent at 15 fathoms to 69 percent at 25 fathoms and 63 percent at 40 fathoms. The percentage of the total sample volume increased to 77 percent at 50 fathoms, and 75 percent for all samples over 70 fathoms. The number of P. affinis per orange-peel dredge sample declined rapidly with increasing depth between 15 and 40 fathoms. The fact that the number of Oligochaetes was constant within these depths accounts for the decreasing percentage of P. affinis in the total sample volume. At depths exceeding 40 fathoms the number of Oligochaetes decreased rapidly with increasing depth allowing for an increasing percentage of P. affinis in the total sample volume. This higher proportion of P. affinis in the deep-water samples also resulted from the absence of species previously seen to be restricted to shallow water.

All samples from 1954 and 1955 were grouped by bottom type. There were six types of bottom deposits recorded at the time the samples were collected. The sediments consisted of sand, clay, or silt or mixtures of any of these. The data for the various bottom types are shown in Appendix B. The volume of samples was analyzed for a significant regression with increasing depth for each bottom type. The procedure followed Snedecor's (1956) method for the analysis of linear regression. The volume of samples collected from either pure sand or silt showed no significant regression at the 90 percent level. A plot of the sample volume from all other sediment types indicated a slope significantly different from zero at the 90 percent level.

Number of Organisms

The plot of the numbers of organisms (Figure 4) shows a linear regression from 15 to 40 fathoms. Eggleton's (1936) data indicated an abundance of organisms between 35 and 50 meters in Lake Michigan. Rawson (1935) noticed a similar increase from 30 to 60 meters in Great Slave Lake. In this study the shallow water samples contained the greatest abundance of organisms. No increase was seen in either total numbers or numbers of <u>Pontoporeia affinis</u> in deeper water. The average number of organisms per sample declined from 393 at 15 fathoms to 275 at 25 fathoms and 60 at 40 fathoms. There were 66 individuals per sample

Figure 4. Relationship of depth to the number of organisms per orange-peel dredge sample in Lake Michigan, 1954 and 1955


TOTAL NUMBER OF ORGANISMS
NUMBER OF PONTOPOREIA
NUMBER OF ORGANISMS OTHER THAN PONTOPOREIA
NUMBER OF ORGANISMS
DEPTH (FATHOMS)
0
50
100
150
200
250
300
350
400
450
500
0
10
20
30
40
50
60
70

at 50 fathoms and 42 at 70 fathoms. The plot of the total sample numbers nearly parallels the numbers of *Pontoporeia affinis*. The numbers of *P. affinis* per orange-peel dredge sample also shows a sharp decline between 15 and 40 fathoms. The 45 *P. affinis* at 40 fathoms represent only 14 percent of the 323 individuals per sample at 15 fathoms. There were approximately 50 *P. affinis* per sample at all depths between 40 and 70 fathoms.

