LIMNOLOGICAL SURVEY OF LAKE ONTARIO, 1964

Great Lakes Fishery Commission

TECHNICAL REPORT No. 14

The Great Lakes Fishery Commission was established by the Convention on Great Lakes Fisheries, between Canada and the United States, ratified on October 11, 1955. It was organized in April, 1956 and assumed its duties as set forth in the Convention on July 1, 1956. The Commission has two major responsibilities: the first, to develop co-ordinated programs of research in the Great Lakes and, on the basis of the findings, recommend measures which will permit the maximum sustained productivity of stocks of fish of common concern; the second, to formulate and implement a program to eradicate or minimize sea lamprey populations in the Great Lakes. The Commission is also required to publish or authorize the publication of scientific or other information obtained in the performance of its duties.

LIMNOLOGICAL SURVEY
OF
LAKE ONTARIO, 1964

GREAT LAKES FISHERY COMMISSION
1451 GREEN ROAD
ANN ARBOR, MICHIGAN

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FOREWORD

The major weakness in our knowledge of the St. Lawrence Great Lakes has been the lack of detailed lakewide hydrographic surveys. The shortage of data from such surveys has made difficult the measurement of environmental changes and in turn has hindered our efforts to recognize, control, and prevent pollution. Studies are urgently needed to provide a base from which we can measure the rate at which the Great Lakes are changing.

Due to an almost complete lack of data from Lake Ontario, the Bureau of Commercial Fisheries conducted a lakewide hydrographic and fishery survey of that lake in September 1964. Samples were collected in the open waters; shallow inshore areas and areas that were obviously polluted were intentionally avoided. The Lake Ontario survey lasted 10 days and included the measurement of several chemical constituents of the water, identification and counts of phytoplankton, and the sampling of bottom fauna and fish populations.

Other studies have been conducted on Lake Ontario since 1964 but very few were lakewide. The combination of isolated studies with lakewide surveys at periodic intervals should give a good base from which to measure changes that will undoubtedly continue in Lake Ontario. As pollution abatement becomes a reality, we should be able to measure the rate of recovery of the lake to a more desirable condition.

The five papers in this publication document the 1964 survey; each paper is complete within itself. Figure 1 of the first paper shows the locations of all stations at which samples were collected. The latitudes and longitudes are listed in the Appendix. The papers on plankton and bottom fauna each contain maps which show only the stations sampled for the particular study. The paper on fish populations describes the fishing locations in the text.

CHEMICAL CHARACTERISTICS OF LAKE ONTARIO[1]

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ABSTRACT

Records are presented of Na+, K+, Ca++, SiO_2, pH, alkalinity, 0,, and specific conductance at 106 stations in Lake Ontario. These data are compared for east-west and surface-subsurface variations. Water quality in Lake Ontario is similar to that in Lake Erie with the exception of dissolved oxygen. The open waters of Lake Ontario had no areas of serious oxygen depletions.

Introduction

The chemical characteristics of Lake Ontario were studied from samples collected in the open water of the lake. Other investigators have used open-water samples to assess eutrophication in the Great Lakes; near-shore water may be influenced by localized pollution.

The present report gives the results of chemical analyses of the water from samples collected in 1964 and compares the findings with earlier conditions in Lake Ontario. Previous chemical surveys of Lake Ontario have been reported by the International Joint Commission (1951), Rodgers (1962), Kramer (1962), the Great Lakes Institute (1965), and Dobson (1967). The Bureau of Commercial Fisheries also conducted a limited survey in 1961 (unpublished).

Methods

Nansen bottles were used to collect surface and subsurface water samples at 106 stations (Fig. 1). A bucket was used at

[1]Contribution No. 366, Ann Arbor Biological Laboratory, U.S. Bureau of Commercial Fisheries.

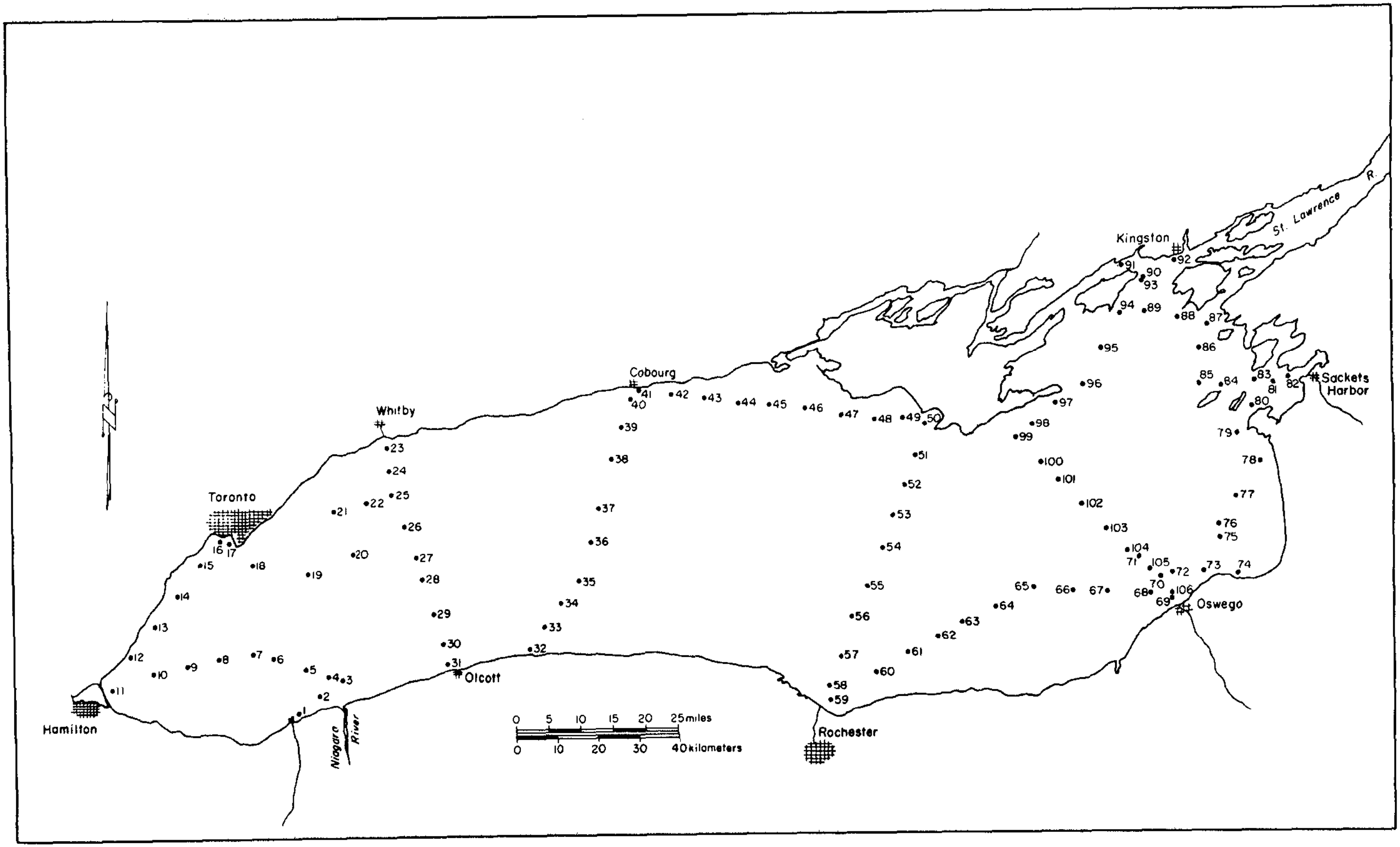

Figure 1. Lake Ontario showing locations of all stations at which samples were collected.

stations where only a surface sample was taken. Surface temperatures were measured with a recording thermograph and subsurface temperatures with reversing thermometers. Several water samples were obtained from near the bottom (without temperature measurements) with a horizontal sampler (Joeris, 1964). Analyses for alkalinity, pH, and dissolved oxygen were performed only on the samples collected in Nansen bottles. Bathythermograph casts were made at all stations.

Samples were analyzed for alkalinity, pH, dissolved oxygen, and specific conductance aboard the Cisco and for Na^+, K^+, Ca^{++}, and SiO_2 at the Biological Laboratory of the Bureau of Commercial Fisheries, Ann Arbor, Michigan. Sodium, potassium, and calcium were determined flame photometrically. Silica was measured colorimetrically as the heteropoly blue. After the pH determination a potentiometric titration was used to measure alkalinity. The Alsterberg modification of the Winkler method was used for oxygen measurements (American Public Health Association, 1965). Conductivity was measured at the ambient temperature and corrected to 18° C by correction factors given by Smith (1962).

Chemical Values and Their Variation

The horizontal variation in the chemical composition of open Lake Ontario was remarkably small (Table 1). The chemical sampling, however, was not designed to detect pollution, and inshore areas with occasional high concentrations of chemicals may not have been detected by this survey. Evidence of enrichment was found only near the mouth of the Oswego Rover. At stations 69 and 106, sodium concentrations were 34.0 and 20.7 ppm, calcium concentrations were 51.3 and 40.5 ppm, and conductivity values were 452 and 318 μmhos respectively. The average values for all stations (Table 2) were 12.0 ppm sodium, 38.18 ppm calcium, and 277.0 μmhos. Enrichment was not detected off the Genesee River (stations 58 and 59) nor in the Toronto area (stations 16 and 17). Hiltunen (1969) reported that both of these areas showed evidence of enrichment on the basis of the numbers and species of bottom fauna.

Average values and ranges for chemical and physical measurements of the water of Lake Ontario are presented in Table 2. Although the range of values for some constituents was large, **most values were within much narrower** ranges. **For example,** the range for sodium in all samples was 10.4 to 34.0 ppm, but in 96% of the samples the range was only 10.8 to 13.2 ppm (Table 3). High or low values may have been caused by errors in sampling or analysis, the influence of tributary streams, unusual biological activity, or equilibrium with bottom sediments.

Table 1. Chemical and physical data for Lake Ontario, 1964
[For station location see Figure 1.]

Date and station	Time (EST)	Depth (meters)	Temperature (° C)	Dissolved oxygen (ppm)	Specific conductance ($K_{18} \times 10^6$)	pH	Bicarbonate alkalinity (ppm $CaCO_3$)	*Total* alkalinity (ppm $CaCO_3$)	Na+ (ppm)	K^+ (ppm)	Ca++ (ppm)	SiO_2 (ppm)
September 8												
1	0700	0	19.4	****	279	***	*	***	11.7	1.2	42.5	0.6
2	0730	0	20.6	****	275	***	*	***	11.7	0.8	41.1	0.7
3	0750	0	18.3	****	272	***	*	***	11.6	0.8	41.1	0.6
4	0759	0	18.6	8.6	279	8.1	0	100	11.4	1.0	41.7	0.6
		11	17.8	9.0	279	8.3	0	102	11.8	1.2	41.3	0.6
		13	16.6	9.2	274	8.0	0	100	11.0	1.4	37.7	0.7
5	0910	0	20.0	9.2	271	8.2	0	103	11.4	1.4	36.9	0.6
		11	15.1	9.4	276	8.1	0	103	11.4	1.4	37.7	0.6
		15	12.4	9.5	287	7.9	0	102	10.9	1.5	37.6	0.7
		31	5.6	11.3	282	7.7	0	102	10.9	1.3	36.7	0.9
		91	4.2	11.8	287	***	0	103	11.2	1.3	42.6	1.6
6	1014	0	18.4	****	269	***	*	***	11.9	1.4	38.7	0.5
7	1041	0	17.6	10.4	276	8.4	4	99	11.9	1.4	38.8	0.4
		18	8.9	10.4	288	7.8	0	101	12.1	1.3	39.8	0.8
		26	5.4	11.3	290	7.6	0	102	11.9	1.4	40.8	0.8
		52	4.3	12.1	292	7.8	0	100	11.5	1.4	38.2	0.9
		100	4.1	11.7	296	7.6	0	102	11.5	1.3	40.1	1.1
8	1200	0	19.0	10.4	280	8.4	6	101	11.9	1.3	37.3	0.6
		12	15.8	9.4	277	8.1	0	99	11.7	1.3	40.1	0.7
		18	9.7	10.1	291	7.7	0	102	11.5	1.3	38.7	0.8
		30	5.3	10.2	286	7.8	0	101	10.9	1.4	38.2	1.2
		91	4.4	11.3	285	7.7	0	102	11.3	1.3	38.8	1.5
9	1250	0	18.8	****	271	***	*	***	12.1	1.4	38.2	0.7
10	1320	0	18.9	****	272	***	*	***	12.0	1.2	35.7	0.7
11	1355	0	19.6	10.2	273	8.6	9	100	12.2	1.4	36.6	0.8
		9	13.3	8.5	306	7.9	0	101	12.0	1.3	37.4	1.2
		18	7.7	9.7	285	7.6	0	103	11.8	1.2	38.7	1.4
12	1455	0	19.5	****	269	***	*	***	11.9	1.4	36.6	0.7
13	1525	0	18.6	****	271	***	*	***	12.3	1.2	36.8	0.6
14	1555	0	17.3	10.4	277	8.4	4	99	12.2	1.3	35.5	0.8
		9	17.7	10.4	278	8.2	*	97	12.9	1.3	37.4	0.8
		12	10.2	9.8	284	7.8	*	102	12.9	1.2	39.6	1.0
		29	6.6	9.2	290	7.6	*	103	11.6	1.3	43.3	1.3

15	1645	0	18.2	****	272	***	*	***	12.3	1.2	40.6	0.7
16	1712	0	17.0	****	274	***	*	***	12.1	1.3	40.0	0.8
September 9												
17	0800	0	16.2	9.9	272	8.2	*	99	11.9	1.3	39.8	0.8
		9	9.6	9.6	285	7.7	*	103	11.4	1.3	39.4	1.2
		18	4.9	10.6	287	7.7	*	104	11.7	1.4	40.9	1.3
18	0853	0	18.0	10.0	273	8.6	4	97	12.0	1.3	39.7	0.7
		11	16.8	9.3	274	8.2	0	99	11.7	1.4	39.8	0.8
		18	5.6	11.2	287	7.7	0	102	11.6	1.4	38.2	1.0
		91	4.2	11.9	289	7.9	0	102	11.4	1.5	39.9	1.4
19	1039	0	18.3	10.3	271	8.5	3	99	11.6	1.3	39.6	0.7
		11	17.2	9.4	280	8.2	0	99	11.5	1.4	39.3	0.8
		15	10.9	9.5	283	7.8	0	100	11.3	1.4	39.2	0.9
		31	5.1	11.8	284	7.8	0	103	10.8	1.3	39.6	1.0
		122	2.7	11.3	282	7.8	0	103	11.2	1.4	39.9	1.8
20	1134	0	18.2	* ***	270	***	*	***	11.1	1.3	40.0	0.7
21	1210	0	18.0	10.3	273	8.3	1	99	11.9	1.3	40.4	0.8
		9	14.8	9.9	279	8.1	0	99	11.5	1.3	38.2	0.9
		15	11.0	9.4	278	7.8	0	101	12.3	1.3	39.4	0.9
		25	5.5	10.6	289	7.7	0	101	13.1	1.5	38.0	1.1
		88	4.2	11.6	283	7.8	0	101	12.0	1.3	38.2	1.3
22	1253	0	18.2	****	270	***	*	***	12.4	1.4	35.4	0.6
25	1320	0	18.3	9.7	269	8.5	4	97	12.6	1.5	34.8	0.7
		12	17.6	9.1	274	8.3	1	99	12.0	1.4	35.4	0.7
		18	8.8	9.6	283	7.8	0	100	11.1	1.3	39.1	0.9
		46	8.1	11.3	283	7.7	0	102	11.1	1.2	38.6	0.9
		91	4.2	11.7	285	7.8	0	102	11.1	1.2	38.4	1.1
23	1423	0	17.0	10.1	275	8.4	3	100	12.1	1.3	36.9	0.7
		9	14.1	9.9	270	8.2	0	100	12.4	1.2	37.6	0.8
		18	9.3	9.7	292	7.6	0	100	12.1	1.2	38.5	1.1
September 10												
24	0755	0	18.2	****	268	***	*	***	11.6	1.3	34.4	0.7
25	0819	0	18.4	****	273	***	*	***	11.7	1.0	36.8	0.5
26	0948	0	18.4	****	271	***	*	***	11.6	1.1	34.1	0.5
27	1018	0	18.3	****	268	***	*	***	10.4	1.0	36.0	0.5
28	1040	0	18.6	9.8	271	8.4	3	96	11.8	1.1	35.3	0.6
		12	18.1	10.2	268	8.4	2	97	11.2	1.1	36.3	0.6
		15	9.1	10.8	278	7.4	0	97	10.6	1.0	38.6	0.7
		30	5.2	11.3	298	7.4	0	100	10.5	1.2	38.4	0.8
		90	4.2	12.0	296	7.8	0	103	11.0	1.3	39.3	0.8

