UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 24

THE DISTRIBUTION AND ECONOMIC IMPORTANCE OF THE BOTTOM FAUNA OF LAKE NIPIGON WITH AN APPENDIX ON THE BOTTOM FAUNA OF LAKE ONTARIO

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1924

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THE DISTRIBUTION AND ECONOMIC IMPORTANCE OF THE BOTTOM FAUNA OF LAKE NIPIGON

Introduction

During the past three summers, 1921-1923, an extensive limnobiological investigation of Lake Nipigon has been carried out under the direction of Dr. W. A. Clemens, of the Department of Biology, University of Toronto. The purpose of this work was to make a thorough survey of the biological and physical conditions obtaining in the lake especially in relation to the fish life. As one phase of this work, a study of the bottom fauna was undertaken, and, as this came largely under the direction of the writer, the results obtained will be presented in this report. The object of this part of the investigation was to learn something of the species of animals inhabiting the lake bottom and more particularly, to determine their abundance, distribution and value as fish food. For this purpose some five hundred samples of the bottom have been worked over and these include specimens representative of a great variety of depths and environmental conditions in the lake. It was also necessary to examine the stomach contents of specimens of the more important species of fish in order to find out the extent to which the bottom organisms were used as fish food.

The writer wishes to take this opportunity of thanking Dr. Clemens and all other members of the party for generous assistance and co-operation. Thanks are also due to those specialists who identified certain classes of material, and to the Honorary Advisory Council for Scientific and Industrial Research for financial aid during the course of the work.

PHYSIOGRAPHICAL FEATURES OF LAKE NIPIGON

Before entering upon a discussion of the work done and the results obtained, it seems advisable to consider briefly the more salient physiographical features of the lake and the country immediately surrounding it. Lake Nipigon is the largest of the inland lakes of Ontario and covers an area of approximately 1,750 square miles. It is situated about fifty miles north of Lake Superior into which it empties through the Nipigon river. The district surrounding the lake is well-wooded, rugged, hilly country, typically Archaean, and composed largely of igneous diabasic rock which bears much evidence of past glacial action. The lake itself existed formerly as a bay of the ancient Lake Algonquin from which it was separated at the close of the last ice age, and its present system of drainage and its physical contours are regarded as largely the result of glacial action (Coleman, 1922). There can be no doubt that the ice sheets removed all loose material from the lake bed and left it, in a sense, entirely rejuvenated.

The shore line is very irregular and is characterized by numerous bays and projecting headlands and long stretches of rocky shore exposed to the full violence of the waves. Scattered throughout the lake are numerous groups of islands which lie roughly in a north and south direction, and divide the lake into eastern and western portions. The channels between these islands and the more protected bays afford stretches of quiet waters in which aquatic organisms abound, but in no place are there extensive stretches of aquatic vegetation. A great variety of environmental conditions are thus represented in the lake (Plate I).

The water of the open lake is quite clear and cold, but near the mouths of rivers it is dark brown in colour and much warmer (Clemens, 1923). In general the water is quite deep, and along the east and west shores there are channels representing the ancient outlets of the lake in which depths of over 300 feet were frequently sounded.

METHODS OF INVESTIGATION

The method employed in studying the animal life of the bottom of the lake was to dredge up samples of the lake floor with all parts undisturbed. A small Ekman dredge, (Birge 1922) was used for this purpose, and it brought up the materials covering 81 square inches of the bottom. The dredge was lowered open upon the end of a small steel cable wound on a windlass, and when the bottom was reached a messenger was dropped down the cable from the boat. This released the jaws of the dredge which closed upon a sample of the bottom. The dredge was then hauled up, and the contents were placed in a numbered tray. Data concerning depth, distance from shore, and character of bottom were tabulated in regard to each sample. Usually a series of from 8 to 10 hauls was taken from any particular locality—the distance between dredgings being governed largely by depth and character of bottom.

The trays in which the materials were kept were made of thin wood lined inside with white oil-cloth so as to be water-tight. Their dimensions were 10″×18″ × 3″—this size having been found sufficiently large to contain the materials brought up in most dredgings. Depth was measured directly by a recording instrument over which the cable passed when the dredge was lowered. Distance from shore was estimated as accurately as possible either by judging short distances or by timing the boat.

The samples obtained in a series of dredgings were taken back to the laboratory to be cleaned by washing them through screens of different grades of fineness. The frames for these screens were made about 18 inches square and 6 inches high, and the material forming the screen was tacked to the frame in such a manner that it sagged to a depth of about 2 inches in the centre. By piling the screens one above the other with the coarsest on top, any material which was washed through the upper one was caught in the next below and washed again. Galvanized iron-wire mosquito-netting was used for the coarsest upper screen, cheese-cloth for the next, and factory cotton for the lowest and finest. Only the smallest organisms, such as Ostracods and Cladocera, were able to get through to the lowest screen composed of factory cotton.

After washing the material it was put back into the tray from which it was originally taken—the tray having been washed in the meantime. Later the cleaned samples were sorted in the laboratory (while the animals were still alive, when possible), and the specimens were preserved in 70% alcohol in vials.

In addition to the Ekman dredge, a drag dredge was used on a few occasions during the earlier operations. This piece of apparatus consisted of an iron frame to which a canvas bag was attached. As it was hauled over the bottom it scraped up any loose material with which it came into contact. It was found to be so difficult to control, however, and gathered up such an enormous amount of material, that the results did not compensate for the labour involved in cleaning and sorting it, in view of the uncertainty as to the actual area of the bottom which any sample represented. As a result this dredge was soon abandoned in favour of the Ekman type, which was very efficient and covered a perfectly definite area. On some occasions, such as when a rocky bottom was encountered, even this dredge could not be used and samples were supplemented by hand collections.

TABULATION OF RESULTS

The details of the results obtained during the summers 1921-22 have already been published along with various other studies of Lake Nipigon, and may be found in the reports of the Ontario Fisheries Research Laboratory of the Department of Biology, University of Toronto—Numbers 22 and 23 of the Biological Series. In the present report the detailed results of the work of 1923 only will be given. Throughout these tables the following usages have been adopted:

Dredgings are grouped in series, according to the locality from which they were obtained.

Distance from shore is expressed in yards, unless otherwise stated.

Depth is expressed in feet.

Character of bottom is represented by the abbreviations:

M = mud; S = sand; C = clay; G = grit; Gr = gravel; R = rock; S/C = sand on clay, etc.

These types of bottom are briefly defined as follows:

Mud: fine particles of inorganic matter containing a small amount of organic substances, not forming a compact plastic mass and usually some shade of brown in colour.

Sand: coarser particles of inorganic matter such as are ordinarily understood by the term.

Clay: fine particles of inorganic matter forming a compact plastic mass usually some shade of gray in colour.

Grit: particles of inorganic matter of irregular shape slightly larger than sand.

Gravel: small pebbles and irregular particles much larger than grit.

Rock: stones, boulders, bed rock.

Sand on Clay: a bottom in which a thin layer of sand rests upon a substratum of clay. There are also various other similar combinations such as mud on clay.

In shallow water it was usually found that the bottom had a very thin covering of ooze except on clean sandy shores, but in deep water the ooze layer was usually at least half an inch thick and in places as much as six inches or more.

NORTH-EAST OF NAONAN ISLAND — SERIES I

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	84	111	120	123	120	81	111	129	
Distance from Shore	300	400	500	600	800	1000	1500	2000	
Character of Bottom	M	C	M	M	M	M	C	C	
Mollusca			1	2	3	3		2	11
Chironomidae	3	1	2	6	5	3		1	21
Amphipoda	57	17	54	94	56	61	32	9	380
Ostracoda	1		1			1	1		4
Oligochaeta	4	1	1	4	2	2	2		16
Nematoda	1								1
Platyhelminthes			1						1
Totals	66	19	60	106	66	70	35	12	434
Average per dredging									54

ORIENT BAY (DEEP CHANNEL) — SERIES II

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	111	156	150	276	291	246	198	153	
Distance*	300	400	800	1200	1600	2000	2400	3200	
Character of Bottom	C	M	C	M	M	M	M	C	
Mollusca	3			5	3		1		12
Chironomidae		2		7		2			11
Amphipoda	37	97	7	69	14	26	37	12	299
Mysidacea				1					1
Ostracoda	1			6					7
Oligochaeta		9	1	24	6	25	4	1	70
Platyhelminthes	1		2						3
Totals	42	108	10	112	23	53	42	13	403
Average per dredging									50

*These dredgings were taken northward up the deep channel of Orient Bay and the distance given is the distance north of Macdiarmid.

NORTH OF NAONAN ISLAND — SERIES III

								Total
Dredging	1	2	3	4	5	6	7	
Depth	240	237	303	327	321	363	303	
Distance from Shore	1 mi.	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	
Character of Bottom	M	M	M	M	M	M	M	
Mollusca	4	2	1	4	2	2	1	16
Chironomidae	7	7	11	1	4	8	1	39
Trichoptera					1			1
Amphipoda	96	28	86	97	53	21	26	407
Mysidacea	2	2						4
Ostracoda	1	2	5	3	10		1	22
Oligochaeta	5	8	12	12	13	7	10	67
Nematoda	1							1
Platyhelminthes							1	1
Totals	116	49	115	117	83	38	40	558
Average per dredging								80

ORIENT BAY (DEEP CHANNEL—S. II Cont'd) — SERIES IV

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	225	183	141	216	225	237	300	291	
Distance*	800	1000	1200	1400	1600	1800	2000	2200	
Character of Bottom	M	C	C	M	M	M	M	M	
Mollusca	1				1	2		8	12
Chironomidae	1	1	4	3		1			10
Amphipoda	76	30	119	111	124	143	102	11	716
Mysidacea				9		4			13
Ostracoda	7			3	5	14	3	33	65
Oligochaeta	11	6	3	8	10	14	11	67	130
Totals	96	37	126	134	140	178	116	119	946
Average per dredging									118

*Distances are measured northward from Dredging 8, Series II.

ORIENT BAY (SOUTH OF MACDIARMID) SERIES V

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	39	30	21	54	45	24	33	36	
Distance from Shore	200	300	400	500	600	700	800	900	
Character of Bottom	M	M	S	M	M	M	M	M	
Mollusca	10	1	3	13	8		23	20	78
Chironomidae	5	1	3	27	11	1	5	10	63
Ephemerida						1			1
Trichoptera						1			1
Amphipoda	22	7		1	38	16	22	18	124
Ostracoda				16					16
Copepoda	1			2					3
Cladocera	1								1
Hydracarina								1	1
Hirudinea					1				1
Oligochaeta		1		8	1				10
Totals	39	10	6	67	59	19	50	49	299
Average per dredging									37

ORIENT BAY (DEEP CHANNEL—S. IV Cont'd) SERIES VI

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	234	228	312	258	240	315	285	321	
Distance	*	$\frac{1}{4}$ mi.	$\frac{1}{2}$ mi.	$\frac{3}{4}$ mi.	1 mi.	$1\frac{1}{4}$ mi.	$1\frac{1}{2}$ mi.	$1\frac{3}{4}$ mi.	
Character of Bottom	M	M	M	M	M	M	M	M	
Mollusca	1		7	3		3	2	3	19
Chironomidae	2	7		3	3	1	7	1	24
Trichoptera	1							1	2
Amphipoda	126	79	86	170	41	117	83	70	772
Mysidacea	5				1	1			7
Ostracoda	15		3	16			6	11	51
Oligochaeta	26	12	24	20	4	10	7	21	124
Nematoda							1		1
Platyhelminthes		2						1	3
Totals	176	100	120	212	49	132	106	108	1003
Average per dredging									125

*Dredging No. 1 was taken in the deep channel of Orient Bay just outside the mouth of the Bay. The other dredgings were taken northward from this point.

ORIENT BAY (DEEP CHANNEL—S. VI Cont'd) SERIES VII

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	342	306	279	297	147	222	279	288	
Distance*	2 mi.	$2\frac{1}{4}$ mi.	$2\frac{1}{2}$ mi.	$2\frac{3}{4}$ mi.	3 mi.	$3\frac{1}{4}$ mi.	$3\frac{1}{2}$ mi.	$3\frac{3}{4}$ mi.	
Character of Bottom	M	M	M	M	C	M	M	M	
Mollusca	2		1						3
Chironomidae	4	2	2	1	2	10	7	2	30
Amphipoda	76	23	30	31		72	65	25	322
Ostracoda			3			6			9
Oligochaeta	15	17	13	2		4	7	13	71
Nematoda						1			1
Totals	97	42	49	34	2	93	79	40	436
Average per dredging									55

*Distance north of Macdiarmid.

BAY WEST OF PIPESTONE POINT SERIES VIII

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	3	5	6	5	9	9	9	6	
Distance from Shore	50	100	150	200	250	300	350	400	
Character of Bottom	M	M	M	S	S	S	M	M	
Mollusca	104	80	77	51	50	19	12	129	522
Chironomidae	181	221	166	140	106	41	34	117	1006
Ephemerida	5	22	17	1	2	4	8	5	64
Trichoptera	2	2	14	2		3	1	7	31
Coleoptera		1					2	2	5
Amphipoda		20	18		3	1	2	29	73
Ostracoda	1	[illegible]	4						13
Hydracarina	13	7	4	1		2		1	28
Hirudinea		1							1
Oligochaeta	15	5	8	8	9	21	12	35	113
Nematoda	1								1
Totals	322	367	308	203	170	91	71	325	1857
Average per dredging									232

DEEP CHANNEL—S. VII Cont'd SERIES IX

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	285	291	294	303	306	303	306	309	
Distance*	8 mi.	$8\frac{1}{4}$	$8\frac{1}{2}$	$8\frac{3}{4}$	9	$9\frac{1}{4}$	$9\frac{1}{2}$	$9\frac{3}{4}$	
Character of Bottom	M	M	M	M	M	M	M	M	
Mollusca		2				1	6	1	10
Chironomidae		1	3	4	1	1	1	2	13
Amphipoda	4	46	110	92	36	70	40	40	438
Mysidacea	1		1						2
Ostracoda		11	2	12	8	36	8	6	83
Oligochaeta	11	13	13	21	25	25	8	15	131
Nematoda				2					2
Platyhelminthes						1			1
Total	16	73	129	131	70	134	63	64	680
Average per dredging									85

*Distance north of Macdiarmid.

