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TITLE THE RELATION OF PHYTOPLANKTON PERIODICITY TO THE NATURE OF THE PHYSICO-CHEMICAL ENVIRONMENT IN CERTAIN MICHIGAN LAKES

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THE RELATION OF PHYTOPLANKTON PERIODICITY TO THE NATURE OF THE PHYSICO-CHEMICAL ENVIRONMENT IN CERTAIN MICHIGAN LAKES

by

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TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	MORPHOMETRY OF THE LAKES	3
	Douglas Lake	3
	Lancaster Lake	4
	Munro Lake	4
	Vincent Lake	5
	Lake Lansing	5
III.	GENERAL PROCEDURE	7
IV.	PHYSICAL AND CHEMICAL CONDITIONS	9
	Methods	9
	Data	18
	Douglas Lake	18
	Lancaster Lake	45
	Munro Lake	54
	Vincent Lake	56
	Lake Lansing	61
V.	PHYTOPLANKTON	68
	Method of Collection and Enumeration	68
	Phytoplankton of Douglas Lake	75
	Phytoplankton of Lancaster Lake	88
	Phytoplankton of Munro Lake	92
	Phytoplankton of Vincent Lake	94
	Phytoplankton of Lake Lansing	95

CHAPTER PAGE

Comparison of Phytoplankton Populations in the Five Lakes 99

Discussion of the Individual Genera of Phytoplankton 104

Comparison of Densities of Extracted Pigment with Phytoplankton Counts . . 118

VI. GENERAL DISCUSSION AND CONCLUSIONS 123

VII. SUMMARY 147

LITERATURE CITED 156

APPENDIX 160

LIST OF TABLES

TABLE		PAGE
1.	Physico-Chemical Data from Douglas Lake During the Summer of 1948	21
2.	Seasonal and Vertical Temperature Series in Douglas Lake 1950-1951	22
3.	Seasonal and Vertical Distribution of Certain Chemical Factors in Douglas Lake 1950-1951	23
4.	Seasonal and Vertical Distribution of Phosphorus in Douglas Lake 1950-1951 . .	34-35
5.	Physico-Chemical Data from Lancaster Lake During the Summers of 1948-1950-1951 . .	46
6.	Phosphorus Data from Lancaster Lake During the Summers of 1950-1951	49
7.	A Comparison of the Soluble Inorganic Phosphorus in Douglas and Lancaster Lakes During the Summer of 1951	51
8.	Physico-Chemical Data from Munro Lake During the Summers of 1948-1950-1951	55
9.	Phosphorus Data from Munro Lake During the Summers of 1950-1951	57
10.	Physico-Chemical Data from Vincent Lake During the Summers of 1948-1950-1951 . .	59
11.	Phosphorus Data from Vincent Lake During the Summers of 1950-1951	60

TABLE PAGE

12. Physico-Chemical Data from Lake Lansing During the Fall of 1950 62

13. Phosphorus Data from Lake Lansing During the Fall of 1950 67

14. Species of Phytoplankton Making up the Genera which have Quantitative Significance in the Plankton Samples Collected from the Five Lakes . . . . . 70 - 72

15. Average of the Three Mean Summer Standing Crops of Phytoplankton and Their Percentage Composition for 1948, 1950 and 1951 in Douglas, Lancaster, Munro and Vincent Lakes 100

16. Comparison of the Mean Fall Standing Crops of Phytoplankton and Their Percentage Composition for 1950 in Douglas Lake and Lake Lansing 103

17. Statistical Analysis Showing Relationship Between Number of Units of Phytoplankton Counted and Density of Pigment Extracted 119

18. Abundance of Total Phytoplankton in Douglas Lake at Various Depths During the Summer of 1948 161

19. Composition of Phytoplankton in Douglas Lake During the Summer of 1948 161

TABLE PAGE

20. Percentage Composition of Phytoplankton in Douglas Lake During the Summer of 1948 . . . 161

21-25. Abundance of the Different Classes of Algae in Douglas Lake During the Summer of 1948. 162-164

26-37. Abundance of the Different Genera of Algae in Douglas Lake During the Summer of 1948. 164-170

38. Seasonal and Vertical Distribution of Total Phytoplankton at Various Depths in Douglas Lake from July, 1950 Through October, 1951 171

39. Composition of Phytoplankton in Douglas Lake from July, 1950 Through October, 1951 . . . 172

40. Percentage Composition of Phytoplankton in Douglas Lake from July, 1950 Through October, 1951 173

41-45. Seasonal and Vertical Distribution of the Different Classes of Algae in Douglas Lake from July, 1950 Through October, 1951 . . 174-178

46-64. Seasonal and Vertical Distribution of the Different Genera of Algae in Douglas Lake from July, 1950 Through October, 1951 . . 179-197

65. Abundance of Total Phytoplankton in Lancaster Lake During the Summers of 1948, 1950 and 1951 198

66. Composition of Phytoplankton in Lancaster Lake During the Summers of 1948, 1950 and 1951 199

TABLE PAGE

67. Percentage Composition of Phytoplankton in Lancaster Lake During the Summers of 1948, 1950 and 1951 199

68-72. Abundance of the Different Classes of Algae in Lancaster Lake During the Summers of 1948, 1950 and 1951 200-202

73-91. Abundance of the Different Genera of Algae in Lancaster Lake During the Summers of 1948, 1950 and 1951 202-211

92. Abundance of Total Phytoplankton in Munro Lake During the Summers of 1948, 1950 and 1951 212

93. Composition of Phytoplankton in Munro Lake During the Summers of 1948, 1950 and 1951 . 213

94. Percentage Composition of Phytoplankton in Munro Lake During the Summers of 1948, 1950 and 1951 213

95-99. Abundance of the Different Classes of Algae in Munro Lake During the Summers of 1948, 1950 and 1951 214-216

100-117 Abundance of the Different Genera of Algae in Munro Lake During the Summers of 1948, 1950 and 1951 216-225

118. Abundance of Total Phytoplankton in Vincent Lake During the Summers of 1948, 1950 and 1951 226

TABLE PAGE

119. Composition of Phytoplankton in Vincent Lake During the Summers of 1948, 1950 and 1951 227

120. Percentage Composition of Phytoplankton in Vincent Lake 227

121-125. Abundance of the Different Classes of Algae in Vincent Lake 228-230

126-139. Abundance of the Different Genera of Algae in Vincent Lake 230-237

140. Abundance of Total Phytoplankton in Lake Lansing During the Fall of 1950 238

141. Composition of Phytoplankton in Lake Lansing During the Fall of 1950 238

142. Percentage Composition of Phytoplankton in Lake Lansing During the Fall of 1950 . . 239

143-147. Abundance of the Different Classes of Algae in Lake Lansing During the Fall of 1950 239-241

148-164. Abundance of the Different Genera of Algae in Lake Lansing During the Fall of 1950 241-246

165. A Comparison of Densities of Pigment Extracted from the Concentrates of Filtered and Centrifuged Water Samples from Douglas Lake 247

166-169. A Comparison of Plankton Counts with Densities of Extracted Pigment from Similar Samples from Lancaster, Munro, Vincent and Lansing Lakes 248-249

LIST OF ILLUSTRATIONS

FIGURE PAGE

1. Variation in Bicarbonates in Douglas Lake (South Fishtail Bay). Years - 1950-1951 . . 31
2. Maximum and Minimum Values of Total Phosphorus Occurring Between Surface and 12-meter Depth in Douglas Lake (South Fishtail Bay). Years 1950-1951 37
3. Maximum and Minimum Values of Soluble Inorganic Phosphorus Occurring Between Surface and 12-meter Depth in Douglas Lake (South Fishtail Bay). Years 1950-1951 37
4. Variations of Total Phosphorus and Soluble Inorganic Phosphorus at 20-meter Depth in Douglas Lake (South Fishtail Bay). Years 1950-1951 39
5. Vertical Distribution of Soluble Inorganic Phosphorus in Douglas Lake (South Fishtail Bay) During the Summer of 1951 53
6. Vertical Distribution of Soluble Inorganic Phosphorus in Lancaster Lake During the Summer of 1951 53
7. Soluble Inorganic Phosphorus and Dissolved Oxygen in Lake Lansing at 8-meter Depth (Bottom), During Fall of 1950 64

FIGURE PAGE

8. Maximum and Minimum Values of Total Phosphorus and Soluble Inorganic Phosphorus Occurring Between Surface and 5-meter Depth in Lake Lansing During Fall of 1950 64

9. Seasonal Variation in Standing Crops of Total Phytoplankton and the Major Classes of Algae in Douglas Lake During the Summer of 1948 and from July 3, 1950, to October 6, 1951 77

10. Seasonal Variation in Standing Crops of Total Diatoms and the Major Genera of This Class in Douglas Lake During the Summer of 1948 and from July 3, 1950, to October 6, 1951 . . 82

11. Vertical Distribution of Total Phytoplankton and the Major Classes of Algae in Douglas Lake During the Summer of 1948 and from July 3, 1950, to October 6, 1951 85

12. Seasonal Variation in Standing Crops of Total Phytoplankton and Their Percentage Composition in Douglas Lake During the Summer of 1948 and from July 3, 1950, to October 6, 1951 87

13. Vertical Distribution and Percentage Composition of Phytoplankton Crops in Lancaster Lake During the Summers of 1948, 1950 and 1951 . . 91

FIGURE PAGE

14. Vertical Distribution of Phytoplankton in Lake Lansing During the Fall of 1950 . . . 98

15. Variation in Standing Crops of Phytoplankton and Their Percentage Composition in Lake Lansing During the Fall of 1950 98

16. Relation Between Density of Extracted Pigment (Measured in Klett Units per Liter) and Units of Count per Liter in Comparable 10 Liter Samples of Plankton Collected From Douglas, Lancaster and Lansing Lakes. (Displayed on double log. scale) 121

17. Seasonal Variation of Standing Crop of Total Phytoplankton and Soluble Inorganic Phosphorus at 20-meter Depth in Douglas Lake. Years 1950-1951 145

INTRODUCTION

Inasmuch as phytoplankton is an important link in the food cycle of aquatic animals in a body of water, knowledge of its abundance might well indicate the productive capacity of that body of water. In the past, the majority of investigations involving quantitative phytoplankton collections and analyses have been limited to summer months. The ineffectiveness of summer investigations in showing the true picture of phytoplankton production has been demonstrated by several workers who conducted year-round investigations on various lakes in this and other countries. Among them, Dailey (1938) and Chandler (1940) have made such studies on Lake Michigan and Lake Erie, respectively. Both have shown the occurrence of two large annual pulses, one in early spring and the other in late fall. Had these investigations been restricted to the summer months, the pulses in these lakes would never have been recorded. Pennak (1946) reported that in seven small Colorado lakes which were studied the year-round, "Only one showed characteristic spring and autumn pulses. Another lake had three pulses, one in spring, one in mid-summer and one in autumn. Each of the other four lakes had only a single peak in the annual population curve; in three of these it occurred sometime during the spring, and in the other during the summer."

Because there may be one, two, or three phytoplankton pulses in a lake annually, and since these may occur at any time of the year, it seems almost imperative to conduct year-round studies in order to gain a perspective of phytoplankton production.

Plankton samples and physico-chemical data were collected from Douglas Lake for 16 consecutive months from July, 1950, through October, 1951. It is the main purpose of this paper to show the seasonal and vertical distribution of phytoplankton in Douglas Lake during that period of time and to discuss the possible roles of some of the physico-chemical conditions - particularly phosphorus - in the metabolism of a lake. In addition, plankton samples and physico-chemical data were collected during the summers of 1948, 1950 and 1951 from Munro, Vincent and Lancaster Lakes in northern Michigan and during the fall of 1950 from Lake Lansing in southern Michigan. These lakes are quite different morphometrically, and part of this paper will be devoted to a comparison of the phytoplankton and physico-chemical conditions of those lakes during the periods mentioned.

MORPHOMETRY OF THE LAKES

Four of the lakes which were studied, namely, Douglas, Lancaster, Munro and Vincent, are situated in the northern part of the Lower Peninsula. All four lie in Munro township, Cheboygan County, and are only a very few miles from each other. Lake Lansing, on the other hand, is about 240 miles south of the previously mentioned lakes. It is situated in Ingham County approximately three miles east of East Lansing.

Eggleton (1935) pointed out the fact that although the four northern lakes lie so near to each other, they differ markedly in their morphometric, physico-chemical and biological conditions. The morphometry of these lakes has already been described in the literature and the following accounts mention only those salient features of each lake which are pertinent to the present investigation. References to the original descriptions are included in the discussion.

Douglas Lake

The first hydrographic map of Douglas Lake was made by the Department of Geodesy and Surveying, University of Michigan, while a surveying camp was maintained on the site where the University of Michigan Biological Station is now situated. Scott (1921) and Welch (1927) thoroughly discuss the

morphometry of this lake; the following data are from their reports. Douglas Lake has an area of 5.83 square miles. Its maximum length is 3.8 miles and maximum width 2.27 miles. The maximum depth, standard low water datum, is 89 feet (27.1 meters). Welch (1927) discussed the seven distinct depressions within its basin and further pointed out that these depressions are isolated from each other by depth contours of 40 feet (12.2 meters) or less, and that from the standpoint of physico-chemical conditions, each depression behaves as a separate lake. The investigation, discussed in this paper, was carried out in the South Fishtail Depression which is situated in the south-east portion of the lake. It has a maximum depth of 24 meters and is isolated from the other depressions of the lake slightly below the 9 meter contour. The area of the basin at that depth is 0.14 square mile.

Lancaster Lake

According to Eggleton (1935), Lancaster Lake has a surface area of approximately 0.08 square mile (51 acres) with a maximum length of 0.4 mile and maximum breadth of 0.28 mile. The maximum depth which occurs near the center of the lake is 17 meters and the slope from surface to bottom is abrupt.

Munro Lake

This lake was mapped by Welch and Eggleton in 1931;

Welch (1938). It is a rather large and shallow bog lake having an area of approximately 0.8 square mile (512 acres), with a maximum depth of 4.2 meters. The major portion of the lake, however, has a depth not greater than 2 meters. The presence of a false bottom in this body of water makes it difficult to make a true sounding (Welch, 1938). The maximum length of the lake is 1.68 miles and its maximum width is 0.78 mile. Obviously the slope of its floor is gradual.

Vincent Lake

Morphometric information about this small bog lake is included in the unpublished thesis of Gorham and also in a paper by Welch (1938). Vincent Lake has a surface area of about 0.05 square mile (32 acres). Its maximum length and breadth are 0.3 mile and 0.22 mile respectively. It has a maximum depth of 6 meters, but as in Munro Lake, it also has a false bottom and hence accurate measurements of depth are difficult to determine. It has a gradual slope from surface to bottom, however, not quite as gradual as that in Munro Lake.

Lake Lansing

A hydrographic map of Lake Lansing was made available for this study by the Institute for Fisheries Research of the Michigan Conservation Department. From this map, various morphometric information was calculated. The area of the

lake is 0.71 square mile (452.5 acres). Its maximum length is 1.26 miles whereas its maximum width measured at right angles to its long axis is 0.83 mile. Most of the lake has a depth of approximately 10 feet (3 meters). There are, however, two depressions; one in the northern part, the depth of which is 35 feet (10.7 meters) and which, incidentally, is also the maximum depth of the lake, and the other in the southern part, the depth there being 25 feet (7.6 meters).

GENERAL PROCEDURE

During the summer of 1948, I established headquarters at the University of Michigan Biological Station and collected vertical series of quantitative net plankton samples for identification and enumeration from each of the four northern Michigan lakes, Douglas, Lancaster, Munro and Vincent. These collections were made with a Birge and Juday 10-liter plankton trap, at about weekly intervals, from a single station in each of the four lakes. The stations chosen were located approximately in the center of each of the three smaller lakes and situated over the deepest part of the respective basins. The samples from Douglas Lake were taken from South Fishtail Bay. At the time of a plankton collection, a vertical temperature series was taken and a vertical series of water samples collected with a Kemmerer sampler for certain chemical determinations including dissolved oxygen, free carbon dioxide, carbonates, bicarbonates, pH and conductivity.

During the summer of 1950 the same procedure was repeated in all four lakes, however, this time at each collection period duplicate vertical series of plankton samples were collected; one for identification and enumeration and the other for pigment extraction (Tucker, 1949). Also, two additional vertical series of water samples were taken; the

first to be centrifuged so that pigment could be extracted from the residue, the other to be used for various phosphorus analyses.