Table 1 (Continued)

Date and station	Time (EST)	Depth (meters)	Temperature (° C)	Dissolved oxygen (ppm)	Specific conductance ($K_{18} \times 10^6$)	pH	Bicarbonate alkalinity (ppm $CaCO_3$)	Total alkalinity (ppm $CaCO_3$)	Na^+ (ppm)	K^+ (ppm)	Ca^{++} (ppm)	SiO_2 (ppm)
September 10												
		142	4.1	11.4	286	7.8	0	106	11.2	1.3	38.8	1.3
29	1158	0	19.1	****	267	***	*	***	11.3	1.3	35.8	0.5
30	1225	0	19.4	9.7	217	8.6	6	102	11.4	1.3	37.2	0.6
		7	19.3	9.3	280	***	*	***	11.4	1.2	37.0	0.6
		15	13.4	9.2	284	***	*	***	12.1	1.2	38.7	0.8
		23	11.3	9.8	283	***	*	***	11.6	1.2	38.0	0.9
		30	7.2	10.4	281	***	*	***	11.2	1.1	38.0	1.1
		38	****[1]	11.0	279	***	*	***	11.2	1.2	37.7	1.0
		45	5.1	11.0	280	***	*	***	10.8	1.2	39.6	1.2
		53	3.4	11.4	283	7.9	0	106	11.4	1.4	40.4	1.2
		61	4.4	11.6	281	7.9	0	107	11.0	1.3	42.0	1.4
		68	4.2	11.2	281	7.9	0	107	11.4	1.3	40.5	1.4
		76	4.1	11.4	285	8.0	0	107	11.4	1.3	39.6	1.4
		83	4.2	11.3	285	7.9	0	108	11.2	1.3	40.0	1.5
31	1425	0	19.5	9.7	273	8.7	7	103	11.7	1.3	38.6	0.6
		9	13.4	8.6	275	8.4	4	103	11.9	1.3	38.6	0.6
		18	11.3	9.8	288	8.0	0	107	11.5	1.3	40.6	1.1
September 12												
32	1021	0	18.1	9.0	272	8.6	3	103	11.4	1.3	37.9	0.6
		10	18.5	8.9	272	8.2	0	100	11.0	1.2	38.0	0.6
		18	12.1	9.4	281	7.9	0	104	10.9	1.3	39.2	0.9
33	1125	0	17.8	9.2	273	8.5	3	104	11.4	1.3	37.8	0.7
		15	18.2	9.3	269	8.3	1	101	11.6	1.2	37.2	0.8
		46	5.8	10.6	283	7.8	0	102	11.5	1.3	39.8	1.2
		86	4.2	11.1	286	7.8	0	104	11.2	1.3	40.3	1.7
34	1235	0	17.4	****	267	***	*	***	11.6	1.3	37.6	0.7
35	1345	0	17.7	9.4	264	8.4	3	101	12.2	1.5	37.4	0.6
		15	17.7	9.0	272	8.3	1	100	11.5	1.3	38.1	0.6
		30	7.6	10.1	277	7.2	0	101	11.1	1.4	37.5	0.8
		91	4.2	12.0	284	7.6	0	102	11.9	1.5	39.5	0.8
		179	3.9	11.4	281	7.5	0	102	11.6	1.4	39.2	1.4
36	1427	0	18.4	****	257	***	*	***	11.9	1.4	36.3	0.5
37	1457	0	18.3	****	261	***	*	***	11.6	1.4	36.2	0.6

September 12

38	1547	0	17.7	9.4	269	8.5	4	99	11.5	1.3	36.6	0.6
		12	17.4	8.9	267	8.2	0	100	11.6	1.4	36.6	0.6
		30	5.0	11.2	282	7.6	0	102	11.5	1.3	37.6	0.8
		61	4.1	12.0	288	7.9	0	105	12.1	1.3	39.2	0.7
		91	4.0	10.9	289	7.8	0	105	12.3	1.4	37.1	1.3
39	1658	0	17.2	****	264	***	*	***	11.9	1.2	38.4	0.7
40	1740	0	16.0	9.6	271	8.2	0	101	11.8	1.2	39.6	0.7
		9	16.0	9.5	275	7.8	0	97	12.1	1.1	38.8	0.7
		18	13.9	8.9	279	7.7	0	102	11.6	1.1	38.6	0.8

September 13

41	0540	0	14.4	****	289	***	*	***	11.3	1.1	38.8	0.9
42	0610	0	15.5	****	282	***	*	***	11.3	1.1	41.2	0.8
43	0640	0	17.1	****	278	***	*	***	11.6	1.1	38.1	0.7
44	0710	0	17.1	****	274	***	*	***	12.0	1.1	39.0	0.6
45	0740	0	17.9	****	271	***	*	***	11.7	1.2	37.2	0.7
		20	17.4	****	271	***	*	***	11.6	1.2	38.4	0.7
		25	12.4	****	274	***	*	***	11.5	1.3	38.6	0.8
		38	7.9	****	268	***	*	***	11.4	1.3	40.4	1.3
46	0900	0	17.0	****	274	***	*	***	11.5	1.3	38.4	0.7
47	0930	0	17.5	****	272	***	*	***	11.2	1.3	38.5	0.6
48	1000	0	****[1]	****	271	***	*	***	11.4	1.4	36.8	0.6
49	1030	0	17.9	****	269	***	*	***	11.2	1.4	38.0	0.6
50	1122	0	18.5	9.2	271	8.3	1	99	11.4	1.3	38.0	0.6
		17	13.6	8.1	279	7.7	0	99	11.3	1.3	39.7	1.0
		18	99.9	8.2	285	7.7	0	103	****	***	****	***
51	1224	0	18.8	****	268	***	*	***	11.2	1.3	36.2	0.6
52	1254	0	18.6	****	275	***	*	***	12.3	1.3	37.6	0.5
53	1324	0	18.9	****	270	***	*	***	12.0	1.4	36.6	0.4
54	1354	0	18.8	****	261	***	*	***	11.9	1.4	36.2	0.5
55	1430	0	18.6	9.1	275	8.3	0	97	12.2	1.5	35.4	0.4
		18	18.0	8.9	272	8.2	0	103	12.0	1.5	36.0	0.5
		30	8.6	9.8	281	7.3	0	99	11.6	1.5	37.2	0.7
		91	4.2	12.3	278	7.9	0	103	11.9	1.5	38.6	0.7
		167	4.0	11.5	284	7.7	0	104	11.8	1.4	37.6	1.4
56	1505	0	18.8	****	268	***	*	***	12.0	1.4	37.6	0.6
57	1628	0	19.0	9.2	271	8.4	3	100	11.6	1.4	36.2	0.5
		21	18.5	8.7	251	8.3	1	100	12.0	1.4	35.7	0.6
		31	9.6	9.4	280	7.6	0	102	11.6	1.4	38.6	0.9
		91	4.2	11.5	285	7.7	0	103	11.4	1.3	38.9	1.3

Table 1 (Continued)

Date and station	Time (EST)	Depth (meters)	Temperature (^{o} C)	Dissolved oxygen (ppm)	Specific conductance ($K_{18} \times 10^6$)	pH	Bicarbonate alkalinity (ppm $CaCO_3$)	Total alkalinity (ppm $CaCO_3$)	Na^+ (ppm)	K^+ (ppm)	Ca^{++} (ppm)	SiO_2 (ppm)
September 13												
58	1732	0	18.8	****	271	***	*	***	11.6	1.3	36.0	0.6
September 14												
59	1015	0	18.3	8.6	276	8.4	1	101	12.6	1.3	37.0	0.6
		17	18.1	8.7	277	8.4	2	101	12.5	1.3	35.3	0.7
		18	****[1]	8.0	283	8.1	0	103	****	***	****	***
60	1128	0	18.6	9.0	265	8.5	4	101	12.0	1.3	37.5	0.6
		18	18.7	8.6	264	8.4	3	102	12.0	1.3	35.6	0.6
		25	8.5	9.6	273	7.4	0	101	12.0	1.4	37.7	1.0
		45	4.9	12.0	285	7.9	0	105	11.7	1.4	38.3	0.9
		86	4.1	11.0	282	7.8	0	105	11.9	1.4	38.9	1.7
61	1221	0	18.3	****	267	***	*	***	12.0	1.3	37.8	0.7
62	1251	0	18.2	****	266	***	*	***	12.3	1.2	36.6	0.6
63	1321	0	18.1	****	268	***	*	***	12.1	1.2	37.7	0.9
64	1351	0	18.5	****	264	***	*	***	13.0	1.3	38.3	0.7
65	1430	0	19.1	9.6	265	8.5	5	101	13.0	1.2	38.2	0.7
		26	16.8	7.7	272	7.8	0	101	13.0	1.3	37.8	0.8
		32	10.5	9.0	274	7.7	0	103	12.5	1.2	38.4	0.9
		60	4.8	12.0	277	7.9	0	104	11.7	1.3	37.5	1.0
		121	4.1	12.2	277	8.0	0	104	11.6	1.1	38.1	1.0
		218	4.0	11.4	276	7.8	0	106	11.2	1.2	39.8	1.8
66	1619	0	19.1	****	266	***	*	***	11.5	1.2	36.8	0.8
67	1649	0	19.1	****	266	***	*	***	12.8	1.3	38.4	0.7
68	1719	0	19.0	****	268	***	*	***	12.1	1.3	35.4	0.7
69	1802	0	19.4	9.1	268	8.6	5	102	11.4	1.2	35.8	0.7
		17	19.4	8.2	452	8.2	0	99	34.0	1.6	51.3	0.7
September 16												
70	0554	0	18.4	8.6	269	7.7	0	101	12.9	1.2	35.1	0.7
		24	18.8	8.5	282	8.2	0	97	13.5	1.5	37.0	0.8
		30	9.1	9.4	277	7.7	0	103	11.4	1.3	38.2	1.0
		90	4.3	11.4	282	7.4	0	103	11.4	1.3	39.9	1.5
71	0638	0	18.3	8.8	282	8.3	3	100	14.3	1.3	36.8	0.7
		24	14.9	8.0	270	7.4	0	101	13.5	1.5	36.4	0.7

		30	9.8	9.0	279	7.3	0	99	11.9	1.4	38.4	0.8
		90	4.2	12.1	280	7.8	0	102	12.0	1.4	39.1	0.9
		178	3.9	11.0	280	7.7	0	105	11.8	1.3	38.9	2.0
72	0759	0	18.3	****	273	***	*	***	11.9	1.3	36.2	0.7
73	0829	0	18.2	****	277	***	*	***	11.5	1.3	36.4	0.7
74	0907	0	18.1	9.0	270	8.3	1	97	11.9	1.3	35.1	0.8
		10	18.5	9.1	274	8.2	0	97	12.3	1.3	36.7	0.9
75	1049	0	18.6	****	269	***	*	***	11.9	1.4	34.6	0.7
76	1100	0	18.6	8.5	260	8.2	0	99	11.9	1.3	36.2	0.6
		24	18.9	8.3	265	8.2	0	99	11.9	1.3	35.4	0.7
		30	15.3	7.7	269	7.4	0	95	13.0	1.5	36.2	0.8
		60	4.7	11.6	286	7.6	0	104	16.7	1.4	35.7	1.0
		90	4.4	11.1	282	7.7	0	106	11.2	1.4	36.7	1.6
77	1144	0	18.4	****	273	***	*	***	12.1	1.4	33.9	0.8
78	1224	0	18.5	8.9	273	8.5	4	101	12.6	1.4	36.2	0.8
		18	18.5	8.5	281	8.2	0	100	13.2	1.5	36.8	0.9
79	1345	0	19.3	9.3	270	8.3	1	100	12.1	1.4	37.2	1.0
		17	18.5	8.5	271	8.2	0	101	12.4	1.4	35.9	1.0
80	1425	0	18.7	****	276	***	*	***	12.8	1.3	37.2	1.0
81	1450	0	19.3	8.9	267	8.3	1	97	13.1	1.3	37.0	1.1
		18	18.1	7.9	269	8.0	0	99	12.7	1.2	37.9	1.3
		18	****[1]	7.2	288	7.8	0	***	****	***	****	***
September 17												
82	0600	0	18.6	****	268	***	*	***	12.3	1.2	36.5	1.2
83	0630	0	18.2	****	271	***	*	***	12.6	1.3	37.8	0.8
84	0700	0	17.7	****	272	***	*	***	11.9	1.3	38.1	0.9
85	0721	0	17.7	9.0	271	8.2	0	101	12.3	1.5	39.1	0.9
		24	14.3	7.4	282	7.7	0	102	12.4	1.4	40.0	1.3
		31	11.0	7.3	287	7.5	0	104	12.3	1.3	40.5	1.8
86	0818	0	17.6	****	261	***	*	***	12.5	1.2	38.2	0.8
87	0842	0	17.6	7.7	273	8.2	0	100	12.7	1.2	38.7	0.9
		21	18.0	8.8	273	8.2	0	100	12.8	1.1	39.6	0.8
		24	15.3	6.4	280	7.5	0	103	11.8	1.3	39.7	1.7
88	0938	0	17.5	****	273	***	*	***	12.0	1.4	39.3	0.9
89	1010	0	17.4	8.6	268	8.1	0	100	12.6	1.4	40.0	0.9
		23	17.4	8.5	269	7.9	0	100	12.5	1.4	39.8	1.1
		28	14.3	5.5	281	7.6	0	104	12.5	1.4	42.1	2.1
		29	****[1]	4.4	286	7.4	0	105	****	***	****	***
90	1058	0	17.4	****	275	***	*	***	12.9	1.4	38.6	0.8
91	1134	0	17.6	8.8	270	8.2	0	102	12.8	1.3	41.0	1.1

Table 1 (Continued

Date and tation	Time (EST)	Depth (meters)	Temperature (^{o} C)	Dissolved oxygen (ppm)	Specific conductance ($K_{18} \times 10^6$)	pH	Bicarbonate alkalinity (ppm $CaCO_3$)	Total alkalinity (ppm $CaCO_3$)	Na^+ (ppm)	K^+ (ppm)	Ca^{++} (ppm)	SiO_2 (ppm)
September 17												
		17	16.9	7.7	274	7.6	0	99	13.0	1.3	40.2	1.5
		27	11.6	3.0	281	7.1	0	107	12.6	1.3	41.8	3.4
		27	****[1]	3.0	282	7.2	0	107	****	***	****	***
92	1240	0	17.5	8.7	268	8.2	0	102	12.0	1.3	41.7	1.2
		18	16.9	6.9	276	7.6	0	102	12.2	1.3	41.1	1.8
September 18												
93	0615	0	17.3	****	276	***	*	***	12.2	1.3	39.0	0.9
94	0645	0	17.1	****	278	***	*	***	11.7	1.3	37.8	1.0
95	0730	0	17.4	8.5	267	8.3	0	102	12.2	1.3	37.7	0.8
		24	16.0	7.3	272	8.0	0	104	11.9	1.3	38.5	1.2
		31	11.7	3.9	291	7.6	0	111	12.5	1.3	41.7	3.4
96	0812	0	17.2	****	272	***	*	***	12.2	1.3	38.6	1.1
97	0842	0	****[1]	****	273	***	*	***	11.9	1.3	37.7	0.9
98	0912	0	17.1	****	276	***	*	***	11.7	1.3	36.6	0.9
99	0930	0	17.7	8.7	270	8.3	3	101	11.9	1.2	37.7	0.8
		27	17.6	8.7	276	8.2	0	101	11.9	1.3	37.7	0.7
		32	16.1	8.4	270	8.1	0	103	11.7	1.2	37.0	1.1
		45	16.3	9.8	292	7.7	0	107	11.9	1.2	39.3	1.8
100	1027	0	17.9	****	264	***	*	***	11.6	1.3	35.9	0.8
101	1047	0	18.0	9.0	261	8.4	2	100	11.2	1.3	36.2	0.8
		31	18.0	8.5	268	8.2	*	103	12.4	1.3	36.2	1.0
		33	17.1	8.1	274	8.1	*	102	11.3	1.3	35.8	0.8
		61	5.8	10.2	283	7.7	*	110	11.1	1.2	38.1	1.6
		91	5.1	10.2	284	7.7	*	109	11.4	1.3	38.6	1.8
102	1137	0	18.1	****	269	***	*	***	11.1	1.2	37.1	0.5
103	1207	0	18.3	****	271	***	*	***	11.9	1.2	36.6	0.8
104	1237	0	18.5	****	271	***	*	***	13.0	1.3	36.5	0.7
105	1307	0	18.5	****	270	***	*	***	12.5	1.3	34.7	0.8
106	1337	0	18.5	****	318	***	*	***	20.7	1.5	40.5	0.8

'Water collected with horizontal sampler; no temperature measurement.

