SOME ASPECTS OF THE DISTIBUTION OF BENTHIC FAUNA IN CEDAR LAKE, MANITOBA.

A Thesis

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ABSTRACT

Cedar Lake is the largest lake on the Saskatchewan River system, having an area of 320,000 acres. The lake can be divided into a main basin and a smaller, irregular north arm. The physical and chemical properties of the lake and the benthic fauna were studied during a period of two and a half months, from June 14 to August 31, 1962. Twenty permanent stations, located in the main basin of the lake were examined during six approximately equally spaced sampling periods. These stations were positioned along 5 transects, at depths of 5, 10, 20 and 30 feet. A total of 600 dredge samples were taken over the summer and from this material the number of organisms for each sample period was counted and the wet and the dry weights determined.

During the study an attempt was made to determine the factors affecting the distribution and abundance of the benthic animals. It was found that wave action in shallow waters and the type of bottom material present were probably the most prominent factors, with depth acting indirectly, since it generally controlled the two previous factors. It was also found that with increase in depth there was a concomitant increase in the numbers of individuals and also of genera represented. The standing crop for each sampling period was determined from the dry weights. The average of the six standing crops gave the

same value of 22 lbs/acre as was determined by summing the products of the average biomass for each depth zone and the area of each of these zones and then dividing the result by the total area of the lake. Cedar Lake can be classified as a eutrophic lake on the basis of the physical and chemical properties and the high productivity of benthic fauna.

ACKNOWLEDGMENTS

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INTRODUCTION

This study was undertaken to determine various aspects of the limnology of Cedar Lake, Manitoba. Much of the lower portion of the Saskatchewan River and its associated delta will be flooded when the dam for hydro-electric power is completed at Grand Rapids in 1964. The present survey was conducted to provide a background for future investigations on the effects of the establishment of this reservoir on biological productivity of the waters in this area.

Cedar Lake, Latitude 53 degrees 15 minutes north, Longitude 100 degrees 15 minutes west, is the largest lake in the Saskatchewan River system, covering an area of approximately 320,000 acres (500 sq miles), (Anon., 1961), at an approximate elevation of 831 ft. above mean sea level, (Anon., 1961). The principal influent is the Saskatchewan river, which drains an area of approximately 129,540 square miles above Cedar Lake, (Anon., 1961). It originated from Lake Agassiz, a glacial lake, which covered a large portion of Manitoba, Ontario, North Dakota and Minnesota, (Butler, 1949). Cedar Lake lies in the west-central portion of the Province, on the Interlake-Westlake plain and is bounded on its western edge by the Summerberry marsh. It is now separated from Lake Winnipegosis by a narrow strip of end moraine, The Pas Moraine, which extends from Grand Rapids to The Pas.

Cedar Lake can be divided into two distinct regions a northern arm and a southern basin. The north arm is separated from the main basin by a narrow channel and has a very irregular shoreline. It is relatively shallow, mostly less than 10 ft. and has a maximum depth of 18 ft. The principal influent of the north arm is the Summerberry River, a branch of the Saskatchewan. A number of smaller streams enter this region of the lake along the north shore. The southern basin, having an area of 147,109 acres (230 sq miles), forms the larger portion of the lake, with an average depth of 19 ft. and a maximum depth of 32.5 ft. It is approximately 18 miles wide with a long arm extending to the southeast, which forms the only outlet of the lake.

The existence of published works in this area of investigation is relatively sparse since studies of quantitative and qualitative aspects of the distribution of benthic fauna were begun only about 60 years ago. Ekman (1911) in his studies of various Scandinavian lakes was one of the initial investigators of benthic fauna. In his development of a closing dredge which could sample a known area of the bottom, he laid the foundations for modern day studies of benthic fauna. Following Ekman's work, a number of investigators entered this field. The literature indicates that in North America, interest in such aspects of benthic fauna was highest between 1915 to 1930. Juday (1922), Birge (1926) and Muttkowski (1918) conducted most intensive studies on Lake Mendota.

Muttkowski (1918), on the basis of a quantitative and qualitative study of the benthos of Lake Mendota, attempted to separate the lake bottom in regions, as follows.

Littoral...........	Eulittoral.........	Rachion.
	....	Shore Line.
	....	Plant Zone.
	Sublittoral.........	Shell Zone.
Aphytal.............	Area below shell zone.	

At the same time, Baker (1918) was studying the productivity of benthic fauna, particularly the molluscs, as fish food in Lake Oneida. Adamstone (1923a, 1923b, 1924), Adamstone and Harkness (1923) conducted four extensive studies on the benthos of Lake Nipigon. Rawson (1930) studied the benthos of Lake Simcoe. He also attempted to correlate the productivity of benthos with the products of depth and areas for a number of lakes which had been studied by various investigators.

Relatively few studies on benthic fauna have been published since 1930. Eggleton (1931) did his study of the profundal fauna of Douglas Lake, Michigan, in which he considered certain factors which could govern the distribution of these animals. Deevey (1941), undertook a study of the bottom fauna of 36 Connecticut and New York Lakes. In 1952, Ricker carried out a study of the bottom fauna of Cultus lake, British Columbia, a typical oligotrophic lake, to determine the extent to which such fauna might control the production of certain fish in the lake. During the last decade, only a few studies have been reported, mostly by Rawson, who examined the bottom fauna of numerous prairie lakes in western Canada, and conducted an extensive study on these animals in Great Slave Lake.

There is a paucity of information on the benthos of lakes in Manitoba. The qualitative and quantitative aspects of the composition of bottom fauna in Cedar Lake was unknown. This study had four principal objectives. One was to measure the physical and chemical conditions present in the lake and their various trends during the summer. The second objective was to determine the distribution and abundance of bottom fauna by periodic sampling. The third objective was to determine as nearly as possible the prime factors which control the distribution and abundance of the benthic animals. The fourth objective was to derive a quantitative statement concerning the production of benthos in terms of the standing crop.

METHODS AND MATERIALS

I. Sampling Stations

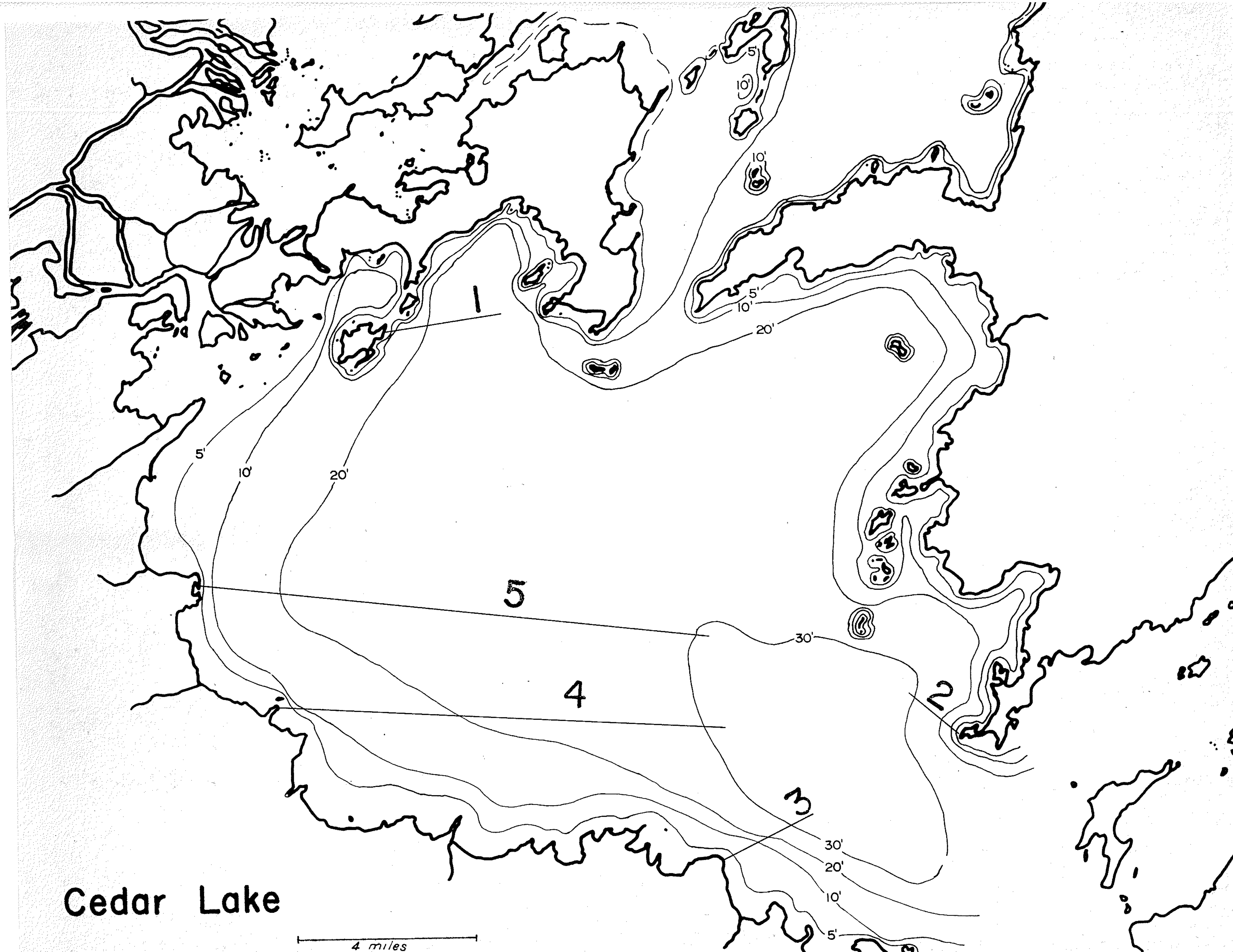
This limnological investigation of Cedar Lake was conducted from mid June to the end of August, 1962. Twenty permanent stations were established in the main basin of the lake, along five transects, indicated hereafter by the numerals '1' to '5', with the locations of these transects selected so that a variety of gradients of the bottom would be obtained. The locations of the transects are shown in Figure 1 and the profiles of these gradients are shown in Figure 2. Four stations were established at depths[1] of 5, 10, 20 and 30 feet and designated hereafter as 'a', 'b', 'c' and 'd' respectively, along each of these five transects. The stations were marked with anchored buoys.

Each of the stations was sampled six times, at approximately 2 week intervals, indicated hereafter as sampling periods, I, II, III, IV, V and VI. The sampling procedures were conducted from a 15 ft. aluminum skiff. One transect could be sampled in half a day (i. e. 5 hrs), weather permitting, so that the minimum sampling period was two and one-half days. However, strong winds and severe wave action often prevented the study from being completed as scheduled. The duration of each of the sampling periods is shown in Table I.

1/ The depth contours were determined in another study (Garside, pers. comm.) from soundings made along approximately 40 predetermined, compass-oriented transects.

Figure 1

Map of Cedar Lake, with contour lines and the location of the established transects.



5'
10'
20'
30'
1
2
3
4
5
Cedar Lake
4 miles

10'
N

Figure 2

Profiles of bottom gradient of Cedar Lake along the five established transects, with stations located at depths of 5, 10, 20 and 30 feet.

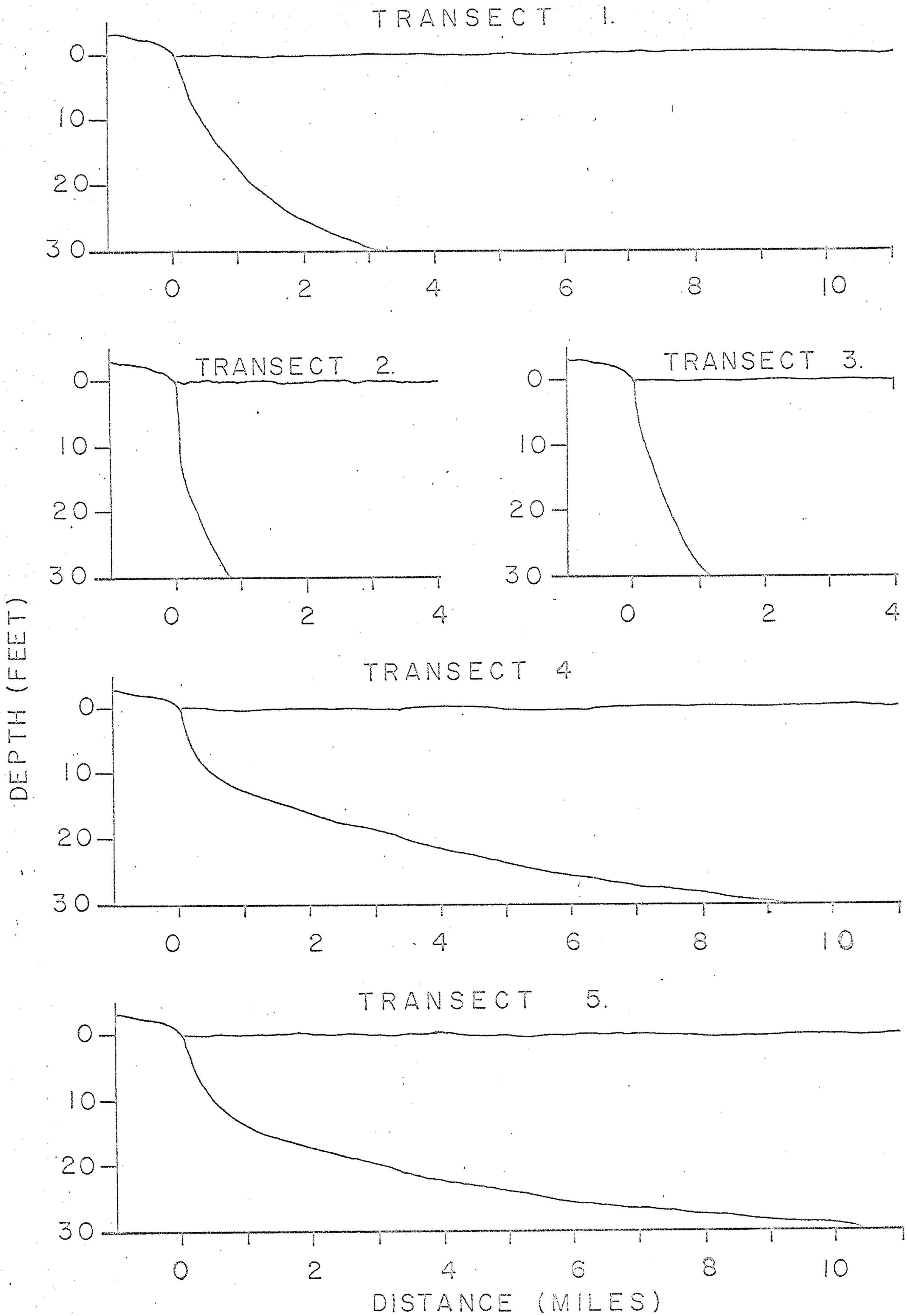

TRANSECT 1.
TRANSECT 2.
TRANSECT 3.
TRANSECT 4
TRANSECT 5.
DEPTH (FEET)
DISTANCE (MILES)
0
10
20
30
0
2
4
6
8
10

Table I

Inclusive dates of the six periods for limnological sampling of 20 selected stations in the main basin of Cedar Lake, Manitoba.

Sample Period Number	Total Sampling Period	Sample Period Number	Total Sampling Period
I	June 14 - June 21	IV	July 30 - Aug. 4
II	June 29 - July 7	V	Aug. 14 - Aug. 20
III	July 18 - July 20	VI	Aug. 30 - Aug. 31

Contours of the main basin were drawn on a map of known scale. The areas within the successive contours were measured by means of a polar planimeter. The perimeters of the shoreline and of the 5, 10, 20 and 30 ft. contours were ascertained by use of a map measurer.

II. Sampling Techniques

(a) Physical and Chemical Measurements

Water temperatures were taken at each station during each sampling period by means of an electric Aqua-Temp thermal recorder, at vertical intervals of 2 ft. Readings of water transparency were made by means of a standard Secchi disc.

Samples of water were taken near the bottom at each station by means of a Kemmerer water sampling bottle of 1,200 cc.

capacity. The concentrations of dissolved oxygen were determined for subsamples of this water by the unmodified Winkler method (Anon., 1960). Determinations of the concentration of dissolved oxygen were also made on the surface water at all 'B' stations. Total alkalinity, expressed by methyl green and phenolphthalein alkalinities, was determined titrimetrically (Welch, 1948). Concentrations of total dissolved solids, were determined by means of a conductivity bridge. This conductivity bridge was a portable type for field use developed by the Fisheries Research Board of Canada (Hoy, 1959). Concentrations of hydrogen-ions in the aforementioned water samples were measured by means of a Beckman pocket pH. meter. The free carbon dioxide in these samples was determined titrimetrically by the sodium hydroxide method (Anon., 1960).