DEEP CHANNEL (SOUTH FROM MACDIARMID) SERIES X

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	159	147	120	90	54	57	57	42	
Distance*	$\frac{1}{4}$ mi.	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	
Character of Bottom	M	M	G/C	C	S/C	S/C	M/C	M	
Mollusca	1	1	1	3	4	14	3		27
Chironomidae	4	2	1	4	3	3			17
Amphipoda	114	58	56	14	7	2	3	3	257
Mysidacea							1		1
Ostracoda	1		3						4
Hydracarina					1				1
Hirudinea			1						1
Oligochaeta	23	5	1				2		31
Nematoda								1	1
Platyhelminthes				2					2
Total	143	66	63	23	15	19	10	3	342
Average per dredging									43

*Distance south of Macdiarmid.

NORTH OF NAONAN ISLAND SERIES XI

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	75	81	84	72	75	84	90	129	
Distance from Shore	50	400	800	1200	1600	2000	2800	4000	
Character of Bottom	C	C	C	C & Gr	C & Gr	C	C	M	
Mollusca			1			3	5		9
Chironomidae	2	1		1	1	4	2	4	15
Amphipoda	59	10	22	1	6	39	40	22	119
Mysidacea						1			1
Ostracoda	2		1			3	3		9
Copepoda							1		1
Oligochaeta		1					2		3
Nematoda								1	1
Platyhelminthes	1							1	2
Total	64	12	24	2	7	50	53	28	240
Average per dredging									30

WINDIGO BAY SERIES XII S.W. TO WHITE SAND SERIES XIII

									Total
Dredging	1	2	3	4	1	2	3	4	
Depth	18	21	20	21	9	9	10	10	
Distance from Shore	$1\frac{1}{2}$ mi.	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$5\frac{3}{4}$	$5\frac{1}{2}$	$5\frac{1}{4}$	5	
Character of Bottom	M	C	S/C	S/C	S	S/C	S/C	S/C	
Mollusca	34	65	95	58	59	71	41	50	473
Chironomidae	5	7	33	16	25	51	47	49	233
Ephemeridae	2	1	4		1	3	3	1	15
Trichoptera	1	1	3						5
Amphipoda	5	4	26	21	52	22	10	51	191
Ostracoda			2	2		2		2	8
Cladocera				1					1
Hydracarina				1		1		1	3
Oligochaeta				1	1	1		2	5
Nematoda			1		17	19	15	8	60
Total	47	78	164	100	155	170	116	164	994
Average per dredging									124

SOUTH FROM WHITE SAND — SERIES XIV

					Total
Dredging	1	2	3	4	
Depth	45	96	72	123	
Distance from Shore	3 mi.	5 mi.	7 mi.	9 mi.	
Character of Bottom	M/C	M/C	M/C	M	
Mollusca	10	1		1	12
Chironomidae	7	1	3	3	14
Amphipoda	14	121	31	145	311
Ostracoda				1	1
Copepoda	1				1
Oligochaeta		9	1	11	21
Nematoda	2	3	2		7
Platyhelminthes			1		1
Total	34	135	38	161	368
Average per dredging					92

SOUTH FROM GIEKIE TO GROS CAP — SERIES XV

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	162	170	180	219	246	249	291	216	
Distance from Shore	2 mi.	3 mi.	4 mi.	5 mi.	6 mi.	7 mi.	8 mi.	9 mi.	
Character of Bottom	M	M	M	M	M	M	M	M	
Mollusca		1				1	2		4
Chironomidae	18	7	1	2	6	6	4	8	52
Amphipoda	49	49	38	43	44	66	79	69	437
Ostracoda	1								1
Copepoda						1	1		2
Oligochaeta	1			3		2	1		7
Nematoda				1					1
Platyhelminthes		1	1	2		1	6	1	12
Totals	69	58	40	51	50	77	93	78	516
Average per dredging									65

SOUTH FROM MUNGO PARK POINT — SERIES XVI

									Total
Dredging	1	2	3	4	5	6	7	8	
Depth	117	102	108	108	240	240	255	237	
Distance from Shore	2 mi.	2½	3	4½	5½	6	7	7½	
Character of Bottom	S/C	S/C	S/C	S/C	M	M	M	M	
Mollusca	1	6	9	2	1				19
Chironomidae		3	5	3	4	2	6		23
Amphipoda	20	53	47	43	70	15	20	16	284
Ostracoda	1		3						4
Copepoda			2						2
Oligochaeta	1	2	1	2					6
Nematoda	1		1				1		3
Platyhelminthes							1		1
Total	24	64	68	50	75	17	28	16	342
Average per dredging									43

DISTRIBUTION OF BOTTOM ORGANISMS

From the data given in the preceding tables and in the results already published (Adamstone, 1923, 1924), a study of the distribution of the various groups of organisms constituting the bottom fauna of Lake Nipigon has been carried out. In this it was found that for any particular group of animals the relation of numerical abundance to depth offered the most satisfactory method of working out distribution. Accordingly, the following groups will be considered in this manner: *Nematoda, Acanthocephala, Platyhelminthes, Oligochaeta, Hirudinea, Crustacea, Insecta, Arachnida* and *Mollusca*. The results are based on the data obtained in the three summers during which the investigation was in progress and represent a total of 505 bottom samples.

NEMATODA

The total number of specimens of nematode worms obtained in all the dredging operations was very small (296), and as a result it is somewhat difficult and of questionable value to make any definite statement in regard to their distribution. From the scarcity of these animals in deep water as determined by the past summer's work and from the numerical data which are summarized in Table I, it seems safe to say that they were most abundant in shallower water, although their numbers, even when at a maximum, were never large. The results indicate a fairly uniform distribution down to depths of 120 feet, which is followed by a sudden decrease, and then a more gradual decline as deeper water is reached.

Some of the material was submitted to Dr. N. S. Cobb of the U.S. Department of Agriculture who reported the following species:

1. *Dorylaimus crassus* de Man.
2. " *speciosus* n. sp. Cobb.
3. " *canadensis* n. sp. Cobb.
4. *Mermithidae* (several species).

TABLE I

Depth	Total	Average	Depth	Total	Average
0-30	194	.65	180-210	2	.25
30-60	52	.76	210-240	3	.20
60-90	18	.60	240-270	1	.20
90-120	14	.63	270-300	1	.08
120-150	5	.29	300-330	2	.12
150-180	4	.33			

ACANTHOCEPHALA

Five specimens representative of this class were dredged up from a depth of 36 feet off a clay bottom (S XIV D8 1921). Their occurrence in this situation was regarded as accidental since most species are parasitic. These were identified by Dr. H. J. Van Cleave of the University of Illinois as *Echinorhynchus coregoni*, Linkins.

PLATYHELMINTHES

During the summer of 1922 two specimens of a flat-worm were dredged up from the deep water off the mouth of the Blackwater river (SXVII, 1922). A number of additional specimens were secured during the past season, mostly in deep water as in the previous year, but some of these, instead of being free living, were found attached externally to the Amphipod, *Pontoporeia hoyi*.

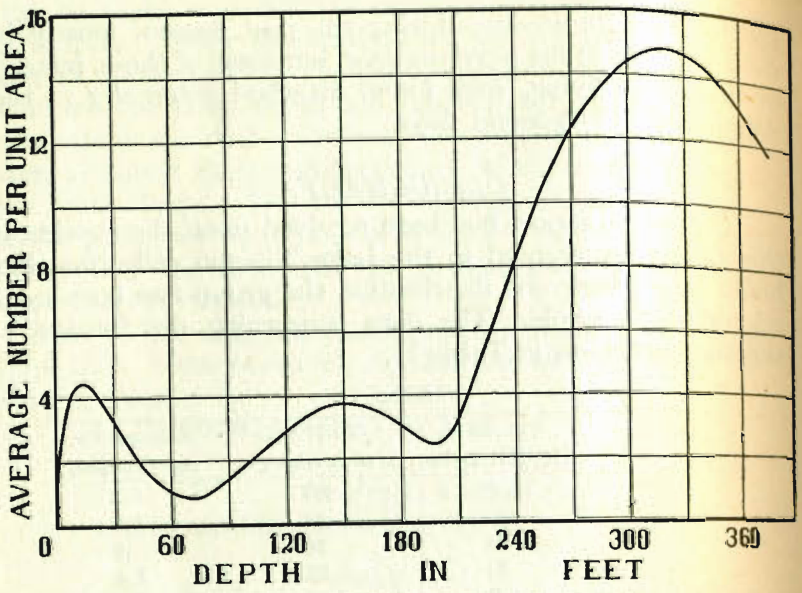
OLIGOCHAETA

As yet no report has been received upon the species of *Oligochaeta* represented in the Lake Nipigon collection and hence in working out distribution the group has been considered as a whole. The data concerning distribution is summarized below in Table II.

TABLE II

Depth	Total No. of Specimens	Total No. of Dredgings	Average No. per Dredging
0-30	1,349	297	4.5
30-60	132	68	1.9
60-90	29	30	.9
90-120	54	22	2.5
120-150	57	17	3.3
150-180	46	12	3.8
180-210	20	8	2.5
210-240	112	15	7.5
240-270	47	5	9.4
270-300	193	13	14.8
300-330	232	16	14.5
330-360	15	1	15.0
360-390	7	1	7.0

The results given in Table II are illustrated by Graph 1, study of which makes it evident that there are many more *Oligochaeta* per unit area in deep water than in shallower areas. In fact, that part of the curve showing their distribution in shallow water is comparatively insignificant, but it shows clearly a maximum in water less than 30 feet deep which was noted in former studies. There are two other maxima in deeper water, but depths of over 240 feet are apparently most productive of *Oligochaeta*, and it is quite possible that the decrease represented in the curve at 360 feet is a negative result based upon an insufficient number of dredgings.



GRAPH 1—Curve illustrating distribution of Oligochaeta according to depth.

HIRUDINEA

In the course of dredging operations leeches were occasionally brought up in small numbers. Collections were also made along rocky shores whenever possible, and some specimens were obtained in small neighbouring lakes. These were all submitted to Dr. J. P. Moore of the University of Pennsylvania, who reported fourteen species as listed below:

1. *Actinobdella triannulata*, Moore.
2. *Dina parva* Moore.
3. *Erpobdella punctata* (Leidy).
4. *Glossiphonia complanata* (Linn).
5. *Haemopis grandis* (Verrill).
6. *Haemopis marmoratis* (Say).
7. *Helobdella fusca* (Castle).
8. *Helobdella nepheloidea* (Graf).
9. *Helobdella stagnalis* (Linn).
10. *Macrobdella decora* (Say).
11. *Nephelopsis obscura* Verrill.

12. *Piscicola milneri* (Verrill).
13. *Piscicola punctata* (Verrill).
14. *Placobdella montifera* Moore.

A paper by Dr. Moore, dealing more exhaustively with the *Hirudinea* of Lake Nipigon is presented elsewhere in this publication.

CRUSTACEA

The *Crustacea* constitute one of the most important groups of organisms in Lake Nipigon not only because of their very great abundance, but also because of their enormous economic value as fish food. In dredging operations and in shore collections representatives of the following subclasses were obtained:

Branchiopoda—Order *Cladocera*
Ostracoda
Copepoda
Malacostraca—Order *Amphipoda*
Mysidacea
Decapoda

CLADOCERA

The number of specimens of *Cladocera* secured in dredgings was quite small due, in some measure no doubt, to the difficulty of retaining such small organisms during the process of washing the samples. The species identified, all of which live on or near the bottom in shallow water, include:

1. *Alona affinis* (Leydig).
2. *Chydorus sphaericus* var. *coelatus* Schoedler.
3. *Eurycercus lamellatus* (Müller).
4. *Ilyocryptus acutifrons* Sars.
5. *Latona setifera* (Müller).
6. *Polyphemus pediculus* (Linn).
7. *Sida crystallina* (Müller).

No idea of the abundance of *Cladocera* can be formed from the numbers brought up in dredgings, but their importance in the economy of Lake Nipigon has been thoroughly demonstrated in plankton studies (Bigelow, 1923) and in fish food studies (Clemens, 1923; Bigelow, 1924).

COPEPODA

A few specimens of *Copepoda* were found in dredging samples, but, like the *Cladocera*, it is impossible to estimate their abundance from these data. The species represented are:

1. *Episcura lacustris* Forbes.
2. *Diaptomus minutus* Lilljeborg.
3. *Limnocalanus macrurus* Sars.
4. *Senecella calanoides* Juday.
5. *Cyclops* sp.

OSTRACODA

A larger number of *Ostracoda* was obtained during the work of the past summer than at any time previously. This goes to show that these organisms are most abundant in the deeper waters of the lake, and the data summarized in Table III serve to corroborate this conclusion. The *Ostracoda* are so small, however, that many were doubtless lost in washing the bottom samples, and as a result the statements concerning them are merely relative. Specific determinations were not made, but there are a fairly large number of species mostly representative of the genera *Candona* and *Limnocythere*.