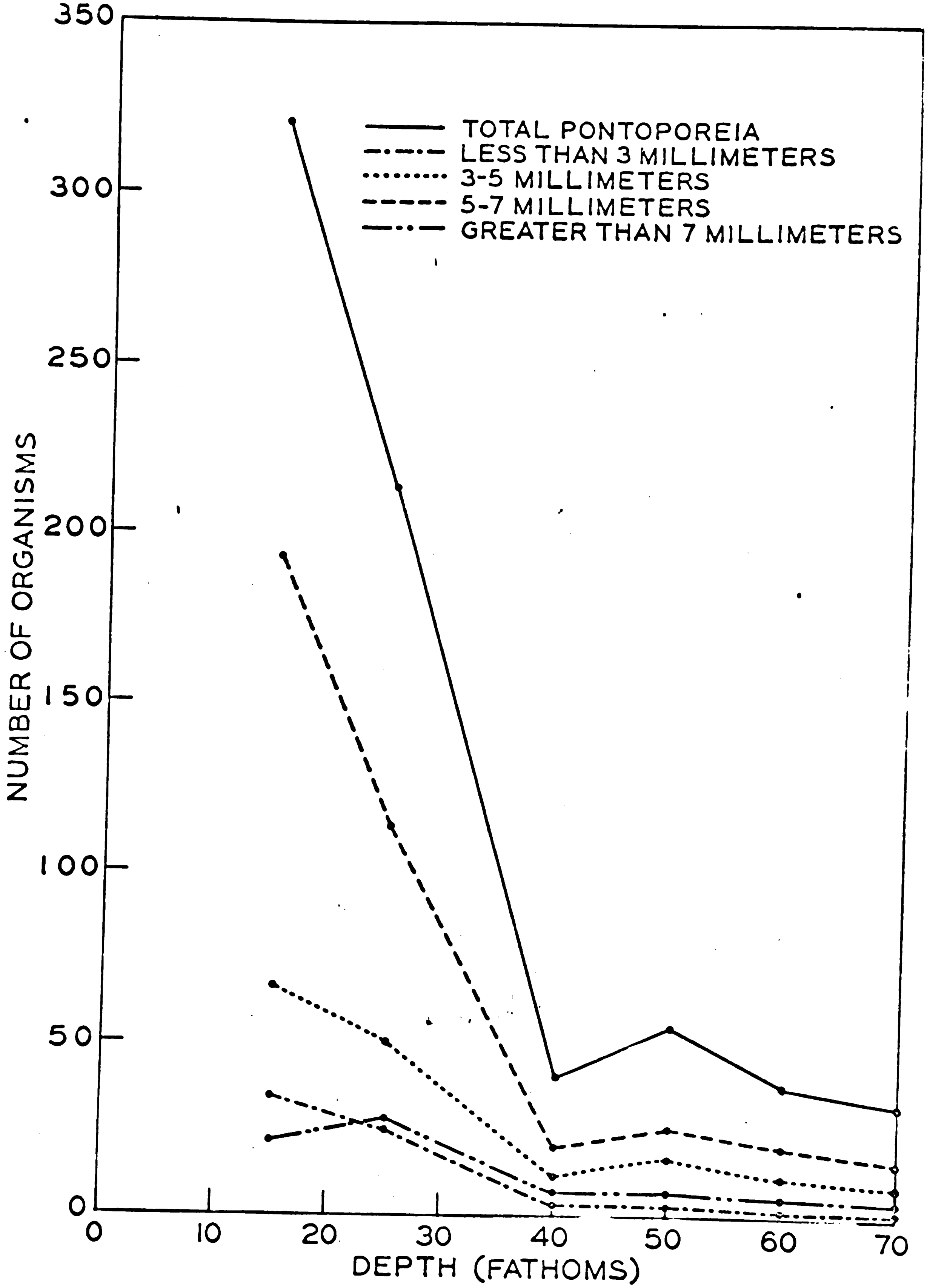
DISTRIBUTION OF PONTOPOREIA AFFINIS

The Pontoporeia affinis from all samples were divided into size groups for the purpose of demonstrating distributional patterns associated with depth, bottom type or seasons. The size-groups were chosen arbitrarily as less than 3 mm., 3 - 5 mm., 5 - 7 mm. and greater than 7 mm.. The average volume per individual has been determined as 0.00047 ml. for the smallest group, 0.0017 ml. for individeuals from 3 to 5 mm., 0.0048 ml. for those 5 to 7 mm. and 0.0098 ml. for those over 7 mm. in total length (Table 2). The total volume of P. affinis per sample was calculated from these figures. An analysis of the correlation between total numbers and volume for 50 samples chosen at random gave a correlation of 0.95. All of the 1954 and 1955 samples were used for the following discussion concerning the distribution of P. affinis.

The size-group from 5 to 7 mm. contributed over 40 percent of the total number of P. affinis for all samples. The average number of P. affinis per sample is shown by size-groups in Figure 5. In this study the P. affinis of Lake Michigan exhibited neither a sublittoral minimum nor zones of concentration such as Larkin (1948) found in Great Slave Lake, and Eggleton (1937) demonstrated in Lake Michigan. It is possible that the number of shallow water samples was insufficient to show a sublittoral minimum if such a phenomenon does exist in Lake Michigan.

The total numbers of P. affinis in all samples declined rapidly between 15 and 40 fathoms. From 40 to 70 fathoms the number of

Figure 5. Relationship of depth to the numbers of Pontoporeia affinis per orange-peel dredge sample in Lake Michigan, 1954 and 1955



TOTAL PONTOPOREIA
LESS THAN 3 MILLIMETERS
3-5 MILLIMETERS
5-7 MILLIMETERS
GREATER THAN 7 MILLIMETERS
NUMBER OF ORGANISMS
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
DEPTH (FATHOMS)

individuals per sample was more constant. The number or organisms in the two extreme size-groups shows less regression with depth than either the 3 to 5 mm. or the 5 to 7 mm. group. However, the decrease in numbers is significant for all size-groups.

The average number of P. affinis per sample for all samples was 115. The extremes of the range were 323 individuals per sample at 15 fathoms and 39 at depths exceeding 70 fathoms. Almost the entire range of numbers per sample was found between 15 and 40 fathoms. The largest number of individuals at all deoths was in the 5 to 7 mm. size-group. At 15 fathoms this one size-group exceeded the total numbers of all other groups combined. There was an average of 193 individuals per sample between 5 and 7 mm. in length, whereas the total of all other sizes was 128. A plot of numbers of this size-group indicates a linear regression from 15 to 40 fathoms, where the average number per sample is 22. No significant change in numbers is evident from 40 to 70 fathoms.

The 3 to 5 mm. size-group ranked second in abundance at all depths. They ranged in numbers from 66 individuals per sample at 15 fathoms, to 12 individuals at 70 fathoms.

The smallest numbers of individuals were in the two extreme size-groups. Small numbers would be expected of the P. affinis exceeding 7 mm. since mortality would diminish their numbers before reaching this size. It is difficult to account for the lack of abundance of individuals less than 3 mm.. In a population of organisms such as P. affinis the smallest individuals normally occur in the greatest abundance. Their numbers are diminished by mortality before reaching maturity. It is possible that very young specimens were lost in the washing process. In Great Slave Lake the young are released from the brood pouch early in the spring when they reach a length of 0.3 mm.. They attain a length of 1.3 to 2.3 mm. by June (Larkin, 1948) and would not be lost in screening after attaining this length. Assuming similar growth in Lake Michigan, the loss of young of the year specimens was probably not significant, as few samples were taken prior to June. It is also possible that the majority of the samples were taken after the young of the year exceeded 3 mm.. Larkin (1948) considered the 5 to 7 mm. size-group to represent one year old specimens. If this is true in Lake Michigan, the lack of abundance of the small individuals would indicate a poor year class in 1954.