(b) Collection of Bottom Fauna

Five dredgings were made at each station during each sampling period by means of a 6 by 6 in. Ekman-Birge dredge, giving a total of 600 dredge samples for the entire summer. A qualitative description of the bottom material was recorded from the dredgings made at each station. The samples of bottom material were washed immediately, in a wire screen of thirty meshes per inch, and the animals from each dredging were picked from the screen and preserved in a separate vial in 70 per cent alcohol. The cases of larval caddis flies (Order Trichoptera) and the shells of molluscs were also collected for possible identification.

Subsequently the collected organisms were identified with the aid of both stereoscopic and compound microscopes. Standard taxonomic keys were used for these identifications, (Eddy and Hodson (1961), Pennak (1953) and Ward and Whipple (1959)). The following works were also consulted when necessary to identify certain of the more difficult and obscure groups. These are as follows: Nematoda, Cobb (1915, 1935); Mollusca, Goodrich (1932); Diptera, Curran (1934), Johannsen (1937a, 1937b); Trichoptera, Peterson (1951), Ross (1944). Organisms were identified as to Genus except for specimens of Ceratopogonidae, where identification was not attempted below the level of Family. The classification of the taxonomic groups used, is based on Pennak (1953) and is given in Appendix I. An accurate count of all organisms was made and the specimens were preserved again and held for later gravimetric analyses.

The wet weight of the animals from each vial was obtained with a torsion balance graduated in milligrams. The animals were first placed on filter paper to remove the excess moisture. The shells of molluscs and the cases of larval caddis flies were not included in these weights. The dry weights of these samples were also determined. The samples of animals were dehydrated in an electric oven at 50° C. for 24 hrs. before weighing.

RESULTS

I. Physical and Chemical Determinations

(a) Temperature

The last ice left Cedar Lake on June 1 and from this time the temperature of the surface water rose gradually to a high of 70° F. on July 31, and then gradually declined to 62° F. by August 31.

No thermocline was formed in the lake. However, the surface temperature was always slightly higher than that of the bottom. The greatest difference in temperature between the surface and the bottom was four Fahrenheit degrees. Table II gives the mean temperatures for the various depths during each of the six sampling periods.

Table II

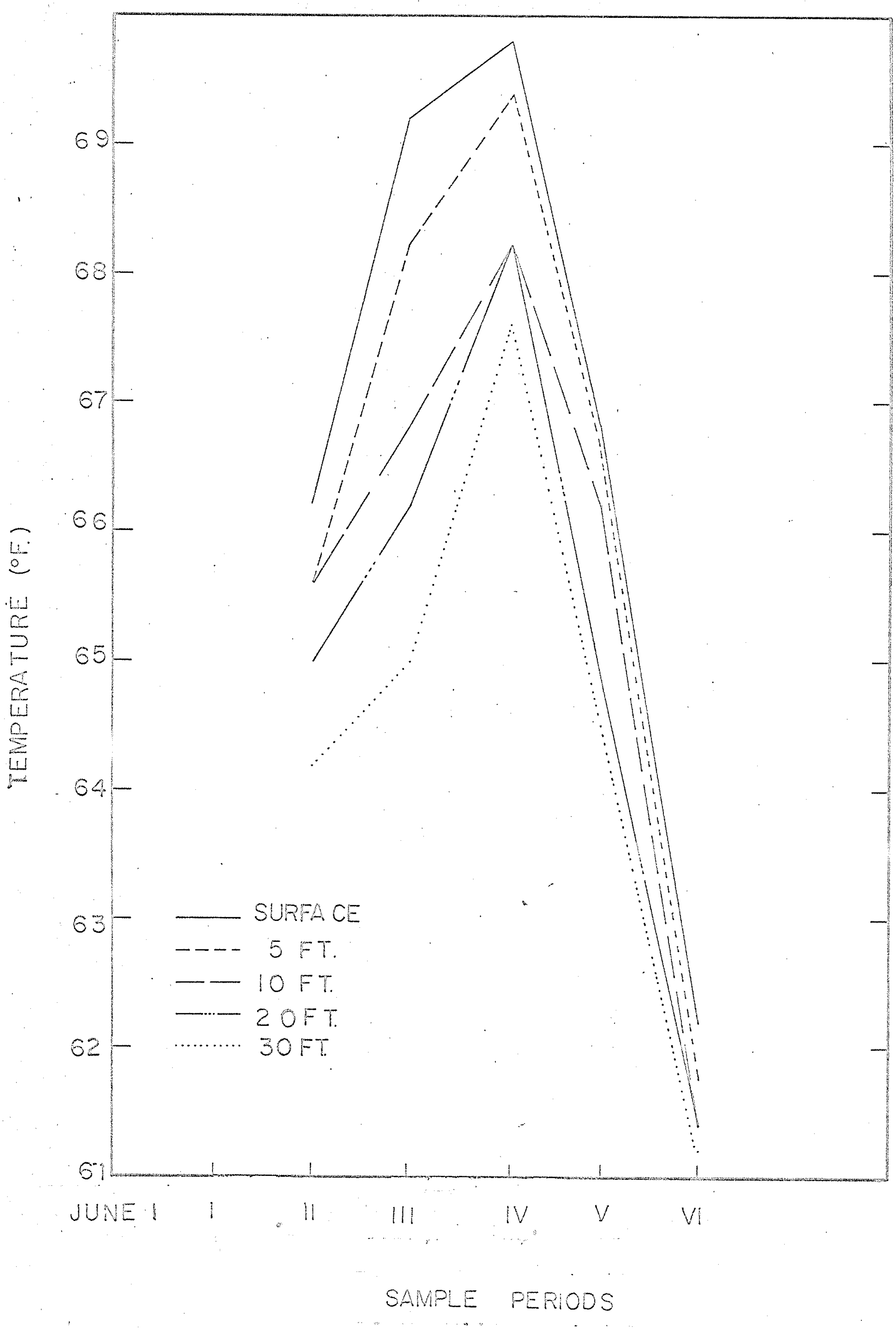
Mean water temperature at various depths for the six sampling periods. The temperatures are recorded in degrees Fahrenheit.

Depth Ft.	Sampling Periods					
	I	II	III	IV	V	VI
Surface	65	66	69	70	67	62
5 Feet	-*	66	68	69	67	62
10 Feet	-	66	67	68	66	61
20 Feet	-	65	66	68	65	61
30 Feet	-	64	65	67	64	61

* Temperature recorder not available.

Figure 3

Temperature distribution at various depths of Cedar Lake during five of the six sampling periods. Temperatures are given in degrees Fahrenheit.



TEMPERATURE (°F.)
69
68
67
66
65
64
63
62
61
SURFACE
5 FT.
10 FT.
20 FT.
30 FT.
JUNE I
I
II
III
IV
V
VI
SAMPLE PERIODS

The temperatures at the various depths during the sampling periods are also shown in Figure 3. Figure 3 indicates that the difference in the temperature between the surface and the bottom becomes progressively less after mid-July.

(b) Transparency

Table III

Depth of transparency of the water at the 20 stations during the six sampling periods. The depths are given in feet.

Stations	Sampling Periods					
	I	II	III	IV	V	VI
1a	1.5	1.0	2.0	1.6	0.9	1.9
b	1.5	1.5	2.5	1.5	0.8	1.5
c	1.0	1.0	2.5	1.5	1.0	1.8
d	1.0	0.5	2.5	2.5	1.5	1.8
2a	1.9	2.0	3.5	3.5	3.3	2.0
b	2.0	2.5	2.5	3.0	2.8	2.0
c	4.5	3.0	2.5	2.5	2.5	2.3
d	4.0	3.0	3.0	2.0	2.5	2.3
3a	0.7	2.0	2.0	2.5	1.5	0.7
b	1.4	2.0	2.5	1.3	1.5	0.7
c	1.5	2.0	2.0	1.3	1.5	0.7
d	1.5	1.5	3.0	3.0	1.3	0.8
4a	1.0	1.0	2.5	1.5	1.5	0.7
b	1.0	1.0	2.5	1.5	1.5	0.7
c	1.5	1.5	2.1	1.5	1.0	0.7
d	2.5	1.5	2.5	1.3	1.5	0.7
5a	1.0	0.5	1.0	0.5	2.0	0.7
b	0.5	1.0	1.0	1.0	1.5	0.7
c	4.5	2.5	1.5	1.0	0.5	2.0
d	3.5	3.0	2.0	3.5	1.8	0.7

Transparency ranged from a maxium depth of 4.5 ft. to a minimum depth of 0.5 ft. during the course of the study. Table III gives the individual Secchi readings and shows the tendency towards reduced transparency following the third sampling period.

During the first half of the survey period, the colour of the water was light brown. However, there was a noticeable change to dull green during the second half of the survey.

(c) Dissolved Oxygen

Dissolved oxygen in the surface waters ranged from 7.8 to 10.4 ppm during the study. The dissolved oxygen in the bottom waters ranged from 8.0 to 9.5 ppm. The concentration of dissolved oxygen was averaged for each depth at each sampling period and these data are shown in Figure 4. The concentrations of oxygen for each station are shown in Table IV. There was no apparent stratification in the distribution of dissolved oxygen during the period of the study, and no indications of oxygen deficiencies at all. The percentages of air-saturation of dissolved oxygen, shown in table V shows the continuously high concentration of dissolved oxygen present in the water during the study. During certain sampling periods the surface waters often possessed values over 100 percent saturation.

Table IV

Concentration of dissolved oxygen of the bottom waters at the 20 stations during the six sampling periods. Results are given in mgm./l. (ppm.). Stations (b) have a surface determination indicated as 'S' and a bottom determination indicated as 'B'.

	Sampling Periods					
Stations	I	II	III	IV	V	VI
1a	8.7	7.7	10.2	8.5	8.2	9.9
b S.	-	7.8	9.8	8.5	8.2	10.2
b B.	8.3	8.1	10.0	8.4	8.0	10.0
c	8.2	8.2	9.0	8.7	8.2	9.6
d	8.5	8.1	9.0	8.3	8.1	9.6
2a	8.8	8.6	10.6	9.3	8.8	10.2
b S.	-	7.2	10.2	8.9	9.1	10.2
b B.	8.8	7.2	9.8	9.2	8.8	10.0
c	8.8	7.8	9.6	8.9	8.6	9.4
d	8.8	7.4	8.8	7.6	8.8	9.6
3a	8.8	8.1	10.4	9.5	9.2	10.5
b S.	8.8	7.8	10.6	8.9	9.1	10.4
b B.	8.8	8.0	10.2	8.9	8.6	9.4
c	9.0	8.3	9.8	7.8	8.5	9.7
d	9.0	8.4	9.0	7.8	8.6	9.4
4a	8.5	8.1	10.4	8.5	8.0	10.7
b S.	-	8.3	10.2	8.9	8.6	10.5
b B.	8.3	7.8	10.0	8.7	8.5	10.4
c	8.7	7.7	10.2	8.5	8.5	9.6
d	8.7	8.3	8.6	8.1	8.8	9.4
5a	8.8	8.2	10.4	9.3	8.5	10.2
b S.	-	7.8	10.6	9.1	8.6	10.2
b B.	8.8	8.4	10.6	9.3	8.3	10.0
c	8.7	8.4	10.0	8.9	8.5	10.0
d	8.7	8.4	9.0	8.8	8.5	9.4

Figure 4

Distribution of methyl green alkalinity at various depths of Cedar Lake during the six sampling periods. Alkalinity is given in parts per million.

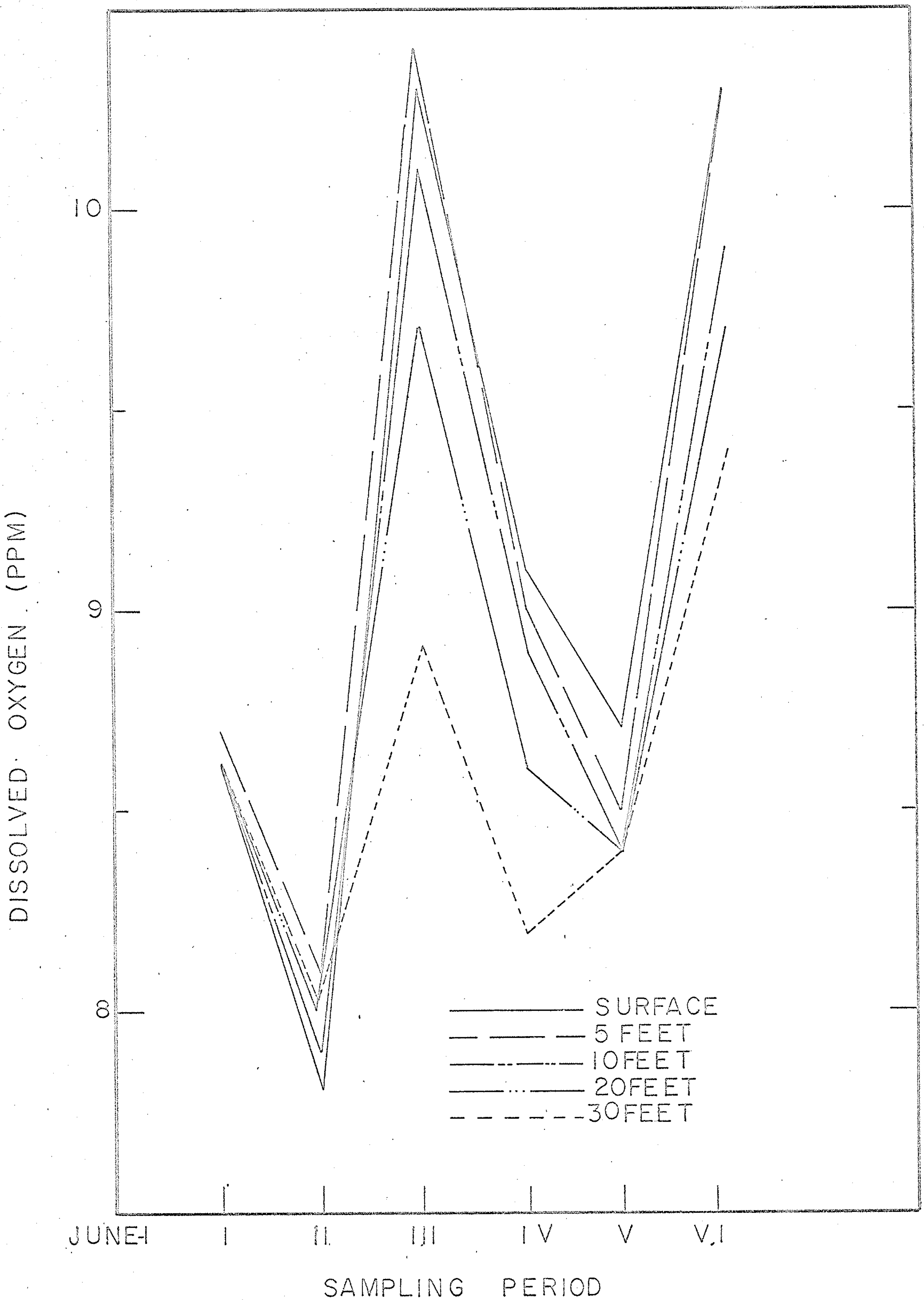

DISSOLVED OXYGEN (PPM)
10
9
8
JUNE-I
I
II
III
IV
V
VI
SAMPLING PERIOD
SURFACE
5 FEET
10FEET
20FEET
30FEET

Table V

Variations in the average percentage of air-saturation of dissolved oxygen, in the water of the surface and of the bottom during the six sampling periods in Cedar Lake.

Depths	Sampling Periods					
	I	II	III	IV	V	VI
Surface	82.9	85.6	114.7	100.2	92.0	104.7
Bottom	78.4	81.8	92.3	88.4	87.1	93.5

(d) Total Alkalinity

In the determination of total alkalinity of samples of water from the bottom, there was no phenolphthalein reaction which indicated that there was no carbonate or hydroxide present in the water. However, the mean values for methyl green alkalinity of the various depths showed a range from 61.2 to 68.4 ppm of bicarbonate. Table VI gives the individual values for each station. There is a trend to increasing alkalinity with increasing depth as shown in Figure 5. However, the greatest variation shown in Figure 5 is only 2.6 ppm and is probably without any significance.