Table 2. Chemical and physical measurements (averages and ranges) for surface and subsurface water of Lake Ontario, September 8-18, 1964

Item	All depths		Surface		Subsurface	
	Average	Range	Average	Range	Average	Range
Oxygen (ppm)	9.57	3.0-12.3	9.29	7.7-10.4	9.66	3.0-12.3
PR	7.94	7.1-8.6	8.32	7.7-9.8	7.81	7.1-8.4
Bicarbonate alkalinity (ppm $CaCO_3$)	0.8	o-s	2.5	o-s	0.1	o-4
Total alkalinity (ppm $CaCO_3$)	101.7	95-111	100.1	96-104	102.2	95-111
Conductivity (μmhos at 18° C)	277.0	251-452	271.3	257-318	281.6	251-452
Sodium (ppm)	12.0	10.4-34.0	12.04	10.4-20.7	11.96	10.5-34.0
Potassium (ppm)	1.26	0.8-1.6	1.24	0.8-1.5	1.27	1.0-1.6
Calcium (ppm)	38.18	33.9-51.3	37.57	33.9-42.5	38.7	35.3-51.3
Silica (ppm)	0.91	0.4-3.4	0.71	0.4-1.2	1.08	0.5-3.4

Ranges which excluded extreme values were chosen by inspection of frequency distributions for all values for each constituent. The exclusion of extreme values permitted a better representation of the chemical composition of the open waters of the lake. The data were further divided by location to represent the western (stations 1-45) and eastern (stations 46-106) portions of the lake. Averages, ranges, and the percentage of the data falling within the selected ranges were computed according to depth and area of the lake (Table 3). Data for pH, oxygen, bicarbonate alkalinity, and total alkalinity are not included because the range in values was small or, as for oxygen, the values falling outside the normal range could not be regarded as abnormal. The average values for the selected samples changed little (about 3%) from the original averages, but for all constituents except potassium the range was greatly reduced (Tables 2 and 3).

To determine if significant east-west or surface-subsurface differences existed, mean values were compared in t-tests (Table 4). The 0.001 level or probability was selected because of the small variation within groups.

Although average surface oxygen concentrations were significantly different between the eastern (8.85 ppm) and western (9.76 ppm) portions of the lake, the differences may reflect meteorological conditions during the sampling period. Although surface and subsurface averages differed for pH, bicarbonate, and total alkalinity, differences between the eastern and western portions of the lake were not significant.

Comparisons of the selected values of potassium showed no difference by depth or area of the lake. The average concentration of potassium (1.26 ppm) is probably representative of all depths and both areas. Differences in values of calcium and conductivity were significant between the surface and subsurface and between the eastern and western areas of the lake. Average concentrations of sodium for the surface (11.95 ppm) and subsurface (11.74 ppm) were not significantly different; however, an east-west discrepancy (average concentrations of 12.05 ppm in the east and 11.64 ppm in the west) was significant. As expected, surface silica concentrations (0.71 ppm average) were significantly lower than the subsurface concentrations (1.03 ppm average). Silica was significantly higher in the east only in surface samples. This difference may indicate that the primary productivity of Lake Ontario differed significantly between the eastern and western portions of the lake, at least during the sampling period. The highest silica concentration, 3.4 ppm, was in two samples collected near the bottom at stations 91 and 95. Both stations are in the extreme northeast end of the lake, are relatively shallow, and have low dissolved oxygen. The high concentration of silica and low concentration of dissolved oxygen may be due to the suspension

Table 3. Selected chemical and physical measurements (averages and ranges) for surface and subsurface water of Lake Ontario, September 8-18, 1964

m	All depths			Surface			Subsurface		
	Average	Range	Percentage'	Average	Range	Percentage1	Average	Range	Percentage [1]
Conductivity (μmhos at 18° C)									
All samples	276.2	264-292	95	271.5	264-289	93	279.9	264-292	96
Western samples	278.0	264-292	95	272.6	264-289	96	281.3	267-292	95
Eastern samples	274.4	264-292	94	270.7	264-282	92	278.2	264-292	97
Sodium (ppm)									
All samples	11.84	10.8-13.2	96	11.95	11.1-13.1	97	11.74	10.8-13.2	95
Western samples	11.64	10.8-13.1	97	11.79	11.1-12.6	98	11.55	10.8-13.1	97
Eastern samples	12.05	10.8-13.2	95	12.08	11.1-13.1	97	12.02	11.1-13.2	92
Potassium (ppm)									
All samples	1.26	1.0-1.6	99	1.25	1.0-1.5	98	1.27	1.0-1.6	100
Western samples	1.24	LO-1.5	98	1.22	1.0-1.4	96	1.26	1.0-1.5	100
Eastern samples	1.28	1.0-1.6	100	1.28	1.1-1.5	100	1.29	1.0-1.6	100
Calcium (ppm)									
All samples	38.09	35.3-41.3	92	37.68	35.3-41.2	90	38.42	35.3-41.3	94
Western samples	38.46	35.3-41.3	93	37.99	35.3-41.2	89	38.74	35.4-41.3	96
Eastern samples	37.67	35.3-41.1	91	37.44	35.4-41.0	90	37.94	35.3-41.1	92
lica (ppm)									
All samples	0.88	0.4-1.8	98	0.71	0.4-1.2	100	1.03	0.5-1.8	97
Western samples	0.86	0.4-1.8	100	0.65	0.4-0.9	100	0.99	0.6-1.8	100
Eastern samples	0.90	0.4-1.8	96	0.76	0.4-1.2	100	1.09	0.5-1.8	92

Percentage of total observations.

Table 4. Average chemical and physical measurements of Lake Ontario according to depth and area

[Opposing arrows indicate significant different means; facing arrows indicate nonsignificant means (0.001 level of probability).]

All measurements

Item		Depths: All	Depths: Surface	Depths: Subsurface
Oxygen (ppm)			→	←
All samples	↑	9.57	9.28	9.66
Western samples		10.24	9.76	10.37
Eastern samples	↓	8.80	8.85	8.78
pH			←	→
All samples	↓	7.94	8.32	7.81
Western samples		7.97	8.40	7.84
Eastern samples	↑	7.90	8.25	7.77
Bicarbonate alkalinity (ppm $CaCO_3$)			←	→
All samples	↓	0.8	2.5	0.1
Western samples		1.0	3.5	0.2
Eastern samples	↑	0.5	1.5	0.1
Total alkalinity (ppm $CaCO_3$)			←	→
All Samples	↓	101.7	100.1	102.2
Western samples	↑	101.5	100.1	101.9
Eastern samples		101.9	100.2	102.6

Selected[1] values

Item		Depths: All	Depths: Surface	Depths: Subsurface
Conductivity (µmhos at 18° C)			←	→
All samples	↑	276.2	271.5	279.9
Western samples		278.0	272.6	281.3
Eastern samples	↓	274.4	270.7	278.2
Sodium (ppm)			→	←
All samples	↑	11.84	11.95	11.74
Western samples		11.64	11.79	11.55
Eastern samples	↓	12.05	12.08	12.02
Potassium (ppm)			→	←
All samples	↓	1.26	1.25	1.27
Western samples		1.24	1.22	1.26
Eastern samples	↑	1.28	1.28	1.29
Calcium (ppm)			←	→
All samples	↑	38.09	37.68	38.42
Western samples		38.46	37.99	38.74
Eastern samples	↓	37.67	37.44	37.94
Silica (ppm)			←	→
All samples	↓	0.88	0.71	1.03
Western samples		0.86	0.65	0.99
Eastern samples	↑	0.90	0.76	1.09

[1]Average values from Table 3.

of bottom material in the water column during storms. Sutherland et al. (1966) reported that the silica concentration of the interstitial water, which may be in thermodynamic equilibrium with the sediment, is 50 to 200 times higher than that in Lake Ontario water.

Average values determined in the present and other studies are compared in Table 5. (The data of the International Joint Commission [1951], Rodgers [1962], and the Great Lakes Institute [1965] are not represented because they did not include values for any of the major cations.) Silica concentrations reported by Sutherland et al. (1966) for November and January range from 0.15 to 0.6 ppm. With the exception of silica, the data ‘from the Bureau of Commercial Fisheries survey in 1961 near the mouth of the Niagara River are similar to those of the present study. Differences in silica concentration between the 1961 and 1964 surveys may be due to the relatively small study area in 1961 or to differences in the method of analysis. A silicomolybdate method was used for the analysis of the 1961 samples whereas a heteropoly blue method was used for the 1964 samples. Sutherland et al. (1966) also employed a silicomolybdate procedure and obtained results in general agreement with the Bureau's 1961 study.

Lake Ontario is chemically similar to Lake Erie from which it receives about 85% of its water. Calcium and sodium were less than 2 ppm higher, silica was about 0.5 ppm lower, and potassium was less than 0.2 ppm lower than in Lake Erie (Beeton and Chandler, 1963). The chemical composition has changed more rapidly and to a greater degree since 1920 in Lakes Ontario and Erie than in the other Great Lakes (Beeton, 1965). Rates of increase of dissolved solids, calcium, sodium-plus-potassium, and chloride in Lake Ontario have closely paralleled increases in Lake Erie but the rate of increase in sulfate was 1.4 times greater in Lake Ontario than in Lake Erie between 1930 and 1960. Most of the increases in chemical content in Lake Ontario are attributable to changes in the quality of water from Lake Erie.

Dissolved Oxygen

Oxygen depletion in the open waters of Lake Ontario is not serious. In contrast, the concentration of dissolved oxygen in Lake Erie was less than 1.0 ppm near the bottom of about 1,390 square miles of the central basin in 1959 and 641 square miles in 1960 (Carr, 1962).

The difference is directly attributable to differences in the depths of the two lakes. The central basin of Lake Erie is relatively shallow (mean depth, 18.5 m) and thermal stratification

Table 5. Average chemical values of Lake Ontario reported by various authors

Study	Year of observation	Total alkalinity (ppm $CaCO_3$)	Na^+ (ppm)	K^+ (ppm)	Ca^{++} (ppm)	SiO_2 (ppm)	Conductivity (μmhos at 18° C)
Bureau of Commercial Fisheries	‘1961		10.8	1.2	39.3	0.3	272
Kramer (1962)	1959	95.5	9.5	1.8	38.8		
Dobson (1967)	1966	94.0	12.2	1.44	42.9		270
Present study	1964	101.7	11.84	1.26	38.09	0.88	276.2

‘Unpublished data of this laboratory collected near the Niagara River.

usually is stable 15 to 17 m below the surface. Since the average depth of Lake Ontario is 83 m, the ratio between the height of the hypolimnion of Lake Ontario and that of the central basin of Lake Erie is about 25:1. The amount of dissolved oxygen present in the hypolimnetic waters of Lake Ontario at the beginning of thermal stratification, therefore, is 25 times that of Lake Erie. If the depletion of oxygen in Lake Ontario is due to the sediments as it is in Lake Erie (Carr et al., 1963), it would take longer for all the oxygen in the hypolimnion of Lake Ontario to be consumed than the period of stratification. The oxygen demand and the rate of consumption of oxygen by Lake Ontario sediments are probably less than that of Lake Erie since the water temperatures are lower and less material from algal or pollutional sources are present.

Oxygen depletion was greatest in the extreme northeast portion of Lake Ontario. The lowest measured concentration of dissolved oxygen (3.0 ppm, 27% saturation) was in the north channel north of Amherst Island (station 91). Concentrations were also low at stations 89 and 95 (4.4 ppm, 42% saturation and 3.9 ppm, 35% saturation, respectively) near Amherst Island. At these stations extension of the metalimnion to within 1.5 m of the bottom left only a small reserve of hypolimnetic oxygen to be consumed by the sediment.

Oxygen depletion in the deepest waters of Lake Ontario is small. The dissolved oxygen at 218 m (station 65), in the deepest area in Lake Ontario, was 86.5% saturation (11.4 ppm). In comparison, dissolved oxygen in the “deep hole” (65 m) of Lake Erie was as low as 47% of saturation in September (Carr, 1962). The oxygen depletion at the deepest station in Lake Ontario, which has a hypolimnetic height three times the average, should be only 0.4 ppm if the water is saturated at the time of stratification. Although the depletion was 1.8 ppm at 218 m, the depletion was only 1.0 ppm (92.7% saturation) at 121 m, which indicates that the hypolimnetic waters are not thoroughly mixed. Dobson (1967) indicated that oxygen saturation in the deepest waters in Lake Ontario was 95% in late June 1966. The depletion of oxygen in the open waters of Lake Ontario cannot be considered critical.

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PLANKTONIC DIATOMS OF LAKE ONTARIO[1]

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ABSTRACT

The major species of diatoms in surface collections from Lake Ontario in September 1964 *were Asterionella formosa, Fragilaria crotonensis,* and *Tabellaris fenestrata.* Dominant species in the deep-water samples were *Stephanodiscus astraea, S. astraea* var. *mintula,* and *F. crotonensis.* The diatom flora in surface collections varied among several stations in the eastern end of the lake.

Introduction

Studies of the phytoplankton of Lake Ontario are few. Tucker (1948) studied the summer populations of phytoplankton in the Bay of Quinte but did not make taxonomic determinations to species. Schenk and Thompson (1965) evaluated data gathered at the Toronto Island Filtration Plant in 1923-54 and listed generic names of the dominant diatoms. Nalewajko (1966a) made a comprehensive, 19-month investigation of phytoplankton populations in 1964-65.

The present study gives more information on the distribution and abundance of planktonic diatoms of Lake Ontario and provides a base for future comparisons.

Methods and Materials

Water samples were collected with Nansen bottles from 24 stations (Fig. 1) at various depths.

To simplify the comparisons of lakewide diatom populations, three strata of water were established: “surface,” which included

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[1]Contribution No. 387, Ann Arbor Biological Laboratory, U.S. Bureau of Commercial Fisheries.

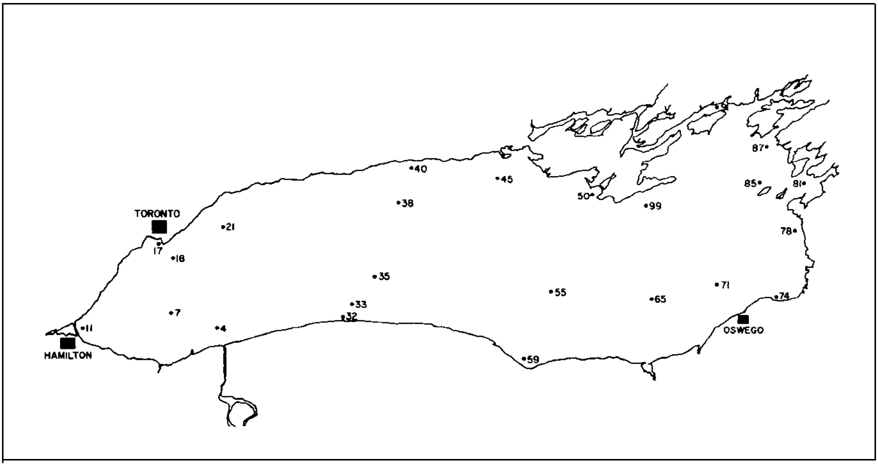

Figure 1. Lake Ontario, showing sampling stations for diatoms.

all samples from the surface to 5 meters; "intermediate," which included samples from 9 to 45 meters; and "bottom," which included collections from 90 to 220 meters.

All plankton samples were preserved by the method described by Utermöhl (1958). A sample of 80° ml was passed through a 47 mm^2 membrane filter. The filter was inserted into a 20 ml glass vial and dissolved in acetone to release the diatoms. Diatoms were cleaned and prepared by the method of Hohn and Hellerman (1963).

Diatoms were examined at 970 X with an oil immersion lens; they were counted by starting at one edge of the coverslip and viewing a row 159μ wide across the width of the coverslip. Each valve was counted as one-half frustule; broken valves were not included. If fewer than 150 frustules were recorded, another row was counted. Quantitative determinations were made by direct proportion.