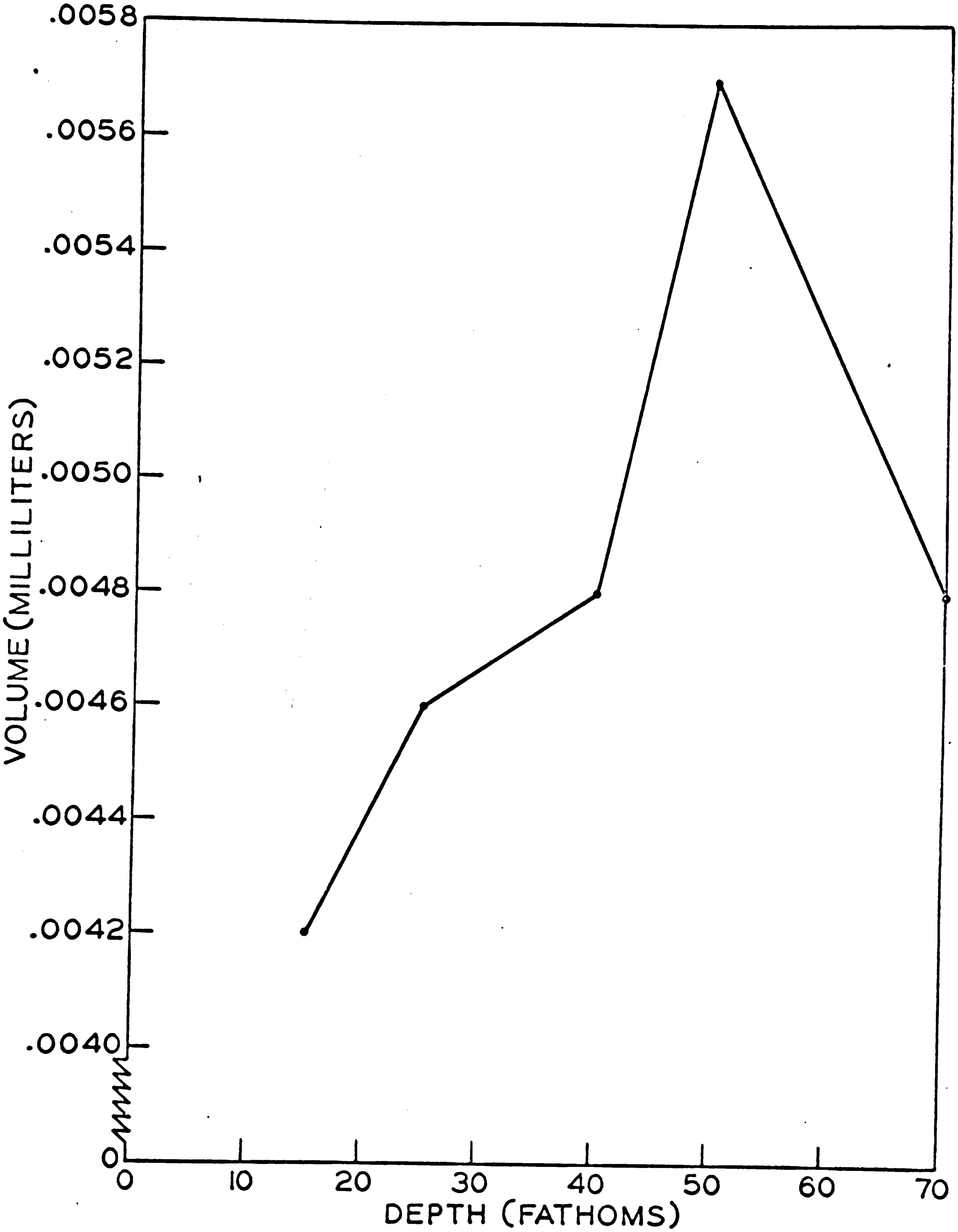
The 5 to 7 mm. size-group comprised approximately 50 percent of the total P. affinis population at all depths. This group exhibited a greater dominance over the other sizes in water under 25 fathoms than at greater depths. The individuals 5 to 7 mm. long constituted 52 to 57 percent of the total population at 15 and 25 fathoms, respectively. At 40 fathoms their relative numbers decreased so they made up only 48 percent of the P. affinis population. There was no significant change in percentage from 40 to 70 fathoms. The increase in percentage contribution (52 percent to 57 percent) of this size-group between 15 and 25 fathoms corresponded with a decrease of similar proportion in the 3 to 5 mm. size-group. The smaller of the two groups contributed 27 percent to the total numbers at 15 fathoms, but only 20 percent at 25 fathoms. At depths of 40 fathoms or more they constituted 27 percent of the total population.

An interesting depth distribution is seen in comparing the two extreme size-groups. Individuals greater than 7 mm. in total length constituted only 11 percent of the total population at 15 fathoms. Their percentage contribution increased to 15 percent at 25 fathoms, 22 percent at 40 fathoms and remained at approximately 20 percent at all depths exceeding 40 fathoms. The abundance of organisms less than 3 mm. varied inversely with that of the larger size-group. The small P. affinis made up nine percent of the population at 15 fathoms, but declined to four percent and three percent at 40 and 70 fathoms, respectively.

The inverse relationship of these two size-groups indicates a predominance of larger individuals in deeper water. This tendency is shown by Figure 6. The average volume of the individual P. affinis per sample was determined for all samples. This figure represents the mathematical average volume per individual calculated from the total volume of P. affinis in each sample. The average volume at each depth is, therefore, the mean of all P. affinis collected at any one depth. The average volume of the individual P. affinis increased from 0.0042 ml. at 15 fathoms to 0.0057 ml. at 50 fathoms. The decrease in average size at 70 fathoms may have been due to the small number of samples available.

A spawning migration into shallow water would explain the size-depth relationship of P. affinis. It is possible that the young are born in shallow water, and gradually disperse into deeper areas as they increase in size. If the mature individuals die soon after the young are born as Larkin (1948) believed, they

Figure 6. Relationship of depth to the average volume of individual *Pontoporeia affinis* in Lake Michigan, 1954 and 1955