Vertical series of plankton samples, water samples and temperature readings were taken from the Douglas Lake station during the fall, winter and spring of 1950-51 by Mr. William Pruitt, Jr. who spent the entire year in this region. The samples were sent to my permanent headquarters at Michigan State College in East Lansing where they were analysed. These analyses consisted of identification and enumeration of phytoplankton, and chemical analysis of the water samples for carbonates, bicarbonates and various fractions of phosphorus. In the summer of 1951, I returned to the University of Michigan Biological Station and continued the investigation on the four northern lakes, repeating the procedures of the summer of 1950.

The Lake Lansing investigation was carried on during the fall of 1950. Here the procedure was, in the main, the same as that in the northern lakes during the preceding summer. All the collections were made from a single station over the deepest part of the northern depression.

By way of summary, then, data were collected from each of the four northern lakes during the summers of 1948, 1950 and 1951. The data from South Fishtail Bay, however, were collected over a period of 16 consecutive months from July, 1950, through October, 1951. Data from Lake Lansing were taken during the fall season of 1950.

PHYSICAL AND CHEMICAL CONDITIONS

METHODS

Temperatures. All temperatures except those from Lake Lansing were taken with an HB reversing thermometer. Those from Lake Lansing were taken with a Taylor maximum-minimum thermometer which had been calibrated against the HB reversing thermometer.

Conductivity. Conductivity determinations do not appear in any of the tables, however, some determinations were made from water samples taken from the four northern lakes and will be mentioned in the discussion concerning the chemical results. These determinations were made with a Digby and Biggs Dionic Water Tester (Evershed, 1911). Conductivity is measured in reciprocal megohms.

Oxygen. Dissolved oxygen was determined by the Rideal-Stewart modification of the Winkler method as given by Standard Methods of Water Analyses.

Free Carbon Dioxide, Carbonates, Bicarbonates. All these were determined according to the procedures described in Standard Methods of Water Analyses. For carbon dioxide determinations, N/44 KOH and phenolphthalein were employed. Carbonates and bicarbonates were determined from phenolphthalein and methyl orange alkalinity titrations.

Hydrogen Ion Concentration. This was determined in the field using color standard tubes and standard indicators prepared by the LaMotte Chemical Products Company.

Phosphorus. Many investigators have postulated that phosphorus is a limiting factor in the production of phytoplankton in freshwater lakes. Such an hypothesis seems logical from a theoretical point of view when the following three facts are considered. First, phosphorus is an important element in the protein molecule. Second, it plays an important role in the energy metabolism of all living things. Third, it occurs in lakes but in very minute quantities. In order to test this hypothesis, extensive analyses of the various forms of phosphorus were made in addition to quantitative phytoplankton analyses.

Various methods have been used by different workers to determine the amount of inorganic phosphate phosphorus present in a sample of lake water. Most of them, however, are modifications of the colorimetric ceruleomolybdate method described by Deniges (1920). The chemistry involved here can be explained very simply. When ammonium molybdate is added to a dilute phosphate solution, a colored phosphomolybdate is produced which, in turn, forms a blue, complex compound on the addition of a reducing agent such as stannous chloride. The different modifications of this method merely vary in the concentrations of the reagent solutions used, and the apparatus employed in determining variations in the color

densities of the blue, complex compound. The method used in this investigation was modified from Ohle (1939) and is described in the following paragraphs.

Reagents

1. Ammonium Molybdate.

   10 per cent ammonium molybdate solution, $(NH_4)_2MoO_4$, was added to 50 per cent sulphuric acid in the ratio of 1:3. This reagent was stored in an amber pyrex bottle and was made up fresh each week.

2. Stannous Chloride.

   1 gram stannous chloride, $SnCl_2.2H_2O$, was dissolved in 10 ml of 25 per cent hydrochloric acid. Fresh reagent was made up every two or three days.

3. Phosphorus Standard.

   0.439 grams of anhydrous potassium dihydrogen phosphate, KH_2PO_4, was dissolved in distilled water and made up to 1 liter. One ml of this solution contained 0.1 milligrams or 100 micrograms of phosphorus. The solution was diluted to the concentration of the desired standard. In this investigation the standard was made up to contain 10 micrograms per liter.

Apparatus. The instrument employed for measuring the densities of the blue color was an industrial model of the Klett Summerson photoelectric colorimeter with a red light filter No. 66 having an approximate spectral range of 640-700 millimicrons. The colorimeter is provided with solution

cells of various sizes so that measurements can be carried out at different solution depths, depending on the color densities of the solutions. Most of the water samples analysed in this investigation had very minute amounts of phosphorus so that all measurements were made using a solution depth of 40 mm. The scale reading is a measure of the optical density of the colored solution as determined by the photo-electric cell. The optical density of the solution, according to Beer's Law, is theoretically proportional to the concentration of the colored substance. Therefore, the scale readings are directly proportional to the concentration of the substances being determined. A useful feature of this colorimeter is the logarithmically spaced scale divisions. This eliminates the necessity of preparing a calibration curve. Concentrations of solutions can be determined directly by calculations from the scale readings.

Procedure.

1. 50 ml of lake water were measured into a 125 ml Erlenmyer flask.
2. 0.5 ml of the molybdate reagent were added and the flask shaken until the solution was well mixed.
3. The mixture was then poured into the colorimeter solution cell, placed in the instrument, and a reading taken. This reading, if greater than zero, was attributed to any color originally in the water plus the color formed by the addition of the molybdate reagent. The machine is constructed in such a way

that the pointer can be adjusted to zero for this reading.

4. The solution was poured back into the 125 ml Erlenmyer flask and one drop of the stannous chloride reagent added. The solution was shaken and replaced in the colorimeter solution cell. The cell was inserted in the colorimeter and when the pointer had ceased to move, another reading was taken. The pointer ceased to fluctuate when the color had reached its maximum density, which occurred in about ten minutes. The difference between this reading and the reading in (3) was due to the blue color formed by the phosphorus upon the addition of stannous chloride. If the pointer had been adjusted to zero in (3), then, of course, the subtraction would not be necessary, and the final reading would be the desired result.

The same procedure was carried out with distilled water and the reading, which was usually about three Klett units, was attributed to the reagents themselves and, hence, three Klett units were subtracted from the results of any samples being analysed. Standard solutions of known phosphorus concentrations were treated in the same manner and in nearly every case it was found that two Klett units equalled one microgram of phosphorus. These figures might well vary in different machines.

The method just described is for the determination of the amount of inorganic phosphate phosphorus present in

water. Determination of the amount of total phosphorus, including that phosphorus bound in organic compounds, necessitates first the breaking down of the organic phosphorus into inorganic phosphate phosphorus. The method used here for this process was modified from Robinson and Kemmerer (1930). Fifty ml of the water sample were measured into a 125 ml Erlenmeyer flask. To the water was added 0.1 ml concentrated sulphuric acid, 0.25 ml concentrated nitric acid, and 1.5 ml concentrated hydrochloric acid. The solution was heated on a hot plate over slow heat until thick, white fumes of sulphuric acid were liberated. When this occurred, there were usually only a few drops of clear liquid remaining at the bottom of the flask. If this liquid was not clear, the flask was heated for a few more seconds whereupon the liquid usually cleared. If, however, the remaining liquid did not become clear with this additional heating, 1.5 ml of concentrated hydrochloric acid and 0.25 ml of concentrated nitric acid were again added and the flask reheated until the sulphuric acid fumes were liberated once more. When the flask had cooled, 50 ml of distilled water were added and the flask shaken vigorously to evenly distribute the few drops of liquid which had remained at the bottom. The solution was now analysed for inorganic phosphate phosphorus according to the method described previously, and the result was considered to be the total phosphorus present in the sample.

The different forms making up the total phosphorus in lakes have been classified according to two schemes. One

scheme (Juday, Birge, Kemmerer and Robinson, 1928) divides the total phosphorus into two components, soluble inorganic phosphorus and organic phosphorus. The soluble inorganic phosphorus is in the form of inorganic phosphate phosphorus and is supposedly dissolved in the water, hence making it available to plant life. Part of the organic phosphorus is tied up in the organic compounds making up the protoplasm of the living organisms and part of it is in solution. Soluble inorganic phosphorus can be determined directly. The organic phosphorus is determined by first analysing the water for total phosphorus and subtracting from this value the amount of soluble inorganic phosphorus. The difference is the organic phosphorus.

A second scheme which has been suggested by Ohle (1938) and Hutchinson (1941) divides the total phosphorus into suspended or sestonic phosphorus, and soluble phosphorus. The sestonic phosphorus may be subdivided into organic sestonic phosphorus and acid soluble sestonic phosphorus. The organic sestonic phosphorus includes organic phosphorus found in living organisms and in certain types of detritus. The acid soluble sestonic phosphorus is really inorganic phosphate phosphorus which has become adsorbed on molecules such as iron hydroxide. The soluble phosphorus is made up of soluble inorganic phosphate phosphorus and soluble organic phosphorus. The soluble organic phosphorus appears mostly in colloidal form, however, some of it may be adsorbed on particulate matter.

In order to determine the amounts of the different forms of phosphorus present in a sample of lake water, it is first necessary to determine the total phosphorus and the inorganic phosphate phosphorus in the sample. Part of the sample must be filtered through a very fine filter and the filtrate analysed for total phosphorus and inorganic phosphate phosphorus. From the results of these analyses, the various forms of phosphorus can be calculated. The sestonic phosphorus is the difference between the total phosphorus of the unfiltered sample and the total phosphorus of the filtrate. The acid soluble sestonic phosphorus is the difference between inorganic phosphate phosphorus of the unfiltered sample and the inorganic phosphate phosphorus of the filtrate. If the acid soluble sestonic phosphorus is subtracted from the sestonic phosphorus, the difference is equal to the organic sestonic phosphorus. The soluble inorganic phosphorus is, of course, the inorganic phosphate phosphorus present in the filtrate. The soluble organic phosphorus is calculated by subtracting the inorganic phosphate phosphorus of the filtrate from the total phosphorus of the filtrate.

In the phosphorus analyses of the present investigation, a combination of schemes one and two were used. The total phosphorus in each sample was determined. The inorganic phosphate phosphorus was also determined and recorded as soluble inorganic phosphorus, according to scheme one. Strictly speaking, not all of this inorganic phosphate phosphorus is soluble because some of it is in suspension as acid soluble

sestonic phosphorus. The amount of acid soluble sestonic phosphorus is usually so small, however, that it is negligible. This form of phosphorus was determined only in a few samples from Lake Lansing. In the remaining samples it would be included in the soluble inorganic phosphorus and the sestonic phosphorus. The organic phosphorus was calculated according to scheme one, whereas the sestonic phosphorus and the soluble organic phosphorus were determined according to scheme two. One point in connection with the filtration of the water sample deserves special comment. For this process Hutchinson (1941) used a 35-second membrane filter. In this investigation, a Seitz filter with three layers of Whatman's No. 44 filter paper was used. It was found that filter pads which are especially made for the Seitz filter could not be used, because quite often the filtrate coming through one of these pads contained more phosphorus than the total phosphorus of the unfiltered sample. This would appear to indicate that the sample picked up phosphorus from the filter pad.

Length of time between collection and analyses. All of the water samples were analysed within six hours after collection, except those that were collected at the Douglas Lake Station from September, 1950, through May, 1951. These had to be shipped by express from Cheboygan to East Lansing, and hence were three days on the way. A few drops of chloroform were added to each sample at the time of collection.

The samples were analysed for phosphorus, carbonates and bicarbonates immediately upon their arrival at the laboratory in East Lansing. Other determinations, such as dissolved oxygen, free carbon dioxide and pH could not be done on these samples, inasmuch as such determinations must be made very soon after the collection of samples.

DATA

Douglas Lake

Several papers have been written which include tables or discussions pertaining to the physico-chemical conditions in South Fishtail Bay. Most of them are restricted to the summer seasons (Welch, 1927; Eggleton, 1931; Welch and Eggleton, 1932 and 1935). One series of such data, however, was collected from this station by Miller (1936) for twelve consecutive months between September, 1933, and August, 1934.

All the data included in Table 3 were collected through 16 consecutive months between July, 1950, and October, 1951, except certain of those for oxygen, carbon dioxide and pH. As has been explained previously, the water samples collected from Douglas Lake between September 16, 1950, and June 21, 1951, had to be sent to me in East Lansing for analysis, and hence were *en route* about three days. Determinations for these particular chemical conditions must be done either at the time of collection or shortly thereafter, and if determinations had been made on these samples, they would not have given the true picture of oxygen, carbon dioxide and pH

values in the lake at the time of collection. In order to show values for these three items in Table 3 for a period similar to that between September 16, 1950, and June 21, 1951, the determinations made by Miller (1936) on comparable dates in 1933 and 1934 are included.

Temperatures. On June 24, 1948, when this investigation was begun on Douglas Lake, thermal stratification was already in process (Table 1). A vertical temperature series demonstrated that the upper limit of the thermocline occurred at 11 meters and the lower limit at 13 meters. As the season progressed, the thermocline gradually descended and on August 12, when work terminated for the summer, it occupied the stratum of water between 14 and 16 meters. At no time during this period did the thickness of the thermocline become less than three or greater than four meters.

The investigation was resumed on July 3, 1950, and on this day the thermocline occurred between 13 and 16 meters (Table 2). By September 16, 1950, its upper limit had been pushed down to 16 meters and its lower limit to 18 meters, a distance of only two meters from the bottom. On October 2, a vertical temperature series demonstrated a homothermous condition in the lake and on November 24, ice first appeared. The ice began to break up on April 13, 1951, but there was still no thermal stratification on May 10. On May 25, however, the lake was definitely stratified so it appears that stratification must have begun sometime between May 10 and May 25. On the latter date, incidentally, the upper limit

EXPLANATION OF ALL TABLES SHOWING DEPTHS AT WHICH SAMPLES WERE COLLECTED

The depths are displayed horizontally in each table rather than vertically. The latter, of course, is the more traditional method; however, if it were employed, the majority of the tables would have occupied twice as many pages. For the convenience of comparative study by the reader, there is great advantage in the single page tables rather than distributing them over two or three pages.

TABLE 1

PHYSICO-CHEMICAL DATA FROM DOUGLAS LAKE DURING THE SUMMER OF 1948

	Water Temperatures in degrees Centigrade												Carbonates ppm				
Depth in Meters	0	10	11	12	13	14	15	16	17	18	19	20	0	3	5	10	20
June 24	19.9	16.7[		14.3		]13.0		12.2		11.3		10.8	0	0	0	0	0
July 1	19.7	18.4		[18.4		14.3		]12.8		11.8		10.9	5	2	2	2	0
July 8	22.4	19.9		[17.4	15.0	13.0		]12.0				10.8	3		4.2	1.6	0
July 15	24.6	19.9		[17.7		13.9		]12.1		11.4		10.9	6		2	0	0
July 22	22.7	20.3		[17.4		13.6		]12.2		11.5		10.8	6		4	4	0
July 29	23.1	20.6		20.0[		17.3		12.3]		11.5		10.8	8		8	8	0
Aug. 5	21.8	20.8		20.6		[18.8		12.6]		11.6		10.8	12			14	0
Aug. 12	20.1	19.9		19.6		[19.0		12.9]		11.4		10.6	10			12	0

TABLE 1 (Continued)

	Bicarbonates ppm					pH					Oxygen ppm					Carbon dioxide ppm				
Depth in Meters	0	3	5	10	20	0	3	5	10	20	0	3	5	10	20	0	3	5	10	20
June 24	109	110	110	111	112	8.0	8.0	8.0	7.7	7.2	7.6	7.4	6.9	6.2	0.3	0	0	0	0.2	1.0
July 1	110	111	115	117	121	8.2	8.2	8.2	8.2	7.3	7.5	7.8	7.5	6.9	0.8	0	0	0	0	0.5
July 8	113		114	117	121	8.2	8.2	8.2	8.2	7.3	7.4		7.1	6.0	0.6	0	0	0	0	0.7
July 15	115		119	122	122	8.4		8.2	8.0	7.3	7.6		7.0	4.8	0.6	0	0	0	0	1.0
July 22	112		114	114	122	8.3		8.3	8.0	7.2	7.3		7.3	5.8	0	0		0	0	1.0
July 29	114		114	116	130	8.3		8.3	8.2	7.1	7.6		7.2	6.7	0	0		0	0	1.5
Aug. 5	111			111	132	8.4			8.1	7.1	6.5			6.7	0	0		0	0	1.0
Aug. 12	113			113	133	8.4			8.1	7.1	6.7			6.4	0	0		0	0	1.0