Several small centric diatoms were difficult to identify to species, especially those of the genus *Stephanodiscus*. Considerable confusion exists regarding the taxonomic treatment of these small centric species. I have examined Nalewajko's (1966a) Lake Ontario cultures of S. *tenuis* Hust. and compared them with Stoermer and Kopezynska's (1967) samples and data from Lake Michigan. *S. tenuis* and *Thalassiosira* nana Lohmann apparently are both in Lake Ontario but I found it very difficult to discern differences between the species. I, therefore, have grouped them under S. *tenuis.*

Whenever possible, diatoms were identified to species but those taxa which could not be positively identified were assigned a tentative name. The following species were identified (asterisks indicate tentative identification):

Achnanthes clevei Grun.
A. Lanceolata (Breb.) Grun.
Amphiprora o nata Bailey
Amphora ovalis Kütz.
A. ovalis var. *pediculus* Kütz.
Asterionella formosa Hass.
Caloneis bacillum (Grun.) Cleve
Cocconeis pediculus Ehr.
C. placentula Ehr. var. *placentula*
Coscinodiscus radiatus Ehr.
**Cyclotella atomus* Hust.
**C. comta* (Ehr.) Kütz.
C. kutzingiana Thwaites
C. meneghiniana Kütz.
C. pseudostelligera Hust
C. stelligera Cleve & Grun.
Cymatopleura elliptica var. *hibernica* (W. Sm.) Hust.
Cymbella affinis Kütz.
C. microcephala Grun.
Diatoma tenue var. *elongatum* Lyngb.
Fragilaria capucina Desm.
F. crotonensis Kitton.
Gomphonema olivaceium (Lyngb.) Kutz.
C. parvulum (Kütz.) Kütz.
Gyrosigma attenuatum (Kütz.) Rabh.
Melosira ambigua (Grun.) 0. Müll.
M. binderana Kütz.
M. granulata (Ehr.) Ralfs.
M. islandica 0. Müll.
M. italica (Ehr.) Kütz.
Navicula anglica Ralfs.
N. cryptocephala Kütz.
**N. menisculus* Schum.
N. radiosa Kütz.
Nitzschia acicularis W. Sm.
N. dissipata (Kütz.) Grun.
N. holsatica Hust.
N. sigmoidea (Ehr.) W. Sm.
Rhoicosphenia curvata (Kütz.) Grun.
Stephanodiscus astraea (Ehr.) Grun.
S. astraea var. *minutula* (Kütz.) Grun.
**S. hantzschii Grun.*
S. niagarae Ehr.
**S. tenuis* Hust.
Surirella ovata Kütz.
Synedra acus Kütz.
S. ulna (Nitzsch) Ehr.
Tabellaria fenestrata (Lyngb.) Kütz.
T. ftocculosa (Roth) Kütz.

Abundance and Species Composition

Diatom numbers were low throughout the lake during September 8-18, 1964 (Table 1). Highest counts in collections from different strata were 204 cells/ml at the surface (station 32, Fig. 2), 220 cells/ml at intermediate depths (station 78, Fig. 3), and 257 cells/ml at the bottom (station 35, Fig. 4). Diatoms were generally more abundant near the shore. Nalewajko (1966a) also found low diatom numbers (15 cells/ml) in surface samples collected on September 18, 1964.

The species composition of diatoms in the present study differed in the surface and bottom collections. *Asterionella formosa, Fragilaria crotonensis* and *Tabellaria fenestrata* were generally dominant species at the surface (Fig. 2) whereas *Stephanodiscus astraea, S. astraea* var. *minutula,* and *F. crotonensis,* predominated in the deepest samples (Fig. 4). Stoermer and Kopczynska (1967) found a uniform distribution of phytoplankton throughout the water column in Lake Michigan in spring collections but numbers were higher in or just below the thermocline in the fall.

Variation of the surface diatom flora was evident at several eastern stations. *Fragilaria capucina,* which was either absent or rare at the western and central stations, was among the best represented species at most eastern station. Nalewajko (1966a)

Table 1. Abundance (cells/ml) of major diatom species in collection from Lake Ontario, September 8-18, 1964

Station number	Depth (m)	*Asterionella formosa*	*Fragilaria capucina*	*Fragilaria crotonensis*	*Melosira ambigua*	*Melosira binderana*	*Melosira islandica*	*Melosira italica*	*Nitzschia acicularis*	*Nitzschia dissipata*	*Stephanodiscus astraea*	*Stephanodiscus astraea* var. *minutula*	*Stephanodiscus niagarae*	*Stephanodiscus tenuis*	*Tabellaria fenestrata*	Total Diatoms
4	0	8.0	-	36.0	-	0.7	-	-	2.0	-	2.7	0.7	-	8.7	13.3	74.1
	11	11.3	-	55.4	-	0.1	-	-	-	-	1.4	0.7	-	2.6	10.0	84.7
	13	3.3	2.0	30.7	-	-	-	-	-	-	-	0.6	-	0.6	9.3	48.0
7	0	16.1	2.0	35.4	-	-	0.1	-	-	-	0.1	1.3	-	2.6	10.0	69.5
	18	14.0	-	88.1	-	-	-	-	-	0.1	2.0	8.0		2.7	16.1	135.6
	100	14.0	1.3	37.3	-	-	0.6	-	1.3	7.3	4.7	54.1	-	16.0	20.7	161.6
11	0	12.1	11.3	30.7	-	-	-	-	-	-	1.3	-		9.3	22.0	34.1
	18	-	2.0	21.7	-	-	2.1	-	0.1	2.0	4.1	6.1	-	2.0	5.4	48.8
17	0	8.1	2.7	67.4	-	-	1.4	-		-	2.1	2.7	-	18.1	18.0	152.2
	9	30.6	10.7	33.3	-	-	1.3	-	-	1.9	1.9	14.7	-	21.3	25.3	148.8
18	0	15.4	10.0	30.7	-	-	-	-		-	0.7	2.0	-	9.4	18.1	87.5
	11	4.6	6.0	17.3	-	-	-	-	-	-	0.7	1.3	-	0.7	11.3	42.6
	so	-	-	4.7	-	-	4.0	-	0.7	0.1	0.4	2.0	-	0.1	2.0	20.0
28	0	2.7	-	33.3	-	-	2.0	-						0.1	9.3	48.6
	12	12.0	-	38.0	-	-	-	-	-	-	-	-	-	-	25.3	76.1
	142	-	4.0	12.6	-	-	2.7	-	5.3	2.6	5.3	26.0	-	6.0	2.6	10.7
32	0	5.9	1.2	118.9	0.6	14.1	0.6	-	-	0.6	15.3	4.7	1.2	6.7	29.4	204.3
	16	2.0	-	54.1	-	-	-	-	-	-	4.6	6.0	0.7	2.0	18.0	87.5
33	0	5.3	-	43.3	-	-	-	-				0.6	-	-	14.7	64.7
	15	4.0	-	18.1	-	-	-	-	-	-	0.6	-		-	23.4	46.7
	91	1.9	10.7	12.6	1.3	1.9	4.0	-	1.9	1.9	26.1	74.8	0.6	11.3	6.6	161.6
35	0	3.3	-	37.4	-	-	-	-				0.6	-	0.6	16.0	58.1
	15	6.0	-	82.1	-							0.7	-	-	22.6	112.7
	180	-	2.6	12.0	-	12.6	67.3	2.6	-	5.9	88.1	34.7	2.6	4.1	8.7	256.9
38	0	6.1	2.0	23.4	-	-	-	-	-	-	1.3	-		-	15.4	49.5
	12	14.0	-	60.1	-					-	2.0	-		-	17.3	94.7
	97	0.7	-	21.4	-	-	21.4	1.4	2.1	4.1	41.4	58.7	-	2.1	10.1	166.8
40	0	25.3	2.6	29.3	-	-	-	-	-	-	0.6	4.6	-	0.6	37.3	105.5
	18	9.4	13.3	34.8	-	-	6.7	-		-	4.6	11.4	-	0.1	30.7	140.2
45	0			...		-	0.6	-		-	0.6	4.0	-	1.3	18.7	59.5
	38	10.7 4.0	..	196.7	..	-	1.4	-	1.3	-	1.4	8.0	-	2.0	17.4	50.1
50	0	11.3	2.7	28.0	-	-	0.6	-	0.6	0.6	2.0	1.3	0.6	1.3	10.1	12.7
	18	12.6	16.7	54.7	-	-	-	-		-	1.3	7.3	0.6	-	27.4	121.6
55	0	15.3	-	44.7	-					-	0.7	-	-		-	84.1
	30	6.7	4.0	48.7	-							1.4	-	-	30.0	90.7
	169	1.3	-	7.3	-	0.7	5.4	-	0.6	2.0	8.0	52.0	-	4.6	8.6	94.1
59	0	8.0	-	12.2	-	-	1.4	-		-	0.6	3.4	0.6	4.0	11.4	105.5
	11	2.0	-	48.1	-					-	2.1	-		0.7	32.0	88.1
65	0	3.4	8.0	56.3	1.3							6.6	-	4.0	8.0	88.7
	30	4.6	6.6	20.6	-				-	-	-	1.3	-	-	5.3	38.6
	220	0.7	-	19.4	-	-	4.6	0.7	-	0.7	15.3	14.6	-	2.0	3.4	62.1
71	0	1.3	8.0	7.4	-							0.7	-	1.3	1.3	21.4
	30	2.1	-	31.4	-	-	0.6	-		-	0.6	-	-	-	4.1	46.7
	118	-	-	1.3	-	1.3	2.0	-	2.0	5.3	1.3	54.1	-	0.7	-	74.7
74	0	4.6	-	21.4	-	-	1.3	-		-	2.0	10.0	-	4.0	7.4	51.5
	10	0.6	-	30.0	-					-	2.0	12.0	-	0.6	8.6	58.1
78	0	2.6	35.3	28.0	2.0	4.0	3.4	-		-	1.3	16.0	-	4.7	6.6	108.7
	18	7.3	58.2	81.5	-	-	1.3	-	0.1	-	14.1	27.3	-	4.0	11.4	220.3
81	0	1.3	104.7	18.0	14.6					-	6.1	4.0	1.4	2.7	4.0'	180.2
85	0	0.3	8.0	16.0	-	0.3	-	-		-	0.4	3.3	0.2	2.6	8.0	44.1
	31	9.4	34.1	50.8	-	2.0	1.3	-	-	-	2.0	6.0	1.3	0.6	8.1	130.2
81	5	8.6	20.7	56.8	-				-	0.7	0.1	6.0	1.3	1.3	16.1	116.8
91	5	14.1	71.4	38.7	-	-	-	-		-	0.6	0.6	31.9	0.6	5.3	164.8
99	0	4.0	10.7	19.4	-									-	10.1	48.1
	45	0.7	86	12.6	1.3	5.3	5.3	0.7	0.7	6.0	44.7	56.7	-	2.0	8.6	166.2

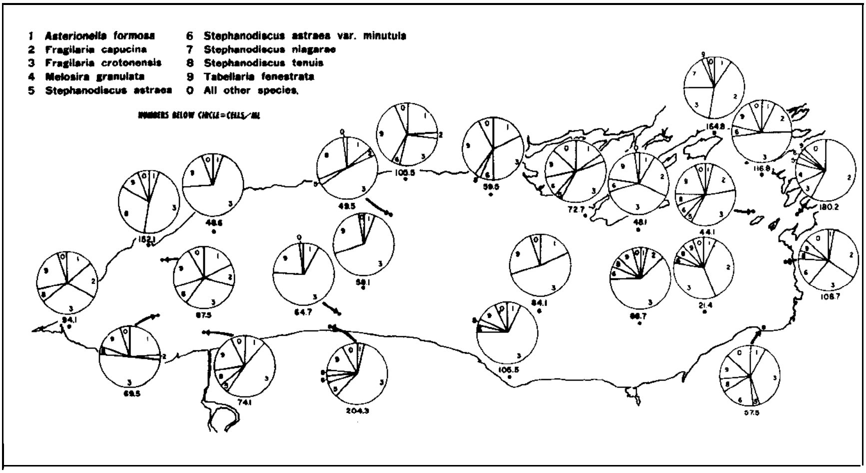

Figure 2. Species composition of diatoms in surface collections, September 8-18, 1964.

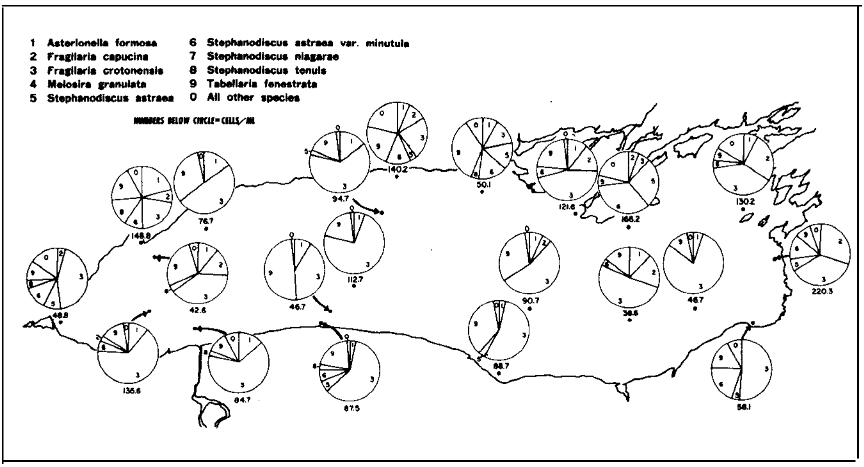

Figure 3. Species composition of diatoms at intermediate depths, September 8-18, 1964.

recorded very low numbers of *F. capucina* in her year-round collections off Gibraltar Point and reported none at two eastern stations during April 26-28, 1965. Holland (1965) reported that *F. capucina* contributed 7% of the total diatom population in the Apostle Islands region of Lake Superior but did not exceed 5% of the total in collections from the rest of the lake. Stoermer and Kopczynska (1967) found *F. capucina* in fairly low numbers at a few stations in Lake Michigan in August-September 1962. Several investigators (Burkholder, 1960; Hohn, 1966; Verduin, 1964, and

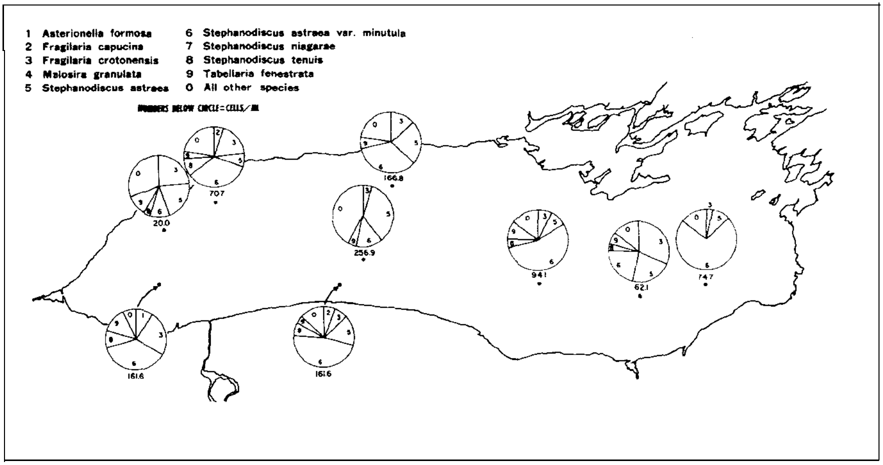

Figure 4. Species composition of diatoms in deep-water samples, September 8-18, 1964.

Wujek, 1967) have emphasized the significance of F. *capucina* in the diatom flora of Lake Erie and its tributaries.

Stephanodiscus niagarae composed 19% of the total diatom population at station 91, but was insignificant at the other stations. The contribution of S. *niagarae* to the total biomass of diatoms is not adequately assessed on a numerical basis because of its large cell volume. Several investigators (Cowell, 1960; Davis, 1954; Lund, 1961, 1964; Nalewajko, 1966b; Rawson, 1956; Verduin, 1954; and Wujek, 1966) have indicated that volume or dry weight of phytoplankton may be a better criterion than enumeration to evaluate productivity.

Melosira ambigua and M. granulata were sparse or absent at most stations, but were common at station 81.

Nalewajko (1966a) reported that *Melosira binderana* and *M. islandica* were the two most important species in her year-round collections. *M. binderana* and *M. islandica were* collected in the present study, but usually only in the bottom strata. Their presence near the bottom may reflect spring or early summer increases of these species which then sank into the deeper waters after thermal stratification. Lund (1954) demonstrated this phenomenon in certain lakes in England for *M. italica* subsp. *subarctica.* He reviewed data collected by Rawson for Great Slave Lake (Lund, 1962) and concluded that periodicity of *M. islandica* is " . . . intimately bound to the changes in the vertical distribution of water density." This same phenomenon may explain the predominance of *S. astraea* and *S. astraea* var. *minutula* in the deepest stations of this study. Nalewajko (1966a) stated that "A very small form of *Stephanodiscus astraea* (Ehr.) Grun., only 8 μ in diameter was very common but was not counted"; she did, however, give data for *S. astraea* which was most abundant in April and May.