(e) Total Dissolved Solids

The total dissolved solids over the summer ranged from 230 to 310 ppm as shown in Table VII. The averages of these data at the different depths are shown in Figure 6.

Figure 5

Distribution of alkalinity at various depths of Cedar Lake during the six sampling periods.

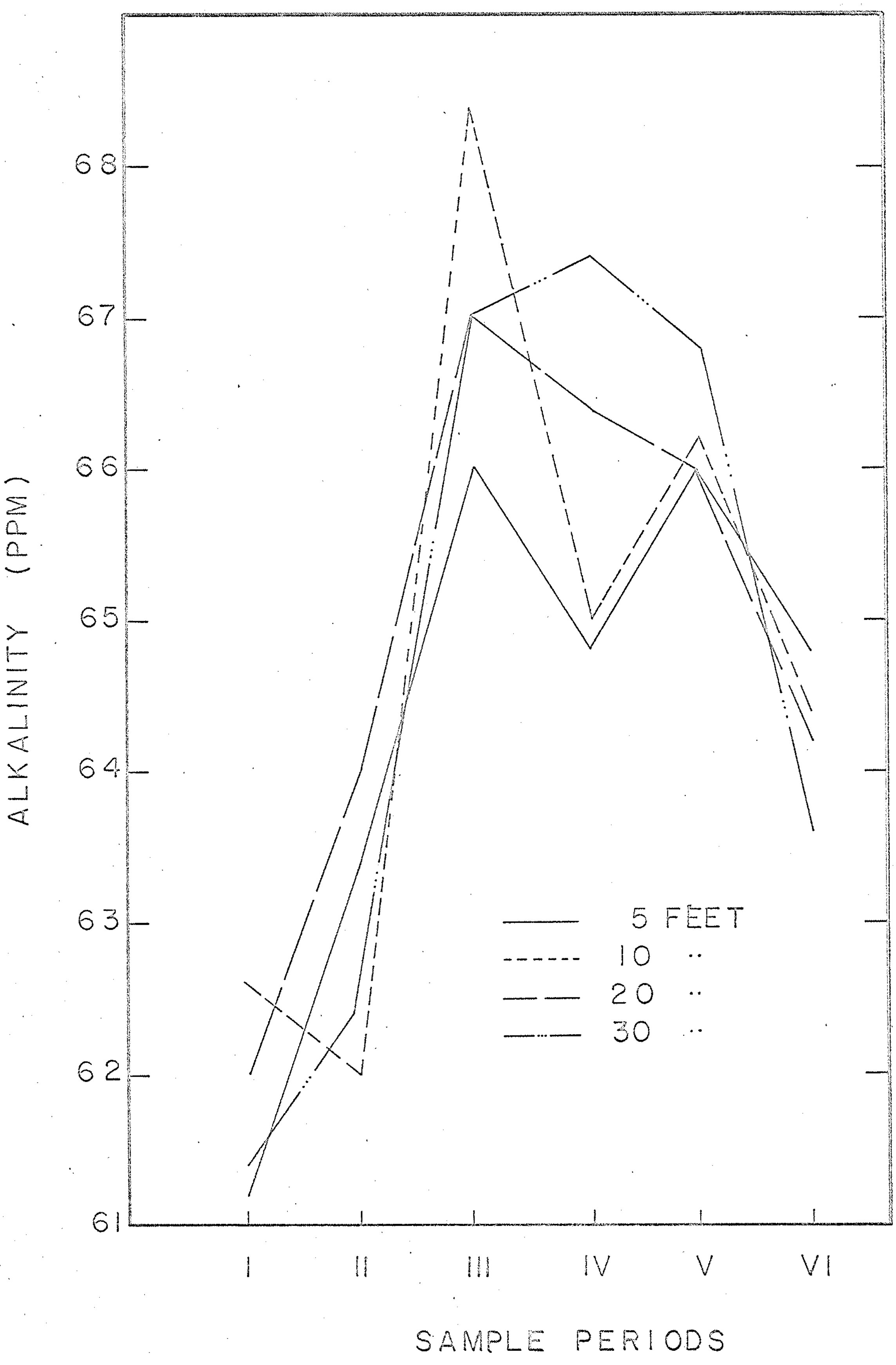
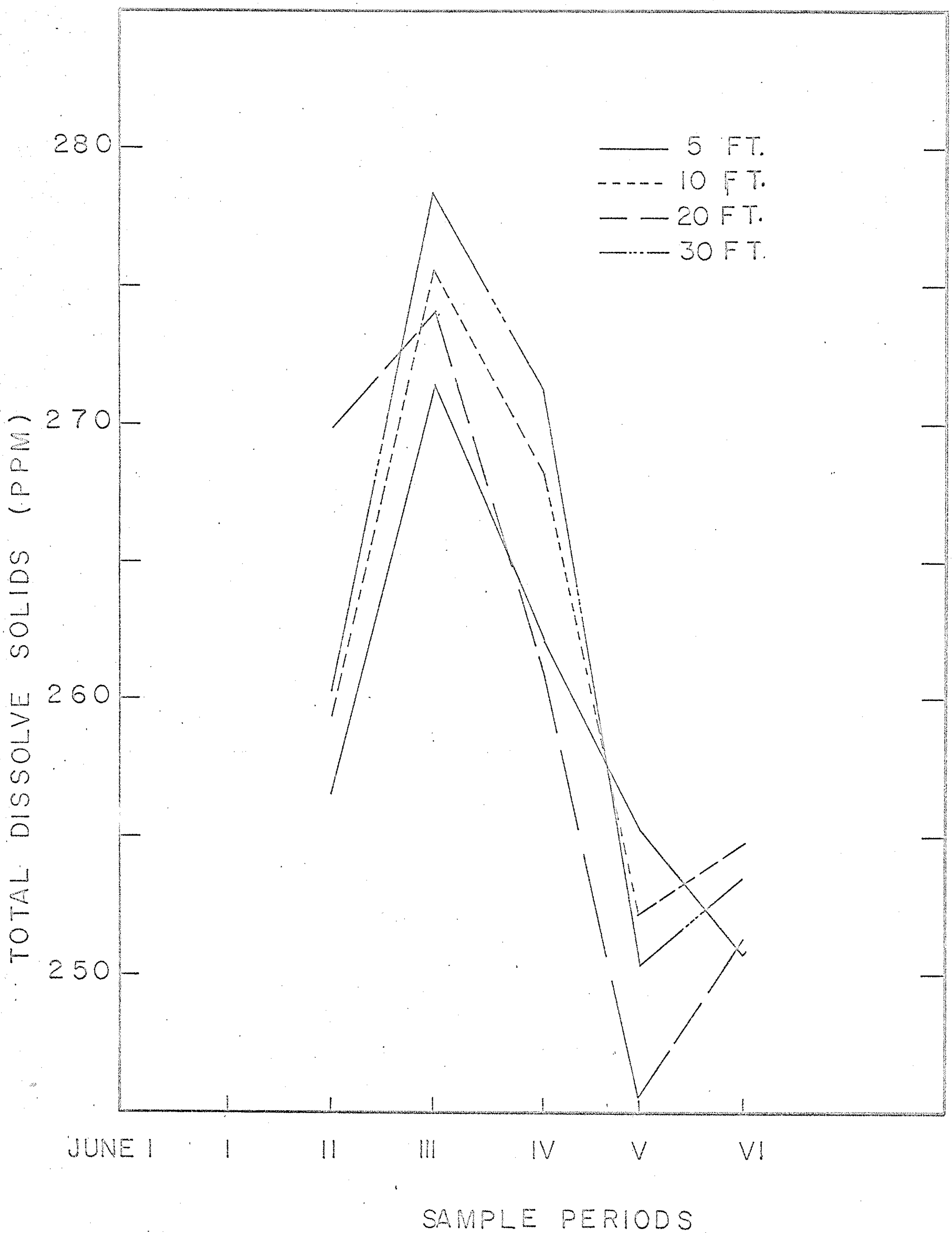

ALKALINITY (PPM)
68
67
66
65
64
63
62
61
I
II
III
IV
V
VI
SAMPLE PERIODS
5 FEET
10 ··
20 ··
30 ··

Figure 6

Distribution of total dissolved solids at various depths of Cedar Lake during the six sampling periods.


TOTAL DISSOLVE SOLIDS (PPM)
280
270
260
250
5 FT.
10 FT.
20 FT.
30 FT.
JUNE I
I
II
III
IV
V
VI
SAMPLE PERIODS

(f) Hydrogen-Ion Concentration and Free Carbon Dioxide.

The hydrogen-ion concentration of the water varied without trend from 7.8 to 8.2, as shown in Table VIII.

The free carbon dioxide remained at an average of about 4 ppm during the period of the survey, as shown in Table IX.

Table VI

Methyl green alkalinity at each of the 20 stations during the six sampling periods. The results are given in ppm of bicarbonate.

	Sampling Periods					
Stations	I	II	III	IV	V	VI
1a	55	68	68	62	70	63
b	65	68	68	65	70	63
c	65	73	66	66	68	63
d	65	61	63	71	69	60
2a	60	62	71	68	66	63
b	64	60	73	68	67	62
c	59	60	71	67	64	60
d	61	61	70	68	64	63
3a	61	61	65	66	63	67
b	55	57	66	64	63	68
c	62	63	66	64	65	64
d	61	62	70	68	66	64
4a	65	64	60	66	66	65
b	65	65	67	64	64	65
c	62	64	65	69	67	68
d	59	63	69	66	69	65
5a	65	62	66	62	65	66
b	63	60	68	64	67	64
c	62	60	67	66	66	66
d	61	65	63	64	66	66

Table VII

Concentrations of total dissolved solids at each of the 20 stations during the six sampling periods. The results are recorded in ppm.

	Sampling Periods					
Stations	I	II	III	IV	V	VI
1a	250	284	276	276	250	277
b	235	284	290	276	256	270
c	235	263	297	256	226	248
d	230	263	284	270	248	254
2a	230	230	276	276	263	248
b	230	230	284	283	242	248
c	230	263	284	264	242	248
d	230	242	284	270	242	254
3a	230	263	250	264	263	242
b	230	263	263	270	263	263
c	269	263	263	270	263	248
d	276	263	284	270	263	270
4a	293	235	310	250	250	248
b	293	256	270	256	250	232
c	293	284	270	259	248	242
d	293	270	276	270	256	242
5a	270	270	244	244	250	238
b	254	263	270	256	250	261
c	293	276	256	256	248	270
d	293	263	263	276	242	248

Table VIII

The pH of both the surface water and the bottom water at each of the 20 stations during the five sampling periods. The pH of the water was not taken during the first sampling period. The bottom sample is indicated by 'B' and the surface by 'S'.

	Sampling Periods									
	II		III		IV		V		VI	
Station	B	S	B	S	B	S	B	S	B	S
1a.	7.3	7.6	8.3	8.6	8.5	8.6	8.0	8.2	8.1	8.3
b.	7.3	7.6	8.2	8.3	8.1	8.2	8.0	8.2	8.0	8.2
c.	7.7	8.3	8.2	8.5	8.2	8.4	8.0	8.1	8.0	8.3
d.	8.0	8.2	8.0	8.4	8.0	8.3	7.9	8.0	7.8	8.2
2 2a.	8.5	8.5	8.1	8.3	8.0	8.1	8.0	8.4	8.0	8.2
b.	8.6	8.6	8.3	8.0	8.1	7.9	8.4	7.9	8.2	7.8
c.	8.2	8.3	8.1	8.2	7.8	8.1	7.8	8.1	7.6	7.8
d.	8.5	8.4	8.0	8.3	8.0	8.2	7.7	8.0	8.2	8.4
3a.	7.8	8.0	8.2	8.3	8.3	8.4	8.0	8.1	7.9	8.1
b.	8.2	8.4	8.2	8.4	8.2	8.3	7.8	7.9	7.8	8.0
c.	8.0	8.3	8.0	8.1	7.9	8.1	8.1	8.2	7.9	8.1
d.	8.0	8.3	8.0	8.0	8.0	8.0	7.9	8.3	7.9	8.2
4a.	7.8	8.3	8.2	8.4	8.3	8.3	8.3	8.4	8.0	8.0
b.	7.6	8.2	8.2	8.4	8.1	8.3	8.2	8.4	7.8	7.9
c.	8.2	8.4	8.0	8.1	8.0	8.2	8.5	8.5	7.7	8.0
d.	8.0	8.4	7.8	8.0	8.3	8.4	8.3	8.5	7.6	7.8
5a.	7.8	8.4	8.3	8.4	8.0	8.0	8.2	8.4	8.0	8.4
b.	8.0	8.4	8.1	8.3	8.0	8.2	8.0	8.2	8.0	8.2
c.	8.4	8.6	8.0	8.2	8.2	8.4	8.2	8.3	8.2	8.4
d.	8.3	8.5	8.0	8.1	8.0	8.1	8.0	8.3	8.2	8.4

Table IX

Concentrations of free carbon dioxide in the water at each of the 20 stations during the six sampling periods. Results are recorded in mgm./l. (ppm).

	Sampling Periods					
Stations	I	II	III	IV	V	VI
1a	2.3	2.3	5.7	4.5	4.5	2.3
b	3.4	3.4	3.9	3.4	3.4	3.4
c	3.4	4.5	3.4	3.9	3.4	4.5
d	4.5	4.5	3.9	4.5	3.4	5.7
2a	5.7	4.5	3.4	3.4	2.3	3.4
b	5.0	3.4	4.5	3.4	2.3	4.5
c	5.0	4.5	3.4	2.3	4.5	3.4
d	4.5	3.4	3.4	3.4	3.4	3.4
3a	2.8	3.4	4.5	4.5	3.4	4.5
b	5.0	2.8	3.4	2.3	4.5	4.5
c	4.5	3.4	3.4	3.4	4.5	4.5
d	5.7	2.8	3.4	3.4	6.8	4.5
4a	2.3	3.4	3.4	3.4	3.4	3.4
b	3.4	2.3	4.5	3.4	4.5	4.5
c	4.5	4.5	3.4	4.5	3.4	4.5
d	3.9	3.9	3.4	2.3	5.7	3.4
5a	4.5	5.7	5.7	4.0	3.4	3.4
b	4.5	3.4	6.8	3.4	2.3	4.5
c	2.3	5.0	4.5	3.4	4.5	4.5
d	2.3	4.5	4.5	4.5	7.9	3.4

II. Collection of Bottom Fauna

(a) Types of Bottom Material

Five distinct types of bottom were found. These were classified as follows; rock, stones over 4 in.; heavy gravel, stones from 1 to 4 in.; light gravel, stones less than 1in.; sandy mud, approximately equal portions of sand and mud; mud, a light brown mud often overlying grey clay. Table X shows that each of the five transects has a variety of the five types of bottom. The bottom of the deep, central basin of the lake appears to be composed entirely of mud.

Table X

The composition of the bottom material found at each station along the five transects.

Transect	Sample Stations			
	a	b	c	d
1	rock	light gravel	mud	mud
2	rock	rock	rock	mud
3	rock	rock	heavy gravel	mud
4	heavy gravel	light gravel	mud	mud
5	sandy mud	sandy mud	mud	mud

(b) Identification and Enumeration of Animals

The total number of animals found at the twenty stations during the first sampling period was 4,431. This number rose to a high of 6,431 animals for sample period II and then declined gradually to 5,367, 4,623, 4,505 and 4,412 respectively, for the remaining four sampling periods. These data are listed in Tables XI to XVI inclusive. The number of animals found at each contour, that is, the total number of organisms for the five stations per sampling period, shows variations within each contour. However, the peak numbers do not occur at the same sampling period for each contour during the study. Table XVII shows these date.

Table XVII

The total number of organisms found for each zone, as represented by the limiting contours, during each sampling period. The totals are the sums of the numbers of animals collected at the five stations at each of the depths.

Zone (contour in ft.)	Sampling Periods					
	I	II	III	IV	V	VI
0-5	51	94	161	495	622	308
5-10	1115	775	996	734	721	659
10-20	1324	2134	1512	1336	1175	1297
20-30	1843	3347	2698	2238	1987	2118

Table XI

The numbers of the various Classes of animals found in bottom samples at each station during the first sampling period, June 14 to June 21. Orders are shown for the Class Insecta.