Thermoclines enclosed in brackets

TABLE 2

SEASONAL AND VERTICAL TEMPERATURE SERIES IN DOUGLAS LAKE 1950-1951

		Water Temperatures in degrees Centigrade										
Depth in Meters		0	10	11	12	13	14	15	16	17	18	20
1950	July 3	18.5	17.8	-	17.8	[17.3	13.5	9.6	8.2]	7.5	-	6.6
	July 10	22.8	-	-	18.1	[17.7	16.5	12.1	9.4]	-	7.8	6.8
	July 18	20.6	-	-	18.8	-	[17.4	12.7	10.0]	-	8.2	7.0
	July 25	21.2	-	-	-	-	[17.4	14.6	10.4	8.6]	-	6.9
	Aug. 4	20.6	-	-	17.9	-	[-	-	7.5]	-	-	6.8
	Aug. 14	20.0	-	-	[18.8	17.8	15.1	10.9	8.4	7.1]	-	6.8
	Aug. 31	17.0	16.5	-	-	-	[16.5	14.5	9.0	7.5]	7.0	7.0
(a)	Sept. 16	15.0	-	-	14.0	-	-	-	[14.0	11.0	8.0]	7.0
	Oct. 2	14.5	13.0	-	12.5	-	12.5	12.5	12.5	12.0	11.5	11.5
	Oct. 19	12.0	12.0	-	11.5	-	-	11.5	-	11.5	11.5	11.5
	Nov. 14	4.5	-	-	-	-	-	-	-	-	-	4.5
(b)	Dec. 27	0.0	1.0	-	-	-	-	-	-	-	-	2.5
1951	Feb. 26	1.0	2.0	-	-	-	-	-	-	-	-	3.0
	March 28	0.0	0.5	-	-	-	-	-	-	-	-	2.5
(c)	April 23	4.5	-	-	-	-	-	-	-	-	-	4.5
	May 10	8.0	10.0	-	-	-	6.0	-	-	-	5.0	4.5
(d)	May 25	16.0	12.0	-	[11.0	9.0	7.5]	7.5	-	6.0	5.0	5.0
	June 8	16.5	14.5	-	[12.5	9.5	7.5]	7.0	-	-	5.0	5.0
	June 21	19.0	16.0	[-	13.0	-	8.0]	-	7.0	-	5.5	5.5
	July 9	19.7	-	-	[17.1	11.7	9.4	8.3	7.3]	6.7	6.3	5.9
	July 23	20.5	19.5	[19.2	17.7	13.4	9.6	8.6]	7.9	7.3	6.9	6.1
	Aug. 10	21.5	20.7	-	[19.9	13.4	11.2	8.6	7.5]	-	7.0	6.3
	Aug. 25	20.3	19.0	-	18.8	[18.4	14.4	10.1	8.2]	7.6	7.0	6.7
	Sept. 15	17.9	-	-	-	[17.5	16.4	14.2	8.5	7.5]	-	6.8
(e)	Oct. 6	12.8	-	-	12.0	-	-	-	-	-	-	11.8

Thermoclines enclosed in brackets

(a) Fall overturn began between Sept. 16 and Oct. 2, 1950

(b) Ice appeared Nov. 24, 1950

(c) Ice disappeared April 13, 1951

(d) Thermal stratification began between May 10 and May 25, 1951

(e) Fall overturn began between Sept. 15 and Oct. 6, 1951

TABLE 3

SEASONAL AND VERTICAL DISTRIBUTION OF CERTAIN CHEMICAL FACTORS IN DOUGLAS LAKE 1950-1951

		Carbonates ppm					Bicarbonates ppm					pH					Oxygen ppm					Free Carbon Dioxide				
Depth in Meters		0	2	5	12	20	0	2	5	12	20	0	2	5	12	20	0	12	16	18	20	0	12	16	18	20
1950	July 3	10		8	0	0	118		120	128	131	8.4		8.3	8.1	7.1	7.8	7.4	5.8	3.1	1.3	0	0	5.6	8.4	11.0
	July 10	6		12	0	0	122		115	127	131	8.2		8.2	8.1	7.0	7.8	7.2	5.6	2.9	1.3	0	0	7.1	9.8	12.5
	July 18	12		12	0	0	112		112	131	132	8.3		8.3	8.1	7.0	7.5	6.8	0.9		0	0	0	11.0		11.0
	July 25	8		12	0	0	118		114	124	129	8.3		8.3	8.1	7.0	7.4	6.3	0.3	0.1	0	0	0	8.4	11.2	13.1
	Aug. 4	8		12	0	0	106		108	124	132	8.3		8.3	8.1	7.0	8.7	7.5	0.1		0	0	0	8.8		14.0
	Aug. 14	6		6	0	0	118		120	128	131	8.2		8.0	7.9	7.0	8.6	6.8			0	0	1.4			16.0
	Aug. 31	6		4	0	0	124		126	131	138															
	Sept.16	3	3	8	8	0	122	122	117	117	136	8.4				6.9	8.5		3.7	1.3	0	0		4.0	7.0	15.0
(a)	Oct. 2	6	8	2	2	0	118	117	123	125	130	8.1				7.7	9.6				8.7	0				0
	Oct. 19	8	8	2	2	0	118	119	125	126	131															
	Nov. 14	7	8	2	2	0	119	118	124	127	129	8.2				8.2	12.0				11.0	0				0
(b)	Dec. 27	0		0	0	0	122		127	130	136															
1951	Feb. 26	0		0	0	0	31		129	131	141	7.7				7.1	13.0			1.4	0.7	0				3.0
	Mar. 28	0		0	0	0	26		128	132	138	7.3				6.9	10.0			1.7	0.4	1				12.0
(c)	Apr. 23	0		0	0	0	110		112	114	119	7.3				7.3	9.0				9.4	1				2.0
	May 10	0		0	0	0	109		113	113	118	7.8			7.6	7.3	11.0	10.5			9.4	0	1			2.0
(d)	May 25	0		0	0	0	110		116	117	119	8.1				7.2										
	June 8	1		1	0	0	116		118	118	120	8.1			7.9	7.1	7.7	7.2			1.0	0	0			5.0
	June 21	1		1	0	0	119		120	120	121	8.1			7.4	6.9	8.2	5.7			0	0	2			10.0
	July 9	1		1	0	0	117		118	121	122	8.3	8.3	8.3	7.9	7.1	8.2	7.0	1.4	0.3	0	0	3			14.5
	July 23	6	6	6	0	0	115			122	130	8.2	8.2	8.2	7.6	7.0	8.0	4.2	0.1		0	0	6	11.9		15.5
	Aug. 10	8	6	6	1	0	112			119	129	8.2			8.0	7.1	8.7	5.5	0.4		0	0	0	16.0		17.0
	Aug. 25	9		7	5	0	114		119	122	131	8.3			8.1	7.0	8.6	5.4	0.1	0	0	0	0	0		17.0
	Sept.25	5	4	2	2	0	117		119	123	133	8.3			8.0	7.1	8.8	5.8	1.4	0	0	0	0	0		18.0
(e)	Oct. 6	8	9	3	0	0	117		119	122	124	8.1			7.8	7.8	9.2				8.7	0	0	0	0	2.0

The data surrounded by rectangle were taken from the data of D. E. Miller, 1936. These determinations were made by Miller on comparable dates in 1933-1934.

(a) Fall overturn began between Sept. 16 and Oct. 2, 1950

(b) Ice appeared Nov. 24, 1950 (c) Ice disappeared April 13, 1951

(d) Thermal stratification began between May 10 and May 25, 1951

(e) Fall overturn began between Sept. 15 and Oct. 6, 1951

of the thermocline was already at 12 meters. No temperature series were taken between these two dates so that the actual rate of descent of the thermocline cannot be determined. It is interesting to note that it did occur during a period of 15 days. As a matter of fact, in none of the temperature series taken during the 16 months of collection in Douglas Lake was the upper limit of the thermocline ever found to be above ten meters.

From May 10 to September 15, 1951, the lake remained thermally stratified, the vertical temperature series being very similar to those of the previous year. By October 6 the lake was once again homothermous. The latter phenomenon occurred at approximately the same time during the year before.

The temperature data collected during each of the summers of 1948, 1950 and 1951 do not differ markedly from each other, neither do they differ greatly from data collected by Welch and Eggleton during other summers. It is interesting to compare the temperature data which I collected between July 3, 1950, and October 6, 1951, with those collected by Miller 17 years previously between September, 1933, and August, 1934. During both of these periods of investigation, thermal stratification began on approximately the same date. Furthermore, the lake became homothermous at almost the same time in each of the two periods. Also, ice appeared at about the same day during both periods and persisted for similar lengths of time in both cases.

Conductivity. During the summer of 1948, these determinations were made along with other routine analyses. On June 24 the conductivity was 220 mhos through the entire depth of the lake. As a matter of fact, none of the determinations made during the early and middle part of the summer varied more than five reciprocal megohms from this reading. On August 5, towards the end of the summer, the conductivity still remained the same in the upper 17 meters, however it had increased to 225 and 235 at 18 and 20 meters respectively. During the summers of 1950 and 1951 conductivity determinations were not made as frequently, but those that were made indicated that these summers were not very different from that of 1948. Determinations made by Welch and Eggleton during previous summers were also very similar to those of the present investigation.

Oxygen. The oxygen content of Douglas Lake varies through the seasons as it does in any other temperate lake of the second order (Tables 1 and 3). During the periods of thermal stratification, oxygen is distributed uniformly throughout the epilimnion. In the hypolimnion, oxygen decreases as the summer progresses and disappears completely from the bottom several months before the autumnal overturn, but during this overturn it is recirculated throughout the whole lake. In the winter, under the ice cover, the bottom waters again become depleted of dissolved oxygen and remain thus until the spring overturn. It is of interest to compare

the dates in the different summers when oxygen disappeared from the bottom waters in Douglas Lake. The following list presents these data and indicates by whom they were collected.

Dates of disappearance		Author	Published
Between July 21 and 27	1923	Eggleton	1931
Before July 1	1926	"	"
Between July 6 and 27	1927	"	"
Before July 27	1928	"	"
Before July 21	1933	"	"
Between June 2 and 16	1934	Miller	1936
Between July 15 and 22	1948	Tucker	Herein
Between July 18 and 25	1950	"	"
Before July 9	1951	"	"

Evidently when the summer investigations were begun in 1926, 1928, 1933 and 1951, the oxygen was already absent from the bottom and, hence, the actual time of disappearance cannot be stated.

As far as I am aware, only one paper (Miller, 1936) has been published which contains continuous data on dissolved oxygen in Douglas Lake during the winter months. According to his records for the year 1934, oxygen began to decrease from the bottom waters soon after the ice cover appeared. It never completely disappeared but reached the low value of 0.4 ppm during the latter part of March. Miller had no oxygen records for the period between this date and April 29 at which time the spring overturn was taking place.

It could very well be that between these dates the oxygen might have disappeared completely from the bottom.

Hydrogen Ion Concentration (Tables 1 and 3). Generally speaking, it may be stated that during the thermal stratification periods in 1948, 1950 and 1951, the pH nearly always varied between 8.0 and 8.4 in the epilimnion and between 7.0 and 8.0 in the hypolimnion, decreasing, of course, from surface to bottom but, nevertheless, demonstrating chemical stratification. No observations on pH were made between the fall overturn in 1950 and the spring overturn in 1951. According to the records of Miller (1936), the pH during the fall overturn in 1933 was 8.2 throughout the entire depth, but under the ice on April 7, 1934, it decreased to 7.3 at the surface and 6.9 at the bottom. During the circulation in the spring overturn it was 7.3 from surface to bottom.

Free Carbon Dioxide (Tables 1 and 3). During the summers of 1948, 1950 and 1951, analyses showed no evidence of free carbon dioxide in the epilimnion at any time. At the bottom of the hypolimnion, during the summer of 1948, the amounts ranged between 0.5 to 1.5 ppm. During the summers of 1950 and 1951 the values in the upper limits of the hypolimnion fluctuated between 5.6 and 16.0 ppm whereas at the lower limit they occurred in amounts ranging between 11.0 and 18.0 ppm; the general trend was towards an increase as the summer progressed.

No data on carbon dioxide were secured during the time between the fall overturn of 1950 and the spring overturn of 1951. Miller's data show, however, that during the fall overturn of 1933, when the pH was 8.2 from surface to bottom, there was no free carbon dioxide throughout the entire depth, but at the beginning of April, 1934, under the ice cover, the surface and bottom waters contained 1.0 ppm and 12.0 ppm respectively. During the spring overturn of the same year, shortly after the ice had broken up, the amount of free carbon dioxide throughout the whole depth was between 1.0 and 2.0 ppm.

Carbonates (Tables 1 and 3). The data collected during the summers of 1948, 1950 and 1951 showed that the carbonate content of the epilimnion waters occurred in amounts between 0.0 and 14.0 ppm. The difference between the amounts of carbonate present in the upper and lower limits of the epilimnion at any one time never exceeded 6.0 ppm. None of the water samples collected in the hypolimnion waters contained any trace of carbonates. After the fall overturn in September, 1950, carbonates still persisted in the upper waters in amounts ranging between 2.0 and 8.0 ppm until the ice appeared, but at the 20-meter depth carbonates were never found. As a matter of fact, they were never found in any of the water samples collected at that depth during the entire time of the investigation. Under the ice cover carbonates did not appear in any of the samples from any of the depths but small traces appeared again soon after the ice broke up in April, 1951.

Bicarbonates (Tables 1 and 3; Figure 1). The data from the summer of 1948 showed that in the upper limit of the epilimnion, the amounts of bicarbonates fluctuated between 109 ppm and 115 ppm and in the lower limit between 111 ppm and 122 ppm. In all cases, the difference between the bicarbonate content of the upper and lower limits of the epilimnion at any one time never exceeded 7.0 ppm. At the 20-meter depth, the quantities of bicarbonate increased progressively from 112 ppm on June 24 to 133 ppm on August 12.

Figure 1 shows the quantitative seasonal variations of bicarbonates at depths of 5 meters and 20 meters during the 16 consecutive months of investigation from September, 1950, to October, 1951. The changes at these depths were arbitrarily chosen to represent the changes occurring in the epilimnion and hypolimnion, respectively. Between July 3 and August 4, 1950, at the 5-meter depth, there was a decrease from 120 ppm to 108 ppm. From the latter date to August 31 the bicarbonate content increased to 126 ppm. On September 16, the first sampling day during the fall overturn, it was down to 117 ppm. By October 19 it had reached a value of 125 ppm. It changed very little during the next five months even during the time of the ice cover, and on March 28, 1951, still under the ice cover, bicarbonates were present in the amount of 128 ppm. On April 23, the first day of sampling after the ice had disappeared, there were present only 112 ppm, the decrease undoubtedly having occurred during the spring overturn. This is a repetition of the phenomenon

Fig. 1 - Variation in Bicarbonates in Douglas Lake
(South Fishtail Bay)
Years - 1950-1951

Explanation of Fig. 1

(a) Fall overturn began between Sept. 16 and Oct. 2, 1950

(b) Ice appeared Nov. 24, 1950

(c) Ice disappeared April 13, 1951

(d) Thermal stratification began between May 10 and May 25, 1951

(e) Fall overturn began between Sept. 15, and Oct. 6, 1951

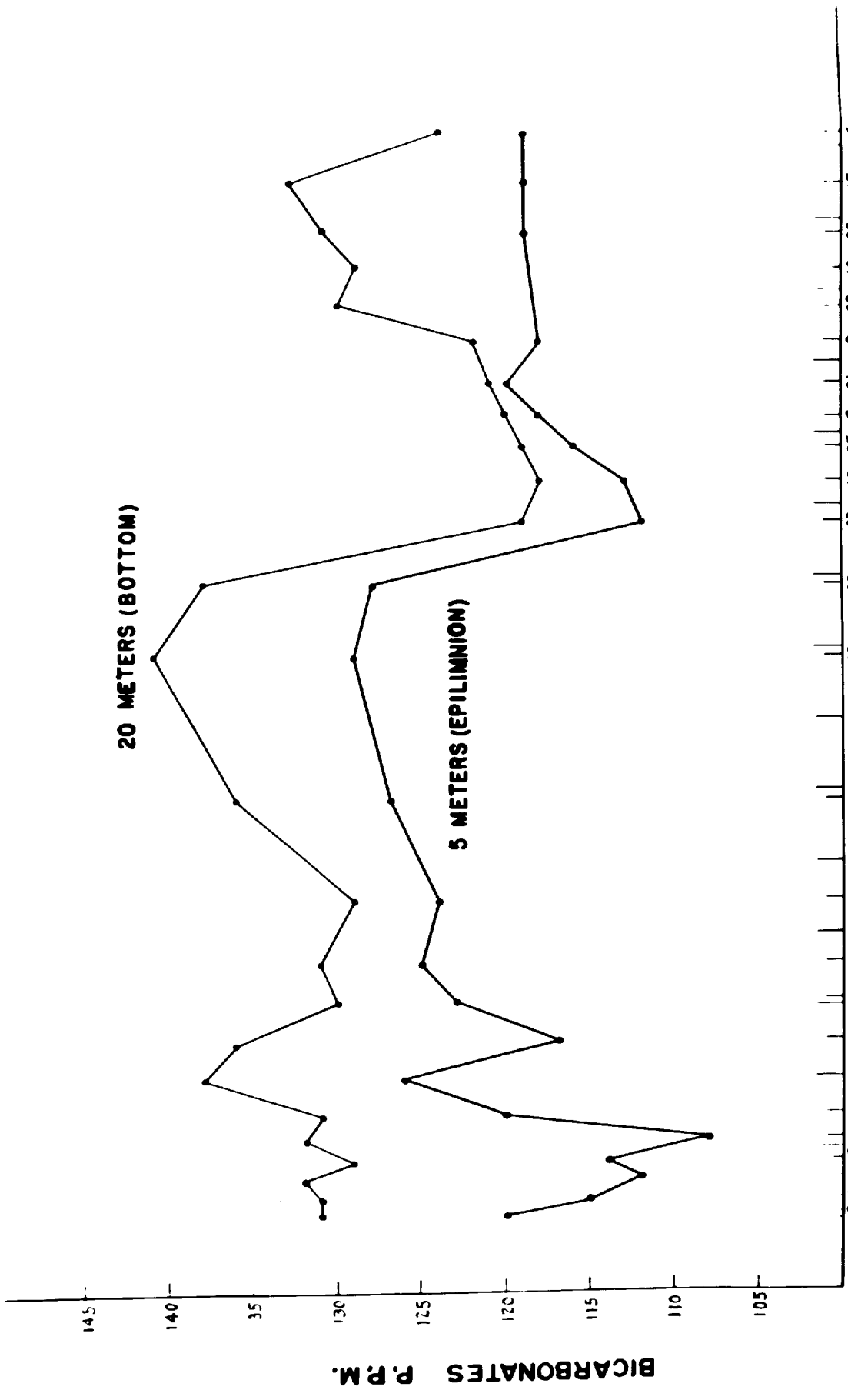

20 METERS (BOTTOM)
5 METERS (EPILIMNION)
BICARBONATES P.P.M.
145
140
135
130
125
120
115
110
105
3 10 18 25 4 14 31 16 2 19 14 27 26 28 23 10 25 8 21 9 23 10 25 15 6
JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.