Melosira italica was recorded at several stations but in very low numbers. I believe the species is new to the list of Lake Ontario diatoms but this belief is difficult to verify, because as Stoermer and Kopczynska (1967) noted for Lake Michigan taxa, "Definitive treatments of some of the dominant groups are entirely lacking, and this is reflected in the confusion of nomenclature that exists between the various publications."

Stephanodiscus tenuis was common in surface collections at station 17 (maximum count was 48 cells/ml) but, in general, the abundance of this species was low throughout the lake. S. *tenuis* was the most abundant plankter of Nalewajko's (1966a) investigation, and was very common (5,191 cells/ml) during the spring pulse of 1965. M. H. Hohn (personal communication) has also found S. *tenuis* to be a common component of the diatom flora of western Lake Erie. The records for S. tenuis demonstrate the value of year-round sampling for the accurate interpretation of phytoplankton populations.

Asterionella formosa and *Tabellaria fenestrata* were ubiquitous in surface samples of the present study, These species are important components of the diatom flora of the Great Lakes and probably tolerate a wide range of ecological conditions. Nalewajko's (1966a) collections included *T. flocculosa* but not *T. fenestrata.* Only two cells of *T. flocculosa* were observed in the present investigation.

Acknowledgments

I thank M. H. Hohn and E. F. Stoermer for their assistance in taxonomic determinations of the difficult diatom species.

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LAKE ONTARIO PHYTOPLANKTON, SEPTEMBER 1964[1]

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ABSTRACT

Phytoplankton counts on samples collected in Lake Ontario on September 8-18, 1964, showed that green algae were the dominant plankters and diatoms were of secondary importance. The greatest abundance of phytoplankton was close to shore from Toronto, along the southern shore of the lake, and up the eastern shore to the North Channel. The open waters of Lake Ontario were characterized by low numbers of phytoplankton. The relationships among phytoplankton abundance, bottom fauna distribution, and enrichment are discussed.

Introduction

The phytoplankton of Lake Ontario unlike that in adjoining Lake Erie has received little attention; the only comprehensive study was that of Nalewajko, 1966. Other investigations have been limited, either in area or scope (Tucker, 1948; Schenk and Thompson, 1965; McCombie, 1967; and Nalewajko, 1967). The present study, although limited by the short sampling period, covered the entire lake and revealed probable relationships among phytoplankton, bottom fauna, and enrichment.

Methods

Fifty-two samples were collected in Nansen bottles at 23 stations at various depths in Lake Ontario (Fig. 1). A sample of 800 ml from each depth was preserved with Lugol's iodine-potassium iodide solution. Samples were concentrated by allowing the phytoplankton to settle, then reduced to 50 ml by drawing off the supernatant. One milliliter of the thoroughly mixed concentrate

[1]Contribution No. 388, Ann Arbor Biological Laboratory, U.S. Bureau of Commercial Fisheries.

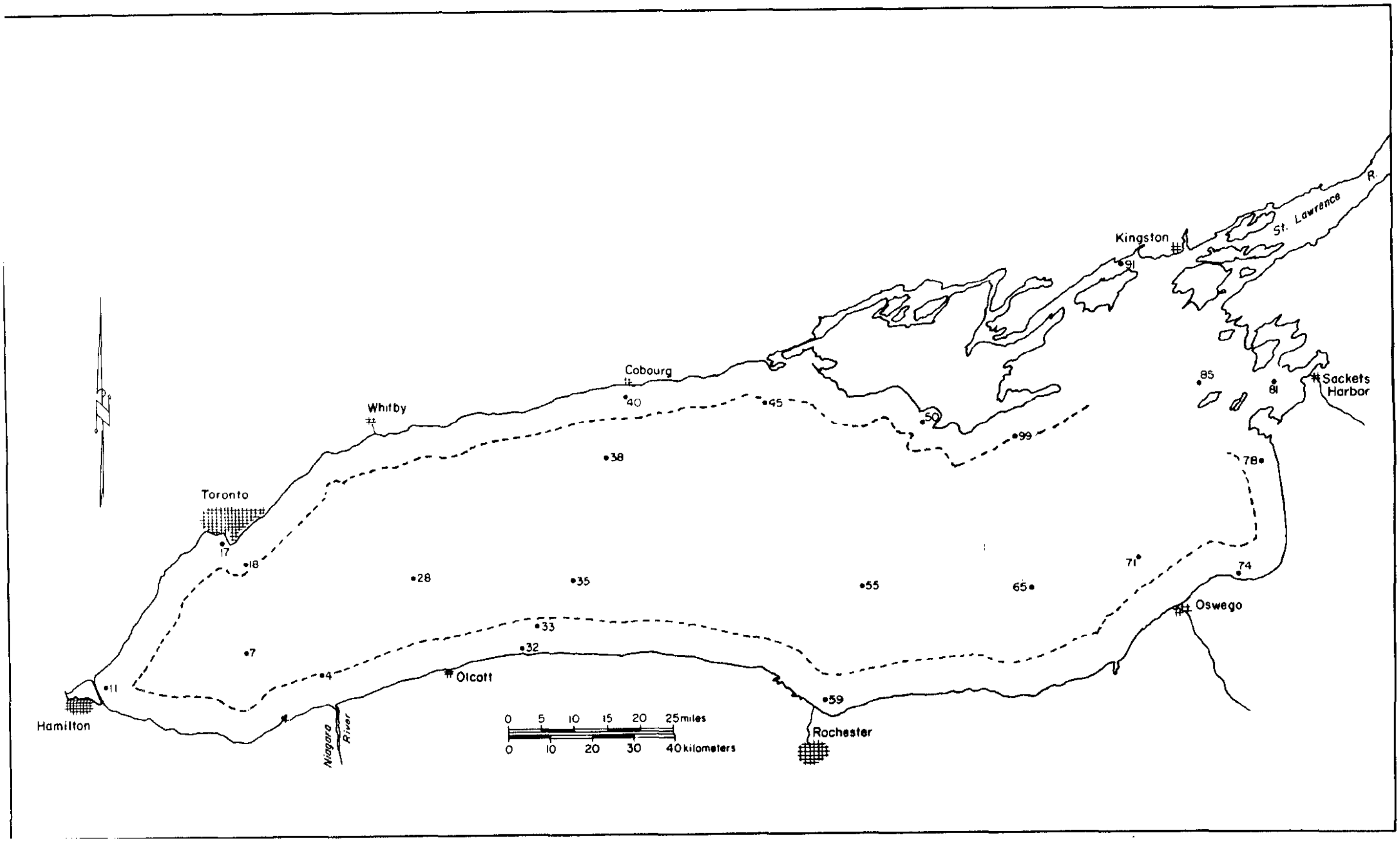

Figure 1. Sampling stations for total phytoplankton. Dotted line delineates the 5-mile inshore waters of the lake from open waters.

was put into a Sedgewick-Rafter cell and counted with a 20X objective and 10X eyepiece. Phytoplankton were counted in one row of the S-R cell if the number of organisms was approximately 500 or greater, and in two rows if the count was substantially less than 500. The field counted was delineated by a Whipple micrometer, 355μ wide, which was calibrated to the microscope. Counts are expressed as the number of cells/ml.

Most of the phytoplankton were identified to species at 200X at the time of counting. Because small plankters cannot be identified to species at 200X, they were identified to genera. Flagellates belonging to the Euglenophyceae were identified only to class. Their small size and the loss of identifying characteristics due to preservation prevented more accurate identification. Diatoms were identified as centrics or pennates. A more detailed account of the diatom population was given by Reinwand (1969).

Total Phytoplankton

Total phytoplankton counts were low (Tables 1, 2, and 3). The number of cells/ml ranged from 257 to 1,755 at the surface (excluding the count of 2,516 at station 81 in Sacket's Harbor), 72 to 1,046 at midwater (5-45 m), and 0 to 44 in the deepest samples (91-220 m).

Counts for surface and midwater samples were highest (642 to 2,516 cells/ml) at inshore stations (1.2 to 5 miles off shore) off Toronto, along the south shore, and up the eastern shore to the North Channel. Abundance of phytoplankton was highest in the Toronto-Hamilton area on the western shore and near the mouth of the Chaumont and Black River Bays at the eastern end of the lake.

The remaining areas of the north shore and most of the central portions of the lake had low densities of phytoplankton.

Although numbers of phytoplankton were greatest at the surface at most stations, numbers were also appreciable at mid-depth. Numbers at mid-depth were greater than those at the surface at four stations (35, 38, 74, and 78).

Major Groups of Phytoplankton

The dominant plankters were green algae, followed by diatoms. These two groups were present in surface and midwater samples at all stations (Table 4). Green algae were 2-5 times as abundant as diatoms in nine surface samples. In midwater samples green algae were 2-9 times as abundant as diatoms at seven stations. Although diatoms were more abundant than green algae in two surface and six midwater samples, abundance of diatoms never exceeded 1.7 times that of the green algae. Blue-

Table 1. Phytoplankton counts (cells/ml)

[AH samples taken at surface; station locations given in Fig. 1;

Taxon	4	7	11	17	18	28	32
Chlorophyceae							
Ankistrodesmus convolutus Corda	4	-	4	9	5	-	-
A. falcatus (Corda) Ralfs	4	2	4	21	24	2	7
Closteriopsis longissima Lemmermann	-	-	-		4	-	-
Coelastrum *cambricum* Archer	-	-		-	-	-	-
C. microporum Naegeli	24	26	859	135	14	23	32
Cosmarium sp. Corda	-	-		2	2	2	4
Oocystis spp. Naegeli	67	65	148	126	65	65	148
Pediastrum duplex Meyen	72	-	-	56	12	-	42
P. simplex var *duodenarium* (Bailey) Rabenhorst	18	-	56	35	82	30	-
Scenedesmus bijuga (Turn.) Lagerheim	51	33	102	67	59	67	51
S. quadricauda (Turp.) de Brébisson	32	-	7		4	-	5
Schroederia Judayi G. M. Smith	2	-	7	10	4	5	-
Sphaerocystis Schroeteri Chodat	68	37	183	111	196	86	179
Staurastrum sp. Meyen	-	-	28	5	9	2	-
Tetraedron minimum (A. Braun) Hansgirg	2	-	7	9	5	-	2
Unidentified filament	-	-		84	30	9	-
Others[2]	-	-	4	-	-	49	2
Total Chlorophyceae	344	163	1,400	674	511	340	482
Bacillariophyceae							
Centrics	172	35	228	32	76	95	179
Pennates	67	68	46	23	107	90	58
Total Baciilariophyceae	239	103	274	255	183	185	237
Myxophyceae							
Anabaena flos-aquae (Lyngb.) de Brébisson	26	14	-		98	54	-
Aphanizomenon *flos-squae* (L.) Ralfs	82	12	-		2	95	21
Gomphosphaeria lacustris Chodat	-	-	-	-	-	-	-
Total Myxophyceae	108	26	-	-	100	149	21
Dinophyceae							
Ceratium hirundinella (O.F.M.) Schrank	-	-	7	4	5	2	-
Peridinium sp. (Ehrenberg) Stein	-	7	4	-	- 2	-	-
Total Dinophyceae		7	11	4	7	2	-
Euglenophyceae	58	9	70	93	184	154	128
Chrysophyceae							
Dinobryon sp. Ehrenberg	- I	-	-	-	-	4	-
Total Phytoplankton	751	308	1,755	1,026	985	834	868

[1] Two surface samples were collected at station 85.
2 *Closterium* sp. Nitzsch, Crucegenia *quadrata* Morren, *Dictyosphaerium ehrenbergianum* Naegeli, *Dimorphococcus lunatus* A. Braun,

from Lake Ontario, September 1964

dash indicates organism was not encountered in the sample.]

Station number															
33	35	38	40	45	50	55	59	65	71	74	78	81	'85	'85	99
-	-			4	5	-	5	2	7	4	-		9	4	4
2	-	-	9	-	4	4	7	5	10	12	18	18	2	4	12
-	-	-	5	-	-	-	-	-	2	-	-		4	2	5
-	-	-	-	-	-		-	-			121	176	70	119	-
7	12	24	32	7	30	70	88	46	46	33	95	77	44	70	65
2	-	4	-	2	-	-	2	-	-	-	-			2	-
53	53	47	49	46	54	33	105	96	84	39	76	53	60	82	65
	9	-	2	-	81	-	28	91	10	91	76	4	58	30	-
33	-	-	37	14	63	-	12	10	23	61	33	77	32	28	14
74	26	26	24	35	21	12	56	56	60	54	126	123	24	35	28
-	-	10	-	-	-	7	-	-	-	-	-		18	-	-
-	-	-	-	-	-	12	2	-	-	-	-			-	-
56	153	-	-	-	-	-	-	26	23	14	24		9	7	9
2	2	5	2	5	7	7	4	2	2	2	-		4	4	-
5	-	-	-	4	12	-	-		4		4		5	12	4
	18	-	-	49	-	9	-	-	-	-	-			-	-
-	-	-												-	-
234	273	116	2	-	24	27	-	74	-	-	188	528	339	399	206
112	23	111	114	65	46	32	144	198	60	191	100	123	70	102	142
61	46	53	135	26	39	102	54	35	5	58	90	372	77	91	53
173	69	164	249	91	85	134	198	233	65	249	190	495	147	193	195
100	37	7	-	-	10	111	-	10	40	-	116	664		133	-
-	-	-	-	-	-	-	149	63	35	14	-	622	19	-	82
-	-	-	-	-	-	204	32	-	-	-	58	14		-	-
100	37	7	-	-	10	315	181	73	75	14	174	1,300	19	133	82
-	-	-	-	-	2	-	-	2	-	4	2	7		4	-
-	-	-	4	-	-	-	-	2	2	2	4	21	-		
-	-	-	4	-	2	-	-	4	2	6	6	7		4	-
79	2	5	28	-	-	-	98	123	72	61	21	165		18	77
2	2	-	-	-	-	-	-	-	-	-	-	-			
588	383	232	443	257	378	637	786	843	485	642	964	2,516	505	747	560

Table 2. Phytoplankton counts (cells/ml)

[Samples taken at mid-depths (5-45 m); station locations given in Fig. 1;

Taxon	4 (11)	4 (13)	7 (18)	11 (18)	17 (9)	18 (11)	28 (12)	32 (16)
Chlorophyceae								
Ankistrodesmus convolutus Corda						2		
A. falcatus (Corda) Ralfs	7				4	9	4	
Closteriopsis longissima Lemmermann		2			2			
Coelastrum microporum Naegeli	7	19		93	2	119	23	
Cosmarium sp. Corda				2		2		2
Lagerheimia ciliata (Lag.) Chodat		2		9		2	2	
Oocystis spp. Naegeli	33	28	10	128	33	74	14	16
Pediastrum duplex Meyen		116	46		96	7		
P. simplex var. duodenarium (Bailey) Rabenhorst	40	37						193
Scenedesmus bijuga (Turp.) Lagerheim	56	46		35	10	65	5	7
S. quadricauda (Turp.) de Brébisson	4	7		18		14		
Sphaerocystis Schroeteri Chodat	86		2	37		51	102	
Staurastrum sp. Meyen		2		2	2	2	2	
Tetraedron minimum (A. Braun) Hansgirg				4	2	2	2	
Unidentified filament						4	18	
Others [1]								
Total Chlorophyceae	233	259	5 8	328	151	353	172	218
Bacillariophyceae								
Centrics	77	63	7	72	79	195	107	146
Per-mates	63	46	5	144	148	256	67	220
Total Bacillariophyceae	140	109	12	216	227	451	174	366
Myxophyceae								
Anabaena flos-aquae (Lyngb.) de Brebisson	54	42						
Aphanizomenon flos-aquae (L.) Ralfs							24	
Unidentified filament	-		-	-	-		-	
Total Myxophyceae	54	4 2					24	
Euglenophyceae	28	33		7	16	137	93	
Others [2]	2		2				2	
Total phytoplankton	457	443	72	551	394	941	465	584

1 Closterium sp. Nitzsch, *Coelastrum cambricum* Archer, *Schroederia* Judayi G. M. Smith.

2 *Dinobryon* sp. Ehrenberg, *Ceratium hirundinella* (O.F.M.) Schrank Peridinium sp. (Ehrenberg) Stein.

from Lake Ontario, September 1964

dash indicates organism was not encountered in the sample.]