								Insecta					
Station	Depth	Nematoda	Oligochaeta	Hirudinea	Crustacea	Pelecypoda	Gastropoda	Trichoptera	Ephemeroptera	Diptera	Hemiptera	Megaloptera	Total
1a	5	-	-	-	-	2	14	1	-	-	1	-	18
b	10	-	-	-	-	14	12	2	6	3	1	-	38
c	20	6	1	-	114	93	111	7	74	59	-	-	465
d	30	-	--	-	522	115	53	1	8	71	-	-	771
2a	5	-	-	-	1	2	10	-	-	3	-	-	16
b	10	-	-	-	-	-	-	-	-	-	-	-	-
c	20	-	-	-	-	-	-	-	-	-	-	-	-
d	30	1	1	1	5	54	6	-	-	128	-	-	196
3a	5	-	-	-	1	-	-	4	-	1	-	-	6
b	10	-	1	-	-	3	5	2	1	2	-	-	14
c	20	-	-	-	-	269	140	2	73	22	-	-	506
d	30	-	1	-	59	77	70	71	138	7	-	-	423
4a	5	-	-	-	-	-	-	-	-	-	-	-	-
b	10	-	5	-	1	139	29	2	10	43	1	-	230
c	20	1	-	-	2	16	66	1	72	7	-	-	165
d	30	-	4	-	7	20	64	2	49	13	-	-	159
5a	5	-	-	-	-	4	5	1	-	-	1	-	11
b	10	2	46	-	182	534	117	-	8	42	-	-	931
c	20	-	44	-	4	29	69	4	3	35	-	-	188
d	30	-	25	-	13	83	145	-	7	21	-	-	294
													4431

Table XII

The numbers of the various Classes of animals found in bottom samples at each station during the second sampling period, June 29 to July 7. Orders are shown for the Class Insecta.

								Insecta					
Station	Depth	Nematoda	Oligochaeta	Hirudinea	Crustacea	Pelecypoda	Gastropoda	Trichoptera	Ephemeroptera	Diptera	Hemiptera	Megaloptera	Total
1a	5	-	-	-	-	-	-	-	-	-	-	-	-
b	10	-	-	-	-	3	-	-	2	-	-	-	5
c	20	6	1	-	114	109	154	7	133	59	-	-	583
d	30	4	5	-	1135	378	121	4	8	94	-	-	1749
2a	5	-	-	-	-	-	1	-	-	1	-	-	2
b	10	-	-	-	-	-	-	-	-	-	-	-	-
c	20	-	-	-	-	5	-	-	-	3	-	-	8
d	30	14	25	4	111	107	158	6	2	66	-	-	493
3a	5	-	-	-	-	3	22	-	-	-	-	-	25
b	10	-	-	-	-	4	26	1	-	2	-	-	33
c	20	2	-	-	100	132	75	3	99	30	-	-	441
d	30	-	1	-	15	30	110	11	101	9	-	-	277
4a	5	-	-	-	-	3	9	1	-	1	2	-	16
b	10	1	-	-	-	116	15	-	14	24	-	-	170
c	20	-	2	-	5	92	142	10	111	27	-	-	389
d	30	-	3	-	6	58	106	5	92	23	-	-	293
5a	5	-	3	-	14	16	-	-	6	13	-	-	52
b	10	-	35	-	327	102	70	4	9	20	-	-	567
c	20	17	94	1	6	191	298	1	12	93	-	-	713
d	30	3	27	-	24	117	216	13	7	128	-	-	535
													6431

Table XIII

The numbers of the various Classes of animals found in bottom samples at each station during the third sampling period, July 18 to July 20. Orders are shown for the Class Insecta.

								Insecta					
Station	Depth	Nematoda	Oligochaeta	Hirudinea	Crustacea	Pelecypoda	Gastropoda	Trichoptera	Ephemeroptera	Diptera	Megaloptera	Hemiptera	Total
1a	5	-	-	-	-	-	-	-	-	-	-	-	-
b	10	-	-	-	-	40	28	1	-	5	-	-	74
c	20	-	4	-	4	63	54	18	72	48	-	-	263
d	30	2	32	3	639	242	222	8	2	25	-	-	1175
2a	5	-	-	-	1	-	16	-	24	2	-	-	43
b	10	-	-	-	2	3	-	2	-	-	-	4	11
c	20	-	-	-	-	-	-	-	-	-	-	1	1
d	30	6	18	-	25	103	111	4	-	221	-	-	488
3a	5	-	-	-	-	-	7	-	-	2	-	-	9
b	10	-	-	-	-	-	4	-	-	2	-	-	6
c	20	-	-	-	209	104	80	2	59	14	-	-	488
d	30	-	-	-	38	71	117	9	95	6	-	-	336
4a	5	-	-	1	-	11	76	9	9	2	-	-	108
b	10	-	6	-	4	124	157	4	21	28	1	-	345
c	20	-	7	-	4	96	178	4	72	18	-	-	379
d	30	-	2	-	4	19	50	3	62	31	-	-	171
5a	5	-	-	-	-	1	-	-	-	-	-	-	1
b	10	-	77	-	232	135	83	11	7	17	-	-	560
c	20	-	27	1	6	145	224	3	2	73	-	-	381
d	30	-	2	-	42	116	324	1	28	15	-	-	528
													5367

Table XIV

The numbers of the various Classes of animals found in bottom samples at each station during the fourth sampling period, July 30 to August 4. Orders are shown for the Class Insecta.

								Insecta					
Station	Depth	Nematoda	Oligochaeta	Hirudinea	Crustacea	Pelecypoda	Gastropoda	Trichoptera	Ephemeroptera	Diptera	Hemiptera	Megaloptera	Total
1a	5	-	-	-	-	2	-	-	-	-	-	-	2
b	10	-	-	-	-	1	-	-	-	-	-	-	1
c	20	1	2	-	13	61	134	11	63	12	1	-	298
d	30	6	11	2	272	157	237	37	-	55	-	-	777
2a	5	-	-	-	-	-	8	-	-	1	-	-	9
b	10	-	-	-	-	-	-	-	-	-	1	-	1
c	20	-	-	-	-	-	-	-	2	-	-	-	2
d	30	-	6	-	1	56	59	-	1	155	-	-	278
3a	5	-	-	-	-	-	15	-	-	-	-	-	15
b	10	-	-	-	-	2	9	3	-	-	1	-	15
c	20	-	-	-	11	57	111	20	78	14	-	1	292
d	30	-	2	-	9	26	58	-	29	14	-	-	138
4a	5	-	-	-	1	110	128	3	13	4	1	-	260
b	10	-	3	-	-	115	109	1	24	22	1	5	281
c	20	-	3	-	1	66	134	3	55	7	-	-	269
d	30	-	5	-	72	55	367	14	38	13	-	-	564
5a	5	-	-	-	1	2	5	-	-	1	-	-	9
b	10	-	18	-	164	157	71	3	9	13	1	-	436
c	20	3	33	-	2	167	225	24	4	17	-	-	475
d	30	-	17	-	40	155	220	1	23	25	-	-	481
													4623

Table XV

The numbers of the various Classes of animals found in bottom samples at each station during the fifth sampling period, August 14 to August 20. Orders are shown for the Class Insecta.

								Insecta					
Station	Depth	Nematoda	Oligochaeta	Hirudinea	Crustacea	Pelecypoda	Gastropoda	Trichoptera	Ephemeroptera	Diptera	Hemiptera	Megaloptera	Total
1a	5	1	-	-	-	1	3	-	-	1	-	-	6
b	10	-	-	-	-	-	-	-	1	1	-	-	2
c	20	-	-	-	5	86	136	17	63	3	-	-	310
d	30	-	-	-	442	95	117	47	30	10	-	-	741
2a	5	-	-	-	-	-	16	1	-	2	-	-	19
b	10	-	-	-	-	-	4	2	2	-	-	-	8
c	20	-	-	-	1	-	1	2	1	2	-	-	7
d	30	1	7	-	8	61	45	2	14	156	1	-	295
3a	5	-	-	2	1	-	28	-	-	2	-	1	34
b	10	-	-	-	-	-	1	6	2	-	-	-	9
c	20	-	-	-	87	52	26	3	37	6	-	-	211
d	30	-	-	-	17	44	109	1	78	3	-	-	252
4a	5	-	1	-	2	159	104	2	35	3	-	3	509
b	10	-	10	-	2	161	237	6	16	11	-	-	443
c	20	-	5	-	4	57	128	2	34	4	-	-	234
d	30	-	1	-	15	58	163	1	52	1	-	-	291
5a	5	-	3	-	11	13	10	-	17	-	-	-	54
b	10	-	24	-	118	58	39	1	8	11	-	-	259
c	20	-	9	-	5	136	230	15	10	8	-	-	413
d	30	-	10	-	68	72	226	5	19	8	-	-	408
													4505

Table XVI

The numbers of the various Classes of animals found in bottom samples at each station during the sixth sampling period, August 30 to August 31. Orders are shown for the Class Insecta.

								Insecta					
Station	Depth	Nematoda	Oligochaeta	Hirudinea	Crustacea	Pelecypoda	Gastropoda	Trichoptera	Ephemeroptera	Diptera	Hemiptera	Megaloptera	Total
1a	5	-	-	-	-	14	121	-	1	-	-	-	136
b	10	-	-	-	2	14	19	-	-	-	-	-	35
c	20	-	-	-	11	39	116	3	73	1	-	-	243
d	30	-	-	-	54	165	246	62	6	15	-	-	545
2a	5	-	-	-	-	18	40	-	-	3	-	-	61
b	10	-	-	-	1	1	6	2	1	-	-	-	11
c	20	-	-	-	5	-	-	-	-	-	-	-	5
d	30	-	4	-	5	85	162	6	8	187	1	-	458
3a	5	-	-	-	-	-	5	8	1	-	-	-	14
b	10	-	-	-	1	-	1	2	3	-	-	-	7
c	20	-	-	-	62	131	43	-	62	9	-	-	307
d	30	-	1	-	11	17	56	4	43	4	-	-	135
4a	5	-	2	-	-	-	4	1	-	-	1	-	8
b	10	-	10	-	15	106	78	10	7	7	-	3	236
c	20	-	1	-	37	56	229	9	61	5	-	-	388
d	30	-	4	-	25	20	88	6	53	2	-	-	198
5a	5	-	2	1	4	66	9	1	4	2	-	-	89
b	10	-	5	-	205	86	64	-	1	9	-	-	370
c	20	-	18	-	-	110	185	9	4	28	-	-	354
d	30	-	20	1	33	208	429	7	2	32	-	-	732
													4412

The 0 to 5 ft. zone, as represented by the data for the 5 ft. contour (stations 'a'), was found to have the least number of organisms during each sampling period and the 20 to 30 ft. zone, as represented by the data for the 30 ft. contour (stations 'd') had the greatest number during each sampling period. The 5 to 10 ft. zone, represented by the data for the 10 ft. contour (station 'b') had a greater number of animals than the 0 to 5 ft. zone but less numbers than the 10 to 20 ft. zone. The 10 to 20 ft. zone, represented by data for the 20 ft. contour (station 'c') had a greater number of animals than the 5 to 10 ft. zone but less than the 20 to 30 ft. zone.

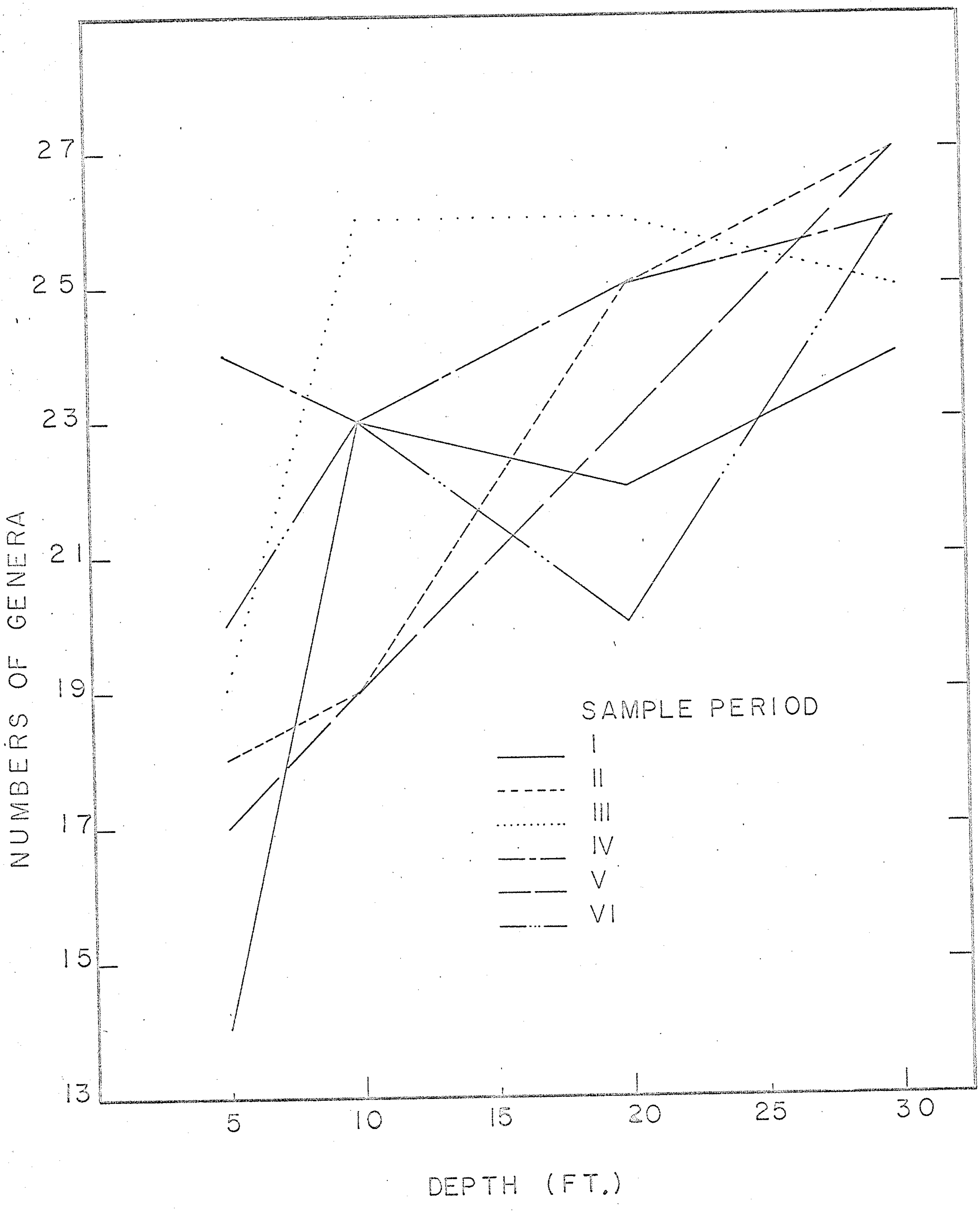
There is an increase in the number of genera, with the increase in depth, as shown in Figure 7. At the 5 ft. contour the most common organism found was the gastropod, Amnicola sp. At the 10 ft. contour, shpaerids, and Gammarus sp. were most prevalent. At the 20 ft. contour, sphaerids, Amnicola sp. and the Crustaceans, Gammarus sp. and Cypriconcha sp. were most predominant, and finally the 30 ft. contour contained mostly sphaerids, crustaceans, Amnicola sp. and diptera larvae.

The various Genera and their numbers found at each station during the six sampling periods are shown in Appendix II.

During the summer the total number of organisms found in each zone varied from sample period to sample period. The two more shallow zones both reached peak numbers at different times and app-to have no correlation. Trends for the two deeper zones tend

Figure 7

Variations in the number of genera present during the six sampling periods, with increasing depth.



NUMBERS OF GENERA
27
25
23
21
19
17
15
13
5
10
15
20
25
30
DEPTH (FT.)
SAMPLE PERIOD
I
II
III
IV
V
VI

to run parallel to one another and have their peak abundance during the same sampling period.

(c) Gravimetric Analyses of Samples of Animals

The wet weights of the samples of animals are listed in Table XVIII.

The dry weights of the samples of animals are listed in Table XIX. The dry weight was found to be approximately 15 per cent of the wet weight.

There are variations in the dry weights of the animals at the various depths and at various sampling periods, as shown in Table XX and as shown by the mean weights for the various depths in Figure 8. The 0 to 5 ft. zone reflected in the samples for the 5 ft. contour is the least productive area of the main basin of the lake in terms of bottom fauna, while, in turn, the 10 to 20 and the 20 to 30 ft. zones are the most productive areas of the bottom.