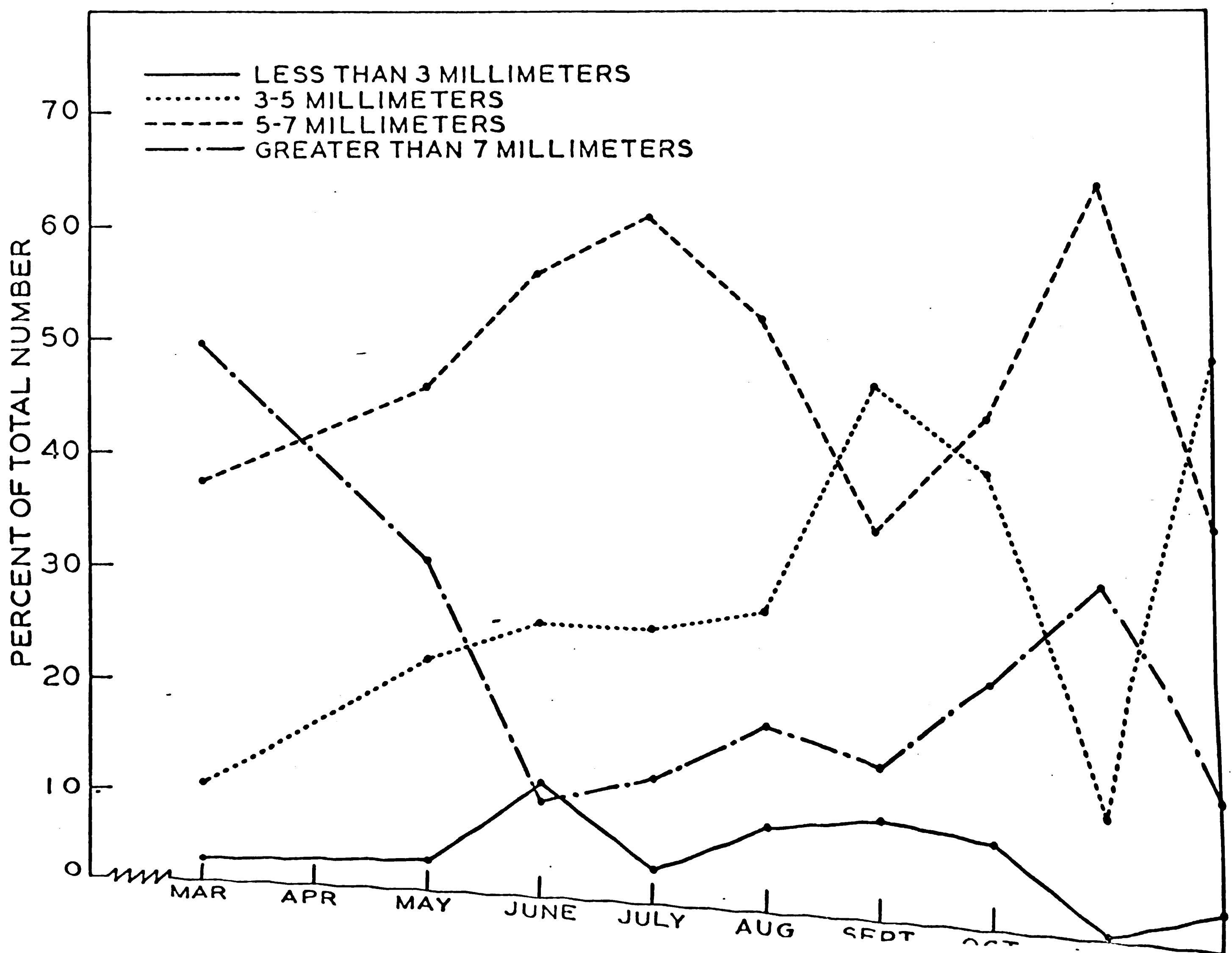

.0058
.0056
.0054
.0052
.0050
.0048
.0046
.0044
.0042
.0040
0
VOLUME (MILLILITERS)
0
10
20
30
40
50
60
70
DEPTH (FATHOMS)

would only be in shallow water for a short period of time. Therefore, the average size of the individuals in shallow water would not be influenced by the breeding population.

The size-depth relationship in Lake Michigan is directly opposite to the relationship in Great Slave Lake (Larkin,1948). Larkin found P. affinis to be of smaller average size in deep water. He considered this to be the result of a stunting or dwarfing factor related to decreasing organic deposits in deeper water.

It is now quite evident that there was a reduction in numbers of P. affinis per sample with increasing depth of water. By assuming that all depths were sampled with the same frequency each month, the 1954 data can be used to show a seasonal distribution. Several seasonal trends in the distribution of P. affinis are evident from a plot of the 1954 data (Figure 7). Birge and Juday (1927) found that P. affinis reproduced in Green Lake during the winter months. Larkin (1948) found that P. affinis at 11 meters depth attained a length of 3 to 4 mm. the first year, 5 to 7 mm. the second year and 7 mm. or more for those living a third year. The Lake Michigan data indicate a similar reproductive and growth pattern. The percentage of the population composed of individuals exceeding 7 mm. declined sharply from March to June. Their percentage of the total population dropped from 49 percent in March to a seasonal low of nine percent in June. Larkin (1948) has shown that the breeding population dies soon after the young are born. If this is true in Lake Michigan, the loss of large individuals after March indicates an early spring breeding season. Throughout the remainder of the

Figure 7. Relationship of seasons of the year to the numbers of *Pontoporeia affinis* in Lake Michigan, 1954


LESS THAN 3 MILLIMETERS
3-5 MILLIMETERS
5-7 MILLIMETERS
GREATER THAN 7 MILLIMETERS
PERCENT OF TOTAL NUMBER
0
10
20
30
40
50
60
70
MAR
APR
MAY
JUNE
JULY
AUG

summer the individuals exceeding 7 mm. gradually increased in abundance due to recruitment into the size-group by growth of the one-year-old individuals.

The 5 to 7 mm. size-group had a gradual recruitment from March to July as a result of growth of the young of the previous year. From July to September the percentage that they contributed to the total population declined from 61 percent to 33 percent. This was due to both mortality and loss into the 7 mm. size-group by growth.

The 3 to 5 mm. size-group followed a similar pattern. Their percentage contribution to the population increased from ten percent in March to 45 percent in September. The recruitment which took place between August and September represents the time at which the majority of the young of the year reached 3 mm.. The data for November and December are unreliable due to the small number of samples.

The number of individuals less than 3 mm. does not give a precise designation of the time of the breeding season. There was an increase between May and June. If the newly hatched individuals were lost in screening, this increase might represent the first time the young were retained in significant numbers. There is also an indication of a late summer brood. This is known to occur in Great Slave Lake (Larkin,1948). The absence of a pronounced mode in the plot of the percentage contribution of the young of the year indicates a poor year class. Extensive sampling from October to March would be necessary to isolate the breeding period.

SUMMARY

1. The bottom fauna of Lake Michigan was studied in the years 1951 to 1955 as part of the Great Lakes investigations conducted by the United States Bureau of Commercial Fisheries. The most extensive sampling of Lake Michigan was conducted in 1954 and 1955 when 203 dredge samples and 13 tow samples were collected from 40 stations.

2. Thirty-one different organisms were listed with comments on their distribution. Several species collected were restricted to shallow shoal areas.

3. *Pontoporeia affinis* was the dominant organism at all depths. This amphipod made up an average of 70 percent of the volume of all samples. The contribution of *P. affinis* to the total sample volume varied with the depth of water.

4. The average volume of organisms per orange-peel dredge sample ranged from 0.01 ml. to 3.5 ml.. The average volume of all samples was 0.79 ml..