33 (15)	35 (15)	38 (12)	40 (18)	45 (38)	50 (18)	55 (30)	65 (30)	71 (25)	74 (10)	78 (18)	85 (31)	91 (5)	99 (45)
			-	-					4	4	2	4	
5	2	4	-	-	7	-	-	2	9	4			
	2	-			2	-	-	-	2	-			2
56	60	40	4	5	4	12	7	7	104	105		14	
2	7	2	2	-	2	-		4	2	2	2	-	
					-	-	-						8
58	61	51	37	2	9	-	14	9	84	26	14	23	19
					53	-	28	-	146	142		112	
19	-	14	28	26	44	-	28	40	142			35	
74	24	21	19	14	7	-	-	-	96	105	23	14	16
	4	-				4	-	-	7				8
	146	23			-	-	-	-	14	-		2	
			4	-	2	-	7	4	5	4	4	2	
4	2	2		4	2	-			4	9		2	
	42	26	174	12		31	-	-	-	-			37
-	-	-	- 2	2	2	-	-	-	-	134	-	158	
218	350	183	270	65	134	47	84	66	619	535	45	366	88
116	19	167	33	72	10	5	16	42	167	153	35	72	8
- 93	74	74	- 42	33	5	21	37	24	49	246	23	133	10
209	93	241	75	105	15	26	53	66	216	399	58	205	18
		86	-	-	-	-	-	-	5	-			
					-	-			12	100		209	
-	-	-	-	-	- -	- -	- -	- -	-	2			
		86			-	-	-	-	17	102		209	
51	181	72	-	-	-	-	-	-	139	10		60	
5	2	-					-	-	7	-		2	
483	626	582	345	170	149	73	137	132	998	1,046	103	842	106

Table 3. Phytoplankton counts (cells/ml) from Lake Ontario, September 1964

[Samples taken just above the bottom; station locations given in Fig. 1; dash indicates organism was *not* encountered in the sample.]

Taxon	Station number and (in parentheses) depth in meters						
	7 (100)	17 (91)	28 (142)	33 (91)	38 (97)	65 (220)	71 (178)
Chlorophyceae							
Coelastrum microporum (Naegeli)			2	-	-	-	-
Bacillariophyceae							
Centrics	2	2	-	28	40	14	28
Pennates	4	5	9	10	4	-	4
Total Baccilariophyceae	6	7	9	38	44	14	32
Total phytoplankton	6	7	11	38	44	14	32

Species

None of the genera or species of phytoplankton were confined to any one section of the lake. Three forms (*Scenedesmus bijuga, Oocystis* spp., and Coelastrum microporum) occurred at all stations, either at the surface, at mid-depth, or both. Organisms at 75% of the stations were *Ankistrodesmus falcatus, Pediastrum duplex, P. simplex* var. *duodenarium, Sphaerocystis Schroeteri, Tetraedron minimum,* Cosmarium, *Staurastrum,* and members of the Euglenophyceae. Diatoms were found at all stations (for a list of the species see Reinwand, 1969).

The trophic nature of Lake Ontario cannot be described simply. According to Beeton (1965) Lake Ontario is a mesotrophic lake, with the biota of oligotrophy and the physicochemical characteristics of eutrophy. Its chemical content is understandably similar to that of Lake Erie, since Lake Erie water moves from west to east, eventually entering Lake Ontario through the Niagara River. Thus, the chemical content which in turn affects the trophic nature of Lake Ontario, is influenced in large measure by the chemical conditions in Lake Erie.

The composition of phytoplankton in Lakes Erie and Ontario was similar. Both lakes are dominated by diatoms for most of the year, but green and blue-green algae often become dominant during the summer (Nalewajko, 1966; Tucker, 1949; Schenk and Thompson, 1965; Davis, 1962, Burkholder, 1960). The mid-september sampling period of this study showed that the Chlorophyceae were most important.

Table 4. Number of cells/ml of various phytoplankton at the surface and mid-depths of Lake Ontario, September 1964

Station	Depth (meters)	Chloro-phyceae	Bacillario-phyceae	Myxo-phyceae	Total phytoplankton
4	0	344	239	108	751
	11	233	140	54	475
7	0	163	103	26	308
	18	58	12	0	72
11	0	1,400	274	0	1,755
	18	328	216	0	551
17	0	674	255	0	1,026
	9	151	227	0	394
18	0	511	183	100	985
	11	353	451	0	941
28	0	340	185	149	834
	12	172	174	24	465
32	0	482	237	21	868
	16	218	366	0	584
33	0	234	173	100	588
	15	218	209	0	483
35	0	273	69	37	383
	15	350	93	0	626
38	0	116	164	7	292
	12	183	241	86	582
40	0	162	249	0	443
	18	270	75	0	345
45	0	166	91	0	257
	38	65	105	0	170
50	0	281	85	10	378
	18	134	15	0	149
55	0	188	134	315	637
	30	47	26	0	73
59	0	309	198	181	786
65	0	410	233	73	843
	30	84	53	0	137
71	0	271	65	75	485
	25	66	66	0	132
74	0	312	249	14	642
	10	619	216	17	998
78	0	573	190	174	964
	18	535	399	102	1,046
81	0	528	495	1,300	2,516
85	0	369	170	76	626
	31	45	58	0	103
91	5	366	205	209	842
99	0	206	195	82	560
	45	88	18	0	106

Table 5. Comparison of high phytoplankton counts (cells/ml) and abundance of certain water-quality-related benthos (number/m^2) at selected inshore stations

Station	Total phytoplankton		Bottom fauna [1]		
			Saprophobes		Saprophile
	Surface	5-45 meters	*Stylodrilus heringianus* [2]	*Pontoporeia affinis* [3]	*Tubifex tubifex* [4]
4	751	457	254	0	160
11	1,755	551	92	2,041	0
17	1,026	394	0	5	794
18	5985	5941	869	3,380	0
32	868	584	1,630	0	0
59	786		0	0	0
[6]65	843	137	27	0	0
74	964	1,046	0	675	0
81	2,516		11	0	0
91		842	583	729	0

1 Data from Hiltunen (1969).
2 Range at other stations: 583 to 4,790; median 1,183.
3 Range at other stations: 383 to 9,968; median 1,674.
4 Range at other stations: 0 to 54.
5 Deep water; high phytoplankton counts may be due to currents.
6 Station about 15 miles offshore.

Although the phytoplankton of Lake Ontario was qualitatively similar to that of Lake Erie, it was quantitatively more similar to Lake Michigan. That Lake Ontario has not progressed to the same level of eutrophy as Lake Erie may be due to the large volume of deep water in its basin (Beeton, 1965), and in this respect Lake Ontario may be considered trophically similar to Lake Michigan.

A study of Lake Michigan by Stoermer and Kopczynska (1967) revealed that total phytoplankton counts on August 7, 1962, ranged from 215 to 1,387 cells/ml. These figures fell within the range observed in Lake Ontario in September 1964. Similarly, data presented by Damann (1966) for average monthly counts at water plants in Chicago in 1928-45 and Milwaukee in 1940-63 fell within the range of counts in Lake Ontario. Stoermer and Kopczynska (1967) and Damann (1945) found that diatoms were dominant in Lake Michigan, but unlike Lake Ontario, green and blue-green algae were relatively unimportant.

The occurrence of the majority of the highest total phytoplankton counts (greater than 700 cells/ml) close to shore, especially near heavily populated areas (stations 4, 11, 17, 59, 78, and 81) suggests that these high densities may be the result of enrichment. This view finds support from data on the bottom fauna (Hiltunen, 1969) in these areas which was characterized by relatively large numbers of the pollution-tolerant *Tubifex tubifex* and by the absence or low numbers of the pollution-intolerant *Stylodrilus heringianus* and *Pontoporeia affinis* (Table 5). Although the large numbers of phytoplankton close to shore conceivably might be due to currents or perhaps to warmer water, the presence of a saprophile and the absence of saprophobes in the bottom fauna in these areas suggest that enrichment offers the better explanation.

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THE BENTHIC MACROFAUNA OF LAKE ONTARIO[1]

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ABSTRACT

The presence and relative abundance of bottom macrofauna in Lake Ontario are documented, Bottom samples were collected at 24 stations in September 1964. The quantity of organisms and the distribution of some species were affected by depth of water. Samples from the shallower stations (47.5 m or less) yielded an average of 41,631 organisms per m2 whereas the deeper stations (91.5 m or more) yielded an average of only 7,938. The Oligochaeta, the most abundant group of macroinvertebrates, was represented by four families - Enchytraeidae, Lumbriculidae, Naididae, and Tubificidae. The lumbriculid worm, *Stylodrilus heringianus,* and the burrowing amphipod, *Pontoporeia affinis,* were rare or absent in areas affected by pollution. In kinds and abundance of organisms, the bottom fauna in Lake Ontario was generally similar to that in Lake Michigan.

Introduction

The only early published data on the bottom fauna of Lake Ontario are the reports of Nicholson (1872 and 1873) and Adamstone (1924), which are brief and deal only with fauna from the western end of the lake. Occasional taxonomic monographs have recorded certain species from the lake, but none of them give a lakewide treatment of the macrobenthos. Consequently, no qualitative or quantitative comparisons can be made between past and present records.

Methods and Materials

Bottom samples for benthos were collected at 24 stations (Fig. 1), which were selected to provide broad and representative

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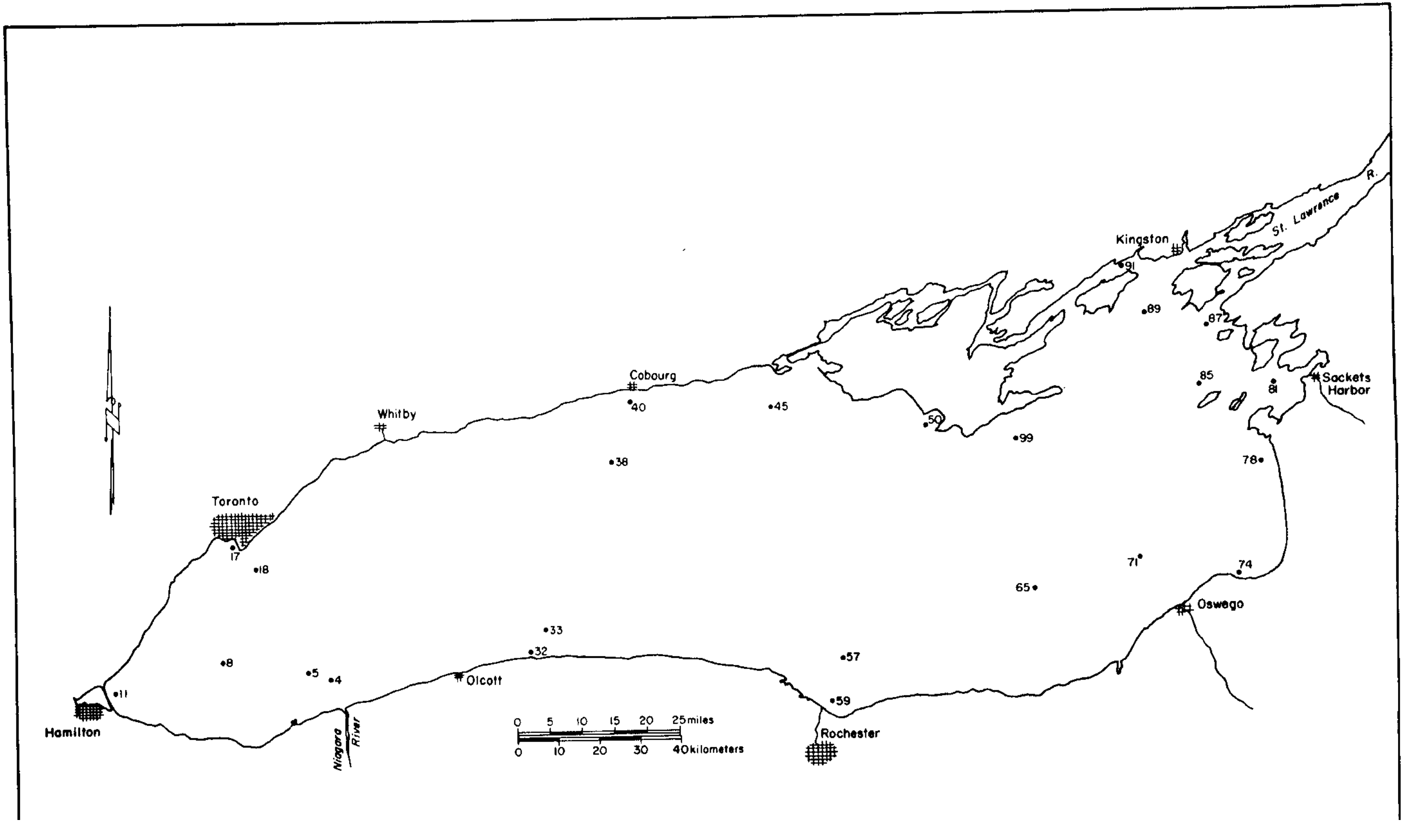

Figure 1. Lake Ontario showing location of stations for bottom samples.

coverage of the lake. Three samples were taken at each station (except where otherwise indicated in Table 1) with a 1/16 m^2 Smith-McIntyre dredge, and washed through a U.S. Standard No. 30 wire mesh screen (about 0.5-mm mesh). The residue was preserved in formalin and the organisms were later sorted under magnification of 15 diameters.

The present work includes primarily those organisms which were in or on the bottom sediment and which were retained in the residue after the samples were screened. Although hydras were found at a few stations, they are not included here because most were undoubtedly lost or destroyed when the samples were sieved. Occasionally some planktonic cladocerans (including *Leptodora kindtii* Focke), calanoid copepods, and *Mysis relicta* were observed but they were most likely trapped in the dredge as it was lowered to the bottom. The presence of several *Mysis relicta,* however, justified inclusion of this form in Table 1.

When possible, the organisms were identified to species. The classification of various groups is according to several current authorities. The nomenclature of the Oligochaeta follows Brinkhurst (1964, 1965) and Brinkhurst and Cook (1966). Over 7,800 oligochaetes were individually examined under microscopic magnification of 35X or more. Their identification to species was based on external or internal organs. The one lumbriculid species, *Stylodrilus heringianus,* and the Naididae were identified by the configuration of their chaetae. Some tubificid species were determined by the shape of their somatic chaetae (which does not change with maturity) and others were recognized by organs evident only at sexual maturity. Those identified solely by their chaetae were: *Aulodrilus, Peloscolex, Rhyacodrilus,* and *Limnodrilus udekemianus, Potamothrix vejdovskyi, Psammoryctides curvisetosus,* and *Tubifex ignotus.* Those identified by anatomical features evident at sexual maturity were: *Limnodrilus cervix, L. hoffmeisteri, L. profundicola, Potamothrix moldaviensis, Tubifex kessleri americanus,* and *T. tubifex.* The abundance of species in the latter group was underestimated because only the sexually mature individuals could be positively identified. Specimens that were sexually immature and could not be identified by other means were categorized as “unidentifiable immature with capilliform chaetae” and “unidentifiable immature without capilliform chaetae” (Table 1). The immature forms of *Potamothrix bavaricus, Tubifex kessleri americanus,* and *T. tubifex,* compose the group with capilliform chaetae, but the first two species were rare. The second category is composed of immature forms of all other species.