Table XVIII

Wet weights in grams of bottom animals at each station during each sampling period. Each weight is a total of five dredge samples. The shells of molluscs and the cases of larval caddis flies are excluded.

Depth ft.	Sample Period	Transects					
		1	2	3	4	5	Total
5 (a)	I	0.010	0.020	-	-	0.005	0.035
	II	-	-	0.010	0.010	0.390	0.410
	III	-	0.115	0.025	0.305	-	0.445
	IV	0.035	-	-	1.375	0.040	1.445
	V	-	-	-	1.760	1.135	2.895
	VI	0.025	0.010	0.020	0.010	0.045	0.110
10 (b)	I	0.100	-	0.025	1.730	0.575	2.430
	II	0.010	-	0.020	1.915	2.610	4.555
	III	0.285	0.065	-	0.765	1.595	2.710
	IV	-	-	0.040	1.785	2.230	4.055
	V	0.020	0.015	0.060	1.570	1.050	2.715
	VI	0.040	0.065	0.015	0.340	0.575	1.035
20 (c)	I	0.280	-	1.795	3.735	0.915	6.725
	II	2.590	0.015	4.165	6.230	1.385	14.385
	III	2.855	-	2.500	5.070	0.130	10.555
	IV	2.085	0.030	3.445	3.840	0.465	9.865
	V	3.630	3.730	1.765	2.150	0.785	12.060
	VI	3.150	0.110	2.680	4.100	0.160	10.200
30 (d)	I	0.165	2.890	2.930	2.290	0.675	8.950
	II	1.205	2.845	4.510	5.285	1.405	15.250
	III	1.770	2.845	4.510	5.285	2.415	13.580
	IV	0.785	0.775	2.035	2.860	3.040	9.495
	V	2.585	2.205	4.440	2.945	4.350	16.525
	VI	0.900	2.495	2.710	3.170	1.160	10.435

Table XIX

Dry weights in grams of bottom animals at each station during each sampling period. Each weight is a total of five dredge samples. The shells of molluscs and the cases of larval caddis flies are excluded.

Depth ft.	Sample Period	Transects					
		1	2	3	4	5	Total
5 (a)	I	0.005	0.011	-	-	0.001	0.017
	II	-	-	0.005	0.005	0.100	0.110
	III	-	0.025	0.005	0.085	-	0.115
	IV	0.005	-	-	0.195	0.010	0.210
	V	-	-	-	0.245	0.150	0.395
	VI	0.025	0.005	0.005	0.005	0.010	0.050
10 (b)	I	0.020	-	0.005	0.255	0.095	0.375
	II	0.005	-	0.005	0.410	0.745	1.165
	III	0.135	0.015	-	0.110	0.325	0.585
	IV	-	-	0.010	0.255	0.365	0.630
	V	0.005	0.005	0.020	0.205	0.195	0.430
	VI	0.040	0.015	0.005	0.095	0.160	0.315
20 (c)	I	0.060	-	0.240	0.545	0.170	1.015
	II	0.415	0.005	0.380	0.700	0.265	1.765
	III	0.520	-	0.265	0.675	0.105	1.565
	IV	0.325	0.010	0.385	0.450	0.090	1.260
	V	0.630	0.930	0.345	0.385	0.195	2.485
	VI	0.505	0.025	0.355	0.735	0.040	1.660
30 (d)	I	0.030	0.355	0.955	0.340	0.135	1.815
	II	0.195	0.280	0.430	0.570	0.290	1.765
	III	0.330	0.180	0.475	0.345	0.325	1.655
	IV	0.160	0.115	0.270	0.385	0.375	1.305
	V	0.450	0.350	0.715	0.485	0.565	2.565
	VI	0.195	0.325	0.425	0.530	0.205	1.680

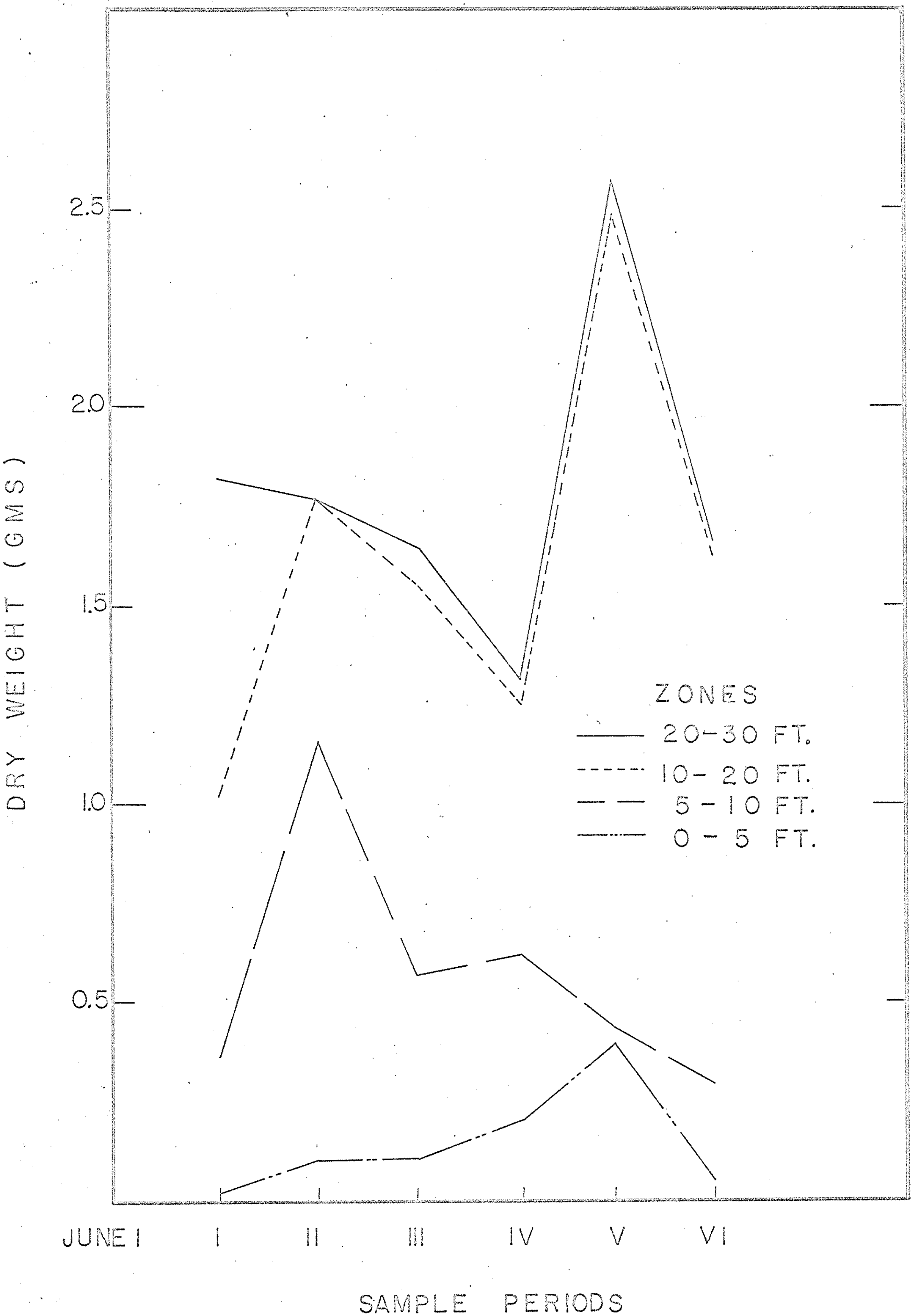
Table XX

The total dry weights in grams of bottom animals in each depth zone during each sampling period. Each weight is a total of twenty five dredge samples.

Zone (ft.)	Sampling Periods						
	I	II	III	IV	V	VI	Total
0 - 5	0.017	0.110	0.115	0.210	0.395	0.050	0.897
5 - 10	0.375	1.165	0.585	0.630	0.430	0.315	3.500
10 - 20	1.015	1.765	1.565	1.260	2.485	1.660	9.870
20 - 30	1.815	1.765	1.655	1.305	2.565	1.680	10.785

Figure 8

Variation in the dry weight of organisms with depth during the six sampling periods.


DRY WEIGHT (GMS)
2.5
2.0
1.5
1.0
0.5
ZONES
20-30 FT.
10- 20 FT.
5 - 10 FT.
0 - 5 FT.
JUNE I
I
II
III
IV
V
VI
SAMPLE PERIODS

DISCUSSION

I. Physical Characteristics

Lakes, on the basis of their biological productivity can be classed as either 'eutrophic' or 'oligotrophic'. Euthrophic lakes, such as Lake Simcoe (Rawson, 1930), are those which are rich in nutrient materials, while oligotrophic lakes are generally relatively poor in nutrient matter, as for example Cultus Lake (Ricker, 1952). Cedar Lake is a typical eutrophic lake, since it possesses the necessary attributes usually ascribed to such lakes. Certain of the differences between these two types of lakes are shown in Table XXI.

Table XXI

The primary physical differences between eutrophic and oligotrophic types of lakes. Adapted from Welch (1952).

Eutrophic	Oligotrophic
a) Relatively shallow; deep, hypolimnion minimal or absent.	Relatively deep; large, cold hypolimnion.
b) Abundant amount of suspended material.	Relatively little suspended material.
c) Electrolytes variable, often high.	Electrolytes generally low.
d) Dissolved oxygen is reduced in hypolimnion of stratified lakes of this type.	Dissolved oxygen remains at high level at all depths.

Cedar Lake can be considered a relatively shallow lake since the maximum depth recorded was 32.5 ft. and the mean depth of the main basin is 18.9 ft. Slightly less than half of the area within the main basin lies within the 20 and 30 ft. contours. Much of the northern arm, which was not included in this study, is less than 10 ft. deep. The greatest depth in the north arm is 18 ft. The main basin deepens gradually as shown in the profiles in Figure 2, with the maximum depth located in the southeast portion, in the vicinity of the outlet to Cross Lake.

There was no thermocline and only a slight difference of four Fahrenheit degrees in the temperatures of the surface and the bottom, which indicated that the entire body of water was in circulation. This small variation in temperature between the surface and the bottom is common in shallow eutrophic lakes. Lawler (1958) found only a slight gradient between the surface and the bottom in Heming Lake and Pearcy (1953) found only a few degrees difference in the temperature between the surface and the bottom of Clear Lake, Iowa. There is a striking difference in this gradient of temperature and that of a typical oligotrophic lake such as Cultus Lake (Ricker, 1937), where a temperature gradient of 59 Fahrenheit degrees was found between the surface and the bottom.

The transparency and color of the water in Cedar Lake also supports the notion that this lake is eutrophic. The depth of transparency of the water did not exceed 4.5 ft. and generally ranged around 2 ft. The color of the water was light brown in the early summer and as the summer progressed the color of the water changed to a dull green, apparently due to algal blooms.

Cedar Lake derives the majority of its suspended materials from the North and South Saskatchewan Rivers. An idea of the amount of suspended materials entering the lake can be taken from Reed (1962), who found that the South Saskatchewan,river contained 1,300 mg/l. of suspended materials at Saskatoon, Saskatchewan, and from this it can be estimated that an average of 8,350 tons of suspended materials pass that point every 24 hrs. To this is added the undetermined load being transported by the North Saskatchewan and by the tributaries of the main Saskatchewan river below the junction of these branches.

The transparency of many other shallow eutrophic lakes compares closely to that found in Cedar Lake. Lawler (1958) found a range of 3.5 to 7.5 ft. for Heming Lake and Pearcy (1953) in his work on Clear Lake, Iowa, found a transparency of 4.8 ft. on the average, with a general decrease in light penetration in late summer as the trasparency dropped to 3 ft.

Continuously high levels of dissolved oxygen are common in shallow, wind-swept lakes which are in more or less continual circulation throughout the summer. Since there was continual circulation in Cedar Lake during the summer, hypoxial conditions did not develop. The concentration of dissolved oxygen was continuously high during this study, the lowest value being 78.4 per cent of air-saturation. The percentage air-saturation ranged around 90 per cent during mid-summer. Some 'supersaturation'[1] occurred during the study and the highest value of dissolved oxygen obtained was 114.7 per cent of air-saturation and is the result of the production of oxygen by photosynthetic activity. Values of percentage saturation such as these are common in other eutrophic lakes, for example Clear Lake Iowa, Pearcy (1953), where the percentage of air-saturation ranged from 67 to 116. The concentration of oxygen in Heming Lake was found to remain near air-saturation throughout the summer, (Lawler, 1958).

Eutrophic lakes generally have relatively high levels of electrolytes in solution. The quantity of electrolytes present in Cedar Lake can be seen in the total alkalinity and the total dissolved solids.

The concentration of bicarbonate ion present in the water in Cedar Lake (up to 73 ppm) is somewhat lower than that found by Reed (1962) in either the North or the South Saskatchewan rivers. The range of bicarbonate ion for the South Saskatchewan was from 92 to 250 ppm while in the north Saskatchewan the range was from 90 to 354 ppm. A possible explanation for this drop

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1/ 'Supersaturation' means the quantity of dissolved oxygen relative to the amount of oxygen dissolved by equilibration of the water with the atmosphere at the given temperature.

in the level of bicarbonate in Cedar Lake is that insoluble compounds especially calcium carbonate have formed precipitates.

This range of concentrations of bicarbonate ion is typical of eutrophic lakes. Eggleton (1952) in his work on Douglas Lake found a bicarbonate range from 125 to 132 ppm. These values and the values obtained in the present study for bicarbonate are several times greater than those found for Cowichan Lake (Carl, 1953) an oligotrophic lake, where the bicarbonate range was only 18 to 22 ppm.

The total quantity of dissolved solids present in the water during the study ranged from 230 to 310 ppm. These values compare closely with the quantities that Reed (1962) found in the North and South Saskatchewan rivers, which were from 158 to 463 ppm and from 128 to 400 ppm respectively. The variations found by Reed were apparently seasonal phenomena with the lower values recorded in summer and the higher values in winter. No explanation is advanced to explain these fluctuations.

II. Bottom Fauna Studies

(i) Factors Affecting the Distribution of Bottom Animals

It was indicated previously that there are both quantitative and qualitative differences in the distribution of the macroscopic bottom fauna of Cedar Lake. The possible extent to which a number of factors, such as depth, wave action, type of bottom, temperature, transparency, dissolved oxygen, alkalinity and season could affect the distribution of bottom organisms is considered in the following discussion.

(a) Depth

There is an apparent correlation between depth and the numbers of both genera and individuals. As the depth increased, so did the numbers of genera, as shown in Figure 7. The 5 ft. contour possessed the smallest number of genera as it had an average of 16 genera per sampling period. The 30 ft. contour by contrast, had an average of 23 genera per sampling period. Muttkowski (1918) and Baker (1918) found in Lake Mendota and Lake Oneida respectively, that the number of species in the benthos was greatest in shallow water of the littoral zone and declined with increasing depth. Since the animals in this study were not identified to the level of species, comparison of numbers of species is not possible. These investigators further found progressive increases in the numbers of individuals in samples of the benthos with increasing depth, which corresponds with the findings presented for Cedar Lake. Such increases are common phenomena in lakes, such as Lake Simcoe, (Rawson, 1930), Lake Mendota (Muttkowski, 1918), Douglas Lake (Eggleton, 1952), Lake Nipigon (Adamstone, 1924) and Shakespeare Island Lake (Cronk, 1932).

It is doubtful that such distribution in Cedar Lake is related to depth directly. More probably this distribution is related to other factors such as differential wave-action and differences in the type or quality of the bottom at various depths. There are instances in which the number of individuals per unit area declines again beyond a certain depth as in Lake Simcoe (Rawson, 1930), Great Slave Lake (Rawson, 1953) and Third Sister Lake (Eggleton, 1931). This is perhaps due to lower temperatures of the water and reduced fertility in the profundal region.

(b) Wave Action

The probable effect of the action of waves on the distribution and abundance of benthos is demonstrated by the fact that during the study the number of organisms found at a depth of 5 ft. was approximately 30 per cent of the number found at 10 ft. and 12 per cent of that found at 30 ft. Wave action appears to be important in determining the distribution of benthic animals near shore and the relative paucity of animals at the 5 ft. depth is evidence that this is true.