TABLE III

Depth	Total	Average	Depth	Total	Average
0-30	220	.74	180-210	2	.25
30-60	19	.28	210-240	53	3.5
60-90	15	.5	240-270	16	3.2
90-120	12	.55	270-300	66	5.1
120-150	4	.24	300-330	107	6.7
150-180	12	.10			

AMPHIPODA

Amphipoda have proven to be one of the most abundant of the bottom organisms in Lake Nipigon, and four species of them were obtained, including:

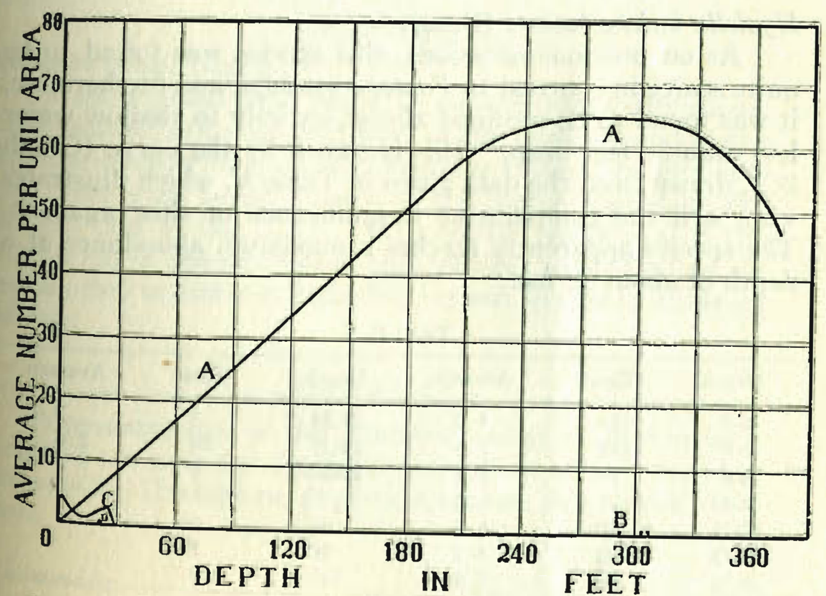
1. *Pontoporeia hoyi* Smith.
2. *Pontoporeia filicornis* Smith (tentative).
3. *Hyalella knickerbockeri* (Bate).
4. *Gammarus limnaeus* Smith.

Pontoporeia hoyi Smith.

This species is by far the most abundant and most widely distributed of the Amphipoda found in Lake Nipigon and it is also one of the most valuable food organisms in the lake. Table IV summarizes the data pertaining to its occurrence at various depths which is illustrated by the curve (Graph 2A).

TABLE IV

Depth	Total	Average	Depth	Total	Average
0-30	1,227	4.0	210-240	1,071	71.4
30-60	792	11.6	240-270	326	67.2
60-90	684	22.8	270-300	576	44.3
90-120	1,049	47.7	300-330	969	60.6
120-150	799	47.0	330-360	76	76
150-180	452	37.7	360-390	21	21
180-210	305	38.1			



GRAPH 2—Curve illustrating distribution of Amphipoda according to depth:
A. Pontoporeia hoyi C. Hyalella knickerbockeri
B. Pontoporeia filicornis? D. Gammarus limnaeus.

From the curve showing the distribution of this species in relation to depth it is evident that the maximum numbers occur in the deepest parts of the lake. After depths of 200 feet are reached, the number of specimens per unit area seems to be fairly uniform over large stretches of the bottom. As in the case of the *Oligochaeta*, the final drop in the curve is not regarded as having any particular significance.

Pontoporeia filicornis Smith (tentative).

Specimens of a species of Amphipod were dredged up from the deep waters off the mouth of the Blackwater River which, in some respects, resembled *P. filicornis* Smith. Only five specimens were obtained, and these from a very circumscribed area (Series IX, Dredgings 2, 4, 6, 7; 1923) at depths close to 300 feet.

Hyalella knickerbockeri (Bate).

As on previous occasions, this species was found to be quite scarce in contrast to *Pontoporeia hoyi*, and furthermore, it was found to be confined almost entirely to shallow water less than 30 feet deep. This is shown by the curve (Graph 2C), drawn from the data given in Table V, which illustrates very well the comparative insignificance of this organism. The species apparently reaches a maximum abundance at a depth of about 10 feet.

TABLE V

Depth	Total	Average	Depth	Total	Average
0-3	164	4.0	21-24	3	.2
3-6	131	2.6	24-27	38	2.5
6-9	70	1.8	27-30	0	
9-12	31	1.0			
12-15	30	1.0	48	3	
15-18	50	1.7	90	2	
18-21	80	2.5	159	2	

Gammarus limnaeus Smith.

Only 7 specimens of this species were secured and these were dredged up in the shallow, well-protected waters of a

narrow channel amongst the Shakespeare islands during the operations of 1921. The species is apparently of little importance numerically, although it is probably quite abundant locally.

MYSIDACEA

Mysis relicta Loven.

A few specimens of *Mysis relicta* were brought up in the dredgings which were made in the deep waters of the Orient Bay channel during the past summer. As this animal is a free-swimming organism most frequently found with other planktonts, its occurrence in dredging samples is regarded as more or less accidental. It would be useless, therefore, to attempt to estimate its abundance or distribution from these results.

DECAPODA

Cambarus virilis Hagen.

In shore collections made in various rocky situations, in the shallow well-protected bays of the northern end of the lake, specimens of the crayfish *Cambarus virilis* were obtained. None were ever found in any of the places visited at the southern end of the lake. This peculiar restriction of the distribution of the crayfish is quite similar to that noted for several other organisms, including certain species of *Mollusca* and fish.

INSECTA

Representatives of the following orders of *Insecta* were identified amongst the organisms secured in bottom samples: *Ephemerida, Trichoptera, Diptera, Odonata, Neuroptera, Coleoptera.*

Ephemerida.

In dredging operations confined to the shallower waters of the lake, especially in shallow bays and channels, *Ephemerida* nymphs were found to be an important part of the bottom fauna. The specimens obtained were identified by Dr. W. A. Clemens, who reports the following species:

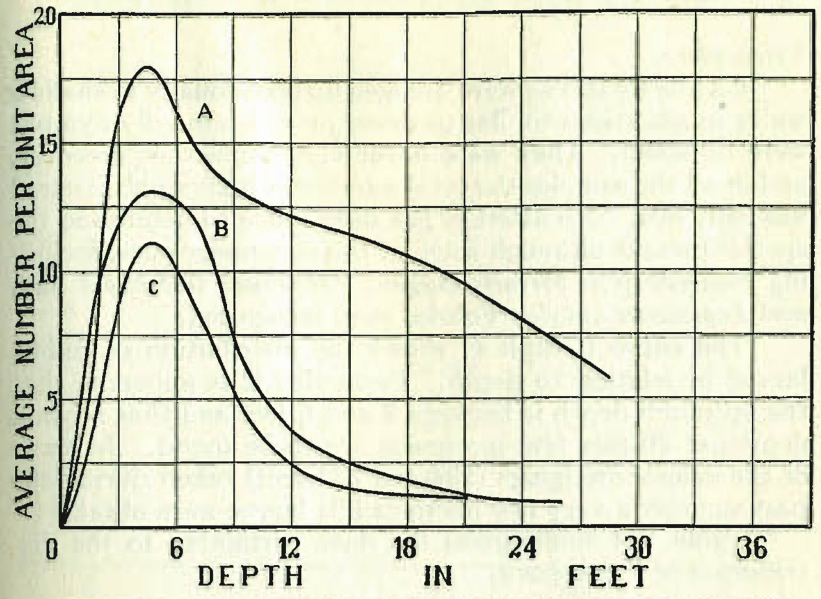
1. *Hexagenia bilineata* Say.
2. *Ephemera simulans* Walker.
3. *Caenis diminuta* Walker.
4. *Ephemerella* sp.
5. *Baetis* sp.
6. *Blasturus cupidus* Say.
7. *Ecdyurus maculipennis* Walsh.
8. *Tricorythus* sp.
9. *Centropilum* sp.

The first three species listed above were the most important, and the most abundant numerically, of the may-fly nymphs. Their distribution is shown by the curve (Graph 3) which is based on the data given below in Table VI. The optimum depth for all three species is between 0 and 9 feet, although the species *Hexagenia bilineata* is fairly abundant over the whole range of depths down to 30 feet.

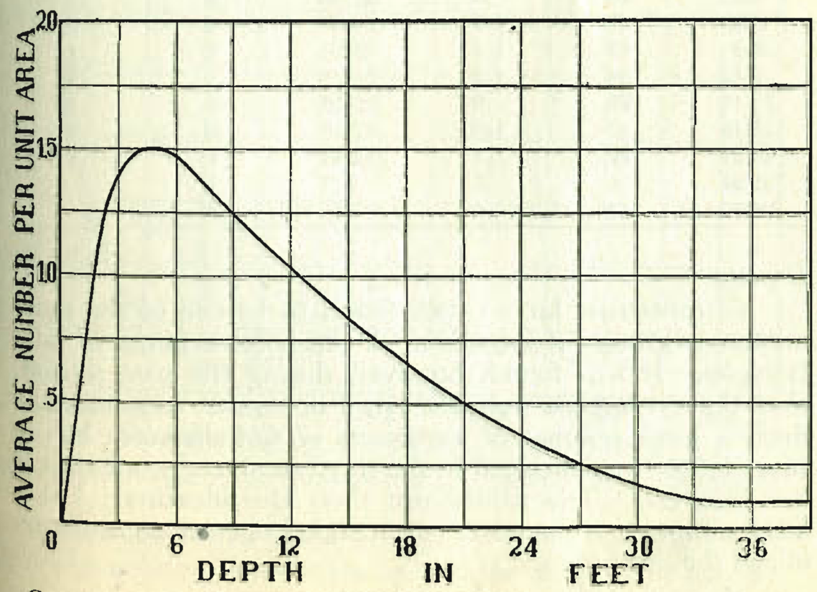
Of these three species which are most easily accessible as fish food, *Hexagenia bilineata* and *Ephemera simulans* are by far the most important. *Caenis diminuta*, although almost as common as *Ephemera simulans*, is relatively of little importance on account of its small size.

TABLE VI

	H. bilineata		*E. simulans*		*C. diminuta*		All species	
	Total	Av.	Total	Av.	Total	Av.	Total	Av.
0-3	20	.5	29	.7	12	.3	63	1.5
3-6	88	1.8	64	1.3	58	1.1	217	4.3
6-9	45	1.2	40	1.1	29	.8	114	3.0
9-12	36	1.2	7	.2	5	.2	49	1.6
12-15	43	1.3	11	.3	5	.2	59	1.8
15-18	38	1.3	8	.3	4	.1	50	1.7
18-21	30	.9	4	.1	7	.2	41	1.3
21-24	16	1.0	2	.1	2	.1	20	1.2
24-27	9	.7	2	.1	1	.1	14	1.1
27-30	8	.6	0				8	.6
30-33			1				1	
33-36	8						8	
36-39	1						1	



GRAPH 3—Curve illustrating distribution of Ephemerida according to depth.
A. Hexagenia bilineata. B. Ephemera simulans.
C. Caenis diminuta.



GRAPH 4—Curve illustrating distribution of Trichoptera according to depth.

Trichoptera.

Caddis-fly larvae were dredged up occasionally in shallow water in situations similar to those in which mayfly nymphs were obtained. They were never very numerous, however, and in all the samples the total number of individuals secured was only 308. No attempt has been made to determine the species present although some of the commoner ones, including *Heliocopsyche borealis* Hagen, *Phryganea interrupta* Say, and *Leptocerus ancylus* Vohries were recognized.

The curve (Graph 4) shows the distribution of caddis larvae in relation to depth. From this it is apparent that the optimum depth is between 3 and 6 feet and that beyond depths of 30 feet few specimens are to be found. In some of the deeper dredgings (234 and 321 feet) taken during the past summer a very few micro-caddis larvae were obtained.

Table VII summarizes the data pertaining to the distribution of *Trichoptera.*

TABLE VII

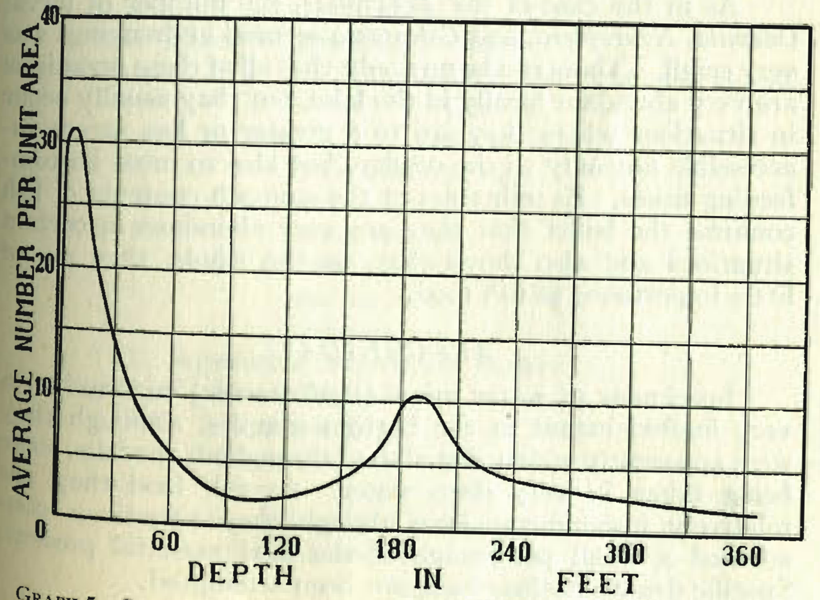
Depth	Total	Average	Depth	Total	Average
0-3	36	.9	27-30	4	.3
3-6	75	1.5	30-33	0	0
6-9	43	1.1	33-36	1	.1
9-12	38	1.2	36-39	1	.1
12-15	35	.9	39-42	1	.1
15-18	30	1.0	42-45	2	.3
18-21	22	.7	45-48	1	.1
21-24	4	.2	234	1	
24-27	12	.9	321	2	

Diptera.

Chironomidae larvae were found to be one of the most numerous groups of organisms of the bottom fauna of lake Nipigon. It was found, however, during the past season, that the *Amphipoda* were almost, if not quite, as numerous. Such a large number of specimens of *Chironomidae* larvae (over 9,000) was obtained in the three summers' work that it has been impossible to attempt their identification. Table VIII summarizes the results of dredging operations as determined for this group.