Valvata sincera and *V. tricarinata* include all forms which have shell characteristics that most nearly fit each respective species. No attempt was made to separate the shell forms which

Table 1. Number of organisms per Square meter
[Depth in meters

Organism	74 (11)	4 (13.5)	11 (18.5)	[1]17 (18.5)	32 (18.5)	40 (18.5)	50 (18.5)	59 (18.5)	78 (18.5)
Platyhelminthes									
Neorhabdocoela	...	16	32	11	59	38	65	...	...
Tricladida	...	...	...	...	5	...	108	...	...
Nemata	103	42	11	5	178	567	270	86	189
Annelida									
Hirudinea	...	...	...	...	...	...	103	32	11
Glossiphoniidae									
Helobdella stagnalis (Linnaeus)	...	...	...	...	...	...	...	...	...
Piscicolidae	...	...	...	...	...	...	...	...	...
Oligochaeta									
Enchytraeidae	...	178	...	...	...	...	...	...	...
Lumbriculidae									
Stylodrilus heringianus Claparede	...	254	92	...	1,630	3,602	4,790	...	167
Naididae									
Arcteomis lomondi (Martin)	...	...	...	...	...	...	...	...	...
Chaetogaster diaphanus (Gruithuisen)	...	...	...	[1]...	...	5	...	...	...
Nais SP.	...	5	...	...	...	5	...	...	...
Ophidomis serpentine (Müller) . . .	...	...	...	16	...	...	...	...	...
Piguetiella michiganensis Hiltunen	5	...	...	...	...	...	...	...	...
Slavina appendiculata (d'Udekem)	...	....	...	...	...	...	...	...	5
Vejdovskyella intermedia (Bretscher)	...	...	...	...	...	...	...	11	...
Tubificidae									
Aulodrilus americanus Brinkhurst and Cook	...	...	...	...	...	...	5	...	5
A. limnobius Bretscher	...	...	...	...	...	...	...	...	...
A. pigueti *Kowalewski*	...	...	...	...	...	...	...	...	16
A pluriseta (Piguet)	...	135	22	...	...	...	...	648	200
Limnodrilus cervix Brinkhurst . . .	...	42	...	49	...	...	...	...	...
L. hoffmeisteri Claparede	...	156	11	923	...	42	5	329	...
L. profundicola (Verrill)	...	...	...	...	...	...	...	...	...
L. udekemianus Claparede	...	27	...	...	...	5	...	11	...
Peloscolex ferox (Eisen)	...	42	5	...	2,036	...	...	81	1,431
P. multisetosus **(Smith)**[3]	...	346	233	1,976	...	...	...	1,114	...
P. variegatus Leidy	...	...	...	...	...	...	...	...	...
Potamothrix bavaricus (Oschmann)	...	...	...	...	...	...	...	...	...
P. moldaviensis Vejdovsky and Mrazek	103	653	259	113	5	...	...	119	540
P. vejdovskyi (Hrabe)	70	2,025	480	49	92	38	227	1,085	205
Psammoryctides curvisetosus Brinkhurst and Cook	...	...	...	...	...	...	16	...	...
Rhyacodrilus coccineus (Vejdovsky)	5	...	...	...	...	...	...	...	...
R montanus (Brinkhurst)	...	...	...	...	...	...	...	...	...
Rhyacodrilus SP.	...	...	...	...	...	...	...	...	...
Tubifex *ignotus (Stolc)*	...	1,528	16	...	...	...	...	...	...
T. kessleri americanus Brinkburst and Cook	...	...	...	...	...	...	...	...	...
T. tubifex (Müller)	...	160	...	794	...	...	...	...	...
Unidentifiable immature									
With capilliform chaetae	...	1,199	1,145	25,677	...	16	...	356	49
Without capilliform chaetae	1,885	13,645	4,909	16,265	70	383	400	9,730	4,099
Polychaeta									
Manayunkia speciosa Leidy	...	...	...	...	2,144	5	...	27	77
Arthropoda									
Arachnoidea									
Hydracarina	22	5	...	...	42	38	22	...	32

1 Abundance of oligochaetes based upon only one grab. *Chaetogaster diaphanus was* present in samples not examined.
[2]All values are based upon only one incomplete grab.
[3]**Includes** the less common subspecies *longidentus* Brinkhurst and Cook,
[4]Species determined as Unionicola *crassipes* **(Müller)** by David R. Cook.

at various sampling stations in Lake Ontario, 1964
in parentheses]

	81 (19)	87 (23.5)	91 (27.5)	289 (29)	85 (32)	45 (38.5)	99 (47.5)	5 (91.5)	8 (91.5)	18 (91.5)	33 (91.5)	38 (91.5)	57 (91.5)	71 (183)	65 (225)
	59	11	...	...	81	77	...	..	...	..	...	...	..	...	...
	86	5	16	11	...	124	...		...	5		11	...	...	11
	92	86	405	270	972	362	891	42	42	151	38	160	42	...	5
	..	...	...	22	5	...	5		...	...	...	...	...	...	...
	108	77	..	...	...	...	..	..	...	...	...	...	11	...	...
	...	...	...	..	5	...	...		...	...	...	...	...	...	...
	..	...	...	.	...	...	194		...	5	...	65	...	...	...
	11	...	583	686	1,183	1,863	2,106	237	42	869	1,237	799	864	32	27
	...	...	...	...	5	...	...		...	...	...	...	...	...	...
	...	...	...	...	...	...	...	..	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	..	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	.	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	..	...	...	..	...
	...	...	...	...	...	...	...	...	...	...	...	.	..	..	...
	...	...	...	...	...	...	22	...	...	...	...	...	...	...	...
	...	70	...	...	...	...	...		...	...	...	...	...	...	...
	11	...	...	...	...	...	...		...	...	...	...	...	...	...
	...	...	...	...	...	...	...	.	...	...	...	...	...	...	...
	27	983	...	...	...	...	...	.	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	.	...	...	...	...	...	...	...
	...	...	16	22	38	32	108	.	42	11	11	38	5	178	38
	...	...	...	...	...	...	...		...	...	...	...	...	11	11
	...	...	...	...	...	...	...	..	...	...	...	...	...	...	...
	966	156	2,057	215	589	...	5	..	...	...	...	...	...	...	5
	...	...	...	...	...	...	...	.	...	11	...	...	...	...	...
	...	...	...	...	...	11	11	..	...	...	...	16	...	...	...
	...	16	...	...	...	...	...	...	...	...	...	...	...	...	...
	38	11	...	...	448	...	...	..	...	...	...	...	...	...	...
	27	156	...	...	540	...	...	..	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	..	...	...	...	...	...	...	...
	11	...	...	...	...	...	...	..	...	...	...	...	...	...	...
	...	...	...	...	...	...	335		5	...	5	...	...	...	...
	...	...	...	...	...	...	...	..	...	...	...	...	...	...	...
	...	...	...	...	...	..	...	..	...	...	...	...	...	27	22
	...	..	...	..	...	...	5	..	54	...	16	...	...	5	...
	5	27	...	97	124	...		49	259	65	92	...	42	145	140
	113	27	243	454	1,145	16	464	11	27	38	11	32	27	383	178
	804	49	16	...	...	...	...	...	...	...	...	...	...	...	...
	...	45	16	11	...	5	...	...	...	...	...	...	...	...	...

Table 1.

Organism	74 (11)	4 (13.5)	11 (18.5)	[1]17 (18.5)	32 (18.5)	40 (18.5)	50 (18.5)	59 (18.5)	78 (18.5)
Crustacea									
Ampbipoda									
Gammarus sp.[5]	1,199	189	...		891	...	22	1,350	232
Pontoporeia affinis Lindstrom	675	...	2,041		...	8,288	4,217	...	1,064
Isopoda									
Asellus comnumis Racovitza[G]	...	...	233	...	49	...	5	327	.
Mysidacea									
Mysis relicta Loven	...	...	...		.	...	..	..	.
Ostracoda	11	16	281		...	77	70	54	..
Insecta									
Diptera									
Ceratopogonidae (=Heleidae)					...	...	...	...	5
Chironomidae (=Tendipedidae)									
Chironomus spp.7	...	...	16	...	...	...	...	...	118
Cryptochironomus cf. abortims Malloch	...	...	...	...	...	...	...	...	5
C. cf. *camptolabis* Kieffer	...	5	..		...	38	...	...	..
C. cf. digitatus Kieffer	11	...	..		...	...	22	...	54
C. cf. *nais* (Townes)	..	..	...	..	5	.. *	...	...	5
c. cf. *vulneratus* (Zetter-sted)[8]	...	..	..		5	...			...
Heterotrissocladius Spp.	...	5	81		27	167	38	:::	38
Micropsectra sp.	49	...	77		70	313	...	...	184
Microtendipes. sp.	5	...	...	.	...	11	11	...	22
Paralauterborniella Sp.	...	...	5	..	...	.	..	...	...
Polypedilum cf. fallax (Johannsen)	.,.	...	...	...	...	11	...	...	.
Potthastia cf. longimana Kieffer	5	...	,.	...	...	...	*11*	...	16
Procladius spp.	.	38	156	178	16	5	27	140	200
Pordiamesa cf. *bathyphila Kieffer*		.	...	..	...	5	42	...	...
Stictochironomus Sp.		.	...	..	...	...	...	...	11
Trichoptera									
Oecetis Sp.	...	..	...	.	..	.	...	.	5
Mollusca									
Gastropoda									
Amnicola binneyana Hannibal	..	...	...	...	11	...	...	...	...
A. limosa Say	..	...	...	...	...	...	...	...	718
A. lustrica Pilsbry	...	...	...	...	5	...	...	...	...
Amnicola spp.	561	...	...	...					..
Bulimus tentaculatus (Linnaeus)		...	...	..	11	..	..	..	..
Lymnaea emarginata say	.	...	...	...	...	..	49	5	27
Physa sp.		11	...	5	5	...	32	5	5
Valvata sincera Say [sensu lato]	680	5	16	...	86	5	184	65	556
v. *tricarinata* (Say) [sensu lato]	..	..	..	...	49	11	5	...	...
Pelecypoda									
Pisidium SPP.	1,889	3,941	2,440	1,733	2,122	2,554	6,188	8,477	3,062
Sphaerium corneum (Linnaeus)	...	685	65		351	11	1,080	1,371	27
S. (Musculium) *lacustre* jayense Prime	...	11	...		...	..	...	5	..
S. nitidum Clessin	...	...	59	11	189	...	297	.	...
S. simile (Say)	..	5	..	.	..	..	.	...	...
S. striatinum (Lamarck)	...	...	..	..	145	...	49	5	...
s. (M.) transversum (Say)	38	167	..	..	49	...	...	...	..

5 Probably G. *fasciatus Say.*
6 Pending taxonomic revision by W. D. Williams.
7 Subgenera *Limnochironomus* and *Chironomus* sympatric at some stations.
8 Cf. species "a" of Curry (1958).

(Continued)

Station number															
	81 (19)	87 (23.5)	91 (27.5)	[2] 89 (29)	85 (32)	45 (38.5)	99 (47.5)	5 (91.5)	8 (91.5)	18 (91.5)	33 (91.5)	38 (91.5)	57 (91.5)	71 (183)	65 (225)
	1,787	740	729	22	16	...	...	...	...	...	...	...	...	...	...
	27	38	729	3,866	7,970	8,186	9,968	432	1,010	3,380	940	1,750	1,674	383	453
	1,912	1,345	1,053	561	5	..	5	...	..			.	.	..	..
		..	..		..	5		11		5		5	...	...	42
	...	599	81	124	...	27	308	...		113	11	97	151	11	22
	...	...	...	...	...	...	...	...	..	..	...	...	...	...	...
	16	1,403	...	11	27	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...		...	...	...	...	...	...
	...	...	...	11	...	...	...	...	.	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	..	,..	...	...	...	...	...
	...	...	...	...	...	...	...	...		...	...	...	...	...	...
	...	...	...	...	...	...	...	...	..	,,..	...	...	...	...	...
	11	...	...	...	...	...	5	324	81	308	173	248	302	189	49
	124	156	2,268	394	329	...	22	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	* .	...	...	...	...	...	...
	...	...	...	...	...	16	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	..	..	.	...	...	...	...
	38	173	65	11	42	...	...	5	.	5	.	...	...	...	...
												...	...	...	...
									...	...	...	...	...	...	...
	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	..	..,	...	...	...	...	...
	...	...	...	...	...	...	...	...	..	...	,..	...	...	...	...
	...	...	...	...	...	...	...	...	..	...	..	...	...	...	...
	200	...	...	...	...	...	...	...	...	..	...	...	...	...	...
	108	...	...	...	...	...	...	...		...	..	...	...	...	...
	5	11	...	11	81	...	...	...	.	...	..	...	...	...	...
	...	...	...	...	5	5	...	...	..	...	* ..	...	...	...	...
	421	302	259	11	38	5	...	...	...	..	.	...	...	...	...
	86	59	...	...	...	...	...	...	...	...	...	...	...	...	...
	616	1,328	2,171	1,539	2,224	3,434	3,958	211	151	556	437	194	637	97	16
	42	146	275	146	454	11	...	...	...	...	...	...	...	...	...
	...	...	...	...	...	...	...	...				...	...	...	...
	...	108	...	...	...	...	...	...		...	...	...	...	...	...
	...	5	...	...	...	...	...	...	.	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	..	...	...	...	...	...	...
	...	...	...	...	...	...	...	...		...	...	..	.	.	.

varied from the typical shape and are sometimes given individual taxonomic status. The species of *Pisidium* are difficult to identify and, except for *P. conventus,* I consider them here only by genus.

The stations listed in Table 1 are ranked according to depth from 11 to 225 *m*. Because the maximum habitat depth for many species is between 47.5 and 91.5 m, the stations were separated into two depth zones -"shallow" (47.5 m or less) and "deep" (91.5 m or more). These arbitrary zones are not intended to correspond to any conventional littoral and profundal zones of lake depth.

Ecology and Abundance

The distribution and abundance of benthos in a body of water depend on a number of environmental factors, but the limited data of this work allow only observations on the influence of depth and water quality on some species.

Bottom organisms were far more abundant in shallow than in deep water. The *average* number of organisms per m^2 was 41,631 in the shallow zone and 7,938 in the deep zone.

Oligochaeta

Oligochaeta was the largest group of macrobenthos found in Lake Ontario. The class was represented by four families-Enchytraeidae, Lumbriculidae, Naididae, and Tubificidae. Enchytraeids (identified here only to family) were widespread, exhibited no distinct depth preference, and apparently were never abundant.

Stylodrilus heringianus (Lumbriculidae) was apparently common throughout the lake except in a few places where the environment may have been unfavorable. Pollution may have caused the absence of this species at station 17 off Toronto, Ontario, and station 59 off Rochester, New York, and reduced its numbers at station 81. Its absence from stations 74 and 87 is inexplicable. Johnson and Matheson (1968) also found the species in western Lake Ontario but not in Hamilton Bay where the waters were contaminated by pollutants. The term "sludge worm," by which aquatic oligochaetes are frequently known, cannot be applied to S. heringianus.

Seven species of Naididae were taken, all from the shallow zone. None were abundant, but many were probably lost when the samples were sieved. Among the naidids, *Vejdovskyella intermedia* attained the greatest depth (47.5 m).

The family Tubificidae contributed the largest number of species (21) and individuals. *Limnodrilus hoffmeisteri was* the most common and widespread species; if a large proportion of the forms that were "unidentifiable immature without capilliform chaetae" are assumed to be this species, *L. hoffmeisteri* would have composed most of the total tubificids at productive stations 4, 17, and 59. The common species - *Potamothrix moldaviensis, P. vejdovskyi, Peloscolex ferox,* and *P. multisetosus* - were found in the shallow zone, as were the less common *Aulodrilus americanus, A. pluriseta, Limnodrilus udekemianus,* and *Tubifex ignotus. Limnodrilus cervix* is nearly saprobiontic and its distribution was probably influenced more by water quality than by depth. Habitat preferences of the rare species, *Aulodrilus limnobius, A. pigueti, Potamothrix bavaricus, Psammoryctides curvisetosus, Rhyacodrilus coccineus,* and *R. montanus,* are not fully known but they apparently do not have a wide depth distribution. *Limnodrilus Profundicola* and *Tubifex kessleri americanus* were found only at the the two deepest stations (183 and 225 m). The location of *L. profundicola* is in sharp contrast to that reported by Johnson and Matheson (1968) who found the species only in Hamilton Bay. I have yet to find *L. profundicola* in a polluted habitat in the Great Lakes. *Peloscoiex variegatus* and *Rhyacodrilus* sp. were collected in both depth zones but may prefer depths between 35 and 195 m. *Tubifex tubifex* showed no depth preferences. Since the species is known to inhabit organically polluted areas, its high abundance at station 17 near Toronto was not unexpected. Most, if not all, of the specimens that were "unidentifiable immature with capilliform chaetae" were probably *T. tubifex*. The species is clearly facultative toward water quality. Not only did it thrive in an area of urban pollution, but it also was in deep water where the substrate was presumed to be comparatively nutrient poor.

Potamothrix vejdovskyi was ordinarily abundant in the productive areas (i.e., stations 4 and 59) but it was poorly represented at productive station 17. Competition with the large numbers of other tubificids may have caused the low abundance of *P. vejdovskyi* at station 17.

The species composition of oligochaetes at station 4 is paradoxical and difficult to explain. The saprophilous species, *Limnodrilus cervix, L. hoffmeisteri, Peloscoiex multisetosus,* and *Tubifex tubifex,* coexist with saprophobic *Stylodrilus heringianus*. The Niagara River may deliver sufficient nutrients to support large numbers of the saporphiles but, on the other hand, the river must also be sufficiently free of elements which could inhibit S. *heringianus*. The presence of large numbers of the uncommon *Tubifex ignotus* at this station resembles its distribution in Lake Michigan where it was also abundant only near a river mouth (Hiltunen, 1967).