FIG. I

occurring during the preceding fall overturn because then, too, there was a marked decrease. From April 23 to October 6 there was a gradual increase to 119 ppm.

At the 20-meter depth, from June 3 to August 14, 1950, the amounts of bicarbonate present fluctuated between 129 ppm and 131 ppm, however by August 31 the bicarbonate content had increased to 138 ppm. About two weeks later, on September 16 it was 136 ppm but after the beginning of the fall overturn, that is the period between September 16 and October 2, it decreased to 130 ppm and remained approximately at this value until the ice cover appeared. Under the ice it increased quite markedly as was indicated by the 136 ppm of bicarbonate present on December 27. The bicarbonates continued to increase in quantity under the ice, reaching a maximum value of 141 ppm on February 26, 1951, but still being present in the amount of 138 ppm on March 28. Sometime between March 28 and April 23 the ice broke up and the spring overturn began. During this period the bicarbonates decreased to 119 ppm which was the amount found on the latter date. From this day to July 9 there was never a greater variation than 2.0 ppm from this amount one way or the other. Between July 9 and July 23, however, it had increased in quantity to 130 ppm. It remained between 129 ppm and 133 ppm until the fall overturn which occurred between September 25 and October 2, for on the latter date the bicarbonate content was 124 ppm.

Phosphorus. (Table 4; Figures 2, 3, 4 and 5). At the beginning of the summer of 1950 it was decided to make phosphorus analyses every two or three days in order to observe whether changes might occur during short periods of time. This procedure was carried on for about three weeks but no significant changes were observed after such short periods of time. For this reason samples were collected and phosphorus determinations made at approximate two-week intervals thereafter.

During the 16 months of investigation, at the surface the amounts of total phosphorus fluctuated between 7 and 14 micrograms per liter. At the 12-meter depth, which was the average depth of the lower limit of the epilimnion during stratification, the amounts varied between 7 and 15 micrograms per liter. The actual difference between the maximum and minimum amounts in the upper 12-meter stratum at any one time never exceeded four micrograms per liter (Figure 2). The fluctuations which occurred in this stratum during the 16-month period were quite irregular and seemed to follow no particular trend which could be related either to the chronological or to the limnological seasons. At the 20-meter depth, however, a different phenomenon occurred. (Figure 4). Between July 3 and August 4, 1950, there were irregular fluctuations in amounts of total phosphorus varying between 10 and 17 micrograms per liter. On August 31, about four or five weeks after the oxygen had disappeared from this depth, the amount of total phosphorus present was

TABLE 4

SEASONAL AND VERTICAL DISTRIBUTION OF PHOSPHORUS IN DOUGLAS LAKE 1950-1951

Values of the total and the various fractions of phosphorus are reported in the body of the table as micrograms per liter

Phosphorus		Total							Soluble Inorganic							Total Organic						
Depth in Meters		0	2	5	12	16	18	20	0	2	5	12	16	18	20	0	2	5	12	16	18	20
1950 July	3	8	8	9	8	12	13	13	2	2	1	1	2	2	3	6	6	8	7	10	11	10
July	7	8	9	8	9	9	9	12	2	1	1	0	0	1	2	6	8	7	9	9	8	10
July	10	8	7	9	9	10	11	13	1	1	2	2	3	3	4	7	6	7	7	7	8	9
July	14	8	8	9	10	13	14	14	0	1	1	1	1	2	3	8	7	8	9	12	12	11
July	18	8		8	7	10	10	10	1	1	1	1	2	2	2	7	7	7	6	8	8	8
July	25	8	13	11	12	11		15	1	1	1	1	1		2	7	12	10	11	10		13
Aug.	4	7	8	7	9	9		14	1	0	0	1	1		2	6	8	7	9	8		12
Aug.	14	14	13	15	15			17	0	1	1	1			1	14	12	14	14			16
Aug.	31	8	9	12	9			50	2	1	1	2			18	6	8	11	7			32
Sept.	16	9	9	9	8			641	3	3	3	3			460	6	6	6	6			181
(a) Oct.	2	9	9	11	10			22	5	6	7	6			12	4	3	4	4			10
Oct.	19	11	12	11	10			13	4	5	4	5			6	7	7	7	5			7
Nov.	14	10	10	9	9			8	6	6	6	5			4	4	4	3	4			4
(b) Dec.	27	9	10	10	11			43	2	3	2	3			31	7	7	8	8			12
1951 Feb.	26	11	11	10	12			48	4	3	4	5			33	7	8	6	7			15
March	28	12	13	11	12			27	3	3	4	4			15	9	10	7	8			12
(c) April	23	9	9	8	9			10	2	1	1	2			2	7	8	7	7			8
May	10	9	9	8	9			12	2	2	1	1			1	7	7	7	8			11
(d) May	25	7	8	9	9			11	1	2	2	1			2	6	6	7	8			9
June	8	9	9	10	9			12	2	3	2	2			2	7	6	8	7			10
June	21	7	9	9	7			12	1	1	2	1			3	6	8	7	6			9
July	9	8	9	9	9			10	1	2	1	2			2	7	7	8	7			8
July	23	9	8	9	9			12	1	1	1	1			3	8	7	8	8			9
Aug.	10	10	9	10	8			14	1	1	1	1			4	9	8	9	7			10
Aug.	25	9	8	11	9	10	10	12	1	1	1	1	1	1	2	8	7	10	8	9	9	10
Sept.	15	10	9	11	10	10	11	34	1	1	1	1	1	3	20	9	8	10	9	9	8	14
(e) Oct.	6	12	11	10	9	9	10	12	2	2	1	1	1	1	2	10	9	9	8	8	9	10

TABLE 4 (Continued)

Phosphorus		Sestonic							Soluble Organic						
Depth in Meters		0	2	5	12	16	18	20	0	2	5	12	16	18	20
1950 July 3		5	4	4	5	3	4	5	1	2	4	2	7	7	5
July 7		4	4	4	5	2	4	5	2	4	3	4	7	4	5
July 10		2	2	2	4	4	6	6	5	4	5	3	3	2	3
July 14		2	2	1	3	5	6	5	6	5	7	6	7	6	6
July 18		5		4	3	4	4	5	2		3	3	4	4	3
July 25		2	6	3	6	4		1	5	6	7	5	6		12
Aug. 4		2	3	4	4	4		3	5	5	3	5	4		9
Aug. 14		3	4	9	7			7	11	8	5	7			9
Aug. 31		2	4	5	5			30	4	4	6	2			2
Sept. 16		2	2	2	2			159	4	4	4	4			22
(a) Oct. 2		3	3	2	3			10	1	0	2	1			0
Oct. 19		3	2	4	2			4	4	5	3	3			3
Nov. 14		2	1	1	1			1	2	3	2	3			3
(b) Dec. 27		2	3	4	3			7	5	4	4	5			5
1951 Feb. 26		3	2	1	3			7	4	6	5	4			8
March 28		3	3	4	4			6	6	7	3	4			6
(c) April 23		2	3	2	1			2	5	5	5	6			6
May 10		2	2	1	2			3	5	5	6	6			8
(d) May 25		2	2	2	3			3	4	4	5	5			6
June 8		2	3	2	1			4	5	3	6	6			6
June 21		1	2	2	2			3	5	6	5	4			6
July 9		2	1	3	2			4	5	6	5	5			4
July 23		2	3	2	1			4	6	4	6	7			5
Aug. 10		2	3	2	3			5	7	5	7	4			5
Aug. 25		1	2	2	1	2	3	3	7	5	8	7	7	6	7
Sept. 15		2	1	3	2	2	3	8	7	7	7	8	7	5	6
(e) Oct. 6		3	1	2	1	1	1	1	7	8	7	7	7	8	9

(a) Fall overturn began between Sept. 16 and Oct. 2, 1950
(b) Ice appeared Nov. 24, 1950
(c) Ice disappeared April 13, 1951
(d) Thermal stratification began between May 10 and May 25, 1951
(e) Fall overturn began between Sept. 15 and Oct. 6, 1951

Fig. 2 - Maximum and Minimum Values of Total Phosphorus Occurring Between Surface and 12-meter Depth in Douglas Lake (South Fishtail Bay), Years 1950-1951

Fig. 3 - Maximum and Minimum Values of Soluble Inorganic Phosphorus Occurring Between Surface and 12-meter Depth in Douglas Lake (South Fishtail Bay), Years 1950-1951

Explanation of Figs. 2 and 3

(a) Fall overturn began between Sept. 16 and Oct. 2, 1950

(b) Ice appeared Nov. 24, 1950

(c) Ice disappeared April 13, 1951

(d) Thermal stratification began between May 10 and May 25, 1951

(e) Fall overturn began between Sept. 15 and Oct. 6, 1951

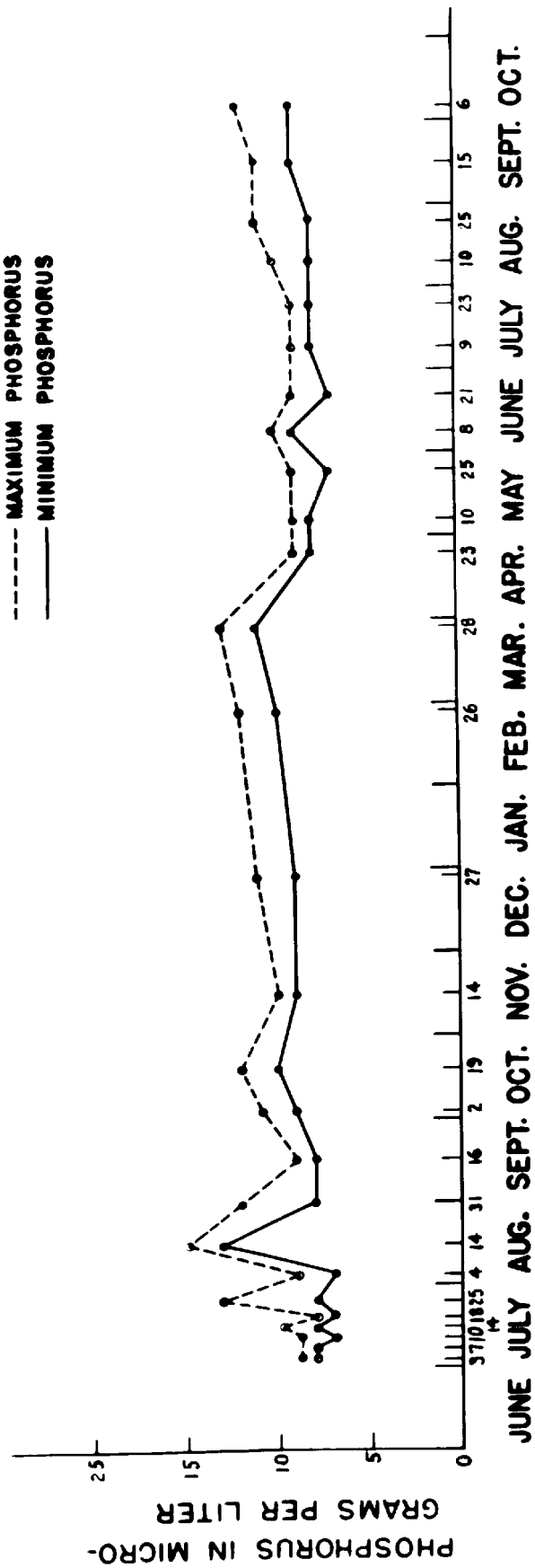

MAXIMUM PHOSPHORUS
MINIMUM PHOSPHORUS
PHOSPHORUS IN MICRO-GRAMS PER LITER
0
5
10
15
25
JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.

FIG.2

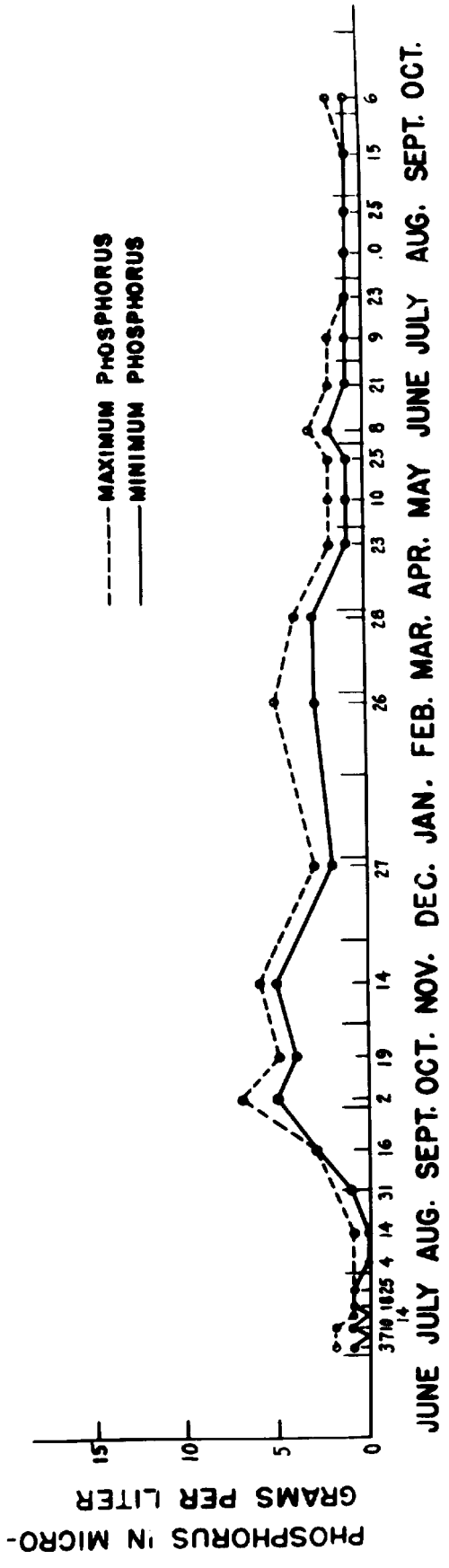

MAXIMUM PHOSPHORUS
MINIMUM PHOSPHORUS
PHOSPHORUS IN MICRO-GRAMS PER LITER
0
5
10
15
JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.