There are no quantitative measures of the degree of severity of wave action in Cedar Lake. However, there is some indirect evidence to be seen in the length of time required to carry out one series of samplings. The minimum time required was two days. This was only achieved once during the six sampling periods. Four of the remaining five periods required from six to eight days (vide Table I), for completion of the direct result of severe wave action which prevented use of the sampling equipment. The bare rock substrate generally distributed inside the 5 ft. contour is further evidence of wave action.

(c) Bottom Characteristics

Since most forms were found on or in more than one type of bottom material, it is difficult to say then just how extensively the type of bottom material controls the distribution of the benthos. Mud appeared to be the most suitable habitat for most bottom animals in Cedar Lake since that type of material regularly contained the largest numbers of individuals and genera. The absence of wave-action at these depths probably contributed in an accessory manner to the relative suitability of this substrate. None of the various types of organisms collected during the study was restricted to only one of the five types of bottom. However, the larva of the alderfly, Sialis sp. was found in those areas having a rocky bottom, whether it was bed-rock or gravel, but at no time was it found in mud or sandy mud. Even in those animals which were found on most or all of the types of bottom there were different degrees of success, quantitatively measured, which probably can be related to specific types of bottom. Examples of this include Gammarus sp. which was always more abundant in sandy mud than in pure mud or any of the dipterid larvae which were always more common in mud than in rock or gravel. Other examples are found in the mayfly naiads, such as Hexagenia sp., which was more prevalent in mud than in gravel while, in turn, Caenis sp. and Stenonema sp. were both more abundant in gravel than in pure mud.

(d) Temperature

Temperature is most probably not of any significance in determining the distribution and abundance of benthic animals in shallow, non-stratified lakes such as Cedar Lake since the greatest variation in the temperature of the bottom among the 20 stations was six Fahrenheit degrees and usually the variation was only three or four Fahrenheit degrees.

It can be seen from the results (Figure 9a and 9b), that there is no correlation between the rise in water temperature during the summer and the peak abundance of the bottom organisms at the various depths. Although peak abundance of organisms for the 20 and the 30 ft. contours occured at the same sampling period, they differed from the peak abundance for the 5 and 10 ft. contours, and the latter in turn varied from that for the 5 ft. contour.

(e) Transparency

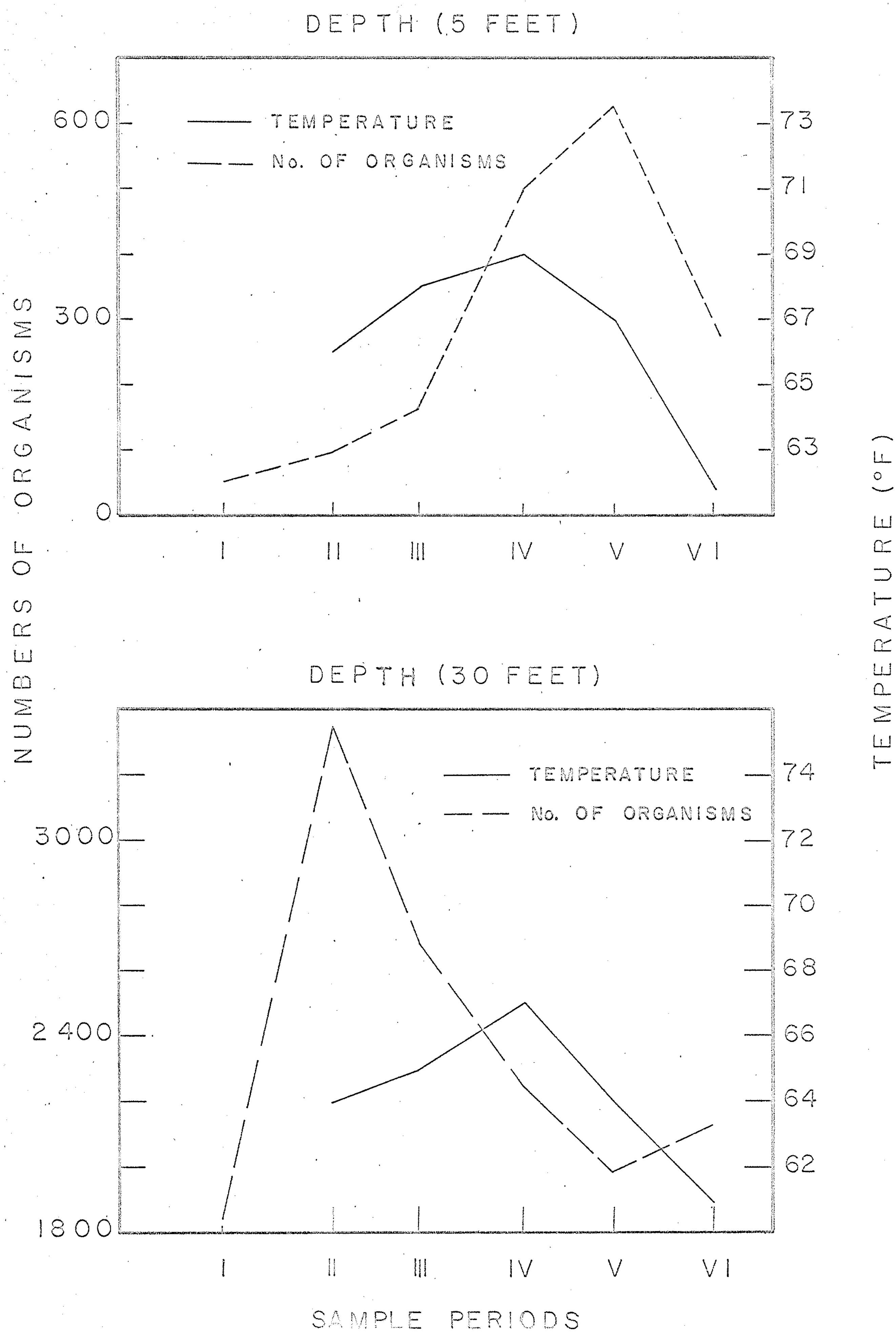
Since the limit of visibility of light, as measured by a Secchi disc, was quite shallow, (2 ft.) it is doubtful that light had any significant influence on the distribution

Figure 9a

The dry weight of bottom organisms plotted against the water temperature at a depth of five feet, during the six sampling periods.

Figure 9b

The dry weight of bottom organisms plotted against the water temperature at a depth of thirty feet, during the six sampling periods.


DEPTH (5 FEET)
TEMPERATURE
No. OF ORGANISMS
600
300
0
73
71
69
67
65
63
I
II
III
IV
V
VI
DEPTH (30 FEET)
TEMPERATURE
No. OF ORGANISMS
3000
2400
1800
74
72
70
68
66
64
62
I
II
III
IV
V
VI
NUMBERS OF ORGANISMS
TEMPERATURE (°F)
SAMPLE PERIODS

of bottom fauna at depths of 10 ft. or more. However, it might have had some influence on such distributions in the more shallow water and this perhaps also partly explains the relative scarcity of animals at the 5 ft. level.

(f) Dissolved Oxygen

Dissolved oxygen is most probably not a limiting factor affecting the distribution or abundance of bottom animals in Cedar Lake. The percentage of air-saturation did not fall below 78 per cent during any part of the study. The greatest variation in the level of dissolved oxygen between a depth of 5 ft. and a depth of 30 ft. throughout the study was 1.8 ppm (10.4 ppm - 8.6 ppm). This difference is probably of a random nature and is not considered to be sufficient to influence critically the distribution of these animals.

(g) Alkalinity

The presence of carbonate or bicarbonate ions in lakes apparently has very little effect on the distribution of most bottom organisms except possibly the molluscs (Pennak, 1953). Since large numbers of sphaerids and gastropods were evenly distributed at all depths on the bottom of the main basin and a generally high concentration of bicarbonate ion (55 to 73 ppm) was present, it can be assumed that the small variations in the alkalinity have no effect on the distribution of these bottom animals in Cedar Lake.

(h) Seasonal Effects

Eggleton (1931) in his study on Third Sister Lake, Michigan, found the major seasonal changes in the profundal bottom fauna to have a distinct midsummer minimum and a midwinter maximum. This appears to be the only recorded investigation to date in which the seasonal abundance of benthos has been studied. Since this study took place only during the summer, it is not possible to determine from these data whether or not there are fluctuations in the numbers and in the distribution of the bottom fauna from one season to another, especially between summer and winter. During the study there was only a small amount of intraseasonal variation as the maximum number of organisms collected during the sampling periods was only 14.5 per cent greater than the minimum number found. The total number of individuals present showed a maximum abundance during the second sampling period (June 29 to July 7) and then this number declined gradually towards the end of summer.

(ii) Productivity

Estimates of production of benthos can be made from the average number of individual organisms present in a specified area. However, this method is not especially satisfactory for measuring the production of biomass since there are considerable differences in the weights of these organisms. The wet wet weights of the various organisms can be taken as an estimate of the biomass present, but here again a rather large error is introduced, since a large but variable proportion of the weight of these animals is water, averaging 85 per cent in this study. A more precise means of deriving an estimate of production is that of determining the average dry weight of animals present per unit area.

In the calculation of the benthic production of the main basin of Cedar Lake, different methods produced variations in results. Three methods were examined in the determination of this production. The first method was the sum of the average number of pounds per acre for each depth zone divided by the number of zones. The second method was to sum all the dry weights found at all depths, and from this, to calculate a grand average of the pounds per acre of the dry weight of biomass. Both methods gave an average of 16 lbs/acre. The third method was to sum the products of the biomass per unit area and the total area for each of the four depth zones (i.e. 0 to 5 ft., 5 to 10 ft., 10 to 20 ft. and 20 to 30 ft. plus) and dividing this sum by the total area of the main basin. This method provided a total of 3,263,102 lbs. of dry weight of benthic biomass for the main basin, which when divided by the total area of the basin, (147,109 acres) gave an average crop of 22 lbs/acre. This value is approximately 15 per cent of the average crop determined for the wet weights of the organisms which is 148 lbs/acre. This is considered to be a more appropriate method than the two previously described for determining the quantity of benthos since it takes into account, relatively more precisely, the abundance of animals in each of the several zones of depth.

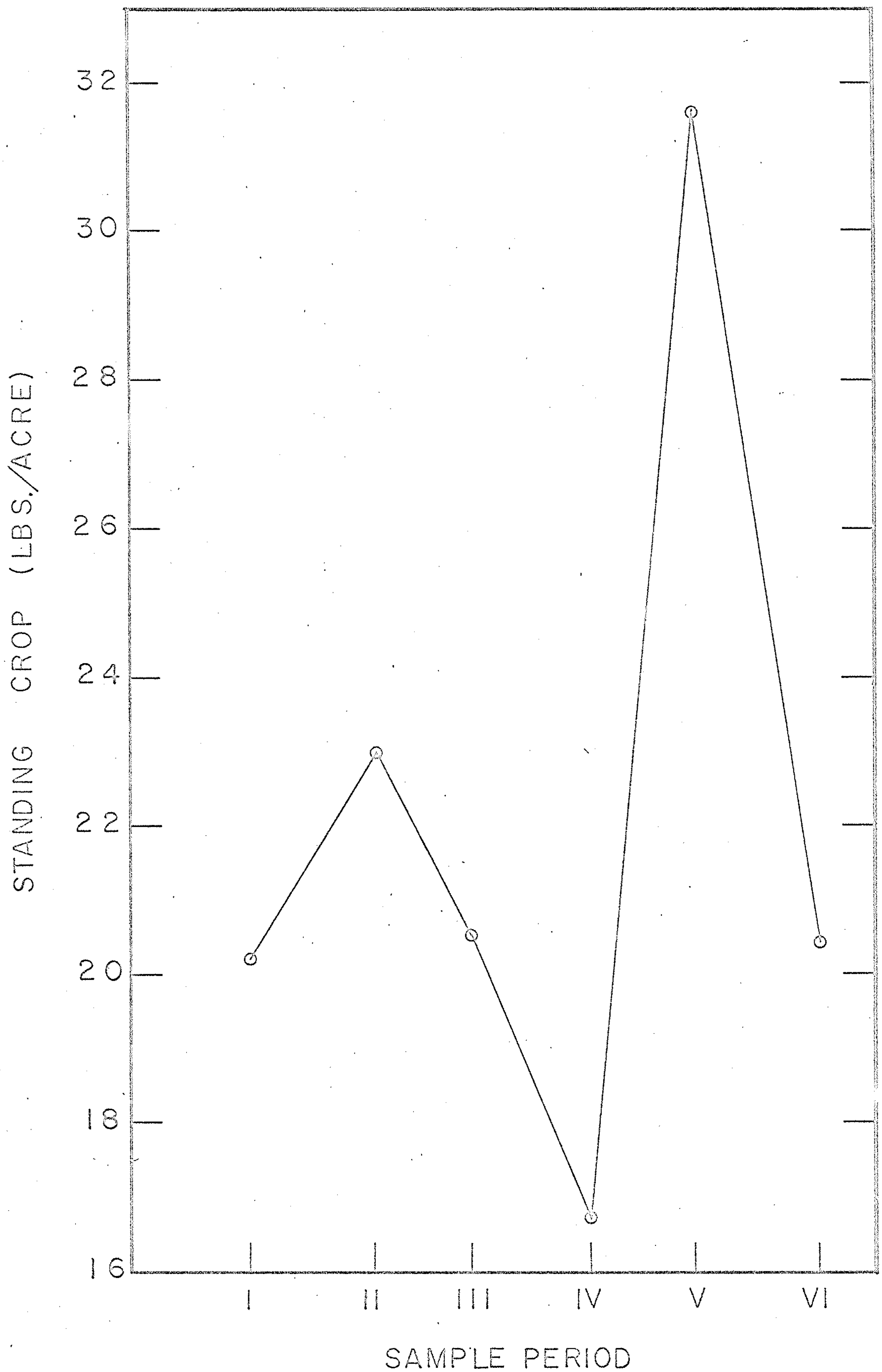
The determination of such production by means of the first two methods makes the basic assumption that all of the various depth zones are of equal size. However, this situation did not exist in the main basin of Cedar Lake. This is suggested as the reason for the difference of 6 lbs. in the values, obtained by the first two methods on the one hand, and the value obtained by the third method on the other. Thus a statement of the average quantity of biomass, based only on the total area of the basin, does not give a true picture of the amount of benthos present, since the increase in density of these animals, with increasing depth, is so pronounced.

The standing crop in Cedar Lake present during the various sampling periods was generally uniform during the study, except for periods IV and V, as shown in Figure 10. The decline in the quantity of biomass between sampling periods III and IV may be due to the emergence of certain insects such as the dipterids and ephemeropterids. The reason for the increase of almost 100 per cent in the pounds per acre of benthic animals from sampling periods IV to V is not clear. One possible explanation for this extreme increase in biomass is simply growth of the individuals. However, it is doubtful that such growth could occur in the short span of two to three weeks. Another possible explanation is that of a random error in sampling.

The general picture of uniformity of the standing crops

Figure 10

Variations in the standing crop present during the six sampling periods.