TABLE VIII

Depth	Total	Average	Depth	Total	Average
0-15	6,025	31.2	195-210	25	8.3
15-30	1,985	19.1	210-225	34	4.9
30-45	484	11.5	225-240	29	3.6
45-60	170	6.5	240-255	20	5.0
60-75	133	8.3	255-270	3	3.0
75-90	30	2.1	270-285	29	4.8
90-105	18	2.6	285-300	11	1.4
105-120	31	2.1	300-315	31	2.6
120-135	20	3.3	315-330	6	2.0
135-150	48	4.4	330-345	4	4.0
150-165	30	3.7	345-360	0	0
165-180	29	7.3	360-375	8	8
180-195	53	10.6			



GRAPH 5—Curve illustrating distribution of Chironomidae according to depth.

From the above graph it can be seen that this group occurs in greatest abundance in shallow water less than 30 feet deep. In this range of depth a total of 8,010 specimens was obtained out of 9,256 from all depths in the three years' work, averaging 702 per sq. yard. The largest number of individuals secured in a single dredging was 238, which represents a total of about 3,800 per sq. yard. This is quite exceptional, however, since the average from all dredgings is about 293 per sq. yard. In addition to the maximum in shallow water, there is a second one at a depth of about 180 feet. This is of interest in that it is probably due to the greater abundance of certain deep-water species.

The larvae of a few *Tabanidae* were brought up in some of the dredgings taken in small sheltered bays, but their numbers were so small as to render them almost negligible.

Odonata, Neuroptera, Coleoptera.

As in the case of the *Tabanidae*, the number of larval *Odonata*, *Neuroptera*, and *Coleoptera* secured in dredgings was very small. There can be no doubt that all of these organisms are very abundant locally in the lake, but they usually occur in situations where they are to a greater or less extent inaccessible not only to the dredge, but also to most bottom-feeding fishes. Examination of the stomach contents of fish confirms the belief that they are very abundant in certain situations and also shows that, on the whole, they are of little importance as fish food.

ARACHNIDA

Specimens of water mites (*Hydracarina*) occurred to a very limited extent in the bottom samples, although they were apparently widely distributed throughout the lake, some being taken in very deep water. As fish food they are relatively insignificant even though they sometimes constituted a small percentage of the food material present. Specific determinations have not been attempted.

MOLLUSCA

The *Mollusca* of Lake Nipigon constitute a very important group of bottom organisms and a large number of species has been obtained. These are mostly *Gastropoda* and the smaller *Pelecypoda* of the family *Sphaeriidae*. The larger clams are for some reason or other very scarce in the lake just as Muttkowski (1918) found them to be in Lake Mendota. For assistance in the identification of specimens the writer is greatly indebted to Dr. Bryant Walker and Dr. V. Sterki. The species obtained are as follows (Plates II, III, IV):

Gastropoda.

1. *Lymnaea apicina* Lea.
2. " *emarginata* Say.
3. " *galbana* Say.
4. " *stagnalis appressa* Say.
5. " *vahlii* Moll.
6. *Planorbis antrosus* Conrad.
   " " approaching var. *corrugatus* Currier.
   " " *striatus* Baker.
7. " *campanulatus* Say.
8. " *crista* Linn.
9. " *exacuous* Say.
10. " *hirsutus* Gould.
11. " *parvus* Say.
12. " *trivolvis* Say.
13. *Segmentina crassilabris* Walker.
14. *Physa ancillaria* Say.
15. " *gyrina* Say.
16. " sp.
17. " sp.
18. *Ferrissia parallela* Haldeman.
19. *Amnicola limosa* Say.
    " " *porata* Say.
20. " *pallida* Haldeman.
21. *Valvata sincera* Say.
22. " *tricarinata* Say.
    " " *perconfusa* Walker.

Pelecypoda.

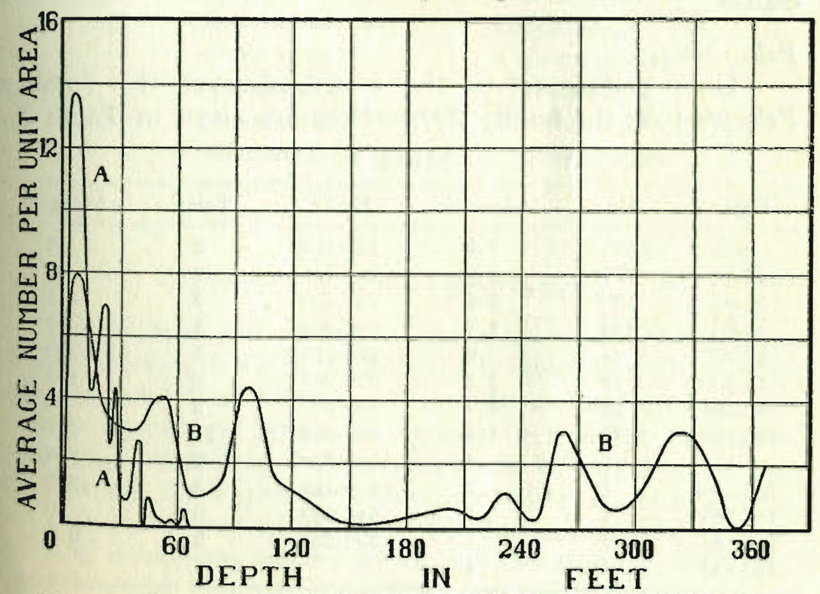
1. *Anodonta kennicotti* Lea.
2. " *marginata* Say.
3. *Lampsilis* (*Ligumia*) *superiorensis* Marsh.
4. *Pisidium compressum* Prime (subsp. *pellucidum*).
5. " *clavatum* Sterki.
6. " *fallax* Sterki (and var. *septentrionale*).
7. " *ferrugineum* Prime.
8. " *griseolum* Sterki.
9. " *idahoense* Roper.
10. " *indianense* Sterki.
11. " *medianium minutum* Sterki.
12. " *monas* Sterki.
13. " *pauperculum* Sterki (subsp. *nylanderi*).
14. " *punctatum* Sterki (form *simplex*).
15. " *rotundatum* Prime.
16. " *scutellatum* Sterki.
17. " " *cristatum* Sterki.
    " *splendidulum* Sterki.
18. " *variabile* Prime.
19. " *ventricosum* Prime.
20. " *vesiculare* Sterki.
21. " *vexum* Sterki.
22. " *walkeri* Sterki.
23. *Sphaerium crassum* Sterki.
24. " *acuminatum* Prime.
25. " *emarginatum* Prime.
26. " *tenue* Prime.
27. " *rhomboideum* Say.
28. " *vermontanum* Prime.
29. *Musculium rosaceum* Prime.
30. " *securis* Prime.
31. " *truncatum* Linsley.

In addition there are likely several other species among the smaller specimens of the genus *Pisidium*.

Data obtained from dredgings and collections show that the distribution of each of the various groups of *Mollusca* was quite characteristic. The larger clams were very scarce, and were entirely restricted to the shallower waters of quiet bays and channels. The *Gastropoda* ranged down to depths of about 30 feet and were most abundant at depths of 3-6 feet. The smaller *Pelecypoda*, on the other hand, were found even out in very deep water although the optimum depth for these was also in shallow water 3-6 feet deep.

Gastropoda.

The distribution of the various species of *Gastropoda* in Lake Nipigon has already been considered in greater detail in a previous paper (Adamstone, 1923) and hence the group will be considered as a whole. A summary of the data concerning distribution is given in the following table (IX) and the results are illustrated by Graph 6A.



GRAPH 6—Curve illustrating distribution of Mollusca according to depth.
A. Gastropoda. B. Pelecypoda (Sphaeriidae).

Study of the curve representing the distribution of the *Gastropoda* shows that the optimum depth is between 0 and 12 feet, with a gradual falling off in numbers down to a depth

TABLE IX

Depth	Total	Average	Depth	Total	Average
0-3	319	7.8	33-36	15	1.4
3-6	683	13.7	36-39	27	2.0
6-9	497	13.1	39-42	0	0
9-12	229	7.4	42-45	5	.8
12-15	139	4.2	45-48	3	.3
15-18	170	5.9	48-51	1	.2
18-21	213	6.9	51-54	1	.1
21-24	40	2.5	54-57	1	.2
24-27	56	4.3	57-60	0	0
27-30	13	.9	60-63	1	.5
30-33	6	.7			

of about 60 feet. A few specimens were found at greater depths.

Pelecypoda.

Data pertaining to the distribution of the smaller *Pelecypoda* of the family *Sphaeriidae* are given in Table X.

TABLE X

Depth	Total	Average	Depth	Total	Average
0-15	1,521	7.9	195-210	2	.6
15-30	377	3.6	210-225	2	.3
30-45	126	3.0	225-240	9	1.1
45-60	148	4.1	240-255	1	.2
60-75	14	.9	255-270	3	3.0
75-90	18	1.3	270-285	8	1.3
90-105	31	4.4	285-300	5	.6
105-120	21	1.4	300-315	21	1.7
120-135	5	.8	315-330	9	3.0
135-150	2	.2	330-345	2	2.0
150-165	1	.1	345-360	0	0
165-180	1	.2	360-375	2	2.0
180-195	2	.4			

The curve (Graph 6B) illustrative of the distribution of the *Pelecypoda* makes it evident that the greatest abundance of these organisms occurred in shallower water between 0 and 15 feet deep. Beyond a depth of 150 feet, the curve shows a second less pronounced maximum which may be due

to larger numbers of specimens of certain species, but the apparent increase is also influenced by the small number of dredgings.

Summary

Detailed study of the distribution of the bottom organisms of Lake Nipigon has shown that there are two distinct groups of animals, the one inhabiting largely the shallower water 0-30 feet deep, and the other forming the characteristic population of all areas more than 180 feet deep. The zone between these depths, that is, 30-180 is relatively unproductive.

Shallow Water Fauna	Deep Water Fauna
Mollusca	*Amphipoda*
Gastropoda	*Oligochaeta*
Pelecypoda	*Chironomidae*
Chironomidae	*Ostracoda*
Ephemerida	*Mollusca*
Trichoptera	*Pelecypoda*
Amphipoda	
Nematoda	

FACTORS LIMITING DISTRIBUTION

Throughout the preceding discussion of the distribution of the various bottom organisms, it has been frequently demonstrated that there is an orderly arrangement of the various species or groups of species in relation to depth. That this orderliness of distribution can be explained on the supposition that depth is the limiting factor, is not assumed, but it is considered rather that it is due to certain combinations of ecological factors which are themselves subject to variation with depth. The influence of depth in this respect will be considered more fully below. Amongst the environmental conditions which might affect distribution are the following: character of bottom, light, presence or absence of vegetation, protection from wave action, abundance of food, temperature and chemical content of the water.

Character of Bottom

The character of the bottom has a decided effect on the distribution of organisms. In the dredging operations four main types of bottom were found, namely: rock, sand, clay, and mud with various mixtures and intergradations of these. From a geological point of view these types of bottom all have a similar origin in that sand is crushed rock, clay a finely powdered sand, and mud (as it has been arbitrarily considered in this report) is also finely powdered sand, with the addition of organic débris. These materials when sorted and worked over by the waves are laid down to form the bottom of the lake. This process of sorting and deposition is closely related to depth, for, at times when the water is rough, particles of various degrees of coarseness are picked up and carried out some distance from shore into deeper water. As soon as a depth is reached such that the agitation of the water is insufficient to keep the particles in suspension they begin to settle out. The sand and coarser grains are dropped first because they are heaviest. Farther out in deeper water the clay is deposited and the mud is carried farthest from shore into the deepest water where it eventually settles out forming a soft layer of ooze having a large admixture of organic matter. The character of the bottom is, therefore, intimately connected with depth.

In dredging operations it was found repeatedly that the character of bottom influenced not only the kinds of organisms found in a given locality, but also the numbers which occurred there. A single example will suffice to illustrate this point. In the series of dredgings (Series VII, 1923) taken in the deep channel of Orient Bay, a shallower ledge at a depth of 150 feet was suddenly encountered, and at this point the bottom was composed of hard gray clay. There was an immediate drop not only in the number, but also in the variety of organisms secured, from an average of about 62 per dredging, which included, *Mollusca*, *Chironomidae*, *Amphipoda*, *Ostracoda*, *Oligochaeta* and *Nematoda*, to 2 specimens of *Chironomidae* larvae. Similar conditions were encountered in many other parts of the lake, and it can be safely stated, therefore, that clay and clean sand bottoms were relatively unproductive as compared with mud bottoms having a certain amount of organic matter. It is quite possible that the character of the bottom accounts also for the unproductive zone between 30 and 180 feet, since hard gray clay is the characteristic type of bottom in this area.

Light and Vegetation

The amount of light which penetrates the water decreases with depth, and hence organisms arrange themselves in zones according to whether they seek light or avoid it. In both cases depth is indirectly related to their distribution. Furthermore, the amount of light limits the abundance of phytoplankton and larger aquatic vegetation on account of the relation of light to the photosynthetic activities of plants. Because of this fact, certain organisms which are normally dependent on vegetation both for food and shelter are greatly restricted in regard to their distribution and abundance. On account of the scantiness of aquatic vegetation in Lake Nipigon this factor is regarded as being of little significance in so far as it influences distribution, but of very great importance in that it reduces to a minimum the numbers of such organisms as depend upon the growth of plants. This, of course, brings about a very great reduction in the productivity of the lake.

Protection from Wave Action

This feature of the environment has a decided effect on the distribution of organisms. Some of them require constantly circulating, well-aerated water and hence are found in shallow more exposed situations. This is well illustrated by some of the *Mollusca* which are equipped with heavy shells so that they can withstand moderate wave action and hence are found in great abundance along open rocky shores where they can retreat into the crevices of rocks when violent storms come up. The great majority of littoral forms, however, are to be found in the smaller well-protected bays and channels and in greatest abundance between depths of 3 and 6 feet, where the effect of wave action dies out. Deep-water organisms, such as amphipods, are doubtless undisturbed by storms on the surface.