FIG.3

Fig. 4 - Variations of Total Phosphorus and Soluble Inorganic Phosphorus at 20-meter Depth in Douglas Lake (South Fishtail Bay), Years 1950-1951

Explanation of Fig. 4

(a) Fall overturn began between Sept. 16 and Oct. 2, 1950

(b) Ice appeared Nov. 24, 1950

(c) Ice disappeared April 13, 1951

(d) Thermal stratification began between May 10 and May 25, 1951

(e) Fall overturn began between Sept. 15 and Oct. 6, 1951

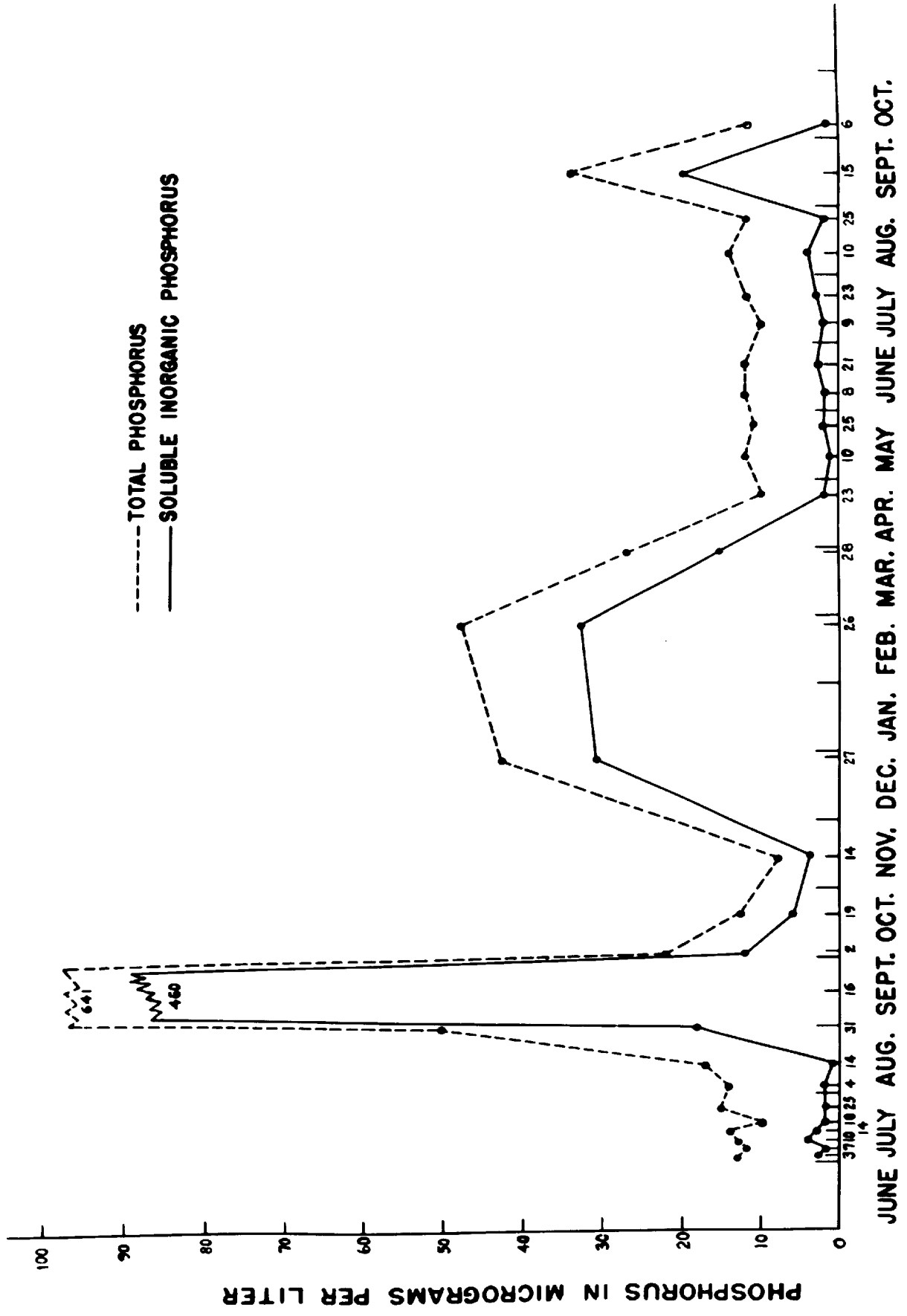

TOTAL PHOSPHORUS
SOLUBLE INORGANIC PHOSPHORUS
PHOSPHORUS IN MICROGRAMS PER LITER
0
10
20
30
40
50
60
70
80
90
100
641
450
JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.

FIG. 4

50 micrograms per liter and by September 16 it had reached the enormous value of 641 micrograms per liter. On October 2, during the fall overturn, it was down again to 22 micrograms per liter and did not exceed this value until the ice cover had formed after which time it continually increased until sometime between February 26 and March 28. The highest value obtained during the winter was 46 micrograms per liter which was the amount of total phosphorus found on February 26, 1951. By April 23, about 10 days after the ice had broken up, a noticeable decrease had taken place. By that date, the value had dropped to 10 micrograms per liter. Indeed, from April 13 through August 25 the amounts never exceeded 14 micrograms per liter. Between August 23 and September 15, however, approximately eight weeks after oxygen depletion from the bottom, the total phosphorus content increased. On the latter date it was found to be present in the amount of 34 micrograms per liter. During the overturn, two weeks later, it was down again to 12 micrograms per liter.

In general, the seasonal variations in the soluble inorganic phosphorus were almost identical with the total phosphorus variations but in lesser quantities. In the top 12-meter stratum the amounts of soluble inorganic phosphorus fluctuated between 0.0 and 7.0 micrograms per liter throughout the entire 16-month investigation. The difference between the maximum and minimum values on any one day, however, never exceeded 2.0 micrograms per liter (Figure 3).

At the bottom (Figure 4) the amounts of soluble inorganic phosphorus ranged between 1.0 and 4.0 micrograms per liter from July 3, 1950, to August 14, increasing to 18 micrograms per liter by August 31 and eventually to 460 micrograms per liter by September 15. During the autumnal overturn the soluble inorganic phosphorus decreased to values between 4 and 12 micrograms per liter but under the ice it began to increase again reaching its highest value on February 26, 1951, at which time it was 33 micrograms per liter. It began to decrease even before the ice had broken up, but a marked decrease was not observed until the ice had disappeared and the spring overturn was in progress. At this time, April 23, it was present in the amount of 2.0 micrograms per liter and it changed very little from this value until sometime between August 24 and September 15, 1951, but on the latter date it was 20 micrograms per liter. On October 2, 1951, during the autumnal overturn it was once again down to the small value of 2.0 micrograms per liter.

During the first few months of the investigation in Douglas Lake starting on July 3, 1950, vertical series of phosphorus determinations were made at close depth intervals, only down to 12 meters which was the lower limit of the epilimnion. Frequent determinations were made only in this stratum because it included the photosynthetic zone and information was desired as to the phosphorus available to the phytoplankton. Each time when a series was taken, however, one determination was also made on the water from the

bottom, more for the record than for anything else, but no determinations were made between 12 meters and the bottom which was at 20 meters. The latter depth was the lowest at which clear samples could be obtained. When the results of the analyses on the bottom water samples showed such a great increase several weeks prior to the autumnal overturn of 1950, it was decided that during the following summer and early fall of 1951, samples would be collected at every meter in the hypolimnion in order to determine how high the phosphorus from the bottom waters would diffuse. This was done and Table 7 and Figure 5 show the vertical distribution of soluble inorganic phosphorus in Douglas Lake on successive dates from July 9, 1951, to October 6 of the same year. Samples collected at 20 meters were clear but those collected at 20.5 meters were muddy. The latter samples were allowed to stand for several hours until the mud had settled and the clear water in the upper part of the bottle was analysed. Table 7 and Figure 5 show that on July 9, 1951, there were only 4.0 micrograms per liter even at 20.5 meters. However, as the season progressed the amount at the bottom increased until on September 15 it was 80 micrograms per liter. It can be seen from Figure 3 that, although this was a large increase in soluble inorganic phosphorus, still it did not diffuse very high into the hypolimnion. As a matter of fact, it diffused only up to the 18-meter depth, a distance of a mere two meters. On October 6, a day during the fall overturn, the soluble

inorganic phosphorus at the bottom was once again among its low values, this time 8 micrograms per liter.

The total organic phosphorus in Douglas Lake (Table 4) also underwent quantitative changes from time to time during the 16 months of investigation. In the upper 12-meter stratum, however, it was never found to be less than 4.0 micrograms per liter and never greater than 11 except on one day, August 14, 1950, at which time it was 14 micrograms per liter both at the surface and at 12 meters. The difference between the maximum and minimum values in this stratum on any one day never exceeded 5.0 micrograms per liter. At the 20-meter depth the amount fluctuated, for the most part, between 4 and 11 micrograms per liter except for short periods just prior to the fall and spring overturns. During these times it increased much more in some years than in others. For example, the maximum amount recorded before the fall overturn in 1950 was 181 micrograms per liter, but under the ice just before the spring overturn of 1951, it had reached only 15 micrograms per liter and before the fall overturn of 1951, after the summer minimum, it had again increased only to 14 micrograms per liter.

The sestonic phosphorus in the upper 12-meter stratum always occurred in amounts ranging between 1 and 9 micrograms per liter (Table 4). At no time did the difference between the maximum and minimum values for any one vertical series exceed 4 micrograms per liter. At the 20-meter depth the amounts fluctuated between 1 and 10 micrograms per liter,

except during the period before the fall overturn in 1950. During this period it reached the high value of 159 micrograms per liter but this amount decreased to the usual range during the overturn. It did not increase markedly before the spring and fall overturns of 1951 as did the phosphorus fractions previously discussed.

The most constant fraction of phosphorus, during the period of investigation, that is from a quantitative point of view, was the soluble organic phosphorus. In only three samples, of all those collected at all the depths and throughout the entire length of the investigation, did the soluble organic phosphorus exceed 9 micrograms per liter (Table 4). The majority of samples contained it in amounts ranging between 0 and 9 micrograms per liter. With regard to the previously mentioned three samples, the first was collected on July 25, 1950, at 20 meters and contained 12 micrograms per liter. The second was collected at the surface on August 14, 1950, and contained 11 micrograms per liter whereas the third was collected at 20 meters on September 16, 1950, and contained 22 micrograms per liter. The latter amount occurred in the same sample that contained large amounts of the other phosphorus fractions and it should be remembered that this sample was collected a very short time before the fall overturn of 1950.

Lancaster Lake

For a lake with such a small surface area, Lancaster Lake has considerable depth in addition to a steeply sloping floor. These features, together with the protection and shelter it receives from the surrounding hills and forests, make for a very marked thermal stratification. This is well demonstrated in Table 5 which presents data on water temperatures collected during the three summers of 1948, 1950 and 1951. Considering the data from the three summers as a whole, it can be seen that on the average, the epilimnion occupies the upper 2 meters of the 17-meter depth. The thermocline in general takes up the next three meters with a temperature difference of approximately 12 degrees centigrade between the upper and lower limits of this stratum. The hypolimnion, therefore, occupies the remaining depth of the lake which amounts to a stratum 12 meters thick. The surface temperatures during each of the summers were always very close to the air temperatures, deviating from it by only two or three degrees. The bottom temperatures always ranged between 4.7 and 5.8 degrees centigrade.

The water of this lake is highly colored. Eggleton (1935) recorded the brown color as 59 units on the platinum-cobalt standard scale using the standard comparator of the United States Geological Survey.

Chemical stratification was also very marked in this lake. Carbonates fluctuated between 0 and 14 ppm in the

TABLE 5

PHYSICO-CHEMICAL DATA FROM LANCASTER LAKE DURING THE SUMMERS OF 1948-1950-1951

	Water Temperatures in degrees Centigrade									Carbonates ppm			
Depth in Meters	0	1	2	3	4	5	6	7	15	0	2	6	15
1948 July 5	23.9		[23.7	17.5	11.2	8.8	6.9]	6.3	5.0	4	14	0	0
July 12	26.2	25.8	[25.0	17.2	12.5	9.0	7.6	6.5]	5.0	4	8	0	0
July 19	23.2	23.2	23.0	[23.0	12.8	9.2	7.3]	6.6	5.0	8	12	0	0
July 26	20.4	20.3	20.3	[20.1	12.6	9.0	7.3]	6.8	5.2	8	12	0	0
Aug. 2	21.2		21.2	[21.0	15.4	9.0	7.7]	6.8	5.0	6	8	0	0
Aug. 9	20.1		20.0	[20.0	15.7	8.9	7.5]	6.7	5.0	7	8	0	0
1950 July 20	20.1		[19.6	12.4	9.4	7.8]	7.3	6.8	5.8	4	4	0	0
Aug. 8	21.6		[18.2	14.2	9.7	7.9]	7.0		5.8	4	4	0	0
1951 July 20	19.7	[19.3	13.8	9.0	5.9]		5.2		4.7	0	0	0	0
Aug. 16	21.2	[19.4	12.0	8.1	6.3]	5.5			4.8	0	0	0	0
Aug. 25	21.0	[18.4	13.1	8.0	6.1]	5.8			4.9	3	3	0	0
Sept.15	17.7	[17.7	16.5	9.3	6.2]	5.8			4.9	4	4	0	0

TABLE 5 (Continued)

	Bicarbonates ppm				pH				Oxygen ppm				Carbon dioxide ppm			
Depth in Meters	0	2	6	15	0	2	6	15	0	2	6	15	0	2	6	15
1948 July 5	134	122	151	195	8.0	8.0	7.2	7.1	6.2	6.2	1.3	0.1	0	0	7	11
July 12	134	134	171	203	8.0	8.0	7.2	7.2	6.6	7.4	1.1	0	0	0	8	10
July 19	128	128	149	182	8.2	8.2	7.3	7.3	6.7	6.7	1.7	0	0	0	10	12
July 26	122	120	139	188	8.2	8.2	7.2	7.2	6.6	6.8	1.7	0	0	0	12	13
Aug. 2	138	137	168	198	8.2	8.2	7.3	7.3	6.5	6.5	1.3	0	0	0	11	12
Aug. 9	136	134	150	200	8.2	8.2	7.2	7.2	6.7	6.8	1.2	0	0	0	12	13
1950 July 20	150	152	169	178	8.3	8.2	7.2	7.1	7.8	7.4	4.3	0	0	0	8	12
Aug. 8	152	153	158	180	8.1	8.1	7.2	7.2	6.9	6.8	4.6	0	0	0	7	10
1951 July 20	138	146	155	199	7.8	7.3	7.1	7.1	6.1	4.2	2.9	0	2	2	8	12
Aug. 16	143	149	161	201	8.0	7.6	7.1	7.1	6.4	4.9	2.4	0	0	2	9	15
Aug. 25	145	149	164	204	8.1	8.0	7.1	7.1	6.8	5.2	2.0	0	0	0	11	16
Sept.15	149	151	169	210	8.2	8.2	7.1	7.1	6.9	5.8	1.6	0	0	0	13	19

Thermoclines enclosed in brackets

epilimnion, and, in general, the difference in amounts present in the upper and lower limits of this stratum never exceeded 4 ppm. The hypolimnion contained no trace of carbonates. The bicarbonate content of the epilimnion ranged between 120 and 153 ppm. The difference between the upper and lower limits never exceeded 5 ppm, and more often was less. At the bottom of the hypolimnion, the bicarbonate content of the waters varied between 180 and 210 ppm, occurring at the lower end of the range in the beginning of the summer and increasing gradually as the summer progressed. Determinations in a single vertical series of samples indicated a gradual increase of bicarbonates toward the bottom of the lake. The pH ranged between 8.0 and 8.2 in the epilimnion and between 7.1 and 7.3 at the bottom of the hypolimnion. Dissolved oxygen occurred in the epilimnion in amounts ranging between 7.8 and 8.2 ppm. In the hypolimnion it gradually decreased from top to bottom, usually disappearing from the bottom very early in the summer. There was no trace of dissolved carbon dioxide in the epilimnion on any day during the three summers. The upper limit of the hypolimnion, however, contained it in amounts varying between 7 and 13 ppm and in the lower limits it was present in amounts ranging between 10 and 19 ppm. The bottom waters of the hypolimnion always contained more than the upper waters of this stratum but the difference between the amounts of carbon dioxide in its upper and lower limits never exceeded 6 ppm. The conductivity of the water,

at the time of thermal stratification increased from surface to bottom. The values obtained showed, on the average, an increase from 240 mhos at the surface to 350 mhos at the bottom.

The total phosphorus in the epilimnion during both summers in which these determinations were made (Table 6) occurred in amounts between 6 and 11 micrograms per liter. In the hypolimnion, the amounts increased toward the bottom, and at the bottom there was an appreciable increase as the summer progressed. In the summer of 1951 on July 20, the amount present at the bottom was 67 micrograms per liter. By August 16 it had increased to 199 micrograms per liter. This was the highest value obtained during the summer of that year. From then on, even before the fall overturn occurred, the amount began to decrease, reaching 150 micrograms per liter by August 25 and 131 micrograms per liter by September 15. No determinations were made during the overturn.