5. There was a distinct drop in both numbers and volume of organisms between 25 and 40 fathoms depth.

6. The abundance of *P. affinis* varied directly with that of the other organisms.

7. There was a regression of numbers of organisms per sample with depth regardless of bottom type.

8. The size distribution of *P. affinis* varied with depth of water and seasons of the year.

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Appendix A

Enumeration of Lake Michigan bottom fauna from all stations sampled in 1954 and 1955

Date	Depth (fathoms)	Sample volume	Pontoporeia <3 mm.	Pontoporeia 3-5 mm.	Pontoporeia 5-7 mm.	Pontoporeia >7 mm.	Oligo-chaetes	Gastro-poda	Pele-cypoda	Chiro-nomidae	Others
						Station 1.					
7-13-54	39	0.52		30	53	10	16				
8-25-54	40	0.65	10	41	27	14	13		1	1	
						Station 2.					
7-13-54	82				1		2				
10-4-54	80	0.20	12	13	28	13	8				
						Station 3.					
7-13-54	40	0.40	2	20	38	7	18		3		
8-25-54	40	0.23	1	22	20	3	1				
10-4-54	40	0.22	9	10	36	9	8				
						Station 6.					
6-2-54	40	0.03	1	1			3				
						Station 7.					
5-30-54	35	0.25	14	4	13	14	18		4		
						Station 8.					
5-30-54	58	0.22		6	3	16	4				
						Station 9.					
5-30-54	60	0.55	sample lost								
						Station 10.					
5-30-54	40	0.05			3		11		1		

Enumeration of Lake Michigan bottom fauna from all stations sampled in 1954 and 1955

Date	Depth (fathoms)	Sample volume	Pontoporeia <3 mm.	Pontoporeia 3-5 mm.	Pontoporeia 5-7 mm.	Pontoporeia >7 mm.	Oligo-chaetes	Gastro-poda	Pele-cypoda	Chiro-nomidae	Others
Station 11.											
5-11-54	40	0.22		5	9	13	18				
5-15-54	40		12	48	43	13	6				
6-25-54	40	0.22	11	16	6	6	7				
7-9-54	40	0.27	10	2	34	4	6		1		
7-29-54	40	0.35	3	19	24	6			1	1	
8-19-54	40	0.50	6	22	53	12		5			
9-11-54	40	0.20		9	17	6	9	8	5		
10-1-54	40	0.10		6	4	3	3				
10-28-54	40	0.15	2	7	17	4	5				
11-12-54	40	0.34		41	100	43	8				Mysis-1
Station 12.											
5-11-54	49	0.41		3	23	44	4			5	
5-15-54	50	0.55	10	20	46	31	5		1	2	
6-25-54	50	0.45	7	16	29	9	6		2		
7-9-54	50	0.24	28	8	12	7	18		4	1	
7-29-54	50	0.75	1	47	83	18	1			1	
8-19-54	50	0.18	4	9	13	1					
10-1-54	50	0.68	19	53	50	18	2	11		1	
10-31-54	50	-				1	1				
11-12-54	50	-		1	4	2	3				
Station 13.											
3-9-55	40	0.11	1		6	12	1			1	
5-11-54	38	0.10		1	3	8	7	7			
5-15-54	40	0.20		9	14	4	23		3		
5-27-54	40	0.10		2	2	5	9				Mysis-1
6-6-54	40	0.25	1	5	17	9					Hirudinea-1
6-25-54	40	0.05		1	8		1				
7-9-54	40	0.21		2	2	3	11			3	
8-7-54	40	0.17		4	20	1	3		10		
8-8-54	40	0.15	1	7	4	7	5		4		
8-19-54	40	0.17		7	4	3	10				
8-25-54	40	0.04		5	1		2				
9-9-54	40	0.20					20				

Enumeration of Lake Michigan bottom fauna from all stations sampled in 1954 and 1955

Date	Depth (fathoms)	Sample Volume	*Pontoporeia affinis* <3 mm.	*Pontoporeia affinis* 3-5 mm.	*Pontoporeia affinis* 5-7 mm.	*Pontoporeia affinis* >7 mm.	Oligo-chaetes	Gastro-poda	Pele-cypoda	Chiro-nomidae	Others
						Station 13. (continued)					
10-1-54	40	0.07	1	5	12		2 -				
10-31-54	40			1	2						
11-12-54	40				9	3	4				
12-14-54	40	0.14			13	7	1				
						Station 14.					
5-9-54	40	0.35	1	7	30	8	58		2		
6-18-54	40	0.65	74	62	56	21	7		17		
7-31-54	40	0.50		39	25	10	15				
9-13-54	40	0.53	4	21	51	25	14		4		
10-22-54	40	0.98	2	35	101	35	29				
						Station 15.					
5-9-54		sample lost									
6-18-54	85				2						
8-1-54	87	0.10		4	6	2	2				
						Station 16.					
6-18-54	35	0.10	1	4	5	2	2				
8-1-54	40	0.18	1	19	6	1	6				
10-22-54	40	0.10		4	12	7	10				
						Station 17.					
8-3-54	40						1				
9-25-54	40	0.10	1	8	6	1	20		1		Planarian-1
						Station 18.					
6-20-54		no organisms									

Enumeration of Lake Michigan bottom fauna from all stations sampled in 1954 and 1955

Date	Depth (fathoms)	Sample volume	Pontoporeia affinis <3 mm.	Pontoporeia affinis 3-5 mm.	Pontoporeia affinis 5-7 mm.	Pontoporeia affinis >7 mm.	Oligo-chaetes	Gastro-poda	Pele-cypoda	Chiro-nomidae	Others
						Station 19.					
6-20-54	40	0.20	3	4	5	5	16				
8-3-54	40	0.35		19	21	2	24				
9-15-54	40	0.64	3	30	34	12	75				
						Station 51a.					
7-12-54	20	1.57	32	105	193	29	6			1	
7-12-54	32	0.70	1	35	32	24	29		1	3	
7-12-54	45	0.12	1	1	16		2				
10-3-54	42	0.14	6	7	12	12			1		
						Station 52a.					
7-14-54	19	0.77	27	30	56	2	31		21		
7-14-54	32	0.51	3	64	24		7		3		
7-14-54	71	0.65		51	89	5	6		1		
10-5-54	15	0.64		24	59	17	18		30		
10-5-54	30	1.12		60	102	55	32		9		
						Station 53a					
7-11-54	15	1.77	6	17	254	11	43		34	1	Planarian-1
7-11-54	27	0.33		11	12	13	25			1	
						Station 55a					
5-29-54	15	2.10	35	28	340	51	50		37	2	
5-29-54	25	0.63	12	28	46	42	31		14	4	
5-29-54	41	0.25			5	6	31				
7-10-54	14	1.40	69		157	11	44		24		
8-20-54	15	2.93	35	2	491	37	29				
8-20-54	25	1.50	55	53	149	57	46		21	1	
8-20-54	50	0.05	1	1	1		7				
10-2-54	25	1.70	98	149	219	90	36		41		
10-2-54	50	0.06	4	6	1	3	3				