Food

The food supply is perhaps the most effective factor in the restriction of distribution. In shallow water the greatest available supply of food is to be found in the small well-protected bays and channels. In these situations plankton organisms abound, and the quiet waters act as settling basins for the precipitation of the organic débris washed in by storms and currents. In deep water the amphipods and other organisms find an almost inexhaustible food supply in the soft flocculent surface ooze with its large mixture of organic matter and "dust fine detritus" (see Appendix, Table II). As a result the small bays and inlets are characterized by a dense population of bottom organisms which is in marked contrast, for example, to the sparse numbers which are found on open sandy beaches.

Temperature

Temperature as a limiting factor in distribution is apparently of very slight significance in Lake Nipigon, since the summer is of very short duration and the temperature of the water is at least as low as 4° C. for the greater part of the year. It is only in the smaller bays and channels that the water is warmed to any great extent during the summer. This short season of warmth may be necessary to some species and, therefore, depth again influences the situation indirectly on account of its relation to temperature.

Chemical Content of the Water

The chemical content of the water, that is, the amount of dissolved oxygen and carbon dioxide is of little importance in restricting distribution in Lake Nipigon, since there is

an abundance of oxygen at all depths during the whole year, and furthermore, the amount of dissolved carbon dioxide present is almost negligible (Clemens, 1923).

It seems reasonable to conclude that the chief ecological factors which tend to influence the distribution of the organisms constituting the bottom fauna of Lake Nipigon are: Character of bottom, protection from wave action, abundance of food, and possibly, light. All of these are to a very large extent controlled by, or correlated with, depth, and, since certain combinations of conditions reach the optimum for particular groups of organisms at various depths, it is possible to work out an orderly distribution of the bottom organisms in relation to depth.

CONSTANCY OF THE BOTTOM POPULATION

In view of the fact that the summer season is of such short duration in Lake Nipigon, it was thought that there might be a decided seasonal variation in the numbers of bottom organisms in a given habitat—especially one that was very productive—over a short period of time. In order to find out whether or not this was the case, two series of dredgings were taken weekly throughout the summer—one at a station located amongst the Virgin Islands and the other in "McL." Bay just west of the mouth of Orient Bay. Each dredging was taken from a different spot but all in very close proximity. The results are given in Table XI.

Considered with respect to any particular group of organisms, the results failed to substantiate this idea, for, with each there occurred a series of fluctuations to which no definite significance could be attached. However, from the total numbers of organisms secured in each dredging it would appear that the latter part of June and early July constitute the period of maximum abundance. Furthermore, it seems certain that the productivity of a given location remains practically constant throughout the whole season. This conclusion is confirmed by the uniformity of the bottom population in deep water as revealed by the work of the preceding summer.

TABLE XI

Weekly Dredgings Series — Depth 2½ feet — Station A—Virgin Islands; B—"McL." Bay

Date	June 17		June 23		June 30		July 7		July 14		July 29		Aug. 4		Aug. 12		Aug. 19	
Station	A	A2	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Mollusca.....	48	110	106	36	110	46	45	19	102	66	35	69	111	53	72	33	50	9
Chironomidae.	26	80	109	244	65	48	123	84	98	37	56	8	54	25	89	17	106	13
Ephemerida...	1	4	1	3	5		1		8		1		9		2		2	
Trichoptera...								2						1	1	3		1
Amphipoda...					1									1			5	
Cladocera.....									13				1					
Copepoda.....									2									
Ostracoda.....	2			1					4		1							1
Nematoda.....	1					1	1	1	4	1			1	1	11	1	6	
Oligochaeta....	3		7	24	11	12	6	7	20	14	10	1	4	5	18	16	18	6
Hirudinea....	2	4	2		3			1	1	3		2	1	2				
Hydracarina..	9	3	3	2	9		9			3			6	1	5		4	
Tabanidae....	2	2						1	1					1			2	1
Totals........	297		538		311		300		377		183		277		268		224	
Average......	148		269		155		150		188		91		138		134		112	

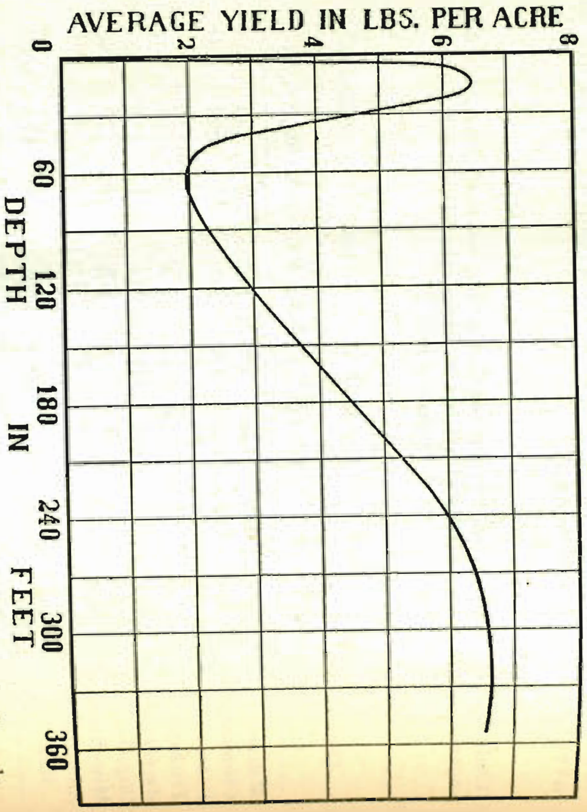
PRODUCTIVITY OF LAKE NIPIGON

In order to make the results of the study of the bottom fauna of Lake Nipigon more comparable with those obtained in other lakes which have been investigated in a similar manner, the data from all dredgings are summarized below in Tables XII-XIV, so as to show the average yield per unit area, both in weights and numbers, of the various food organisms. The weights are based on the dry weights of average-sized specimens.

TABLE XII, showing the average number of the six more important food organisms, per square yard and per square metre, throughout the whole lake for the summers 1921-23.

Organism	1921		1922		1923		1921-1923	
	Sq. Yd.	Sq. M.	Sq. Yd.	Sq. M.	Sq. Yd.	Sq. M.	Sq. Yd.	Sq. M.
Mollusca.......	138	165	159	190	169	202	149	178
Chironomidae...	253	303	403	482	218	261	293	351
Ephemerida.....	20	25	30	36	11	13	21	25
Trichoptera.....	8	10	15	18	6	7	10	12
Amphipoda.....	131	160	176	210	724	864	270	324
Oligochaeta......	51	63	74	88	112	134	73	87
Miscellaneous...	27	29	68	76	51	61	42	51
Animals of all Kinds.........	630	753	925	1100	1310	1568	875	1057

The general average results given in the final column of Table XIV are illustrated by Graph 7, which brings out very clearly the occurrence of a highly productive zone in shallow water, 0-30 feet, and another in the deeper waters of the lake, over 180 feet deep. Between these depths there is a region which is relatively unproductive.



GRAPH 7—Curve showing the Average Yield of Food Organisms, in Pounds per Acre, at various depths throughout the lake.

TABLE XIII, showing the average number of each of the six more important food organisms, as well as the general average, per unit area of the bottom, at 30 foot intervals of depth.

Depth	*Mollusca*		*Chironomidae*		*Ephemerida*		*Trichoptera*		*Amphipoda*		*Oligochaeta*		General Average	
	Sq. Yd.	Sq. M.	Sq. Yd.	Sq. M.	Sq. Yd.	Sq. M.	Sq. Yd.	Sq. M.	Sq. Yd.	Sq. M.	Sq. Yd.	Sq. M.	Sq. Yd.	Sq. M.
0-30	229	274	432	517	33	40	16	19	99	118	72	86	930	1112
30-60	69	82	153	183	2.(4)	2.(8)	1.(4)	1.(7)	187	224	30	36	474	566
60-90	17	20	86	103					336	402	16	19	477	570
90-120	38	45	35	42					762	912	40	48	854	1020
120-150	66	7.9	64	77					752	898	54	65	882	1052
150-180	2.6	3.2	78	93					604	723	61	73	775	925
180-210	8	9.6	155	186					609	730	40	48	827	988
210-240	11.7	14	67	80					1141	1365	118	141	1434	1712
240-270	12.8	15.3	74	89					1039	1242	150	180	1344	1606
270-300	16	19.2	50	60					718	848	239	286	1245	1488
300-330	30	36	37	44					974	1162	232	278	1286	1537
330-360	32	38	64	77					1218	1452	240	287	1554	1854
360-390	32	38	128	153					336	402	112	134	608	727
0-390	149	178	293	351	21	25	10	12	270	324	73	87	875	1057

TABLE XIV, showing the average stocks of food organisms in pounds per acre and kilograms per hectare at 30-foot intervals of depth

Depth	*Mollusca*		*Chironomidae*		*Ephemerida*		*Trichoptera*		*Amphipoda*		*Oligochaeta*		Animals of all Kinds	
	Lbs.	Kgm.	Lbs.	Kgm.	Lbs.	Kgm.	Lbs.	Kgm.	Lbs.	Kgm.	Lbs.	Kgm.	Lbs.	Kgm.
0-30	3.99	4.45	.53	.59	.89	1.0	.09	.11	.49	.55	.44	.5	6.43	7.20
30-60	.65	.71	.19	.21	.06	.07	.008	.01	.94	1.05	.19	.21	2.03	2.26
60-90	.078	.088	.11	.12					1.67	1.89	.10	.11	1.96	2.21
90-120	.173	.19	.042	.048					3.82	4.28	.25	.27	4.29	4.79
120-150	.03	.034	.078	.087					3.77	4.23	.33	.37	4.21	4.72
150-180	.012	.014	.095	.11					3.03	3.41	.38	.42	3.52	3.95
180-210	.037	.041	.19	.21					3.06	3.44	.25	.28	3.54	3.97
210-240	.054	.060	.082	.091					5.73	6.43	.73	.81	6.60	7.39
240-270	.059	.066	.090	.10					5.22	5.84	.92	1.03	6.30	7.04
270-300	.073	.082	.061	.068					3.61	3.99	1.47	1.65	5.21	5.79
300-330	.14	.15	.045	.051					4.88	5.47	1.43	1.60	6.49	7.27
330-360	.15	.16	.078	.087					6.12	6.83	1.48	1.66	7.83	8.74
360-390	.15	.16	.16	.18					1.67	1.89	.69	.77	2.67	3.00
0-390	2.45	2.74	.36	.40	.56	.62	.058	.065	1.35	1.52	.45	.50	5.23	5.93

The average dry weights, in milligrams per individual, upon which the above table is based are as follows: *Gastropoda* 2.58; *Pelecypoda* .43; *Chironomidae* .114; *Ephemerida* 2.53; *Trichoptera* .554; *Amphipoda* .471; *Oligochaeta* .577.

VALUE OF THE BOTTOM ORGANISMS AS FISH FOOD

Examination of the stomach contents of various species of fish establishes the fact that the organisms constituting the bottom fauna of the lake are of enormous economic importance as food for fish. Some species, for example, the sturgeon, feed almost exclusively upon them, and in other cases they form a very high percentage of the food materials present. In Lake Nipigon the number of species of commercially valuable fish is very small, for J. R. Dymond, who investigated this phase of the problem, found a total of only 35 species and of these only 5 are marketed in any quantity. The stomach contents of specimens of the more important of these have been very thoroughly studied by various members of the staff of the Ontario Fisheries Research Laboratory, but, since the results of this work are to be incorporated in another paper, it is proposed to give here merely a summary of the conclusions arrived at concerning the value of the bottom organisms as fish food.

Sturgeon (*Acipenser rubicundus* Le Sueur)

An exhaustive study of the food and rate of growth of the sturgeon in Lake Nipigon has recently appeared in the publications of the Ontario Fisheries Research Laboratory (Harkness, 1924). It is shown, therein, that the chief food of the sturgeon consists of bottom organisms including, in greatest proportion, those which are most abundant in shallow water, namely, *Chironomidae*, *Mollusca*, and *Ephemerida*. Other bottom organisms, such as the crayfish, which are particularly plentiful in certain localities are also of considerable importance.

Common Whitefish (*Coregonus clupeaformis* (Mitchill))

The common whitefish is the most abundant and, from a commercial point of view, the most valuable fish in Lake Nipigon. For the past six years, 1918-1923, the value of the annual catch has averaged $115,000 and the quantity of fish taken out of the lake 1,146,904 pounds per year. However, there has been a gradual decline in the annual catch since 1919 in spite of the increase of fishing equipment on the lake (Reports of the Dept. of Game and Fisheries of Ontario, 1918-1923). During the regular fishing season many tons of whitefish are caught and shipped out each week. It is evident, therefore, that the fishing industry of Lake Nipigon depends to a very great extent upon the common whitefish. In view of this fact the food of this fish is very important.

The stomach contents of 212 specimens have been examined and these show that this species is essentially a bottom feeder. When taken in deep water, where it usually lives at depths of about 120-180 feet, its stomach contents were composed largely of *Amphipoda* of the species *Pontoporeia hoyi*, but occasionally *Mysis relicta* or *Ostracoda* formed the bulk of the food material present. At times, the whitefish apparently wanders into shallower waters to feed, and on some occasions, especially in the early morning, large schools could be seen swimming about in the waters of quiet bays and inlets. At such times the whitefish apparently subsists on the bottom organisms characteristic of shallow water including *Mollusca*, *Chironomidae*, and *Ephemerida* nymphs. These frequently constituted over 90% of the stomach contents. This shows that the bottom fauna is of the utmost importance in maintaining the whitefish of the lake, and from the following list some idea can be gained of the diversity of bottom organisms found in the food of the whitefish.

Mollusca:
- *Valvata sincera.*
- " *tricarinata.*
- *Amnicola pallida.*
- " *limosa.*
- " " *porata.*

(Twenty-one other species of *Mollusca*, most of which, except smaller species of *Sphaeriidae*, are comparatively insignificant in whitefish food.)