In the epilimnion, the soluble inorganic phosphorus was present in very small amounts, fluctuating between 0 and 3 micrograms per liter. In the hypolimnion, its trend of distribution was very similar to that of total phosphorus. There was a gradual increase toward the bottom and, as was the case with the total phosphorus in the summer of 1951, there was also an increase of soluble inorganic phosphorus in the bottom waters as the summer progressed. Here too, however, the amounts began to decrease before the inception of the fall overturn. This trend can best be illustrated

TABLE 6

PHOSPHORUS DATA FROM LANCASTER LAKE DURING THE SUMMERS OF 1950-1951

Values of the total and the various fractions of phosphorus are reported in the body of the table as micrograms per liter

Phosphorus		Total									Soluble Inorganic								
Depth in Meters		0	3	6	9	12	13	14	15	15.5	0	3	6	9	12	13	14	15	15.5
1950	July 20	8	10	5					39		1	2	2					23	
	Aug. 8	8	7	8					62		2	2	3					41	
1951	July 20	9	11	10		9	15	23	43	67	1	1	2		3	7	13	30	49
	Aug. 16	8	10	9		12	25	42	136	199	1	1	1		5	15	30	120	175
	Aug. 25	6	6	6	10	12	23	76	102	150	0	0	1	3	6	14	65	85	130
	Sept 15	11	10	9	11	12	52	95	110	131	3	2	2	3	6	42	83	95	110

TABLE 6 (Continued)

Phosphorus		Total Organic									Sestonic								
Depth in Meters		0	3	6	9	12	13	14	15	15.5	0	3	6	9	12	13	14	15	15.5
1950	July 20	7	8	3					16		2	3	2					5	
	Aug. 8	6	5	5					21		2	1	3					6	
1951	July 20	8	10	8		6	8	10	13	18	2	3	3		2	3	4	4	10
	Aug. 16	7	9	8		7	10	12	16	24	2	3	2		3	4	4	5	11
	Aug. 25	6	6	5	7	6	9	11	17	20	2	1	2	2	2	3	3	6	10
	Sept 15	8	8	7	8	6	10	12	15	21	2	2	3	3	4	4	6	8	11

TABLE 6 (Continued)

Phosphorus		Soluble Organic								
Depth in Meters		0	3	6	9	12	13	14	15	15.5
1950	July 20	5	5	1					11	
	Aug. 8	4	4	2					16	
1951	July 20	6	7	5		4	5	6	9	8
	Aug. 16	5	6	6		4	6	8	11	13
	Aug. 25	4	5	3	5	4	6	8	11	10
	Sept 15	6	6	4	5	2	6	6	7	10

by stating the amounts of soluble inorganic phosphorus in the bottom waters on various successive dates during the summer. These values were 49, 175, 130 and 110 micrograms per liter. The amount present at the bottom on September 15, the last day of collection, was still high compared to the amount present in the early summer.

The vertical distribution of soluble inorganic phosphorus in Lancaster Lake during the summer of 1951 is demonstrated in Table 7 and Figure 6. The increases that occurred at the bottom during the summer have been discussed but it can be seen how slowly it diffuses upward into the hypolimnion. By September 15 it had diffused up to 13 meters, a distance of only 2.5 meters. The upper limit of the hypolimnion on that day was between 4 and 5 meters.

The amount of total organic phosphorus in the epilimnion fluctuated between 6 and 8 micrograms per liter during both summers. It decreased in amount toward the bottom of the hypolimnion. At the extreme bottom, the total organic phosphorus varied between 18 and 24 micrograms per liter.

The sestonic phosphorus was present in amounts which nearly always ranged between 1 and 6 micrograms per liter at all depths except at the 15.5-meter depth. Here it fluctuated between 10 and 11 micrograms per liter. The tendency seemed to be a very gradual increase from top to bottom.

The values of soluble organic phosphorus obtained from water samples, collected through the summers at various depths, in the upper 14 meters ranged between 4 and 8

TABLE 7

A COMPARISON OF THE SOLUBLE INORGANIC PHOSPHORUS IN DOUGLAS AND LANCASTER LAKES DURING THE SUMMER OF 1951

Values of the total and the various fractions of phosphorus are reported in the body of the table as micrograms per liter

Lakes	Depth in Meters	0	2	3	5	6	9	12	13	14	15	15.5*	16	17	18	19	20	20.5*
Douglas	July 9	1	2		1			2									2	4
	July 23	1	1		1			1									3	6
	Aug. 10	1	1		1			1					1		1	1	4	15
	Aug. 25	1	1		1			1					1	1	1	1	2	85
	Sept. 15	1	1		1			1					1	1	3	7	20	80
	Oct. 6	2	2		1			1					1		1	1	2	8
Lancaster	July 20	1		1		2		3	7	13	30	49						
	Aug. 16	1		1		1		5	15	30	120	175						
	Aug. 25	0		0		1	3	6	14	65	85	130						
	Sept. 15	3		2		2	3	6	42	83	95	110						

* Water samples taken at these bottom depths were muddy. These samples were collected with a Kemmerer sampler and transferred to 250 cc. bottles. Each bottle was allowed to stand for two or three hours until the mud settled to the bottom. The clear water in the upper part of the bottle was analyzed.

Fig. 5 - Vertical Distribution of Soluble Inorganic Phosphorus in Douglas Lake (South Fishtail Bay) During the Summer of 1951

Fig. 6 - Vertical Distribution of Soluble Inorganic Phosphorus in Lancaster Lake During the Summer of 1951

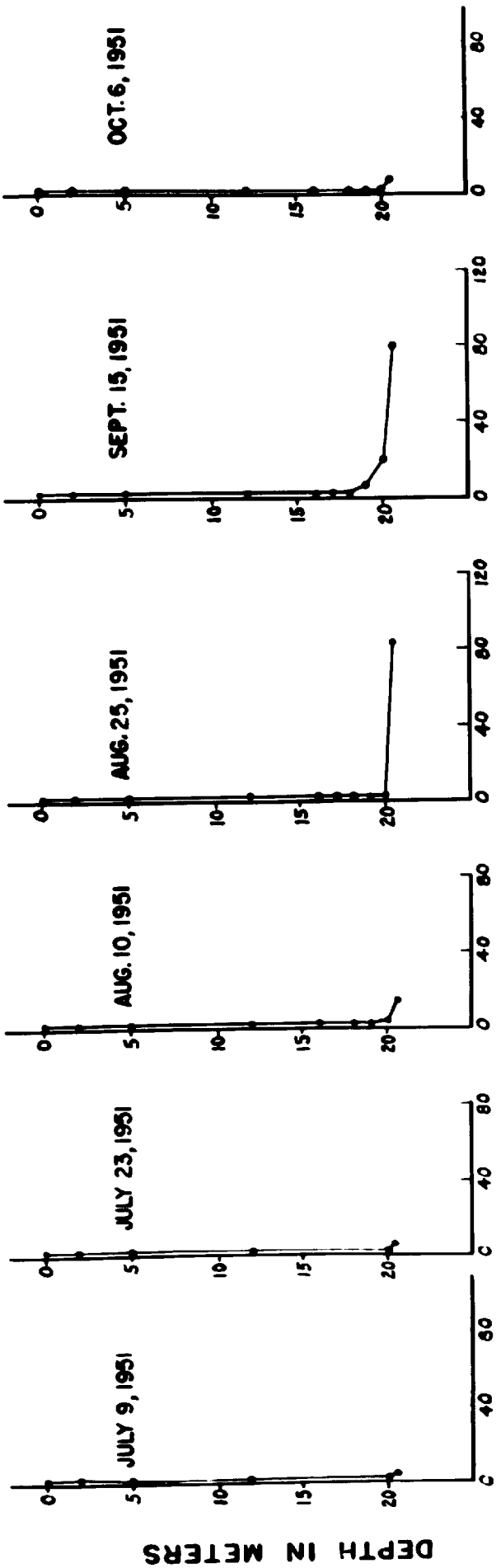

JULY 9, 1951
JULY 23, 1951
AUG. 10, 1951
AUG. 25, 1951
SEPT. 15, 1951
OCT. 6, 1951
DEPTH IN METERS
PHOSPHORUS IN MICROGRAMS PER LITER

FIG. 5

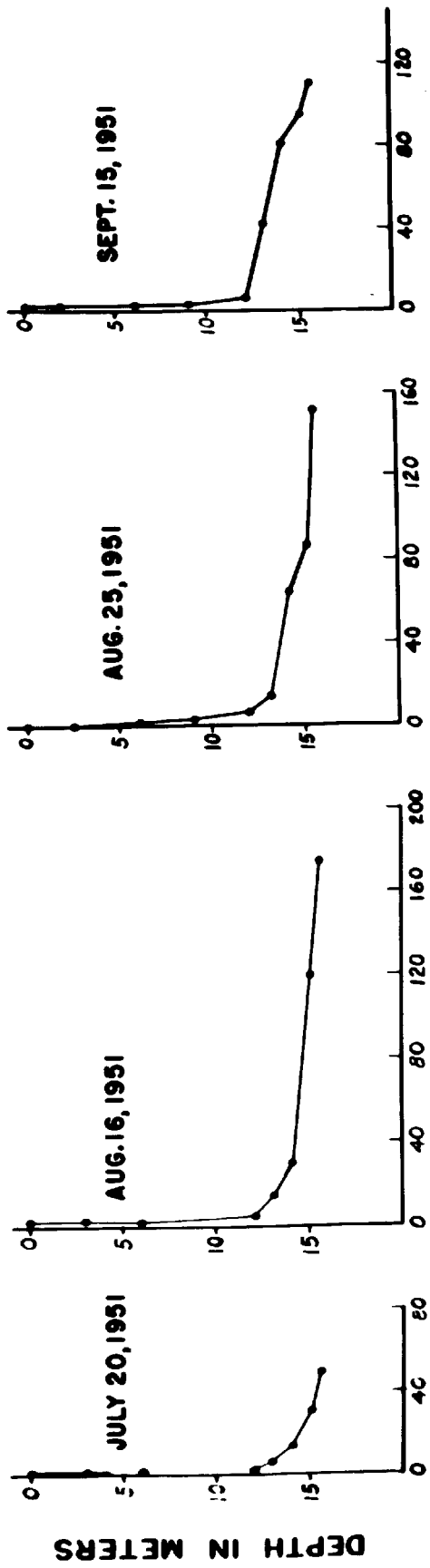

JULY 20, 1951
AUG. 16, 1951
AUG. 25, 1951
SEPT. 15, 1951
DEPTH IN METERS
PHOSPHORUS IN MICROGRAMS PER LITER

FIG. 6

micrograms per liter in the majority of samples. At the bottom depth, it occurred in amounts ranging between 10 and 16 micrograms per liter in most cases. Those samples which contained soluble organic phosphorus in amounts outside of the ranges mentioned were few and their deviations small.

Munro Lake

This lake is shallow and relatively unprotected, hence its waters are in constant circulation during the absence of an ice cover. Most of the physico-chemical data collected during the summers of 1948, 1950 and 1951 (Table 8) demonstrate a uniformity of conditions from top to bottom at any single time of sampling. Considering the data from the three summers as a whole, it can be seen that the water temperatures always ranged between 18.4 and 27.4 degrees centigrade. The differences between the surface and bottom temperatures at any one time never exceeded more than one degree. The carbonates occurred in amounts ranging between 4 and 12 ppm, whereas the bicarbonates were present in quantities varying between 74 and 112 ppm. The hydrogen ion concentration was always between 8.0 and 8.3 pH during the three summers, never differing from surface to bottom by more than 0.2 pH. Dissolved oxygen in this lake was present in amounts ranging from 6.2 to 8.7 ppm. Here, again, the difference between the quantities in the surface and bottom waters on a single day was only a fraction of a part per million. No trace of dissolved carbon dioxide was found in any of the

TABLE 8

PHYSICO-CHEMICAL DATA FROM MUNRO LAKE DURING THE SUMMERS OF 1948-1950-1951

	Water Temperatures in degrees Centigrade		Carbonates ppm		Bicarbonates ppm		pH		Oxygen ppm		Carbon dioxide ppm	
Depth in Meters	0	2	0	2	0	2	0	2	0	2	0	2
1948												
July 3	20.0	19.6	4	8	94	90	8.2	8.0	8.2	8.0	0	0
July 10	27.4	26.4	12	8	90	96	8.3	8.3	7.2	7.1	0	0
July 24	18.5	18.4	8	12	82	74	8.2	8.1	8.1	8.0	0	0
July 31	21.0	21.0	6	8	87	86	8.4	8.4	7.1	7.2	0	0
Aug. 12	20.8	20.4	6	6	90	92	8.3	8.3	6.8	6.8	0	0
1950												
July 27	22.5	22.2	4	4	108	112	8.3	8.3	7.4	7.2	0	0
Aug. 15	22.8	22.8	6	6	110	112	8.2	8.2	7.1	7.0	0	0
1951												
July 18	22.8	22.6	6	6	97	97	8.3	8.3	8.7	8.6	0	0
Aug. 15	20.6	20.4	5	5	107	107	8.3	8.3	8.1	8.0	0	0

water samples collected. Welch (1938) reported the color of the water in this lake to be usually less than 20 on the platinum cobalt scale. Conductivity measurements from this lake showed variations between 180 and 200 mhos.

The amounts of total phosphorus (Table 9) in Munro Lake during the two summers in which these determinations were made fluctuated between 10 and 12 micrograms per liter whereas the soluble inorganic phosphorus occurred in amounts between 1 and 2 micrograms per liter. The total organic phosphorus was present in quantities ranging between 9 and 11 micrograms per liter. Determinations of sestonic phosphorus indicate its presence in amounts varying between 2 and 5 micrograms per liter while the soluble organic phosphorus occurred in quantities ranging between 5 and 8 micrograms per liter. It will thus be seen that, in terms of total phosphorus, Munro Lake is quite similar to the epilimnion of Lancaster and Douglas Lakes.

Vincent Lake

This lake is also shallow, hence thermal stratification ordinarily does not persist throughout a whole summer. Due to much flocculent material in the lower levels, the lake is quite turbid. Welch (1938) states that in times of calm, however, the surface water is quite transparent and the color low varying from about 27 to 31 on the platinum cobalt scale. Physico-chemical conditions were usually

TABLE 9

PHOSPHORUS DATA FROM MUNRO LAKE DURING THE SUMMERS OF 1950-1951

Values of the total and the various fractions of phosphorus are reported in the body of the table as micrograms per liter

Phosphorus	Total		Soluble Inorganic		Total Organic		Sestonic		Soluble Organic	
Depth in Meters	0	2	0	2	0	2	0	2	0	2
1950 July 27	10	12	1	1	9	11	2	3	7	8
Aug. 15	12	11	2	1	10	10	4	5	6	5
1951 July 18	11	10	1	1	10	9	3	4	7	5
Aug. 15	12	12	1	1	11	11	3	4	8	7

uniform from surface to bottom on any one day when determined during this investigation (Table 10). During the three summers of investigation the water temperatures fluctuated between 20.0 and 27.1 degrees centigrade. There was no trace of carbonates at any time, and the bicarbonate content of the water varied between 4 and 9 ppm which was much less than was present in the other lakes under investigation. The pH values obtained for this lake during the present investigation are interesting when compared to those values obtained by other workers in previous years. Jewell and Brown (1929) reported the pH as varying between 4.4 and 7.2 during the years 1923 and 1926. Eggleton (1935) found the pH to vary between 5.7 and 7.0 for the years 1926 and 1933. I obtained values between 6.4 and 7.5 for the years 1948 and 1951 but in only one third of the samples collected was the pH below 7. Considering the data from the three reports, it appears that as the years go by there is a gradual change taking place in Vincent Lake from an acid to an alkaline condition. Dissolved oxygen occurred in abundance varying in amounts from 6.3 to 7.6 ppm. Dissolved carbon dioxide, on the other hand, occurred in small amounts ranging between 0.3 and 1.5 ppm. Conductivity readings from this lake varied between 18 and 25 mhos, which is very low compared to the other lakes.