Enumeration of Lake Michigan bottom fauna from all stations sampled in 1954 and 1955

Date	Depth (fathoms)	Sample volume	*Pontoporeia affinis* <3 mm.	3-5 mm.	5-7 mm.	>7 mm.	Oligo-chaetes	Gastro-poda	Pele-cypoda	Chiro-nomidae	Others
						Station 58a.					
5-12-54	25	0.42	1	11	16	9	85			6	
7-7-54	25	0.85	4	9	64	13	46		3		
7-28-54	25	0.68		24	73	13	3			1	
8-29-54	30	0.15	1	7	12	2	15		2		
10-21-54	25	2.58	39	63	164	44	25		17		
11-10-54	27	1.76	52	63	118	138	67				
						Station 58b.					
5-8-54	50	0.10		3	4	3	10				
	50	0.10	2	5	8	9	14			1	
7-28-54	48	0.50		36	51	7	14			5	
8-29-54	51				3	4					
10-21-54	49	0.17	1	3	22	9					
						Station 58c					
5-16-54		0.13		7	8	7	10				
5-17-54	13	3.50	3	87	340	16	335				
5-17-54	18	3.05		72	324	65	79		3	16	
5-17-54	23	2.20		48	121	68	153	1		4	Hirudinea-1
6-5-54	20	0.53	2	73	47	37	24		2		
6-5-54	8	0.88	29	2	125					3	
6-25-54	10	2.00	282	6	207		79	7	28		
8-7-54	15	2.50	12	12	104	70	63		0		
10-7-54	14	0.85		78	14	65	6		2		
10-20-54	13	1.62	2	96	29	116					Hirudinea-1
11-18-54	15	2.86	33	339	129		174	12	38	5	
12-14-54	15	2.62	16	222	139	47	140	1	4	2	Trichoptera-2
3-10-55	15	0.83		34	71	59	127		8	2	

Enumeration of Lake Michigan bottom fauna from all stations sampled in 1954 and 1955

Date	Depth (fathoms)	Sample volume	Pontoporeia affinis <3 mm.	Pontoporeia affinis 3-5 mm.	Pontoporeia affinis 5-7 mm.	Pontoporeia affinis >7 mm.	Oligo-chaetes	Gastro-poda	Pele-cypoda	Chiro-nomidae	Others
						Station 59a.					
5-14-54	25	0.80	8	41	84	7	45		3		
6-19-54		0.88	13	73	36	27	5				
8-5-54		0.28	2	10	10	19	39		11		
10-23-54	25	1.16	10	31	109	43	35		6		
						Station 59b.					
5-14-54	52	0.25		5	33	4	5				
6-19-54	52	0.48		33	39	12	2			3	
8-5-54	52	0.12			24	2	14			2	
10-23-54	52	0.37		71	41	16	16				
						Station 59c.					
5-10-54	40	0.43	10	18	19	10	32		9		Mysis-3
6-24-54	15	0.40	5	11	60	5	14		4	2	
6-24-54	40	0.42	7	27	23	4	19		2		
6-24-54	50	0.55		13	57	15	10				
7-30-54	50	0.32		7	29		10		1	3	
7-30-54	30	0.50	9	35	33	8	27		5		
9-12-54	30	0.50	14	35	29	17	9				
9-12-54	50	0.52	4	86	31	4	2		8		
9-12-54	50	0.78		72	64	13	24	1	3		
9-12-54		1.18	27	39	78	55	23		8		
10-23-54	50	0.45		82	44	5			57		
10-23-54	30	0.78	12	36	49	19	16				
						Station 59d.					
5-13-54	70	0.07		6	5	1	3				
						Station 59e.					
5-13-54		0.03	5	1	12		1			1	

Enumeration of Lake Michigan bottom fauna from all stations sampled in 1954 and 1955

Date	Depth (fathoms)	Sample volume	*Pontoporeia affinis* <3 mm.	*Pontoporeia affinis* 3-5 mm.	*Pontoporeia affinis* 5-7 mm.	*Pontoporeia affinis* >7 mm.	Oligo-chaetes	Gastro-poda	Pele-cypoda	Chiro-nomidae	Others	No. of* grabs
						Station 60						
5-8-54		0.36	2	10	35	3	9		4	2		
						Station 61a						
8-4-54	15	1.77	11	42	191	13	70		45	5		
8-4-54	25	0.55			53	3	10		12	2		
8-4-54	50	0.20	4	10	19	12	7			3		
						Station 62a						
6-21-54	15	1.75	18	227	12	42	31		15	5		
6-21-54	29	1.50	3	72	63	51	86		1	4		
6-21-54	41	0.25	1	22	9	7	13			3		
8-2-54	15	2.61	205	23	238		64	2	135	2		
8-2-54	25	1.02		36	135	8	9		3	6		
8-2-54	41	0.40		13	29	7	35		1			
						Station 71c.						
6-12-55	50	0.30		12	16		108					3
6-6-55	25	2.50	28	118	215	3	228		30	11	Trichoptera-1	3
6-6-55	15	4.85		7	903	2	77	2	12	6	Isopoda-2 Hirudinea-4	3
6-6-55		0.23	180		6		1			39		3
9-7-55	50	0.37		22	13		14			2		4
9-7-55	25	4.65	278	531	209	71	199			13		4
9-7-55	15	9.05	1247	1003	20	4	174		3	8	Hirudinea-4 Trichoptera-2	4
9-7-55	5	1.05	9	287	8		15			20		1

* In 1955 several orange-peel dredge grabs were combined to form one sample

Enumeration of Lake Michigan bottom fauna from all stations sampled in 1954 and 1955