Amphipoda:
- *Pontoporeia hoyi.*

Mysis relicta.
Ostracoda.
Copepoda.
Cladocera.
Hydracarina.
Fish Eggs.
Algae and Plant materials.

Ephemerida:
- *Ephemera simulans.*
- *Hexagenia bilineata.*

Chironomidae.
Trichoptera.
Other insects (adults and larvae).

Round Whitefish (*Coregonus quadrilateralis* Richardson)

The round whitefish, while fairly abundant in Lake Nipigon, is of no commercial importance, since it does not reach a size large enough to be taken in the 4½ inch gill net. Like the common whitefish it feeds to a large extent upon bottom organisms, but the kinds of animals occurring most frequently in its food are entirely different. A total of 56 specimens of the food of this fish were examined, and in these *Trichoptera* were found to be the favourite diet. The extent of the food list given below is very small, and this is quite likely due to the fact that the round whitefish inhabits a different stratum in the lake to that occupied by the common whitefish, and the food organisms available are, therefore, somewhat different.

Trichoptera (very high percentage).
Chironomidae.
Mollusca (8 species).
Ephemerida.

Common Sucker (*Catostomus commersonnii* (Lacépède))

The common sucker is of no commercial value in Lake Nipigon, but it is of very great economic importance in that it represents a serious competitor to the valuable whitefish and sturgeon. It is exclusively a bottom feeder, as was shown by the examination of 60 stomachs, and feeds to a very large extent upon *Mollusca*, *Chironomidae*, *Ephemerida*, and most of the other bottom organisms characteristic of shallow water. There are enormous numbers of common suckers in the lake and the extent of their food list gives some idea of their depredations.

Mollusca (18 species).

Ephemerida:
Caenis diminuta.
Ephemera simulans.
Hexagenia bilineata.

Chironomidae.

Trichoptera.

Other *Insecta.*
Amphipoda:
Pontoporeia hoyi.
Hyalella knickerbockeri.

Cladocera (several species).

Northern Sucker (*Catostomus catostomus* (Forster))

The contrast between the food of the common whitefish and round whitefish is closely parallelled by that between the common sucker and northern sucker and is also due to the different habitat of the latter species. The northern sucker is not nearly as abundant as the common sucker, but it also consumes food material, valuable to the whitefish. A total of 39 stomachs were examined and in these *Amphipoda,* mostly *Pontoporeia hoyi,* formed a very large part of the food of the fish together with a filamentous *Alga* and *Chironomidae.* Other bottom organisms were eaten only to a very limited extent. The forms identified include:

Amphipoda:
Pontoporeia hoyi.
Chironomidae.
Mollusca (11 species).
Algae.

Nematoda.
Ostracoda.
Cladocera.
Trichoptera.
Hydracarina.

Ciscoes (*Leucichthys* sp.)

There are apparently six species of ciscoes in Lake Nipigon, but, as these can only be distinguished with considerable difficulty, the stomach contents of all will be considered together. In 47 specimens examined it was evident that the ciscoes depend almost entirely upon the free-swimming plankton organisms of the lake for food materials. On a few rare occasions, and more especially in the case of younger fish, bottom organisms were eaten to the extent of 100%. More frequently their inclusion was accidental. The following organisms were identified:

Mysidacea:
Mysis relicta.
Amphipoda:
Pontoporeia hoyi.
Copepoda
Cladocera.
Ostracoda.

Chironomidae.
Mollusca.
Ephemerida:
Ephemera simulans.
Hexagenia bilineata.
Hydracarina.

Red Horse (*Moxostoma aureolum* (Le Sueur))

Like other members of the sucker family this fish is commercially valueless, but it does not occur in very great abundance in Lake Nipigon. Examination of the contents of the stomachs of four individuals shows that the species feeds extensively upon bottom organisms which are of greatest value to the whitefish and sturgeon. In the stomachs examined, mayfly nymphs were most numerous, and the organisms identified were as follows:

Chironomidae.
Tabanidae.
Mollusca:
Valvata sincera.

Ephemerida:
Hexagenia bilineata.
Ephemera simulans.

Pike Perch (*Stizostedion vitreum* (Mitchill))

Twelve stomachs were examined and these, in most cases, contained the remains of fish. Bottom organisms were sometimes eaten, and of these mayfly nymphs seemed to be the favourite. Several other kinds were occasionally present as the following list shows:

Ephemerida:
Hexagenia bilineata.
Trichoptera.
Odonata:
Aeshna umbrosa.

Fish—Unidentified.

Sauger (*Stizostedion canadense* (Smith))

The sauger seems to be confined largely to the northern end of the lake, and during a trip to that part a large number were caught. The stomachs of twelve of these, which were full, were examined. In these mayfly nymphs seemed to be the chief food, but this may have been due to the fact that emerging subimagos were unusually plentiful at that particular time. Small fish, which generally constitute the bulk of the food of the sauger, were also present in small numbers. The chief constituents of the stomachs examined were:

Ephemerida: *Trichoptera.*

Hexagenia bilineata.

Remains of small fish. Eggs.

Yellow Perch (*Perca flavescens* (Mitchill)).

The yellow perch is of very little importance in Lake Nipigon, and, although it is found in most parts of the lake, the larger specimens are confined to the northern end. The organisms identified in four stomachs were:

Ephemerida:

Hexagenia bilineata.

Decapoda:

Cambarus virilis.

The remaining species of the larger fish of the lake are not competitors of the whitefish and sturgeon. The lake trout (*Cristivomer namaycush* (Walbaum)) and the pike (*Esox lucius* Linn.) are piscivorous, while the black bass (*Micropterus dolomieu* (Lacépède)) and speckled trout (*Salvelinus fontinalis* (Mitchill)) are largely insectivorous. The smaller species, including the darters, minnows, sticklebacks, etc., feed to a very large extent upon minute plankton organisms which are abundant in shallow water.

From the study of the foods of the various species of fish taken in Lake Nipigon it is evident that the bottom fauna of the lake plays a very important part in the maintenance of the fishing industry of the lake. The common whitefish is almost entirely dependent upon this source of food, and the sturgeon, which is also of considerable commercial value, is likewise totally reliant upon it. Of the other species of fish inhabiting the lake, some, such as the pike perch (pickerel), are of economic importance, and hence

their occasional foraging amongst the bottom fauna is not objectionable; but, in the case of the suckers, it is scarcely possible to see any result other than the destruction of valuable whitefish food by a useless and particularly gluttonous competitor.

The examination of the stomach contents of the various species of fish shows that the bottom organisms which are of greatest value as fish food are: *Mollusca*, *Chironomidae*, *Ephemerida*, *Amphipoda*, *Oligochaeta*, and *Trichoptera*. The *Oligochaeta* must be considered of very great importance because of their abundance on the lake bottom and because of the frequency with which they were present in fish stomachs, although usually recognizable only through the presence of podal spines.

FOOD OF THE BOTTOM ORGANISMS

Because of the enormous value of the organisms of the bottom fauna as fish food, it becomes a matter of considerable importance to know what constitutes the food of these organisms, and thus to further complete the food cycle. With this object in view, the food material was dissected out of the alimentary tracts of a number of specimens, and this was examined under the microscope. The specimens had been killed as soon as caught in order that the material in the alimentary tract might remain unchanged. The results obtained are indicated below.

Mollusca. The larger *Mollusca* which inhabit shallow water near shore feed on materials rasped off the surface of aquatic plants or on *Algae* and other matter scraped off the rocks. The smaller species, such as the *Amnicolas* and *Valvatas*, which live in deeper water and occur most frequently in fish stomachs were found to have eaten ooze. This ooze, when examined under the miscroscope, consisted of minute grains of mineral substances with a large admixture of particles of organic matter. Occasionally a few diatoms or pollen grains were present in it.

Chironomidae. The food of the chironomid larvae was found to consist mainly of ooze containing a plentiful amount of organic debris. Some of the stomachs were largely filled with diatoms, including species of *Epithemia*, *Stauroneis* and *Navicula*, and occasionally a smaller chironomid larva had been consumed.

Ephemerida. In the case of the mayfly nymphs the alimentary tracts were also mostly full of ooze. In it pollen grains, diatoms, desmids, and protozoan cases were present in relatively insignificant proportions.

Trichoptera. Ooze with a large proportion of organic detritus formed the food of most *Trichoptera*. A few contained large numbers of diatoms, including species of *Amphora*, *Cocconeis*, *Epithemia*, *Fragillaria*, *Gomphonema*, *Navicula*, *Melosira*, and *Tabellaria*. In a few instances the loricae of rotifers were found as well as protozoan cases and filaments of *Algae*.

Amphipoda. In every specimen examined ooze formed the bulk of the material present. In some cases a few pollen grains and the valves of diatoms were recognized.

Oligochaeta. The food of the *Oligochaeta* examined consisted almost entirely of ooze containing unrecognizable fragments of organic matter. In rare cases diatoms or fragments of their valves were distinguished.

The results of this study show that the food of the bottom organisms which are of most importance as fish food consists largely of ooze and microscopic organisms which have settled to the bottom. The ooze is apparently eaten for the organic detritus which it contains, and chemical analysis of the bottom deposits of deep water shows that there is an abundance of organic matter available in it (see Appendix I—chemical analyses of Lake Ontario bottom samples). The presence of diatoms and other recognizable materials in the food of bottom organisms appears to be largely accidental except in the case of *Chironomidae* larvae and *Trichoptera*. These animals apparently exercise a certain amount of discrimination in selecting their food. It may be possible, also, that the ooze is eaten, not only for the detritus which it contains, but also for bacteria which are present in

it. The detritus in the ooze is very probably composed of disintegrated plant remains and settled limnetic plankton.

In order to determine whether the waters of the open lake contained organic matter similar to the detritus found in the ooze, an examination was made of a number of samples of plankton representing vertical hauls from various strata in the lake. At all depths the results showed an abundance of material, which was apparently identical with the detritus. It seems safe to conclude, therefore, that the organic content of the bottom ooze consists of small particles of disintegrated phyto- and zoo-planktonts which slowly settle out from suspension in the water. In short, this material is simply the "dust fine detritus" which was considered of such very great importance by Petersen (see Baker, 1916, 1918).

COMPARISONS

Very little work has as yet been done in the matter of quantitative studies of the bottom fauna of North American lakes. A large number of qualitative studies have been carried out, however, and some of these are highly valuable although in most cases they are confined to the study of one particular group of organisms.

One of the first systematic attempts at the quantitative study of a body of fresh water was made by Richardson (1919, 1921) on the Illinois River and its connecting lakes. Before these results were published, however, Baker (1916-1918) had completed a study in the shallower waters of Oneida Lake in New York State. Shortly after this Muttkowski (1918) carried out a quantitative study in the littoral areas of Lake Mendota. This work was later extended by Juday (1922) so as to include the deeper waters of the lake. Another investigation has recently been carried out by Juday (1924) on the bottom fauna of Green Lake in Wisconsin. Other than the work outlined above, very little has been done except that, from time to time, various investigators have presented the results of small numbers of dredgings, which they have been enabled to secure, even though the amount of data obtained was insufficient to make the work of much practical value.

It is a difficult matter to make comparisons concerning the results of work of this nature, because, apart from the fact that the studies so far completed have been carried out in bodies of water where conditions are essentially different in almost every respect, the investigator has approached his problem from an entirely different aspect, in nearly every case, and, as a consequence, the interpretation of results varies accordingly. Such results as are available will be briefly considered in comparison with those obtained in Lake Nipigon and are summarized later in Table XV.

Illinois River and its Connecting Lakes (Forbes and Richardson 1919, Richardson 1921)

The Illinois River and its connecting lakes have been very thoroughly studied by Forbes and Richardson and their findings are presented in several comprehensive reports. Conditions such as are found in a river system are very different to those which exist in a lake due to the fact that the waters of the river are continually moving, but the back-waters and connecting lakes present some conditions very similar to those of other lakes. In addition to this the environments presented by the Illinois River system had begun to undergo an entire change, even before Richardson began his work, due to the pollution of the river by sewage emptied into it from the Chicago drainage canal.

In the course of the earlier investigations Richardson found that the upper reaches of the river were by far the most productive of bottom organisms and that quiet eddies and along-shore vegetation supported the largest fauna. Comparing the connecting lakes with the river proper it was found that the yield per unit area of lake bottom was practically the same as that for the river. In all these investigations *Mollusca* were found to constitute by far the largest part of the fauna. In the upper reaches of the river over ninety per cent. of the bottom population consisted of *Mollusca*, but downstream, where mayfly nymphs were more numerous,

the proportion of *Mollusca* decreased slightly. The connecting lakes showed a greater abundance of insects and crustacea and in them there were large weedy areas producing a great abundance of organisms.

By way of comparison some of the smaller lakes of north-eastern Illinois were also studied, and their productivity was found to be considerably lower than that of the river system. In these the proportion of *Mollusca* was quite low, and in weedy areas *Hyalella knickerbockeri* was very abundant. Lake Nipigon presents conditions very different to those encountered in the Illinois River system. There is almost, if not quite, as great a variety of organisms in Lake Nipigon, but there is not such an enormous excess of *Mollusca*. Furthermore there were no large areas covered with aquatic vegetation where organisms are so numerous as Richardson found them to be. This helps to decrease the yield of Lake Nipigon and is doubtless one reason why the productivity of Lake Nipigon is so very much lower than other bodies of water which have been studied.

Since the completion of the earlier quantitative studies further researches have been conducted in the river system in order to determine the effect of the sewage pollution on the bottom fauna (Richardson, Dec., 1921). The results showed a remarkable decrease in the food stocks of the river in the five-year period, 1915 to 1920, and the practical extermination of some of the characteristic bottom organisms which are highly valuable as fish food. In their place, a bottom fauna composed of forms highly tolerant of polluted conditions established itself.