Determinations of total phosphorus (Table 11) showed its presence in quantities varying from 14 to 18 micrograms per liter. Soluble inorganic phosphorus occurred in minimal

TABLE 10

PHYSICO-CHEMICAL DATA FROM VINCENT LAKE DURING THE SUMMERS OF 1948-1950-1951

	Water Temperatures in degrees Centigrade		Carbonates ppm		Bicarbonates ppm		pH		Oxygen ppm		Carbon dioxide ppm	
Depth in Meters	0	2.5	0	2.5	0	2.5	0	2.5	0	2.5	0	2.5
1948												
July 3	21.1	20.6	0	0	6	7	6.6	6.6	7.3	7.1	1	1
July 10	27.1	23.8	0	0	4	5	7.5	7.4	6.9	6.4	1	1
July 24	22.4	22.0	0	0	4	4	7.2	7.2	7.6	7.7	1	1
July 31	24.0	23.2	0	0	5	5	7.0	6.8	7.6	7.4	1	1.5
Aug. 12	22.1	21.8	0	0	5	5	7.1	7.0	7.5	7.4	1	1
1950												
July 28	24.0	21.8	0	0	7	7	7.3	6.4	7.2	6.3	0.3	1.2
Aug. 17	23.0	22.6	0	0	8	9	7.1	6.6	7.4	7.0	0.3	1.0
1951												
July 18	23.1	22.9	0	0	7	7	7.2	7.0	7.0	6.9	0.5	1.0
Aug. 15	20.3	20.0	0	0	8	9	7.3	6.8	7.5	7.0	0.8	1.2

TABLE 11

PHOSPHORUS DATA FROM VINCENT LAKE DURING THE SUMMERS OF 1950-1951

Values of the total and the various fractions of phosphorus are reported in the body of the table as micrograms per liter

Phosphorus		Total		Soluble Inorganic		Total Organic		Sestonic		Soluble Organic	
Depth in Meters		0	2.5	0	2.5	0	2.5	0	2.5	0	2.5
1950	July 28	16	18	0.5	0	15.5	18	4.5	3	11	15
	Aug. 17	16	15	0.0	1	16	14	10	9	6	5
1951	July 18	14	16	1.0	1	13	15	9	10	4	5
	Aug. 15	17	17	1.0	1	16	16	8	9	8	7

quantities ranging between 0 and 1 micrograms per liter. The total organic phosphorus varied in amounts from 13 to 18 micrograms per liter. Analysis of the sestonic phosphorus showed that it occurred in amounts ranging from 3 to 10 micrograms per liter and the soluble organic phosphorus was present in quantities varying from 4 to 15 micrograms per liter. It thus is evident that the total organic phosphorus is higher than in any of the other three lakes previously discussed.

Lake Lansing

Work was conducted on this lake from August 28 through November 9, 1950. On August 28 there was evidence of a slight thermal stratification (Table 12), the thermocline occurring between 4 and 5 meters and having a temperature difference of only 1.1 degrees centigrade between its upper and lower limits. During the remainder of the period of investigation there were, sometimes, slight decreases in temperature from top to bottom but they were not sufficiently great to form a thermocline which would fit the classical definition of a one-degree centigrade drop per meter of depth. On August 28 and September 4 there was an abundance of dissolved oxygen at all depths except at the bottom (Figure 7). At the latter depth, there was no oxygen on the first day and only 0.2 ppm on the second. By September 16, circulation was in progress and there was oxygen present at all depths during the remainder of the fall, in amounts

TABLE 12

PHYSICO-CHEMICAL DATA FROM LAKE LANSING DURING FALL OF 1950

	Water Temperatures in degrees Centigrade					Oxygen ppm			
Depth in Meters	0	2	4	5	9	0	2	5	9
Aug. 28	23.3	22.2	[21.1	20.0]	18.9	7.9	7.5	5.0	0.0
Sept. 4	20.6	20.6	20.6	20.6	19.4	6.1	6.1	6.1	0.2
Sept. 16	19.9	18.9	18.9	18.9	18.4	6.2	6.2	6.3	5.7
Oct. 3	18.3				16.6	8.4	8.0	6.4	4.7
Oct. 24	11.6				11.6	7.6			5.2
Nov. 9	10.0				10.0	6.8			6.2

TABLE 12 (Continued)

	pH				Carbonates ppm				Bicarbonates ppm				Carbon dioxide ppm			
Depth in Meters	0	2	5	9	0	2	5	9	0	2	5	9	0	2	5	9
Aug. 28	8.4	8.4	7.9	7.4	8	10	0	0	98	95	106	112	0.0	0.0	0.6	4.8
Sept. 4	8.0	8.0	8.0	7.4	0	0	0	0	104	105	105	116	0.0	0.0	0.0	0.5
Sept. 16	7.7	7.7	7.7	7.7	0	0	0	0	108	108	107	108	0.8	0.8	0.8	0.8
Oct. 3	8.1			7.4	0	0	0	0	115	115	115	114	0.0			12.0
Oct. 24	7.9			7.9	0	0	0	0	117	117	116	114	0.3			0.3
Nov. 9	7.9			7.8	0	0	0	0	114	114	114	115	0.3			0.4

Thermoclines enclosed in brackets

Fig. 7 - Soluble Inorganic Phosphorus and Dissolved Oxygen in Lake Lansing at 8-meter Depth (bottom), During Fall of 1950

Fig. 8 - Maximum and Minimum Values of Total Phosphorus and Soluble Inorganic Phosphorus Occurring Between Surface and 5-meter Depth in Lake Lansing During Fall of 1950

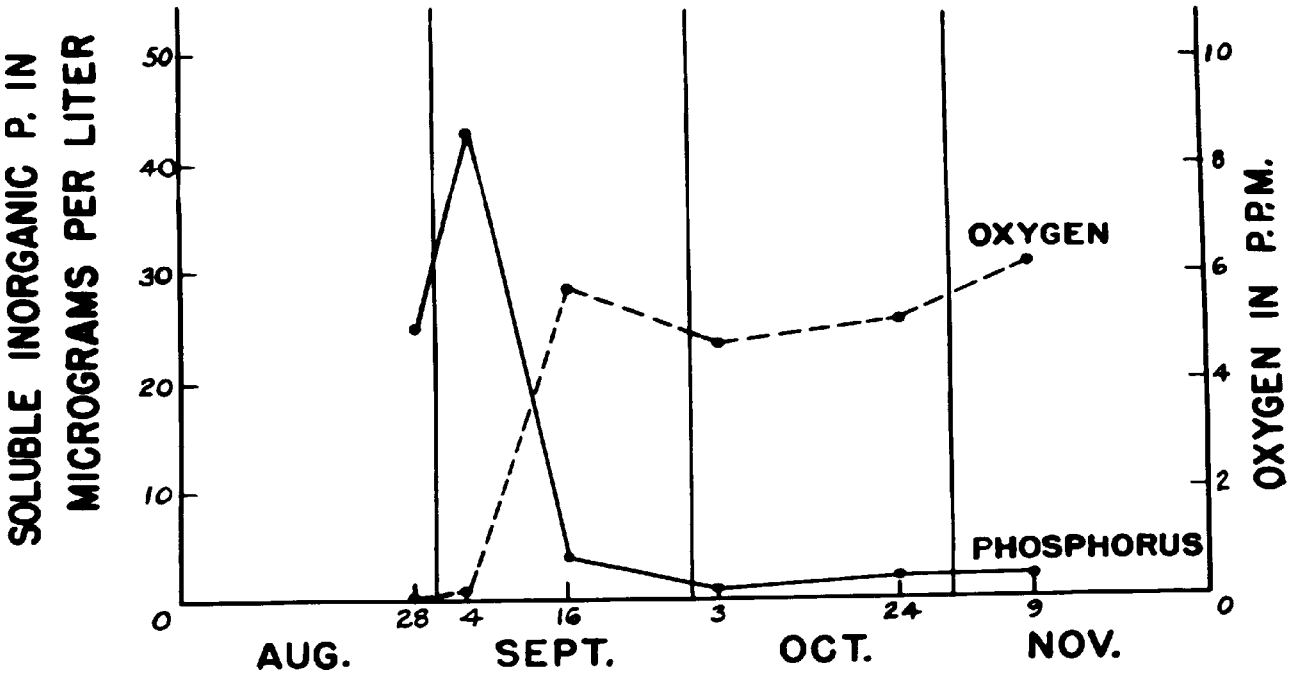

SOLUBLE INORGANIC P. IN MICROGRAMS PER LITER
OXYGEN IN P.P.M.
OXYGEN
PHOSPHORUS
0
10
20
30
40
50
2
4
6
8
10
28
4
16
3
24
9
AUG.
SEPT.
OCT.
NOV.

FIG. 7

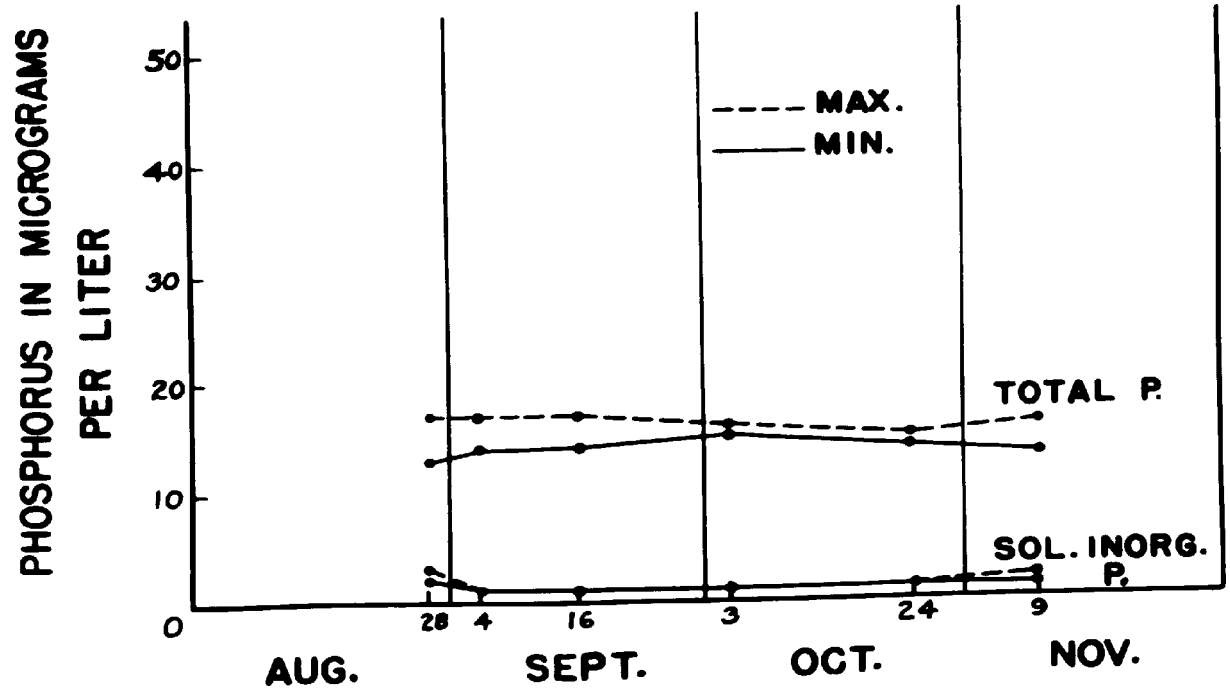

PHOSPHORUS IN MICROGRAMS PER LITER
MAX.
MIN.
TOTAL P.
SOL. INORG. P.
0
10
20
30
40
50
28
4
16
3
24
9
AUG.
SEPT.
OCT.
NOV.

FIG. 8

varying between 4.7 and 8.4 ppm. On August 28, all through the epilimnion, the pH was 8.4 while in the hypolimnion it was 7.9 and 7.4 at its upper and lower limits respectively. During the remainder of the investigation the pH fluctuated between 7.7 and 8.1 at the surface and between 7.4 and 7.9 at the bottom. On the first day of collection carbonates occurred only in the upper two meters and in amounts between 8 and 10 ppm. On the other days of collection there was no trace of carbonates at any depth. The bicarbonate content on August 28 occurred in amounts between 95 and 98 ppm in the epilimnion and between 106 and 112 ppm in the hypolimnion. On September 4, approximately one week later, there were between 104 and 105 ppm of bicarbonates at all the depths except the bottom which contained 116 ppm. During the remainder of the period of investigation the bicarbonate content in the surface varied between 108 and 117 ppm whereas at the bottom it fluctuated between 108 and 115 ppm; the difference between the amounts in the surface and bottom never exceeding 3 ppm. On August 28 there was no trace of dissolved carbon dioxide in the upper two meters, but from the 5-meter to the 9-meter depth it appeared in increasing amounts from 0.6 to 4.8 ppm. On September 4, it occurred only at the bottom depth in the amount of 0.5 ppm. On all the remaining days in the field, except October 3, it occurred at all depths in amounts ranging from 0 to 0.8 ppm. On October 3 there was no carbon dioxide in the surface sample but at the bottom it was present in the

amount of 12 ppm.

All of the water samples collected from Lake Lansing with the exception of two, contained total phosphorus in amounts ranging between 13 and 17 micrograms per liter (Table 13). The two samples just referred to were collected at the bottom on August 28 and September 4 and contained 33 and 57 micrograms per liter respectively. With the exception of the same two samples, soluble inorganic phosphorus occurred in all the collections in quantities varying between 1 and 3 micrograms per liter. In the two exceptions, it occurred in amounts of 25 and 43 micrograms per liter respectively. The amounts of total organic phosphorus throughout the entire depth of the lake and during the whole period of investigation varied from 8 to 16 micrograms per liter. The soluble organic phosphorus occurred in quantities between 1 and 8 micrograms per liter except in the two samples collected at the bottom on August 28 and September 4. In the latter samples no soluble organic phosphorus was found. All of the samples, with the exception of the two bottom ones previously mentioned, contained sestonic phosphorus in amounts ranging between 7 and 13 micrograms per liter. The exceptions contained it in amounts of 23 and 27 micrograms per liter respectively. It should be remembered that these two bottom water samples collected singly on August 28 and September 4 were the ones which contained no oxygen or just a trace thereof.

TABLE 13

PHOSPHORUS DATA FROM LAKE LANSING DURING THE FALL OF 1950

Values of the total and various fractions of phosphorus are reported in the body of the table as micrograms per liter

Phosphorus	Total				Soluble Inorganic				Total Organic				Sestonic				Soluble Organic			
Depth in Meters	0	2	5	9	0	2	5	9	0	2	5	9	0	2	5	9	0	2	5	9
Aug. 28	14	17	13	33	3	2	2	25	11	15	11	8	10	13	7	23*	1	2	4	0
Sept. 4	16	14	17	57	1	1	1	43	15	13	16	14	11	9	12	27**	4	4	4	0
Sept. 16	14	17	15	15	1	1	1	4	13	16	14	11	7	12	9	9	6	4	5	2
Oct. 3	15	16	16	15	1	1	1	1	14	15	15	14	7	9	8	9	7	6	7	5
Oct. 24	14	14	15	15	1	1	1	2	13	13	14	13	6	7	8	8	7	6	6	5
Nov. 9	16	14	13	14	1	2	1	2	15	12	12	12	7	8	6	7	8	4	6	5

* On Aug. 28, the 23 micrograms of sestonic phosphorus at 9 meters included 15 micrograms of acid soluble sestonic phosphorus leaving 8 micrograms of actual organic sestonic phosphorus.

** On Sept. 4, the 27 micrograms of sestonic phosphorus at 9 meters included 13 micrograms of acid soluble sestonic phosphorus leaving 14 micrograms of actual organic sestonic phosphorus.

PHYTOPLANKTON

Method of Collection and Enumeration

Collection. A single station was chosen in each of the lakes, from which to take vertical series of plankton samples. The apparatus employed to collect these samples was a Birge and Juday 10 liter trap with number 25 silk bolting cloth. The samples were concentrated to approximately 15 or 20 ml, depending upon the concentration of plankton in the lake at the time, and transferred to one ounce packer bottles. About eight drops of formalin were added to each bottle as a preservative.

Enumeration. Enumeration of phytoplankton was done in general as outlined in Whipple (1927). A binocular compound microscope was used with 16 mm objectives and 10X oculars. In the right ocular was placed a Whipple ocular micrometer calibrated to include a square field one mm X one mm. The counting chamber was a Sedgewick-Rafter cell, 50 mm long, 20 mm wide and 1 mm deep having a capacity of one ml.

The phytoplankton were counted only according to genus due to the impossibility of placing the high power objective over the Sedgewick-Rafter cell. Some qualitative studies, however, were done and members of those genera which

appeared in the samples in sufficiently large numbers to make them quantitatively significant were identified to species where possible (Table 14), while those which occurred in very small numbers were ignored from the standpoint of species identification.

The actual enumeration of the phytoplankton in a single field under the microscope was done in such a way that one organism did not necessarily constitute one unit but to each genus was allotted a certain number of cells per unit or a certain number of micra per unit if it were a filamentous alga. This system was used to reduce inconsistencies in results arising from the variations in size of different individuals of the same genus. The number of cells or micra allotted to a single unit of a genus was the same as that used by Chandler (1940) in his counts of Lake Erie phytoplankton and by myself in the analysis of the phytoplankton of the Bay of Quinte (Tucker, 1948). By using a common system of enumeration, the results obtained from different lakes by various workers may be compared if desired, without the cumbersome task of converting the results of these investigations into comparable units. The units used in this investigation are shown in the following list.