Date	Depth (fathoms)	Sample volume	*Pontoporeia affinis* <3 mm.	*Pontoporeia affinis* 3-5 mm.	*Pontoporeia affinis* 5-7 mm.	*Pontoporeia affinis* >7 mm.	Oligo-chaetes	Gastro-poda	Pele-cypoda	Chiro-nomidae	Others	No. of grabs
Station 74a.												
6-3-55	26	0.13			3	7	2			2	*Mysis*-1	4
9-2-55	100			4	4	3						1
9-2-55	35	2.50		28	8	184	11			5		2
9-2-55	12	0.20		4	2					31		2
Station 74b.												
6-2-55	65	0.40	12	14	29		7		1	1		1
Station 72d.												
7-19-55	10	0.35		16	7		9			6		4
7-19-55	14	1.50	86	35	163	9			14	8	Isopoda-1	4
7-19-55	25	4.45	54	2	570	8	107			16		4
7-19-55	50	0.70	8	86	66	3	6					1
Station 75c.												
5-14-55	50	0.17		11	28	14	4		1	9		4
5-14-55	25	0.80	3	30	76	42	114		3	9		4
5-14-55	15	1.00	1	4	192		15		24			4
Station 75d												
6-25-55	30	4.20	153	116	365		131		119			4
6-25-55	50	0.50	1	12	46	26	20		2	3		4
9-24-55	30	2.40	14	204	123	7	77		8			7
9-24-55	50	1.08	13	160	116	14						4
Station 75e												
6-25-55	15	6.20	58	12	672	243	18		369	17		4
9-24-55	15	6.27	49	569	641	21			53			4

Enumeration of Lake Michigan bottom fauna from all stations samnled in 1954 and 1955

Date	Depth (fathoms)	Sample volume	Pontoporeia affinis <3 mm.	Pontoporeia affinis 3-5 mm.	Pontoporeia affinis 5-7 mm.	Pontoporeia affinis >7 mm.	Oligo-chaetes	Gastro-poda	Pele-cypoda	Chiro-nomidae	Others	No. of grabs
						Station 76e.						
5-20-55	25	1.91	74	20	224	147	259		82	16		4
5-20-55	15	2.35	3	2	184	1	277		56	58		4
6-27-55	50	0.65	2	7	42	15				34		4
6-27-55	24	4.50	36		365	105	19			1		4
6-27-55	15	0.90	252		75	18	2	5		8		4
10-1-55	15	3.88	16	767	68	61	74			61		3
10-1-55	25	6.30	25	885	54	324	130		28			4
10-1-55	50	0.80	5	135	47	17				2		3

Appendix B

Enumeration of Lake Michigan bottom fauna from all sediment types represented in the 1954 and 1955 samples

Date	Depth (fathoms)	Station	Sample volume	*Pontoporeia affinis* <3mm.	3-5 mm.	5-7 mm.	>7 mm.	Oligochaetes	Pelecypoda	Chironomidae	Others
						Sand					
9-7-54	5	71c	1.05	9	287	8		15		20	
6-5-54	8	58c	0.88	29	2	125				3	
6-25-54	10	58c	2,00	282	6	207		79	28		Gastropoda-7
10-20-54	13	58c	1.62	2	96	29	116				Hirudinea-1
5-17-54	13	58c	3.50	3	87	340	16	335			
10-7-54	14	58c	0.85		78	14	65	6	2		
12-14-54	15	58c	2.65	16	222	139	47	140	4	2	Gastropoda-1 Trichoptera-2
3-10-55	15	58c	0.83		34	71	59	127	8	2	
8-4-54	15	61a	1.77	11	42	191	13	70	45	5	
7-11-54	15	53a	1.77	6	17	254	11	43	34		Planarian-1
7-14-54	15	52a	0.64		24	59	17	18	30		
8-20-54	15	55a	2.93	35	2	491	37	29			
5-17-54	18	58c	3.05		72	324	65	79	3	16	
4-5-54	19	52a	0.77	27	30	56	2	31	21		
7-12-54	20	51a	1.57	32	105	193	29	6		1	
9-12-54	25	59c	0.50	14	35	29	17	9			
7-11-54	27	53a	0.33		11	12	13	36		1	
10-23-54	25	59a	1.16	10	31	109	43	35	6		
7-13-54	82	2				1		2			
						Silt					
8-2-54	25	62a	1.02		36	135	8	9	3	6	
11-10-54	25	58a	1.76	52	63	118	138	67			
6-21-54	29	62a	1.50	3	72	63	51	86	1	4	
8-29-54	30	58a	0.15	1	7	12	2	15	2		
6-18-54	35	16	0.10	1	4	5	2	2			
8-1-54	35	16	0.18	1	19	6	1	6			
10-22-54	35	16	0.10		4	12	7	10			
9-15-54	40	19	0.64	3	30	34	12	75			
8-3-54	40	19	0.35		19	21	2	24			
6-20-54	40	19	0.20	3	4	5	5	16			

Enumeration of Lake Michigan bottom fauna from all sediment types represented in the 1954 and 1955 samples

Date	Depth (fathoms)	Station	Sample volume	Pontoporeia affinis <3 mm.	Pontoporeia affinis 3-5 mm.	Pontoporeia affinis 5-7 mm.	Pontoporeia affinis >7 mm.	Oligochaetes	Pelecypoda	Chironomidae	Others
Silt (continued)											
11-12-54	40	13				9	3	4			
10-31-54	40	13			1	2					
10-1-54	40	13	0.07	1	5	12		2			
9-9-54	40	13	0.20					20			
8-25-54	40	13	0.04		5	1		2			
8-19-54	40	13	0.17		7	4	3	10			
8-8-54	40	13	0.15	1	7	4	7	5	4		
8-7-54	40	13	0.17		4	20	1	3	10		
6-2-54	40	6	0.03	1	1			3			
5-30-54	40	10	0.05			3		12	1		
6-25-54	40	13	0.05		1	8		1			
6-21-54	41	62a	0.25	1	22	9	7	13		3	
8-2-54	41	62a	0.40		13	29	7	35	1		
8-20-54	50	55a	0.05	1	1	1		7			
10-2-54	50	55a	0.06	4	6	1	3	3			
5-8-54	50	58b	0.10	2	5	8	9	14		1	
6-18-54	85	15	0.01			2		1			
8-1-54	85	15	0.10		4	6	2	2			
Sand-Silt											
8-2-54	15	62a	2.61	205	23	238		64	135	2	
8-20-54	25	55a	1.50	55	53	149	47	55	21	1	
5-12-54	25	58a	0.42	1	11	16	9	85		6	
7-7-54	25	58a	0.85	4	9	64	13	45	3		
10-21-54	25	58a	2.58	39	63	164	44	25	17		
10-23-54	30	59c	0.78	12	36	49	19	16		1	
5-11-54	40	13	0.10		1	3	8	31			
5-15-54	40	13	0.20		9	14	4	23	3		
5-27-54	40	13	0.10		2	2	5	27			Hirudinea-1
6-6-54	40	13	0.25	1	5	17	9	63			
7-9-54	40	13	0.21		2	2	3	11		3	
11-14-54	40	13	0.40			13	7	41			