STANDING CROP (LBS./ACRE)
32
30
28
26
24
22
20
18
16
I
II
III
IV
V
VI
SAMPLE PERIOD

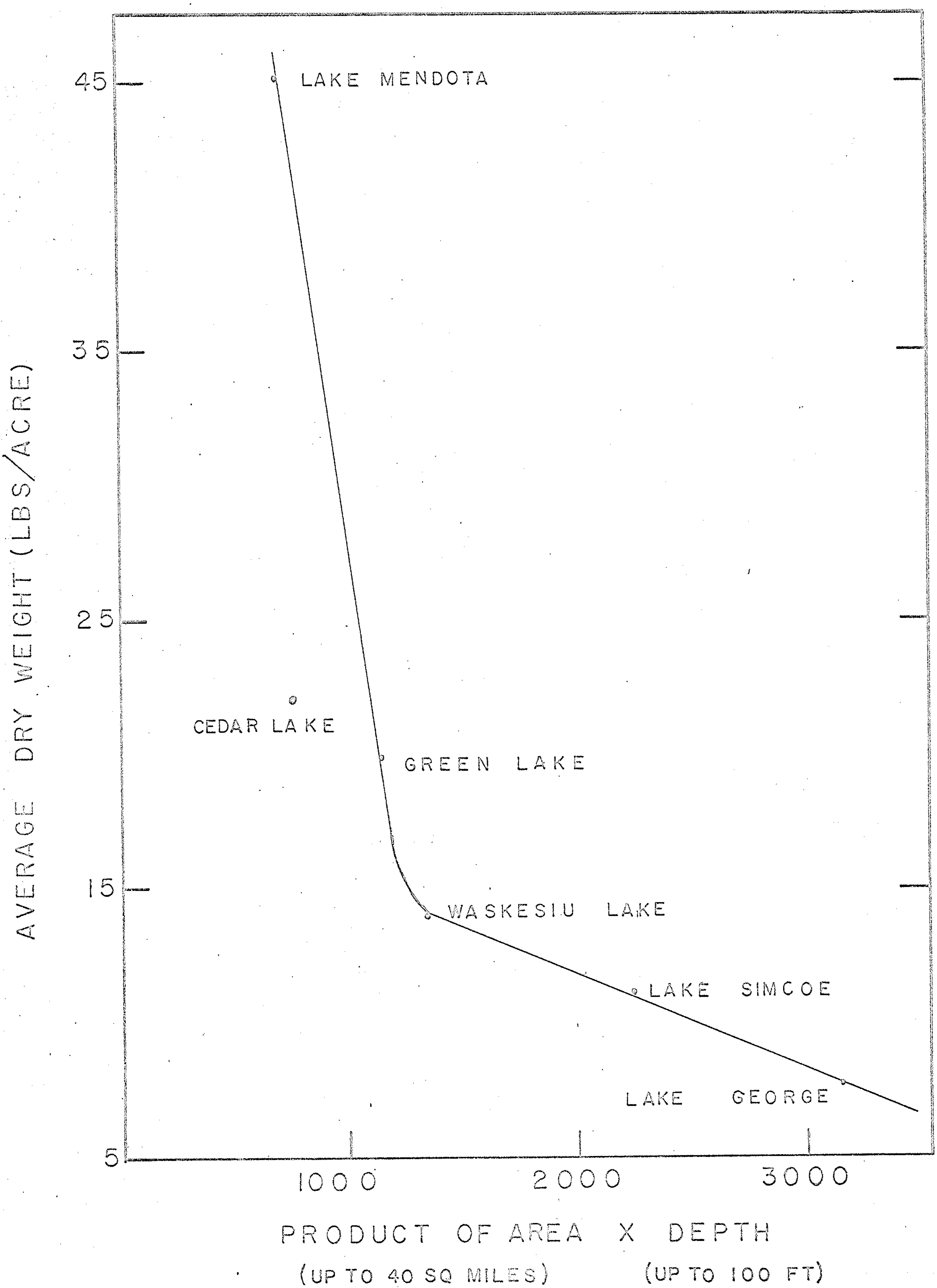
which results from the progressive addition of new animals through reproduction and the continuing growth of animals already present are sufficient to keep pace with the removal of benthic animals through predation, other forms of mortality and the emergence of insects whose adult stage is non-aquatic.

The average of the standing crops for the six sampling periods was found to be 22 lbs/acre, which is the same value as was determined for the average dry weight of bottom fauna for the main basin. In four of the six estimates of standing crop (sampling periods I, II, III and VI) the values varied only slightly about the mean weight (from 20.2 to 23 lbs/acre) as can been seen in Figure 10. This suggests that a relatively reliable estimate of the benthic productivity of a lake can be made from a standing crop determined during the early portion of the summer, although the determination of such productivity probably becomes more accurate with an increase in the number of standing crops determined.

The average dry weight of bottom fauna determined for the main basin of Cedar Lake, 22 lbs/acre, indicates a relatively high level of productivity when compared to the curve which Rawson (1930) presented for various North American lakes as shown in Figure 11. From this it is seen that Cedar Lake is, for example, more productive than Lake Simcoe, Lake George, Waskesiu Lake and Green Lake. Cedar Lake also compares closely to certain prairie lakes such as lakes Wakaw, Sturgeon,

Figure 11

The relation between the amounts of bottom fauna and the product of the depth and area (within limits) of Lakes. Adapted from Rawson (1930).


45
35
25
15
5
AVERAGE DRY WEIGHT (LBS/ACRE)
LAKE MENDOTA
CEDAR LAKE
GREEN LAKE
WASKESIU LAKE
LAKE SIMCOE
LAKE GEORGE
1000
2000
3000
PRODUCT OF AREA X DEPTH
(UP TO 40 SQ MILES)
(UP TO 100 FT)

Montreal and Bigstone in central Saskatchewan, where Mendis (1956) found average values of 22.9, 23.7, 20.4, and 29.9 lbs/acre respectively. Rawson (1957) found an average of 23.2 lbs/acre in Little Peter Pond Lake. These authors appear to have used only the mean values of all samples in their computations. Cedar Lake which is in circulation throughout the summer is considerably more productive than examples of eutrophic lakes which stratify thermally. Rawson (1930) in his study of Lake Simcoe found an average of 11 lbs/acre and Rawson and Atton, (1953) in their study on Lac La Ronge found an average of 13 lbs/acre. A distinct difference in productivity of benthos is noted when Cedar Lake is compared with typical oligotrophic lakes. Rawson (1947) determined that the average productivity of Great Slave Lake was 3.4 lbs/acre, while Ricker (1952) in his study on Cultus Lake found an average of 4.7 lbs/acre. Thus the high production of benthic fauna in the main basin of Cedar Lake is quite in keeping with the notion that Cedar Lake is a eutrophic lake in all respects.

SUMMARY

1. Cedar Lake can be described as a eutrophic lake as it possesses the necessary physical and chemical parameters for such a lake.

2. The major factors influencing the distribution and abundance of bottom animals in Cedar Lake are wave action in shallow waters and the type of bottom material present. Depth of water is indirectly involved because of its control over wave action and bottom type. Other variables such as temperature, oxygen, transparency, alkalinity and season could not be shown to affect the distribution of organisms within the main basin.

3. There is a general increase in both the number of individuals and the number of genera with increasing depth during any sampling period.

4. The average dry weight of bottom fauna determined for the main basin of Cedar Lake was 22 lbs/acre. The total dry weight of biomass estimated for the main basin of Cedar Lake was 3,263,102 lbs.

5. The standing crop is an estimate of the weight of benthic fauna present at any one time. An average of a number of standing crops gives a reliable estimate of the average amount of bottom fauna present in Cedar Lake.

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Appendix I

Taxonomy

The classification of benthic organisms used here follows that in Pennak (1953).

Class Nematoda

Order Enoplida

Family Dorylaimidae

Genus Dorylaimus

Class Oligochaeta

Order Plesiopora

Family Tubificidae

Genus Limnodrilus

Class Hirudinea

Order Rhynchobdellida

Family Glossiphoniidae

Genera Glossiphonia

Helobdella

Class Crustacea

Order Conchostraca

Family Caenestheriella

Genus Caenestheriella

Order Podocopa

Family Cypridae

Genus Cypriconcha

Order Amphipoda

Family Gammaridae

Genus Gammarus

Appendix I (continued)

Class Crustacea (continued)

Order Decapoda

Family Astacidae

Genus Orconectes

Class Insecta

Order Ephemeroptera

Family Ephemeridae

Genera Hexagenia

Ephemera

Family Baetidae

Genus Caenis

Family Heptagenidae

Genus Stenonema

Order Hemiptera

Family Corixidae

Genus Trichocorixa

Order Megaloptera

Family Sialidae

Genus Sialis

Order Trichoptera

Family Helicopsychidae

Genus Helicopsyche

Family Molannidae

Genus Molanna

Family Psychomyiidae

Genus Polycentropus

Appendix I (continued)

Class Insecta (continued)

Order Trichoptera (continued)

Family Hydroptilidae

Genera Agraylea

Oxyethira

Family Leptoceridae

Genus Athripsodes

Family Rhyacophilidae

Genus Rhyacophila

Order Diptera

Family Tendipedidae

Genera Procladius

Coelotanypus

Tendipedes

Cryptochironomus

Phaenopsectra

Harnischia

Family Ceratopogonidae

Genus ....

Class Gastropoda

Order Pulmonata

Family Physidae

Genus Physa

Family Planorbidae

Genera Promenetus

Gyraulus

Appendix I (continued)

Class Gastropoda (continued)

Order Pulmonata (continued)

Family Lymnaeidae

Genus Lymnaea

Order Ctenobranchiata

Family Valvatidae

Genus Valvata

Family Amnicolidae

Genus Amnicola

Class Pelecypoda

Order Heterodonta

Family Sphaeriidae

Genera Sphaerium

Pisidium

Order Eulamellibranchia

Family Unionidae

Genus Lampsilis

Appendix II

The numbers and genera of benthic animals collected at each sample station during the six sampling periods.

Sample Station 1A	Sample Period Dates					
?Organisms	14/6	29/6	18/7	30/7	14/8	31/8
Class Nematoda						
Order Enoplida						
Genus Dorylaimus					1	
Class Crustacea						
Order Amphipoda						
Genus Gammarus					1	
Class Insecta						
Order Ephemeroptera						
Genus Ephemera						1
Order Hemiptera						
Genus Trichocorixa	1					
Order Trichoptera						
Genus Oxyethira	1					
Class Gastropoda						
Order Pulmonata						
Genera Gyraulus						2
Promenetus						6
Order Ctenobranchiata						
Genera Valvata						2
Amnicola	14				3	111
Class Pelecypoda						
Order Heterodonta						
Genus Sphaerium	2			2	1	13
Number of Genera	4	0	0	1	4	6
Number of Organisms	18	0	0	2	6	135

Appendix II (continued)

Sample Station 1B Organisms	14/6	29/6	18/7	30/7	14/8	31/8
Class Crustacea						
Order Amphipoda						
Genus Gammarus						3
Class Insecta						
Order Ephemeroptera						
Genera Ephemera	4					
Caenis	1					
Hexagenia	1	2				
Stenonema					1	
Order Trichoptera						
Genera Polycentropus	2					
Helicopsyche			1			
Order Hemiptera						
Genus Trichocorixa	1					
Order Diptera						
Genera Coelotanypus					1	
Procladius			4			
Cryptochironomus			1			
Phaenopsectra	3					
Class Gastropoda						
Order Pulmonata						
Genus Physa			1			
Order Ctenobranchiata						
Genera Amnicola	12		26			18
Valvata			1			1
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium	12	1	40	1		13
Pisidium	2	2				
Order Eulamellibranchia						
Genus Lampsilis		1				1
Number of Genera	9	4	7	1	2	5
Number of Organisms	38	6	74	1	2	36

Appendix II (continued)

Organisms — Sample Station 1C	Sample Period Dates: 14/6	29/6	18/7	30/7	20/8	31/8
Class Nematoda						
Order Enoplida						
Genus Dorylaimus	6	3		1		
Class Oligochaeta						
Order Plesiopora						
Genus Limnodrilus	1	4	5	2		
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella	13	5	3	5	5	10
Order Podocopa						
Genus Cypriconcha	89	12				
Order Amphipoda						
Genus Gammarus	12	1	1	8		
Class Insecta						
Order Ephemeroptera						
Genus Hexagenia	74	133	72	63	63	73
Order Hemiptera						
Genus Trichocorixa				1		
Order Trichoptera						
Genera Agraylea	7	2	15	9	15	2
Oxyethira			2			1
Rhyacophlia			1	2	2	
Order Diptera						
Genera Procladius	51	36	28	9		1
Cryptochironomus		8			3	
Phaenopsectra	1		8	2		
Harnischia			7			
Coelotanypus	2	4	2			
Tendipedes	5	3	2	1		
Ceratopogonidae		2	1			
Class Gastropoda						
Order Pulmonata						
Genus Gyraulus	12	17		2		
Order Ctenobranchiata						
Genus Amnicola	99	137	54	132	136	116
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium	63	56	17	28	40	5
Pisidium	30	53	45	33	46	34
Number of Genera	15	16	16	15	8	8
Number of Organisms	465	476	264	298	310	241

Appendix II (continued)

Organisms (Sample Station 1D)	14/6	3/7	18/7	4/8	20/8	31/8
Class Nematoda						
Order Enoplida						
Genus Dorylaimus		4	2	6		
Class Oligochaeta						
Order Plesiopora						
Genus Limnodrilus		5	32	11		
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella	6	22	28	20	10	21
Order Podocopa						
Genus Cypriconcha	516	1118	611	250	431	501
Order Amphipoda						
Genus Gammarus		5		2	1	
Class Hirudinea						
Order Rhynchobdellida						
Genus Helobdella			3	3		
Class Insecta						
Order Ephemeroptera						
Genus Hexagenia	8	8	2		30	6
Order Diptera						
Genera Procladius	42	70	112	25	3	11
Cryptochironomus		4	4	3	4	3
Coelotanypus	3				3	1
Harnischia		6	2	20		
Phaenopsectra	26	12	18	4		
Tendipedes		2	1	1		
Ceratopogonidae				2		
Order Trichoptera						
Genera Agraylea	1	80	8	35	24	41
Rhyacophilus		4			12	
Oxyethira				2	11	21
Class Gastropoda						
Order Pulmonata						
Genera Gyraulus		15	7	32	3	15
Lymnaea		1				2
Order Ctenobranchiata						
Genera Amnicola	53	105	194	189	114	223
Valvata			21	15		6
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium	63	232	107	76	49	69
Pisidium	52	146	135	80	46	96
Number of Genera	10	18	17	20	14	14
Number of Organisms	770	1837	1287	777	741	1016

Appendix II (continued)

Organisms	Sample Station 2A	Sample Period Dates 19/6	3/7	19/7	1/8	17/8	30/8
Class Crustacea							
Order Amphipoda							
Genus Gammarus		1		1			
Class Insecta							
Order Ephemeroptera							
Genus Caenis			24				
Order Diptera							
Genera Cryptochironomus					1		
Procladius		3	1	2		2	3
Order Trichoptera							
Genus Agraylea						1	
Class Gastropoda							
Order Pulmonata Genus Lymnaea							
Genus Lymnaea			7	3	7	3	
Order Ctenobranchiata							
Genera Valvata				2			37
Amnicola		10	1	7	5	9	18
Class Pelecypoda							
Order Heterodonta							
Genus Pisidium		2					
Number of Genera		16	33	15	13	15	58
Number of Genera		4	4	5	3	4	3

Appendix II (continued)

Organisms	Sample Station 2B	Sample Period Dates 19/6	3/7	19/7	1/8	17/8	30/8
Class Crustacea							
Order Conchostraca							
Genus Caenestheriella				1			
Order Amphipoda							
Genus Gammarus							1
Order Decapoda							
Genus Orconectes				1			
Class Insecta							
Order Ephemeroptera							
Genus Stenonema						2	
Order Hemiptera							
Genus Trichocorixa				4	1		
Order Trichoptera							
Genera Polycentropus						1	
Agraylea						1	
Helicopsyche							1
Oxyethira							1
Class Gastropoda							
Order Ctenobranchiata							
Genus Amnicola				2		4	6
Class Pelecypoda							
Order Heterodonta							
Genus Sphaerium				3			1
Number of Genera		0	0	5	1	4	6
Number of Organisms		0	0	11	1	8	11

Appendix II (continued)

Sample Station 2C	Sample Period Dates					
Organisms	19/6	4/7	19/7	1/8	17/8	30/8
Class Crustacea						
Order Amphipoda						
Genus Gammarus						3
Order Decapoda						
Genus Orconectes					1	2
Class Insecta						
Order Ephemperoptera						
Genus Stenonema				2	1	
Order Hemiptera						
Genus Trichocorixa			1			
Order Diptera						
Genera Procladius					2	
Tendipedes		3				
Order Trichoptera						
Genera Polycentropus						1
Athripsodes						1
Class Gastropoda						
Order Pulmonata						
Genus Lymnaea						1
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium		3				
Pisidium		2				
Number of Genera	0	2	1	1	6	2
Number of Organisms	0	8	1	2	7	5

Appendix II (continued)