Oneida Lake (Baker, 1916, 1918)

In contrast to Lake Nipigon, Oneida Lake in New York State is a small shallow body of water. It covers an area of approximately 80 square miles, its greatest length being 21 miles and maximum width 5.5 miles. The greatest depth recorded is 55 feet. In view of the last fact it is quite likely that the temperature of the water rises considerably in summer and that there is a period during which anaerobic conditions prevail in the deeper waters of the lake. No temperature records or oxygen determinations are available to establish this point, but, in view of the conditions obtaining in other similar bodies of water, it is quite likely to be the case. In addition to these differences there is apparently an enormous development of vegetation in large areas. The environmental conditions are, therefore, different from those found in Lake Nipigon in almost every respect.

In the shallow water in which the dredgings were carried on (less than 18 feet) there was a large and varied bottom fauna characterized by an abundance of *Mollusca* which made up over 50% of the organisms present. The larger clams were found to be quite plentiful and *Chironomidae* larvae and the amphipod *Hyalella knickerbockeri* were fairly numerous. In Lake Nipigon the molluscan fauna is not so prominent a part of the bottom population of shallow water, and other organisms, chiefly *Chironomidae* larvae and *Amphipoda*, are very numerous.

Lake Mendota (Muttkowski, 1918; Juday, 1922)

Studies on the bottom fauna of Lake Mendota were carried out in the shallower parts of the lake by Muttkowski, and his work was later extended by Juday, so as to include the deeper areas. Just as in the case of Oneida Lake, it is rather difficult to compare Lake Mendota with Lake Nipigon on account of the enormous differences between them in physical features. Lake Mendota is much smaller in size covering an area of only 15.2 square miles in contrast to 1,769 square miles (1,530 square miles water surface) in Lake Nipigon. Its maximum depth is 25.6 metres (84 feet) as compared with 402 feet recorded by MacInnis (1894) for Lake Nipigon. The limnological conditions prevailing in the two lakes are quite different. In Lake Mendota the water becomes very warm during the summer, and there is an annual period during which anaerobic conditions prevail in the deeper waters (Birge and Juday, 1911). In Lake Nipigon, on the other hand, the water is very cold during the greater part of the year, and there is a plentiful supply of oxygen

at all times even in the deepest waters (Clemens, 1923). Lake Mendota has large areas which are thickly covered with plant growth just as has Oneida Lake, but in Lake Nipigon there is practically an entire absence of aquatic vegetation. Furthermore, on account of its size, Lake Nipigon experiences storms of considerable violence, but it is very unlikely that in Lake Mendota such disturbances are very severe. It would appear, therefore, that from the standpoint of environments and physical features Lake Mendota is much more comparable to Oneida Lake than to Lake Nipigon.

Muttkowski's work in the shallower areas (0-7 metres) showed that Lake Mendota had a large and widely diversified bottom fauna which in many respects is quite unlike that of Lake Nipigon. The species of animals typical of each lake are quite different. For example, in regard to the mayfly nymphs, the species *C. diminuta* was found to be very abundant in Lake Mendota, and of very great value as fish food, whereas in Lake Nipigon it was found that *Hexagenia bilineata* was predominant. *Ephemera simulans* was about equal in numerical abundance to *C. diminuta*, but much more prominent on account of its large size. Among *Crustacea*, the Amphipod *Hyalella azetica* was most abundant in Lake Mendota but in Lake Nipigon its relative *H. knickerbockeri* was quite insignificant in comparison with *Pontoporeia hoyi*. Small *Oligochaeta* were found to be the most numerous of the bottom organisms, followed by *Chironomidae, Mollusca, Crustacea*, and *Trichoptera* in order of importance. In Lake Nipigon the various groups of organisms take a different ranking in order of numerical abundance, as follows: *Chironomidae, Mollusca, Crustacea, Oligochaeta, Ephemerida*, and *Trichoptera*. Muttkowski makes several references to regular seasonal successions of species and periods when certain organisms are almost entirely absent from the bottom fauna due to the emergence of adult forms. A similar fluctuation is scarcely noticeable in Lake Nipigon, although there is a period, as was pointed out in connection with the seasonal dredgings, during late June and early July, when the shallow water dredgings yield a larger number of organisms. This may possibly be a consequence of a shoreward migration at the time of emergence, such as Muttkowski notices, but this is exceedingly doubtful.

In the deeper waters of the lake Juday found an abundant bottom fauna composed of *Corethra* larvae, *Oligochaeta*, *Chironomus*, *Protenthes*, and *Pisidium* (arranged in order of numerical abundance). In Lake Nipigon the amphipod *Pontoporeia hoyi* and several species of *Oligochaeta* made up the bulk of the deep-water fauna. There is a very striking contrast noticeable here, in the fact that, while Juday found enormous numbers of *Corethra* larvae (maximum 33,800 per sq. metre, average 3,460), not a single specimen was taken from the bottom of Lake Nipigon, and specimens were but rarely obtained in plankton collections. The same thing is true of many other organisms which are abundant in other lakes and are almost entirely lacking in Lake Nipigon.

Green Lake (Juday, 1924)

Although Green Lake is of comparatively small size it is much deeper than the other lakes studied, reaching a maximum of 193 feet. The results of Dr. Juday's work in Green Lake have only recently been published, and a short summary is included here.

In Green Lake shallow water (0-1 metre) was found to be the least productive part of the lake, but in it the greatest variety of organisms was found. As deeper water was reached the productivity steadily increased to a maximum between 20-40 metres. Beyond this depth there was a slight decrease. The characteristic organisms on the bottom of the deepest parts of the lake were *Pontoporeia* and *Oligochaeta*; and in the 20 and 40 metre zone, *Pontoporeia*, *Chironomus*, and *Tanytarsus* were the chief organisms present. In these results there is some similarity to those obtained for Lake Nipigon, but the size of this lake precludes any satisfactory comparison.

Lake Ontario

Some of the larger lakes, such as the Great Lakes, seem to the writer to be much more nearly comparable to Lake

Nipigon than any which have up till the present been studied, not only in regard to size, but in physical conditions as well. No published quantitative studies are available, but in the autumn of 1922 the writer was able to secure a series of dredgings across Lake Ontario opposite Toronto in co-operation with the Hydro-Electric Power Commission of Ontario. The results of this work (Appendix) are interesting in several respects, notably in the great depth, lack of vegetation, and general similarity of physical conditions to those of Lake Nipigon, as well as in the variety of organisms in shallow water and in the abundance of *Amphipoda* and *Oligochaeta* in deeper water such as was found in Lake Nipigon. It is quite likely, moreover, in view of the general similarity of conditions, that the productivity of Lake Ontario is relatively low just as was found to be the case in Lake Nipigon.

Summary of Comparative Data

TABLE XV, showing the average stocks of food organisms in pounds per acre and kilograms per hectare in various bodies of water.

Lake	Zone (metres)	Pounds per acre	Kilograms per Hectare
Illinois River		261	293
Connecting lakes of Illinois River		255	286
Lakes N.E. Illinois		82.8	92.6
*Oneida		245	275
*Mendota	0-1	60	67.3
* "	1-3	64	71.8
"	8-20	42.9	48.2
Green Lake	0-1	7.75	8.7
" "	1-10	14.2	15.9
" "	10-20	26.6	29.9
" "	20-40	29.9	33.5
" "	40-66	27.6	30.9

*The figures given are Richardson's (1921) estimate.

This table should be compared with the results for Lake Nipigon given in Table XIV.

The comparative results presented in Tables XIV and XV show that the productivity of the bottom fauna of Lake Nipigon is very small in contrast to that of other bodies of water which have been similarly studied. At first sight this seems rather surprising in view of the enormous value of its fisheries, yet, after more careful consideration, the results seem reasonable enough, and quite consistent, especially when the conditions prevailing in the various lakes are taken into account. There may be a slight underestimation of the productivity due to the omission of the larger clams and crayfish, for example, but this is not very serious in view of the general scarcity of the former and the extreme localization of the latter. Furthermore, this affects only the shallow water 0-30 feet deep, and has no influence on the enormous areas of deeper water. Several factors contribute towards an explanation of the seeming deficiency in the productivity of the bottom fauna.

As pointed out above, the physical conditions obtaining in Lake Nipigon are such as to make comparison with the smaller bodies of water already studied very difficult. There is a great difference in climate due to the geographical position of the various lakes, and there is also an enormous difference in size. Conditions in the other lakes, which are warm in summer and are small tranquil bodies of water, make for a greater concentration of organisms. Lake Nipigon is not only much colder, but is also larger and deeper, and at times experiences violent storms. These latter produce long stretches of barren rocky or sandy shore where bottom organisms are few and where aquatic vegetation is absolutely unable to gain a foothold. It is only in the small sheltered bays that conditions prevail which are in any way comparable to those generally existing in the smaller lakes. In similar situations in Lake Nipigon the productivity is very high, but it does not seem probable that such a high yield would occur in the open waters of a lake.

In a former publication (Adamstone, 1923) attention was drawn to the fact that Lake Nipigon was to be considered a young, primitive lake in contrast to the lakes studied in the United States which were regarded as examples of more highly evolved lakes as defined by Pearsall (1921). On this basis of classification, Lake Nipigon would not be as productive as the other lakes. However, this difference can not be regarded as due to age, since these lakes are nearly all products of the Ice Age, but rather to differences in the geological formations in which they occur—the smaller lakes being situated in sedimentary areas, whereas Lake Nipigon is in an Archaean region.

It must also be remembered that there is a continual turnover in the bottom population throughout the year, so that dredgings taken early in spring yield about the same average number of individuals per unit area as samples taken at any other time during the summer. In view of this fact the yield of 5.2 pounds per acre, which is the general average obtained, may be looked upon as representing the standard of productivity of Lake Nipigon at all times.

CONCLUSIONS

I. The results of the dredging operations carried out in Lake Nipigon have shown that the lake supports a large and varied population of bottom organisms, although in contrast to the smaller lakes of the northern United States which have been similarly studied, the bottom is relatively unproductive. It is probable, nevertheless, that the small yield of food organisms from the bottom of Lake Nipigon is quite typical of large lakes in contrast to a greater yield from smaller ones.

II. The actual yield of dry organic matter from the bottom organisms was found to be 5.2 pounds per acre or 5.9 kilograms per hectare.

III. The bottom fauna forms two natural groups of organisms, one of which, containing the greater variety of organisms, is to be found in the shallow littoral areas (0-30 feet deep), while the other is characteristic of deep waters (180 feet and over). Between these depths (30-180) there is a relatively unproductive area.

IV. The organisms characteristic of these zones are:

Shallow water (0-30 feet)	Deep water (180 feet and over)
1. *Insect Larvae.*	1. *Amphipoda:*
Chironomidae.	*Pontoporeia hoyi.*
Ephemerida	2. *Oligochaeta.*
Trichoptera.	3. *Insect Larvae:*
2. *Mollusca.*	*Chironomidae.*
Gastropoda.	4. *Mollusca:*
Pelecypoda.	*Pelecypoda.*
3. *Amphipoda:*	
Hyalella knickerbockeri.	
4. *Oligochaeta.*	
5. Miscellaneous:	
Insect Larvae (other than 1).	
Crustacea (Cladocera).	
Arachnida.	
Hirudinea.	

V. The examination of the stomach contents of various species of fish has shown that the bottom fauna constitutes a highly valuable food resource, which is drawn upon extensively by the whitefish and sturgeon. As a result of this the maintenance of the fishing industry of Lake Nipigon depends to a very great extent upon this source of food in the lake.

VI. The organic detritus, which forms a large part of the thin superficial layer of bottom ooze, constitutes one of the most important food resources of the bottom organisms of the lake.

SUGGESTIONS

By way of increasing the food supply available in the bottom fauna of the lake a few practical methods of applying the results of this study suggest themselves:

I. It might be possible to introduce into the lake other food organisms which could maintain themselves on the bottom and thus increase the food supply. In this connection some of the larger *Amphipoda* seem to offer opportunities for experiment, especially some of the *Gammaridae*, which reach a large size.

II. Since Lake Nipigon so largely lacks aquatic vegetation, amongst which other investigators have found enormous numbers of organisms, it might be possible to introduce species of plants not already found there or to disseminate more widely those which have already established themselves to some extent. It is recognized, however, that any such procedure would of necessity be confined to the small shallow bays and channels since conditions in the open lake are such as to make the growth of aquatic vegetation impossible.

III. Besides the possibilities of increasing the available food supply it is also evident that methods of conservation might be adopted to advantage. In this connection it is apparent that the food material consumed by the suckers represents an enormous waste since these fish are not only worthless, but also very abundant. It would appear advisable, therefore, to adopt some means of eliminating them, and in this manner to preserve the food resources of the lake for more valuable species of fish. The most feasible course to pursue would appear to be to discontinue the practice of putting these fish back into the lake when they are caught in gill nets and also to capture them in spring time at the mouths of the rivers which they ascend when spawning. The fish taken out of the lake in this way could be utilized as indicated below for the production of detritus.

IV. The fact that the bottom organisms feed to such a large extent upon detritus suggests a valuable and practical method of increasing the productivity of the lake and at the same time offers a satisfactory method of disposing of the organic wastes connected with the fishing industry. The fishing operations carried on in the lake result in the continuous removal of organic matter which, under natural conditions, would ordinarily be restored to the water in disintegrated form. During the preparation of fish for the market the viscera are removed, and these represent about one-fifth of the weight of the fish. Since it is unlawful to deposit this material in the water, it is taken to shore, where it slowly accumulates and putrifies. It would be much better to convert this material into some form in which it could be put back into the lake. In order to do this it would only be necessary to install a plant for grinding the material into particles of microscopic size—to produce, in other words, "dust fine detritus." It would be necessary to sterilize the ground-up matter in order to destroy pathogenic bacteria and the eggs of fish parasites. After being treated in this manner it could be taken out by boat into the deeper, open waters of the lake and there, by means of cable and bucket, lowered to within a short distance of the bottom. It could then be released, and as it slowly settled it would spread out over a fairly large area. In this way it would again become available to the detritus-eating organisms of deep water and through them to the whitefish.