Enumeration of Lake Michigan bottom fauna from all sediment types represented in the 1954 and 1955 samples

Date	Depth (fathoms)	Station	Sample volume	Pontoporeia affinis <3 mm.	Pontoporeia affinis 3-5 mm.	Pontoporeia affinis 5-7 mm.	Pontoporeia affinis >7 mm.	Oligochaetes	Pelecypoda	Chironomidae	Others
Sand-Silt (continued)											
3-9-55	40	13	0.11	1		6	12	1		1	
9-2-54	100	74a	0.05		4	4	3				
Sand-Clay											
5-29-54	15	55a	2.10	35	28	340	51	50		2	
6-24-54	15	59c	0.40	5	11	60	5	14	4	2	
6-21-54	15	62a	1.75	18	227	12	42	31	15	15	
11-18-54	15	58c	2.86	33	339	129		174	38	5	
7-10-54	15	55a	1.40	69		157	11	44	24		
5-29-54	25	55a	0.63	12	28	46	42	21	14	4	
10-2-54	25	55a	1.70	98	149	219	90	36	41		
8-4-54	25	61a	0.55			53	3	10	12	2	
10-5-54	30	52a	1.12		60	102	55	32	9		
9-12-54	30	59c	0.50	14	35	29	17	9			
7-12-54	32	51a	0.70	1	35	32	24	19			
7-13-54	39	1	0.52	1	30	53	10	16		1	
8-25-54	39	1	0.65	10	41	27	14	13	1	1	
7-31-54	40	14	0.50		39	25	10				
6-5-54	40	58c	0.53	2	73	47	37	24	2		
5-30-54	41	7	0.25	14	4	13	14	18	4		
7-13-54	50	3	0.40	2	20	38	7	18	3		
8-25-54	50	3	0.23	1	22	20	3	1			
10-4-54	50	3	0.22	9	10	36	9	8			
6-19-54	50	59b	0.25		5	33	4	5			
5-14-54	50	75c	0.27		11	28	14	4	1	9	
5-8-54	50	58b	0.10		3	4	3	10			
Clay-Silt											
9-7-54	40	11	0.22		11	16	6	7			
9-11-54	40	11	0.20		9	17	6	9	5		Gastropoda-8
10-1-54	40	11	0.10		6	4	3	3			
10-28-54	40	11	0.15	2	7	17	4	5			

Enumeration of Lake Michigan bottom fauna from all sediment types represented in the 1954 and 1955 samples

Date	Depth (fathoms)	Station	Sample volume	*Pontoporeia affinis* <3 mm.	3-5 mm.	5-7 mm.	>7 mm.	Oligochaetes	Pelecypoda	Chironomidae	Others
					Clay-Silt (continued)						
11-12-54	40	11	0.54		41	100	43	8			
10-3-54	42	51a	0.14	6	7	12	2		1		
8-4-54	50	61a	0.20	4	10	19	12	7		3	
8-19-54	50	12	0.18	4	9	13	1				
11-12-54	50	12			1	4	2	3			
8-29-54	50	58b				3	4				
10-21-54	50	58b	0.17	1	3	22	9				
5-30-54	58	8	0.22		6	3	16	4			
5-13-54	70	59d	0.07		6	5	1	3			
					Sand-Clay-Silt						
7-28-54	25	58a	0.68		24	73	13	3		1	
7-14-54	32	52a	0.51	3	64	24		7	3		
9-13-54	40	14	0.53	4	21	51	25	14	4		
10-22-54	40	14	0.98	2	35	101	35	29			
5-11-54	40	11	0.22		5	9	13	7			
5-15-54	40	11		12	48	43	13	6			
7-9-54	40	11	0.27	10	2	34	4	6	1		
7-29-54	40	11	0.35	3	19	24	6		1	1	
8-19-54	40	11	0.50	6	22	53	12				Gastropoda-5
5-9-54	40	14	0.35	1	7	30	8	58	2		
9-25-54	40	17	0.10	1	8	6	1	23	1		
8-5-54	40	59a	0.28	2	10	10	19	29	11		
7-30-54	40	59c	0.32		7	29		10	1	3	
6-24-54	50	59c	0.55		13	57	15	10			
5-11-54	50	12	0.41		3	23	44	10		5	
5-15-54	50	12	0.55	10	20	46	31	5	1	2	
6-25-54	50	12	0.45	7	16	29	9	6	2		
7-29-54	50	12	0.75	1	47	83	18	1		1	
7-28-54	50	58b	0.50		35	51	7	14		5	
9-12-54	50	59c	0.52	4	86	31	4	2			
9-12-54	50	59c	0.78		72	64	13	24	3		

Enumeration of Lake Michigan bottom fauna from all sediment types represented in the 1954 and 1955 samples

Date	Depth (fathoms)	Sta- tion	Sample volume	Pontoporeia affinis <3 mm.	3-5 mm.	5-7 mm.	>7 mm.	Oligo- chaetes	Pele- cypoda	Chiro- nomidae	Others
					Sand-Clay-Silt (continued)						
6-19-54	52	59b	0.48		33	39	12	2		3	
8-5-54	52	59b	0.12			24	2	14		2	
10-23-54	52	59b	0.37		71	41	16	16			
7-14-54	71	52a	0.65		51	89	5	6	1		