Sample Station 2D Organisms	19/6	4/7	19/7	1/8	17/8	30/8
	Sample Period Dates					
Class Nematoda						
Order Enoplida						
Genus Dorylaimus	1	14	6			
Class Oligochaeta						
Order Plesiopora						
Genus Limnodrilus	1	25	18	6	7	4
Class Hirudinea						
Order Rhynchobdellida						
Genus Helobdella	1	4				
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella	1	15	7	1	8	5
Order Podocopa						
Genus Cypriconcha	4	96	17			
Order Amphipoda						
Genus Gammarus			1			
Class Insecta						
Order Ephemeroptera						
Genus Hexagenia		2		1	14	8
Order Hemiptera						
Genus Trichocorixa					1	1
Order Diptera						
Genera Tendipedes	111	62	4	6	129	119
Coelotanypus			1			4
Procladius	9	35	192	74		22
Cryptochironomus	8	5		1	10	21
Harnischia		2	1	74	8	19
Phaenopsectra		16	23		9	2
Family Ceratopogonidae		2				
Order Trichoptera						
Genera Agraylea		6	2		2	6
Oxyethira			2			
Class Gastropoda						
Order Pulmonata						
Genera Lymnaea				1		1
Gyraulus		57	7		4	
Order Ctenobranchiata						
Genera Amnicola		80	85	46	34	121
Valvata	6	21	19	12	7	40
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium	32	73	63	26	37	35
Pisidium	22	34	40	30	24	50
Number of Genera	11	18	17	12	14	16
Number of Organisms	196	549	488	278	293	457

Appendix II (continued)

Organisms (Sample Station 3A)	19/6	4/7	19/7	1/8	17/8	30/8
Class Hirudinea						
Order Rhynchobdellida						
Genus Glossiphonia					2	
Class Crustacea						
Order Amphipoda						
Genus Gammarus	1				1	
Class Insecta						
Order Ephemeroptera						
Genus Stenonema						1
Order Megaloptera						
Genus Sialis					1	
Order Diptera						
Genera Procladius	1				2	
Coelotanypus			2			
Order Trichoptera						
Genera Helicopsyche	1					
Molanna	1					
Oxyethira	2					
Polycentropus						8
Class Gastropoda						
Order Pulmonata						
Genus Physa					1	
Order Ctenobranchiata						
Genera Amnicola		22	6	15	27	5
Valvata			1			
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium		1				
Pisidium		2				
Number of Genera	5	3	3	1	6	3
Number of Organisms	6	25	9	15	34	14

Appendix II (continued)

Organisms	Sample Station 3B	Sample Period Dates 19/6	4/7	19/7	1/8	17/8	30/8
Class Oligochaeta							
Order Plesiopora							
Genus Limnodrilus		1					
Class Crustacea							
Order Amphipoda							
Genus Gammarus							1
Class Insecta							
Order Ephemeroptera							
Genera Caenis		1					
Stenonema						2	2
Hexagenia							1
Order Hemiptera							
Genus Trichocorixa					1		
Order Diptera							
Genus Procladius		2	2	2			
Order Trichoptera							
Genera Polycentropus		2				4	2
Helicopsyche			1				
Agraylea					3		
Athripsodes						2	
Class Gastropoda							
Order Pulmonata							
Genus Gyraulus			2		1		
Order Ctenobranchiata							
Genera Amnicola		5	22	4	7	1	1
Valvata			2		1		
Class Pelecypoda							
Order Heterodonta							
Genera Sphaerium		3	3		2		1
Number of Genera		6	6	2	6	4	6
Number of Organisms		14	32	6	15	9	8

Appendix II (continued)

Organisms (Sample Station 3C)	19/6	4/7	19/7	1/8	17/8	30/8
Class Nematoda						
Order Enoplida						
Genus Dorylaimus		2				
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella		1	7	4		
Order Amphipoda						
Genus Gammarus		99	201	7	87	62
Order Decapoda						
Genus Orconectes			1			
Class Insecta						
Order Ephemeroptera						
Genus Hexagenia	73	99	59	78	37	62
Order Megaloptera						
Genus Sialis				1		
Order Diptera						
Genera Procladius	8	22	12	9	4	9
Tendipedes	9		2	3	1	
Harnischia	2				1	
Phaenopsectra		4		2		
Coelotanypus	2	1				
Cryptochironomus	1	3				
Order Trichoptera						
Genera Agraylea	2	1	2	15		
Rhyacophila		2		4		
Oxyethira				1	3	
Class Gastropoda						
Order Pulmonata						
Genera Gyraulus	7		7	1		
Lymnaea		1				
Order Ctenobranchiata						
Genera Amnicola	122	73	72	110	26	43
Valvata	11	1	1			
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium	269	133	103	56	52	131
Pisidium				1		
Order Eulamellibranchia						
Genus Lampsilis			1			
Number of Genera	11	14	12	14	8	5
Number of Organisms	506	472	466	285	211	307

Appendix II (continued)

Organisms (Sample Station 3D)	19/6	4/7	19/7	1/8	17/8	30/8
Class Oligochaeta						
Order Plesiopora						
Genus Limnodrilus	2	1		2		1
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella	5	2	26	9	13	9
Order Podocopa						
Genus Cypriconcha	28					
Order Amphipoda						
Genus Gammarus	26	13	12		4	2
Class Insecta						
Order Ephemeroptera						
Genus Hexagenia	138	101	95	29	78	43
Order Diptera						
Genera Cryptochironomus	1	1			1	
Procladius	4	5	3	9	1	4
Harnischia	1				1	
Tendipedes			3	3		
Coelotanypus	1	3		2		
Order Trichoptera						
Genera Agraylea	66	10	5			2
Oxyethira	5		3		1	2
Rhyacophila		1	1			
Class Gastropoda						
Order Pulmonata						
Genera Physa						1
Gyraulus	2		1			
Lymnaea		1				1
Order Ctenobranchiata						
Genera Amnicola	68	104	114	52	97	49
Valvata		5	2	6	6	5
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium	53	28	54	14	29	13
Pisidium	24	2	17	12	16	4
Number of Genera	15	14	13	10	11	13
Number of Organisms	424	277	336	138	247	136

Appendix II (continued)

Organisms (Sample Station 4A)	15/6	29/6	20/7	4/8	14/8	30/8
Class Oligochaeta						
Order Plesiopora						
Genus Limnodrilus					1	2
Class Hirudinea						
Order Rhynchobdellida						
Genus Helobdella			1			
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella				1	2	
Class Insecta						
Order Ephemeroptera						
Genera Hexagenia			7	13	27	
Ephemera					7	
Caenis			2		1	
Order Hemiptera						
Genus Trichocorixa		2		1		1
Order Megaloptera						
Genus Sialis					3	
Order Diptera						
Genera Cryptochironomus				2	3	
Procladius		1		2		
Phoenopsectra			2			
Order Trichoptera						
Genera Helicopsyche		1	7	1	1	
Molanna			2	1		
Agraylea				1	1	
Polycentropus						1
Class Gastropoda						
Order Pulmonata						
Genera Physa			1			1
Gyraulus			12	3	1	2
Order Ctenobranchiata						
Genera Amnicola		9	58	125	101	1
Valvata			5		2	
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium		3	10	107	154	
Pisidium			2	3	3	
Order Eulamellibranchia						
Genus Lampsilis					2	
Number of Genera	0	5	12	12	15	6
Number of Organisms	0	16	109	260	309	8

Appendix II (continued)

Organisms (Sample Station 4B)	15/6	29/6	20/7	4/8	14/8	30/8
Class Nematoda						
Order Enoplida						
Genus Dorylaimus		1				
Class Oligochaeta						
Order Plesiopora						
Genus Limnodrilus	5		6	3	10	10
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella			1			2
Order Podocopa						
Genus Cypriconcha			3			
Order Amphipoda						
Genus Gammarus	1				2	13
Class Insecta						
Order Ephemeroptera						
Genera Hexagenia	10	14	21	24	15	7
Ephemera					1	
Order Hemiptera						
Genus Trichocorixa	1			1		
Order Megaloptera						
Genus Sialis			1	5		3
Order Trichoptera						
Genera Agraylea	2		4	1	5	10
Oxyethira					1	
Order Diptera						
Genera Procladius	9	4	23	6		3
Coelotanypus	8	2		1		2
Tendipedes	21	9	2	6	5	1
Cryptochironomus		4			2	1
Harnischia	1			3	3	
Phaenopsectra				4		
Ceratopogonidae			2			
Class Gastropoda						
Order Pulmonata						
Genera Gyraulus	1		12	2	2	
Lymnaea					1	
Order Ctenobranchiata						
Genera Valvata		1				
Amnicola	28	14	145	107	234	78
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium	122	116	101	107	125	88
Pisidium	16		23	8	36	18
Number of Genera	13	9	13	14	14	13
Number of Organisms	223	165	344	278	442	236

Appendix II (continued)

Organisms — Sample Station 4C	Sample Period Dates 21/6	4/7	20/7	4/8	19/8	30/8
Class Nematoda						
Order Enoplida						
Genus Dorylaimus	1					
Class Oligochaeta						
Order Plesiopora						
Genus Limnodrilus		2	7	3	5	1
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella	2	4	4	1	2	2
Order Amphipoda						
Genus Gammarus		1			2	35
Class Insecta						
Order Ephemeroptera						
Genera Stenonema						1
Hexagenia	72	111	72	55	34	60
Order Diptera						
Genera Tendipedes			1		1	2
Cryptochironomus	1				3	1
Procladius	5	24	16	7		2
Coelotanypus	1	3				
Harnischia		2				
Family Ceratopogonidae			1			
Order Trichoptera						
Genera Agraylea	1	8	4	3	2	6
Oxyethira						3
Class Gastopoda						
Order Pulmonata						
Genera Lymnaea	1					
Gyraulus		8		1		1
Order Ctenobranchiata						
Genera Amnicola	64	134	178	134	128	167
Valvata	1					1
Class Pelecypoda						
Order Eulamellibranchia						
Genus Lampsilis					1	
Order Heterodonta						
Genera Sphaerium	12	62	50	41	26	41
Pisidium	4	31	46	25	30	15
Number of Genera	12	12	10	9	11	15
Number of Organisms	165	390	379	270	236	358

Appendix II (continued)

Sample Station 4D Organisms	21/6	4/7	20/7	1/8	17/8	30/8
Class Oligochaeta						
Order Plesiopora						
Genus Limnodrilus	4	3	2	5	1	4
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella	7	6	1	10	14	7
Order Amphipoda						
Genus Gammarus			3	62	1	18
Class Insecta						
Order Ephemeroptera						
Genera Stenonema		1			1	2
Hexagenia	49	91	62	38	51	51
Order Diptera						
Genera Cryptochironomus	2	1				2
Phaenopsectra	2	2		4	1	
Procladius	4	16	27	4		
Coelotanypus		4		1		
Tendipedes	5		3	3		
Family Ceratopogonidae			1	1		
Order Trichoptera						
Genera Agraylea	2	1	3	5	1	3
Rhyacophila		4		9		
Oxyethira						3
Class Gastropoda						
Order Pulmonata						
Genera Lymnaea	1	1			1	
Gyraulus		8	2	14		
Order Ctenobranchiata						
Genera Amnicola	56	91	46	339	155	85
Valvata	7	6	2	14	7	3
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium	14	34	11	36	21	13
Pisidium	16	24	8	19	37	7
Number of Genera	13	16	13	16	12	12
Number of Organisms	169	293	171	554	291	198

Appendix II (continued)

Organisms (Sample Station 5A)	Sample Period Dates 18/6	29/6	18/7	4/8	14/8	31/8
Class Oligochaeta						
Order Plesiopora						
Genus Limnodrilus		3			3	2
Class Hirudinea						
Order Rhynchobdellida						
Genus Glossiphonia						1
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella					1	
Order Amphipoda						
Genus Gammarus		14			10	4
Order Decapoda						
Genus Orconectes				1		
Class Insecta						
Order Ephemeroptera						
Genus Hexagina		6			16	3
Ephemera					1	1
Order Hemiptera						
Genus Trichocorixa	1					
Order Diptera						
Genera Procladius		3		1		2
Cryptochironomus		9				
Tendipedes		1				
Order Trichoptera						
Genera Polycentropus	1					
Helicopsyche						1
Class Gastropoda						
Order Pulmonata						
Genus Gyraulus	1					
Order Ctenobranchiata						
Genus Amnicola	4			5	10	9
Class Pelecypoda						
Order Eulamellibranchia						
Genus Lampsilis		1				
Order Heterodonta						
Genera Sphaerium	4	11	1	3	11	62
Pisidium		4			2	4
Number of Genera	5	9	1	4	8	10
Number of Organisms	11	52	1	10	54	89

Appendix II (continued)

Sample Station 5B Organisms	Sample Period Dates 18/6	29/6	18/7	4/8	14/8	31/8
Class Nematoda						
Order Enoplida						
Genus Dorylaimus	2					
Class Olicochaeta						
Order Plesiopora						
Genus Limnodrilus	46	35	77	18	24	5
Class Crustacea						
Order Amphipoda						
Genus Gammarus	182	327	231	164	118	205
Order Decapoda						
Genus Orconectes			1			
Class Insecta						
Order Ephemeroptera						
Genus Hexagenia	8	9	7	9	8	1
Order Hemiptera						
Genus Trichocorixa				1		
Order Diptera						
Genera Procladius	19	10	7	11		5
Cryptochironomus	11	10	3		1	1
Tendipedes					1	
Phaenopsectra	5		5	1	1	
Harnischia	4		2	1	8	3
Family Ceratopogonidae	3					
Order Trichoptera						
Genus Agraylea		4	10	3	1	
Oxyethira			1			
Class Gastropoda						
Order Pulmonata						
Genus Gryaulus			4	1		
Order Ctenobranchiata						
Genus Amnicola	117	70	79	70	39	64
Class Pelecypoda						
Order Heterodonta						
Genera Sphaerium	452	177	100	151	49	75
Pisidium	82	25	35	7	9	12
Number of Genera	12	9	14	12	11	9
Number of Organisms	931	667	462	437	259	371

Appendix II (continued)

Organisms — Sample Station 5C	21/6	7/7	18/7	4/8	19/8	31/8
Class Nematoda						
Order Enoplida						
Genus Dorylaimus		17		3		
Class Oligochaeta						
Order Plesiopora						
Genus Limnodrilus	44	94	27	33	9	18
Class Hirudinea						
Order Rhynchobdellida						
Genus Helobdella		1	1			
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella	2	1	6	2	5	
Order Podocopa						
Genus Cypriconcha	2	5				
Class Insecta						
Order Ephemeroptera						
Genus Hexagenia	3	12	2	4	10	4
Order Diptera						
Genera Procladius	8	74	55	8	3	6
Cryptochironomus	1		2	1	5	3
Tendipedes	3	2	3	3		
Harnischia	2	5	10	4		
Phaenopsectra	17	7	3	1		
Coelotanypus	4	5				
Order Trichoptera						
Genera Agraylea	4	1	3	24	9	26
Oxyethira					6	2
Class Gastropoda						
Order Pulmonata						
Genus Gyraulus		11	9	29	14	
Order Ctenobranchiata						
Genera Amnicola	69	287	215	196	215	177
Valvata					1	8
Class Pelecypoda						
Order Eulamellibranchia						
Genus Lampsilis			1			
Order Heterodonta						
Genera Sphaerium	12	110	46	115	76	41
Pisidium	17	81	98	52	60	64
Number of Genera	14	16	15	14	12	10
Number of Organisms	189	713	481	455	413	349

Appendix II (continued)

Organisms (Sample Station 5D)	21/6	7/7	18/7	4/8	17/8	30/8
Class Nematoda						
Order Enoplida						
Genus Dorylaimus		3				
Class Oligochaeta						
Order Plesiopora						
Genus Limnodrilus	25	27	2	17	10	20
Class Hirudinea						
Order Rhynchobdellida						
Genus Helobdella						1
Class Crustacea						
Order Conchostraca						
Genus Caenestheriella	13	24	8	40	68	33
Order Amphipoda						
Genus Gammarus			34			
Class Insecta						
Order Ephemeroptera						
Genus Hexagenis	7	7	28	23	19	2
Order Diptera						
Genera Tendipedes	1					9
Cryptochironomus	7	2			2	9
Procladius	9	89	14	17	5	14
Coelotanypus					1	
Harnischia		8		3		
Phaenopsectra	4	29	1			
Order Trichoptera						
Genera Agraylea		11	1	5	5	4
Oxyethira		1		1		3
Rhyacophila		1				
Class Gastropoda						
Order Pulmonata						
Genera Lymnaea		1				
Gyraulus		8	16	22	14	94
Order Ctenobranchiata						
Genera Amnicola	119	151	292	176	158	241
Valvata	26	56	16	22	54	94
Class Pelecypoda						
Order Eulamellibranchia						
Genus Lampsilis					1	
Order Heterodonta						
Genera Sphaerium	46	92	32	100	33	97
Pisidium	37	125	84	55	38	111
Number of Genera	11	17	12	12	13	14
Number of Organisms	294	635	528	481	408	642