There can be no ground for objection to such a plan since it is proposed that the material used should be thoroughly sterilized and should be deposited only in the colder, deeper parts of the lake. The rate of disintegration would be very slow in such situations, and furthermore it is highly probable that the material would be consumed by bottom organisms long before it had become much altered. Moreover, even though it should remain for some time it would have very little effect on the water, for sanitary engineers assure us that the open waters of the great lakes are practically as pure as they originally were in spite of the fact that sewage has been dumped into them for many years. The material could not be scattered indiscriminately on the surface or deposited in the shallow water of small bays, since in either case there would be considerable loss through the material being washed on shore and through its subsequent decomposition.

The adoption of such a scheme for enriching the food resources of the bottom of the lake would simply be the application to aquiculture of methods similar to those which have been employed with such marked success in agriculture. Attempts have been made to cultivate food organisms intensively for use as fish food, but such methods have not

been developed so that they could be applied to large bodies of water. It may be possible, however, to solve the problem indirectly by utilizing organic wastes of all kinds (including useless species of fish, such as the suckers) to produce detritus as food material for those organisms which are eaten by fish. The method outlined for such a venture is not only quite practical, but it could also be carried out at small cost.

APPENDIX

The Bottom Fauna of Lake Ontario

On October 3, 1922, a series of dredgings was secured in the waters of Lake Ontario on a line between Toronto and the mouth of the Niagara River. An Ekman dredge covering an area of 81 square inches was used, and the usual method of screening and sorting was followed. The data obtained are presented herewith (Table I) for comparative purposes, with the permission of the Hydro-Electric Power Commission of Ontario.

TABLE I

Dredging	2	3	5	6	9	10	11
Depth (feet)	177	279	372	411	306	102	39
Distance from Shore	$1\frac{1}{4}$ mi.	$4\frac{1}{4}$ mi.	$9\frac{3}{4}$ mi.	$12\frac{3}{5}$ mi.	21 mi.	$23\frac{4}{5}$ mi.	$25\frac{1}{4}$ mi.
Character of Bottom	M	M	M	M	M	S	S
Mollusca	12	8	1		8	11	116
Chironomidae	1	1				18	35
Odonata							1
Amphipoda	28	10	3	2	45	2	1
Oligochaeta	23	1		1	7	157*	12
Nematoda	2	1	4	2	12	1	
Total	67	21	8	5	72	189*	165

*The remainder of the material was left overnight, with the result that a great many *Oligochaeta* disintegrated.

The *Mollusca* were composed mostly of *Pelecypoda*, but a number of specimens of dead Gastropod shells were also obtained representing species listed below. Of the other organisms only the *Amphipoda* were identified.

Mollusca:

Gastropoda.

1. *Lymnaea* sp.
2. *Physa gyrina* Say.
3. *Valvata sincera* Say.
4. *Valvata tricarinata* Say.
5. *Amnicola limosa* Say.
6. " " *portata* Say.
7. *Goniobasis* sp.

Pelecypoda.

8. *Pisidium amnicum* Müller.
9. " *compressum* Prime.
10. " *griseolum* Sterki.
11. " *indianense* Sterki.
12. " *levissimum* Sterki.
13. " *punctatum surplex* Sterki.
14. " *scutellatum* Sterki.
15. " " *cristatum* Sterki.
16. " *vesiculare* Sterki.
17. " *walkeri* Sterki.
18. *Sphaerium corneum* Linn.

Amphipoda

Pontoporeia hoyi Smith.

" *filicornis* Smith.

The samples obtained indicate that Lake Ontario has a rich and varied bottom population, and it would also appear that the deeper waters have larger numbers of organisms than were found in Lake Nipigon. It is impossible, however, to arrive at any conclusion from such a small number of dredgings.

The bottom samples were also analysed in order to determine their chemical composition, and the results which are highly interesting are given below (Table II).

The materials obtained in these dredgings were in many respects very similar to those obtained in Lake Nipigon, and there are, therefore, several points of interest about them.

TABLE II

Dredging	1	2	3	4	5	6	7	8	9	10	11
Depth (in feet)	15	177	279	354	372	411	384	342	306	112	39
Silica and insoluble silicates	79.40	74.80	88.94	70.26	70.00	70.80	72.13		80.80	78.47	85.33
Aluminium and Iron Oxides	7.86	7.20	7.93	19.20	27.06	19.20	13.86		11.06	10.40	5.33
Lime CaO	5.82	7.60	0.27	0.66	0.40	0.40	0.40		1.06	1.20	3.20
Sulphuric anhydride (SO_3)	0.14	0.02	0.03	0.15	0.18	0.20	0.14		0.36	0.27	0.01
Total Carbonates CO_2	3.12	5.03	0.44	4.02	0.92	1.79	0.71	1.54	0.65	2.41	2.49
Organic Matter	1.54	4.17	2.42	5.18	0.42	6.60	9.62	9.26	6.15	6.39	2.34
Totals	97.88	98.82	100.93	99.47	98.98	98.99	97.06		100.08	99.14	98.70

(1) In shallow water there is a relatively high percentage of lime, which decreases with depth. This fact may have considerable bearing upon the distribution of the *Mollusca*, which require a certain amount of calcium carbonate in building up their shells and possibly explains why they are so much more abundant in shallow water.

(2) The percentage of organic matter gradually increases with depth. This is an important fact in view of the food relations of the deep-water organisms. Thus the food of *Pontoporeia hoyi* was apparently made up entirely of ooze, and it seems almost self-evident that the ooze was eaten for the high percentage of organic matter which it contained.

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Fig. 1

Fig. 2

PLATE I.

Fig. 1—Typical stretch of rocky shore near Macdiarmid.

Fig. 2—Typical clean sandy shore near Sand Point.

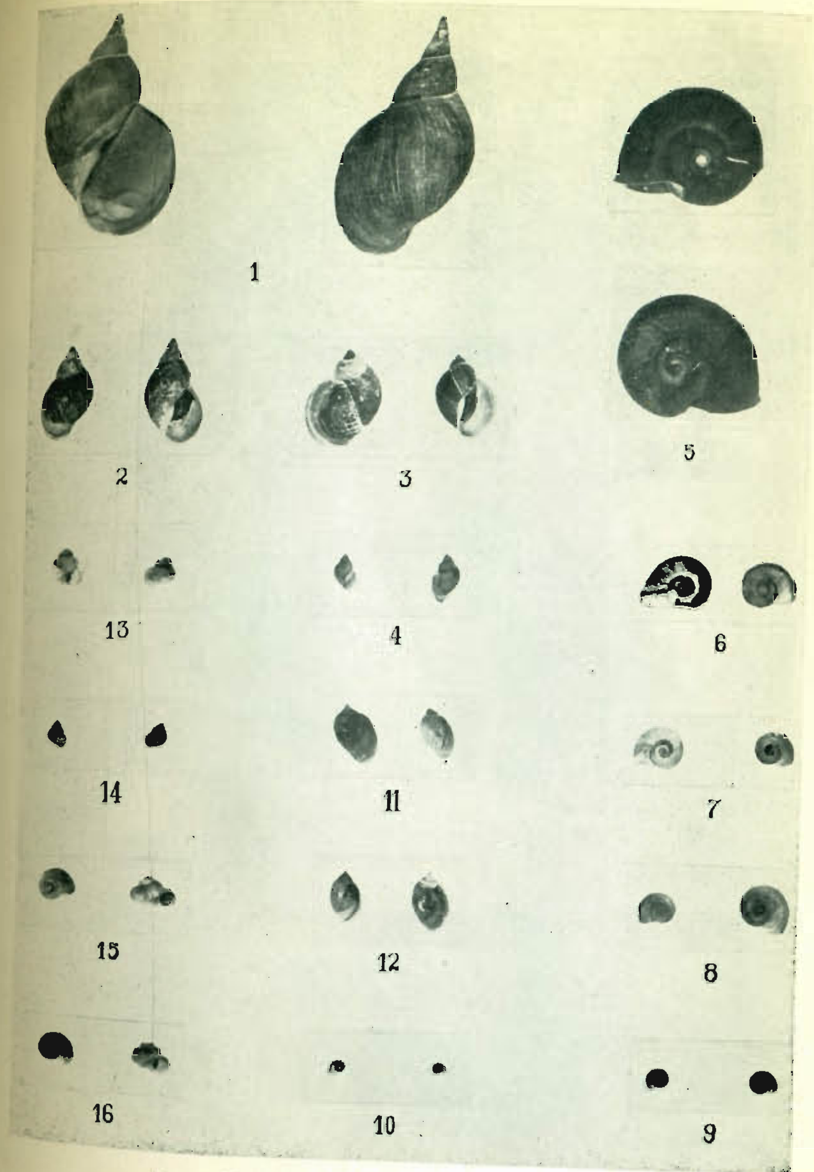

PLATE II. Gastropoda (two-thirds natural size).

Fig. 1 *Lymnaea stagnalis appressa* Say
" 2 " *emarginata* Say
" 3 " *apicina* Lea
" 4 " *galbana* Say
" 5 *Planorbis trivolvis* Say
" 6 " *antrosus* Conrad
" 7 " *exacuous* Say
" 8 " *hirsutus* Gould
Fig. 9 *Planorbis parvus* Say
" 10 " *crista* L.
" 11 *Physa ancillaria* Say
" 12 " *gyrina* Say
" 13 *Amnicola limosa porata* Say
" 14 " *pallida* Haldeman
" 15 *Volvata sincera* Say
" 16 " *tricarinata* Say

1

2

3

PLATE III. Pelecypoda (two-thirds natural size).

Fig. 1 *Anodonta marginata* Say
" 2 *Lampsilis* (*Ligumia*) *superiorensis* Marsh
" 3 *Anodonta kennicotti* Lea

Plate IV, Pelecypoda—Sphaeriidae.

Fig. 1 *Sphaerium rhomboideum* Say
" 2 " *acuminatum* Prime
" 3 " *vermontanum* (?) Prime
" 4 " *emarginatum* Prime
" 5 " *crassum* Sterki
" 6* " *corneum* L.
" 7* *Pisidium amnicum* Müller
" 8 " *indianense* Sterki
" 9 " *idahoense* Roper
" 10 " *scutellatum* Sterki
" 11 " *compressum* Prime
" 12 " sp. ?
" 13 " *scutellatum cristatum* Sterki
" 14 " *clavatum* Sterki

Fig. 15 *Pisidium pauperculum* Sterki
" 16 " *splendidulum* Sterki
" 17 " *fallax* Sterki
" 18 " *griseolum* Sterki
" 19 " *medianum minutum* Sterki
" 20* " *levissimum* Sterki
" 21 " *vesiculare* Sterki
" 22 " *monas* Sterki
" 23 " *ferrugineum* Prime
" 24 " *punctatum simplex* Sterki
" 25 *Musculium rosaceum* Prime
" 26 " *truncatum* Prime
" 27 " *securis* Linsley

*Lake Ontario Specimens.

Nos. 1-9 enlarged 2½ times, Nos. 10-27 enlarged 4 times.

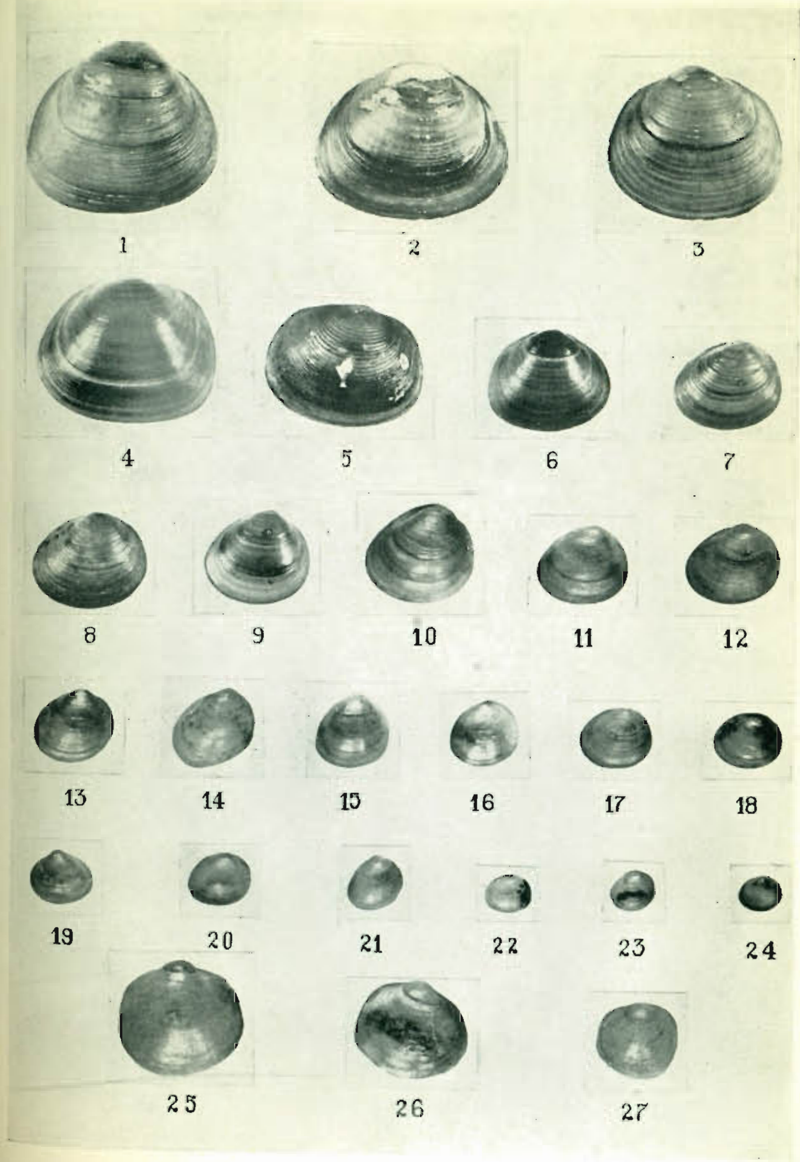

Plate IV, Pelecypoda—Sphaeriidae.