Nicholson (1873) recorded some oligochaetes in Lake Ontario as *"Saenuris canadensis," "Saenuris* sp.," and *"Lumbriculus* sp.," but his descriptions are inadequate and the taxonomy of these early names is so obscure that none can be reliably related to current oligochaete classification. His *Lumbriculus* sp. may have been *Stylodrilus heringianus.* Adamstone (1924) recorded only the group Oliogochaeta.

Amphipoda

The abundance of *Pontoporeia affinis* in the shallow zone was apparently reduced by pollution or by excessive competition with organisms that thrive in a polluted environment. The species was rare or absent from stations near areas of urban contamination, e.g., stations 4 and 59 (Table 1). The current from the Niagara River may have affected its abundance at station 4. The scarcity of *P. affinis* at stations 81 and 87 may have been due to pollution from the Black River at station 81 (near Sackets Harbor) and low dissolved oxygen in the hypolimnion at station 87. Depth should not have been limiting since the species was taken at station 74, which was the shallowest (11 m) station sampled. The absence of *P. affinis* at station 32 is unexplained.

Although data on depth distribution are scanty, *P. affinis* appeared to be more abundant in the shallow zone (3,621 individuals per m^2) than in the deep zone (1,252 individuals per m^2). If the stations affected by pollution were omitted from the analysis, the average numbers in the shallow zone would have been even higher. The general irregularity of abundance of *P. affinis* resembled that found by Marzolf (1965) in Lake Michigan. Two sizes or age groups-5 mm and less, and 7-8 mm (measured in length from base of antennae to the extremity of terminal uropod) - were found at some stations, but no relationship appeared between size of individuals and depth of water, except that the smallest (1 mm) were collected only in the deep area.

The effect of environmental conditions on *Gammarus* was not apparent. Gammarus was abundant off Rochester but absent off Toronto. This amphipod crustacean was limited to depths of less than 33 m.

Others

The influence of depth was reflected in the populations of Chironomidae (Table 1). Except *Heterotrissocladius* and *Procladius*, the genera were not found at stations deeper than 47.5 m. The presence of *Procladius* at the more profundal stations 5 and 18 was in contrast to the observation of Brinkhurst, Hamilton, and Herrington (1968) who reported the group only from near shore.

Manayunkia speciosa, Asellus communis, most midgefly larvae, *Oecetis* sp., and all gastropods were restricted to the shallow zone.

All of the *Pisidium* from the deep zone were *P. conventus,* which has been found throughout the Great Lakes (Heard, 1962;

Henson, 1966; Herrington, 1962) and ordinarily at depths greater than 15 m. The various species of *Sphaerium* inhabited only the shallow zone (*S. corneum* was most common).

The profundal bottom macrofauna of Lake Ontario was similar to that of Lakes Michigan and Huron. The abundance of sphaeriid clams, oligochaetes, and *Pontoporeia affinis,* was nearly alike in Lakes Michigan and Ontario but in Lake Huron the relative abundance of these organisms (Teter, 1960; Schuytema and Powers, 1966) was considerably less than in the other two lakes.

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FISHERY SURVEY OF U.S. WATERS OF LAKE ONTARIO[1]

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ABSTRACT

Gill nets and trawls were fished by the Bureau of Commercial Fisheries R/V Cisco during September 19-23, 1964, at several locations and depths in the offshore United States waters of Lake Ontario. Water temperatures were low (3.7-8.3° C) at all fishing stations except one (16.4° C). Supplementary data were provided by the Bureau's R/V *Kaho* in 1966. Alewives and smelt were common. Ciscoes were extremely scarce, but large; most of those caught were bloaters. Slimy sculpins were abundant, but no deepwater sculpins were caught. Yellow perch were scarce. Although the warm water species were inadequately sampled, trout-perch seemed to be abundant. Other species, all caught in small numbers, were lake trout, spottail shiners, burbot, threespine sticklebacks, and johnny darters from cold water and northern pike, lake chubs, white suckers, white bass, white perch, and rock bass from warm water.

Introduction

Fish populations of the U.S. waters of Lake Ontario are poorly described. The most comprehensive report is that of Stone (1947) who restricted his study to ciscoes taken from gill nets. The distribution and abundance of fish in Canadian waters of the lake are somewhat better documented, but no general information covering the offshore waters has been published since the work of Dymond et al. (1929). Pritchard (1931) discussed the abundance of ciscoes in Canadian waters of Lake Ontario. Commercial catch statistics indicate marked changes in fish populations in recent decades. Although the data for the present report are scanty and

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apply almost entirely to offshore U.S. waters, their publication here seems justified by the nearly total lack of information on the subject in the literature.

Methods and Materials

Experimental fishing gear consisted of bottom trawls and nylon gill nets. The trawl was semiballoon with a 39-foot headrope and a 1/2-inch mesh (extension measure) cod end. Trawls were towed for 10 minutes, along bottom contours, at about 3 mph. In seven of nine gill net sets the gangs included 150 feet each of 1-1/4- and 1-1/2-inch mesh (extension measure) and 300 feet each of the following mesh sizes (inches): 2, 2-3/8, 2-1/2, 2-3/4, 3, 3-1/2, and 4. In two sets the 1-1/4-, 2-3/8-, and 2-3/4-inch meshes were eliminated, and the length of the 1-1/2-inch mesh net was reduced to 50 feet. Seven of the gill net gangs were fished for one night and two for two nights. All fishing was conducted by the R/V Cisco off Oswego, Olcott, and Rochester, New York, during September 19-23, 1964. Additional information was provided by the Bureau of Commercial Fisheries R/V *Kaho* from trawl catches during November 1-15, 1966. The *Kaho* used a 52-foot headrope bottom trawl with a l-inch mesh cod end and made 30-minute tows at various depths in several locations in U.S. waters. The relatively large mesh of the cod end allowed the escape of most small fish.

All references to southeastern Lake Michigan are from Wells (1968).

Water Temperature

Bottom water temperatures were low at all fishing locations except one. An upwelling was in progress along the south shore until the final day of fishing. Bottom temperatures ranged from 4.0 to 6.2° C in trawling areas, and 3.7 to 8.3° C at all gill net sets except at 3 fathoms off Olcott, where the temperature was 16.4° C (Tables 1 and 2). All catches but one, therefore, provide information primarily on the cold-water species.

Catches in Cold Water

Alewife *(Alosa pseudoharengus)*

Alewives were taken in small to moderate numbers in most trawl tows, and in two gill net sets in cold water (Tables 1 and 2). They were most abundant in shallow water. All except one (1.7 inches long, total length) were older than 1 year. The range in length of the older fish was 5.2-7.8 inches (average, 6.5). Alewives were by far the most common species caught by the *Kaho*

Table 1. Number of fish of various species caught per lo-minute tow in Lake Ontario off Oswego (September 19) and Rochester (September 21), 1964

Species	Location, depth (fathoms), and (in parentheses) bottom water temperatures (° C)											
	Oswego						Rochester					
	[1] 10 (5.1)	(5.1)	20 (4.6)	30 (5.1)	40 (4.0)	50 (4.1)	[2] 3 (6.2)	15 (4.5)	20 (4.4)	30 (4.2)	40 (4.0)	50 (4.0)
Alewife	2	102	42	2	1	-	2	165	174	1	38	1
Smelt (YOY)	552	25	5	1			242	26	58	-	1	-
Smelt (adult)	14	266	305	12	1	-	5	12	121	2	50	6
Spottail shiner	10	-	-	-	-	-	-	-				
Burbot		1	-	-	-	-	-	-				
Threespine stickle-back					-	-	-	-		1	-	-
Trout-perch	780	2	-	-								
Johnny darter	18	10	16	-				8	3	-		
Yellow perch					1	-						
Slimy sculpin		12	5	1,618	2,369	252		23	30	204	12	21

1 5-minute tow; catch figures adjusted to 10 minutes.
2 4-minute tow; catch figures adjusted to 10 minutes.

Table 2. Number of fish of various species caught in gill nets set overnight (unless otherwise stated) in Lake Ontario off Oswego, Rochester, and Olcott, September 20-23, 1964

Species	Location, depth (fathoms), and (in parentheses) bottom water temperature (° C)								
	Oswego			Rochester				Olcott	
	(23,	50 (4.0)	80 (3.9)	[1] 7 (4.7)	[2] 25 (4.6)	[2] 50 (3.9)	80 (3.7)	[1] 3 (16.4)	25 (8.3)
Alewife				4	-	2	-	70	
Lake herring						2	-		
Shortnose cisco						2	-		
Bloater		2			1	7	-		
Kiyi		1				-	-	-	-
Lake trout					1				
Smelt (adult)	53	1	1	17	73	11	1	19	28
Northern pike								1	
Lake chub	-	-	-	-	-			2	
White sucker	-	-	-	-	-			15	
White bass	-	-	-	-	-			2	
White perch	-	-	-	-	-			6	
Rock bass	-	-	-	-	-			9	-
Yellow perch								5	-
Slimy sculpin	1	7			15				1

1 Some mesh sizes eliminated or reduced. See text.
2 2-night set.

in November 1966; catches in about 10 hours of trawling off Youngstown, Rochester, and Oswego, totaled 8,331 pounds (probably about 100,000 individuals). Greatest numbers were at 15 to 30 fathoms, but one large catch was made at 45 fathoms.

Ciscoes (Coregonus spp.)

Ciscoes are evidently extremely scarce in Lake Ontario. None were taken in the trawls and only 15 in the gill nets. Most common among the ciscoes was the bloater (C. hoyi); nine were caught in the combined 50-fathom sets and one in the 25-fathom set off Rochester. Two shortnose ciscoes (C. *reighardi),* one kiyi (C. *kiyi),* and two lake herring *(C. artedii)* made up the remainder of the cisco catches. All of the ciscoes were large: bloaters averaged 11.2 inches (range, 10.1-12.0), shortnose ciscoes 12.2 inches, and lake herring 16.7 inches; the single kiyi was 12.1 inches long. The only cisco caught by the *Kaho* in 1966 was a large (2 pounds) lake herring. Ciscoes, particularly bloaters, were appreciably more abundant in U.S. waters of Lake Ontario in the 1940's (Stone, 1947) than at present. In gill nets of three mesh sizes (2-3/8, 2-1/3, 2-3/4 inches) set at similar depths in 1942 and 1964, Stone took 52 ciscoes per thousand feet per lift (average set, 2 nights) as compared with only 1 in the present study. Stone's catches almost certainly would have been larger if he had used nylon rather than cotton nets. The single cisco caught in all trawl tows in Lake Ontario contrasts markedly with catches of up to several hundred regularly caught in similar tows in southeastern Lake Michigan in 1964.

American smelt *(Osmerus mordax)*

Smelt were relatively common in the catches. Young-of-the-year smelt were numerous in the trawl catches in shallow water, especially at 3 fathoms off Rochester and 10 fathoms off Oswego. Older smelt were caught in nearly every tow, and in all gill net lifts. Greatest numbers (over 100 per tow) in trawls were at 20 fathoms off Rochester and at 15 and 20 fathoms off Oswego. The average lengths of smelt in the trawls were 2.2 inches (range, 1.1-3.4) for the young fish and 6.1 inches (range 3.9-9.4) for the older ones. Smelt were nearly always the only fish besides alewives caught by the *Kaho* in November 1966; they were taken in 17 of 20 tows (up to 65 pounds per tow), but numbers were small at depths greater than 30 fathoms.

Spottail shiner (Notropis *hudsonius)*

The trawl tow at 10 fathoms produced the only catch (10 individuals) of spottail shiners. These small numbers may not be indicative of actual abundance, however, since this species prefers warmer water than that at the trawling depths. Spottail shiners were seldom found in southeastern Lake Michigan in water colder than 13° C in the warm season.

Trout-perch *(Percopsis omiscomaycus)*

The trawl tow at 10 fathoms off Oswego took 780 trout-perch; only 2 others were taken, both at 15 fathoms in the same area. Trawling in warmer water might have produced more trout-perch since this species in southeastern Lake Michigan preferred water temperatures of 10 to 16° C.

Slimy sculpin *(Cottus cognatus)*

This species was taken in all but the shallowest tows in both trawling areas (Oswego and Rochester). The catches at 30 and 40 fathoms (1,618 and 2,369, respectively) were much larger than any ever made by the *Cisco* in the other Great Lakes.

Deepwater sculpin *(Myoxocephalus quadricornis)*

This species was not taken, but is mentioned here because its apparent scarcity or absence was in striking contrast to its former abundance. Gill nets set by the University of Michigan in Lake Ontario around 1920 took deepwater sculpins at about the same rate as nets fished by the Bureau of Commercial Fisheries in recent years in the Upper Great Lakes (Stanford Smith, personal communication), where deepwater sculpins are considered rather abundant. Dymond et al. (1929) reported them as abundant in the deep Canadian waters of Lake Ontario.

Other species

A single lake trout *(Salvelinus namaycush),* 11.5 inches long, was taken in the gill nets set in 25 fathoms off Rochester; one burbot *(Lota lota),* length 23.6 inches, was caught in the trawl tow at 15 fathoms off Oswego; a threespine stickleback *(Gasterosteus aculeatus)* was in the 30-fathom trawl catch off Rochester; and a yellow perch *(Perca* flavescens) was taken in the trawl tow at 40 fathoms off Oswego. Johnny darters *(Etheostoma nigrum)* were caught in small numbers (total, 55) in the tows at 10-20 fathoms off Oswego, and at 15-20 fathoms off Rochester.

Catches in Warm Water

The catches from the gill nets set at 3 fathoms off Olcott were from considerably warmer water than were the other catches (Table 2). Most species taken in this set were not caught elsewhere. The numbers of each species were as follows: alewife, 70; smelt (adult), 19; northern pike *(Esox lucius),* 1; lake chub *(Hybopsis plumbea), 2;* white sucker *(Catostomus commersoni*), 15; white bass *(Morone chrysops),* 2; white perch *(Morone* *americanus), 6;* rock bass *(Ambloplites rupestris), 9;* and yellow perch, 5.

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APPENDIX
Locations of Stations on Lake Ontario

Station	Latitude	Longitude	Station	Latitude	Longitude
1	43° 15'	79° 12'	54	43° 36'	77° 24'
2	43 17	79 08	55	43 31	77 27
3	43 19	79 04	56	43 27	77 30
4	43 19	79 06	57	43 22	77 32
5	43 20	79 10	58	43 18	77 34
6	43 22	79 16	59	43 16	77 34
7	43 22	79 20	60	43 20	77 26
8	43 22	79 26	61	43 22	77 20
9	43 21	79 32	62	43 24	77 15
10	43 20	79 38	63	43 26	77 10
11	43 18	79 46	64	43 28	77 04
12	43 22	79 42	65	43 30	76 57
13	43 26	79 38	66	43 30	76 50
14	43 20	79 34	67	43 30	76 44
15	43 34	79 30	68	43 29	76 36
16	43 36	79 26	69	43 29	76 32
17	43 37	79 24	70	43 31	76 34
18	43 34	79 20	71	43 34	76 38
19	43 33	79 10	72	43 32	76 32
20	43 36	79 02	73	43 32	76 26
21	43 41	79 05	74	43 32	76 20
22	43 42	78 59	75	43 36	76 23
23	43 50	78 56	76	43 38	76 23
24	43 46	78 55	77	43 42	76 20
25	43 43	78 55	78	43 46	76 15
26	43 39	78 52	79	43 50	76 20
27	43 35	78 50	80	43 53	76 17
28	43 32	78 48	81	43 56	76 13
29	43 28	78 47	82	43 57	76 10
30	43 24	78 45	83	43 56	76 16
31	43 21	78 44	84	43 56	76 22
32	43 23	78 29	85	43 56	76 26
33	43 26	78 27	86	44 01	76 26
34	43 29	78 23	87	44 04	76 24
35	43 32	78 20	88	44 05	76 30
36	43 37	78 18	89	44 06	76 36
37	43 41	78 16	90	44 10	76 36
38	43 48	78 14	91	44 12	76 40
39	43 52	78 12	92	44 12	76 30
40	43 56	78 10	93	44 10	76 36
41	43 57	78 08	94	44 06	76 40
42	43 56	78 02	95	44 01	76 44
43	43 56	77 56	96	43 56	76 48
44	43 55	77 50	97	43 54	76 52
45	43 55	77 44	98	43 51	76 56
46	43 54	77 38	99	43 50	77 00
47	43 53	77 32	100	43 46	76 56
	43 53	77 25	101	43 44	76 53
49	43 53	77 20	102	43 41	76 48
50	43 52	77 16	103	43 38	76 44
51	43 48	77 18	104	43 35	76 40
52	43 44	77 20	105	43 32	76 36
53	43 40	77 22	106	43 29	76 32

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