TABLE 14

SPECIES OF PHYTOPLANKTON MAKING UP THE GENERA WHICH HAVE QUANTITATIVE SIGNIFICANCE IN THE PLANKTON SAMPLES COLLECTED FROM DOUGLAS, LANCASTER, MUNRO, VINCENT, AND LANSING LAKES

Phytoplankton	Lakes				
	Douglas	Lancaster	Munro	Vincent	Lansing
Blue-Green Algae					
Anabaena flos-aquae (Lyngb.) Breb.	x	x			x
Anabaena sp.			x		x
Aphanizomenon flos-aquae (L.) Ralfs			x		
Chroococcus giganteus W. West			x		
Chroococcus limneticus Lemm.			x	x	
Chroococcus minor (Kuetz.) Nag.				x	
Chroococcus sp.		x			
Coelosphaerium Kuetzingianum Nag.	x				
Coelosphaerium sp.		x		x	x
Merismopedia punctata Meyen	x				
Merismopedia sp.			x	x	x
Microcystis aeruginosa Kuetz.	x		x	x	x
Microcystis flos-aquae (Wittrock) Kirchner			x	x	
Microcystis ichthyoblabe Kuetz.	x		x		
Microcystis incerta Lemm.	x				x
Microcystis sp.		x		x	
Oscillatoria tenuis Ag.	x				
Oscillatoria sp.	x				x

TABLE 14 (Continued)

Phytoplankton	Lakes				
	Douglas	Lancaster	Munro	Vincent	Lansing
Diatoms					
Asterionella formosa Hass.	x	x	x		x
Fragilaria crotonensis Kitt.	x	x	x		x
Fragilaria sp.					x
Melosira granulata (Ehr.) Ralfs	x				
Melosira varians Ag.	x			x	x
Melosira sp.		x	x		
Navicula sp.	x	x	x	x	x
Stephanodiscus niagarae Ehr.	x	x			
Stephanodiscus sp.			x	x	x
Synedra acus Kuetz.	x				
Synedra pulchella v. longissima W. Smith	x				x
Synedra ulna (Nitzsh.) Ehr.	x				
Synedra sp.		x	x	x	
Tabellaria fenestrata Kuetz.	x			x	
Tabellaria flocculosa (Roth) Kuetz.	x			x	
Tabellaria sp.		x	x		
Dinoflagellates					
Ceratium hirundinella (O.F.M.) Schrank	x	x	x		x
Peridinium cinctum Ehr.		x			
Peridinium Westi Lemm.	x				
Peridinium wisconsinense Eddy					
Peridinium sp.		x	x	x	
Chrysophyceae					
Dinobryon sertularia Ehr.	x	x			x
Dinobryon sociale Ehr.	x	x	x	x	x
Dinobryon divergens Imhof			x		x
Synura uvella Ehr.		x			

TABLE 14 (Continued)

Phytoplankton	Lakes				
	Douglas	Lancaster	Munro	Vincent	Lansing
Green Algae					
Arthrodesmus sublatus Kuetz.				x	
Arthrodesmus Ralfsii W. West				x	
Arthrodesmus sp.	x	x			
Cosmarium sp.	x	x			x
Dictyosphaerium pulchellum Wood					x
Eudorina elegans Ehr.		x	x		x
Pediastrum Boryanum (Turp.) Menegh.	x	x	x		
Pediastrum duplex Meyen	x		x	x	x
Pediastrum sp.	x				x
Pediastrum tetras (Ehr.) Ralfs			x		
Scenedesmus armatus (Chod.) G. M. Smith	x				
Scenedesmus acuminatus (Lagerh.) Chod.	x				
Scenedesmus quadricauda (Turp.) Breb	x				
Scenedesmus bijuga (Turpin) Lag.	x		x	x	
Staurastrum arctiscon (Ehr.) Lundell			x	x	
Staurastrum brachiatum Ralfs			x		
Staurastrum leptocladum v. sinuatum G. M. Smith	x				
Staurastrum cuspidatum Breb.				x	
Staurastrum paradoxum Meyen	x		x	x	
Staurastrum polymorphum Breb.	x				
Staurastrum sp.					x
Staurastrum arachne Ralfs				x	
Staurastrum O'Mearii minutum W. West				x	
Tetraedron sp.					x
Xanthidium antilopaeum (Breb.) Kuetz.				x	

Phytoplankton	Quantity equalling one unit
Bacillariophyceae (Diatoms)	
Asterionella	8 cells
Fragilaria	100 micra
Melosira	300 micra
Navicula	1 cell
Stephanodiscus	1 cell
Synedra	1 cell
Tabellaria	8 cells
Cyanophyceae (Blue-green algae)	
Anabaena	300 micra
Aphanizomenon	300 micra
Chroococcus	4 cells
Coelosphaerium	1 colony
Merismopedia	4 cells
Microcystis	10,000 sq. micra
Oscillatoria	300 micra
Chlorophyceae (Green algae)	
Arthrodesmus	1 cell
Cosmarium	1 cell
Dictyosphaerium	4 cells
Eudorina	1 colony
Pediastrum	1 colony
Scenedesmus	4 cells
Staurastrum	1 cell
Tetraedron	1 colony
Xanthidium	1 cell
Chrysophyceae (Yellow-green algae)	
Dinobryon	5 cells
Synura	1 colony
Dinophyceae	
Ceratium	1 colony
Peridinium	1 colony

It has always been a problem in estimating phytoplankton populations to know how many random fields should be counted under the microscope in order to assure reliable results. Many workers have published papers critically discussing plankton counting techniques and suggesting methods which they believed would give the most accurate estimates. The literature pertaining to plankton enumeration has been

reviewed by Serfling (1949). Chandler (1940) and Tucker (1948) in their enumeration technique filled the counting chamber twice from each sample and counted 10 random fields each time, making a total of 20 fields counted for each sample. Serfling (1949) believes that the number of fields counted should depend on the concentration of the samples. He states, "The distribution of plankton in the counting chamber may vary from the expected distribution of a Poisson function by varying amounts. The departure varies with the species, the concentration of plankton and also from one preparation to another." As a result of his calculations he proposed that sets of 10 fields be counted until a total of 62 units are observed. This criterion was used in the present investigation. The counting cell was filled and 10 random fields counted. If the number of units in these 10 fields did not total 62, the counting cell was again filled from the same sample and 10 more fields counted. If the number of units from the 20 fields already counted still did not total 62, then a third set of 10 fields were counted and so on until the total number of units obtained was at least 62.

In most of the samples, the minimum requirement of 62 units could be fulfilled by counting 20 fields. In some cases 10 fields yielded the desired number of units and in others it was necessary to count 30 and occassionally 40 fields. A factor was calculated for each genus so that its quantity in units per liter could be determined. The

standard crop of phytoplankton at a certain station on a given day was calculated by averaging the counts in the vertical series of samples collected on that day. The composition of phytoplankton was also determined in respect to percentages that each component group contributed to the total in a single standing crop and in the mean standing crops of certain seasons. The significance of these percentages was considered on an empirical rather than statistical basis.

The Phytoplankton of Douglas Lake

During the summer of 1948, at least during that part of the summer in which work was being carried on, the standing crop of total phytoplankton was very poor, ranging between 2,806 and 8,276 units per liter (Figure 9; Table 18, Appendix). If there had been a phytoplankton pulse, it must have occurred sometime before June 24. For the purpose of this investigation, a pulse has arbitrarily been defined as a standing crop containing at least 50,000 units per liter. This value was selected because it had been used in previous investigations (Chandler, 1940; Tucker, 1948) and it was thought desirable to adopt a value which had already been used so that phytoplankton populations from different lakes, investigated by various workers, might be compared quantitatively in terms of the presence or absence of a pulse.

Fig. 9 - Seasonal Variation in Standing Crops of Total Phytoplankton and the Major Classes of Algae in Douglas Lake During the Summer of 1948 and from July 3, 1950, to October 6, 1951

Explanation of Fig. 9

(a) Fall overturn began between Sept. 16 and Oct. 2, 1950

(b) Ice appeared Nov. 24, 1950

(c) Ice disappeared April 13, 1951

(d) Thermal stratification began between May 10 and May 25, 1951

(e) Fall overturn began between Sept. 15 and Oct. 6, 1951

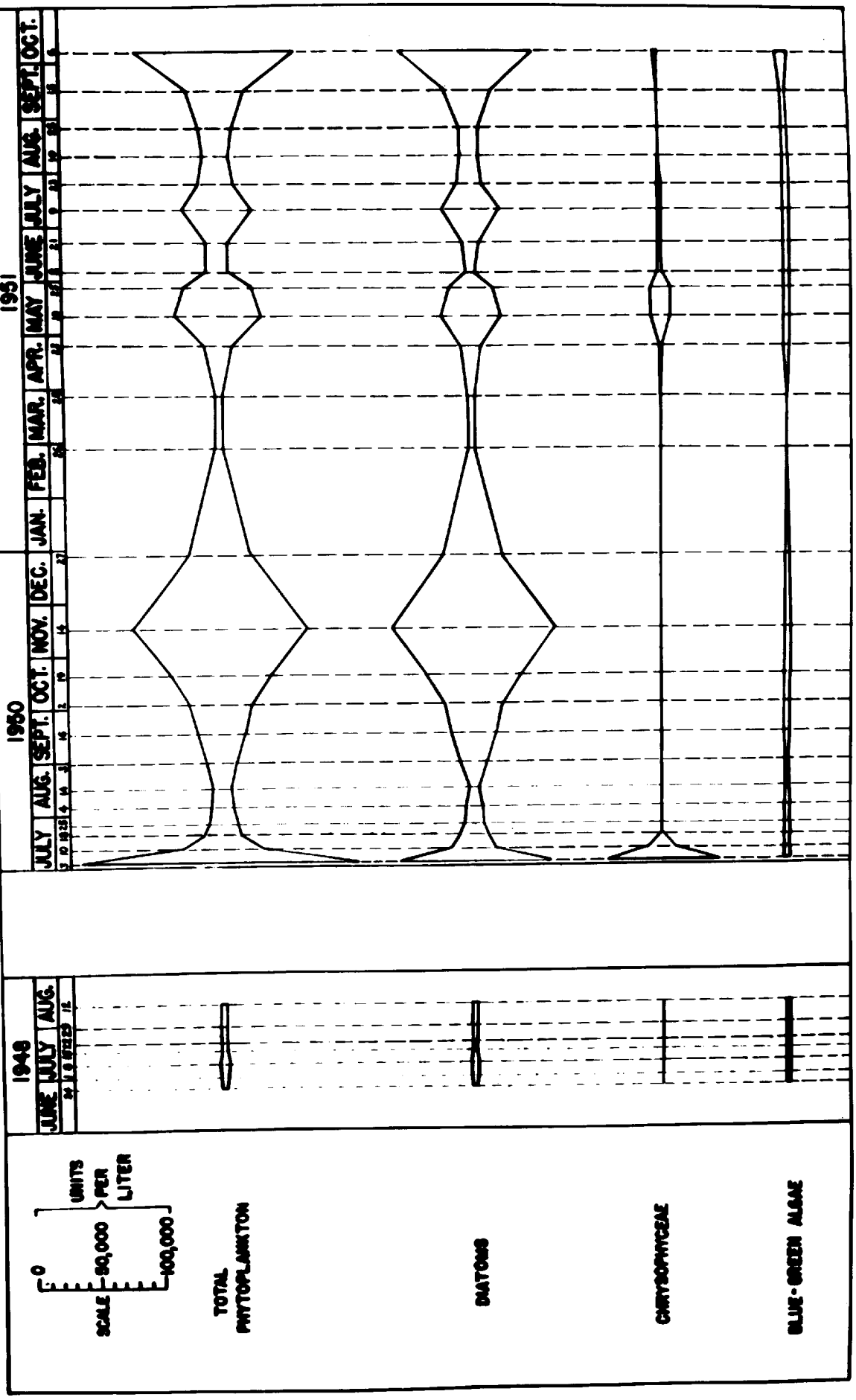

1948
JUNE JULY AUG.
1950
JULY AUG. SEPT. OCT. NOV. DEC.
1951
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.
SCALE 0 50,000 100,000 UNITS PER LITER
TOTAL PHYTOPLANKTON
DIATOMS
CHRYSOPHYCEAE
BLUE-GREEN ALGAE

FIG. 9

On July 3, 1950, the first day of the 16-month investigation, there was already in the Douglas Lake station a pulse consisting of 219,352 units per liter (Figure 9; Table 38, Appendix). By July 10, this had decreased to 66,088 units per liter and on July 18 there were present only 29,954 units per liter. Evidently the investigation had started just in time to witness the end of the spring pulse. The amount of total phytoplankton continued to decrease slightly until August 14 and from then on it began to increase; however, it never reached the status of a pulse until after October 2, which, incidentally, was a day not far past the beginning of the fall overturn. By that day the amount of phytoplankton had increased quite markedly, reaching its maximum, however, on November 14 when it was 136,440 units per liter. The days that followed saw a continual decrease which persisted under the ice and reached a low of 3,809 units per liter on February 26, 1951. There was not much of a quantitative change in the standing crop until after April 23. By this time, of course, the ice had disappeared and the lake was in the process of the spring overturn. On May 10, a pulse was present in the amount of 67,103 units per liter, however it persisted only for two or three weeks and was followed by a decrease which was evidenced by the fact that on June 8 the standing crop was only 16,030 units per liter. In the two weeks that followed there was very little change but on July 9 another small pulse occurred (55,035 units per liter). This one persisted

for an even shorter period of time than had its predecessor one month previously and on July 23 it was no longer present. From that day forward the standing crop did not increase sufficiently in amount to be called a pulse until sometime between September 15 and October 6. On the latter date there were present 125,550 units per liter. This was probably the beginning of the fall pulse of 1951.

During the 16-month period of investigation, then, five separate pulses were observed. The first one was not observed in its entirety but, fortunately, plankton samples had been collected early enough in the season to observe the end of what must have been the spring pulse. The second pulse began almost immediately after the fall overturn of 1951 and may be called the fall pulse of that year. The spring pulse of 1951, for some reason, occurred in two shifts; the first of which commenced very soon after the spring overturn. The fall overturn of 1951 was followed very closely by the beginning of the fall pulse, and since field work was terminated on October 6, 1951, the actual fate of this fall pulse was not observed.

A single glance at Figure 9 demonstrates without a doubt that Douglas Lake is a diatom lake. Tables 20 and 40 (Appendix) show that the average percentage of Bacillariophyceae occurring in the standing crop of phytoplankton (considering the entire investigation as a whole) varied between 54.3 and 95.4 with a mean of 76.2 per cent (Figure 12). The fall phytoplankton pulses of 1950 and 1951 each

contained over 85 per cent Bacillariophyceae, the remainder of the crop being made up of the other four classes of algae. The genera which were most abundant among the Bacillariophyceae in both of the fall pulses were Asterionella, Melosira and Synedra (Figure 10). The diatom population of the spring pulses in each of the two years made up only between 55 and 65 per cent of the crop whereas the Chrysophyceae consisting wholly of Dinobryon contributed between 30 and 40 per cent of the population. Dinobryon evidently shows up in significant numbers only in the spring. The genera making up the Bacillariophyceae in the spring pulses were Tabellaria, Melosira, Synedra and Fragilaria. The genus Asterionella contributed to the spring pulse of 1951 but did not show up significantly in the plankton samples collected during the spring pulse of 1950. As was previously mentioned, the latter pulse was already in progress when the investigation was started and it could very well be that an Asterionella-peak had appeared and disappeared before the investigation was begun.

Cyanophyceae occurred in all the samples and made up, on the average, about 10 per cent of the crop, varying between 2.3 and 23.9 per cent (Figure 12). They contributed very little to any pulse and for the most part were quite consistent quantitatively. Quite often in late July and August, a dense bloom of Anabaena and Gloeotrichia was observed near the shore. This apparent phenomenal abundance of Cyanophyceae is really a heavy local concentration

Fig. 10 - Seasonal Variation in Standing Crops of Total Diatoms and the Major Genera of This Class in Douglas Lake During the Summer of 1948 and from July 3, 1950, to October 6, 1951

Explanation of Figure 10

(a) Fall overturn began between Sept. 16 and Oct. 2, 1950

(b) Ice appeared Nov. 24, 1950

(c) Ice disappeared April 13, 1951

(d) Thermal stratification began between May 10 and May 25, 1951

(e) Fall overturn began between Sept. 15 and Oct. 6, 1951

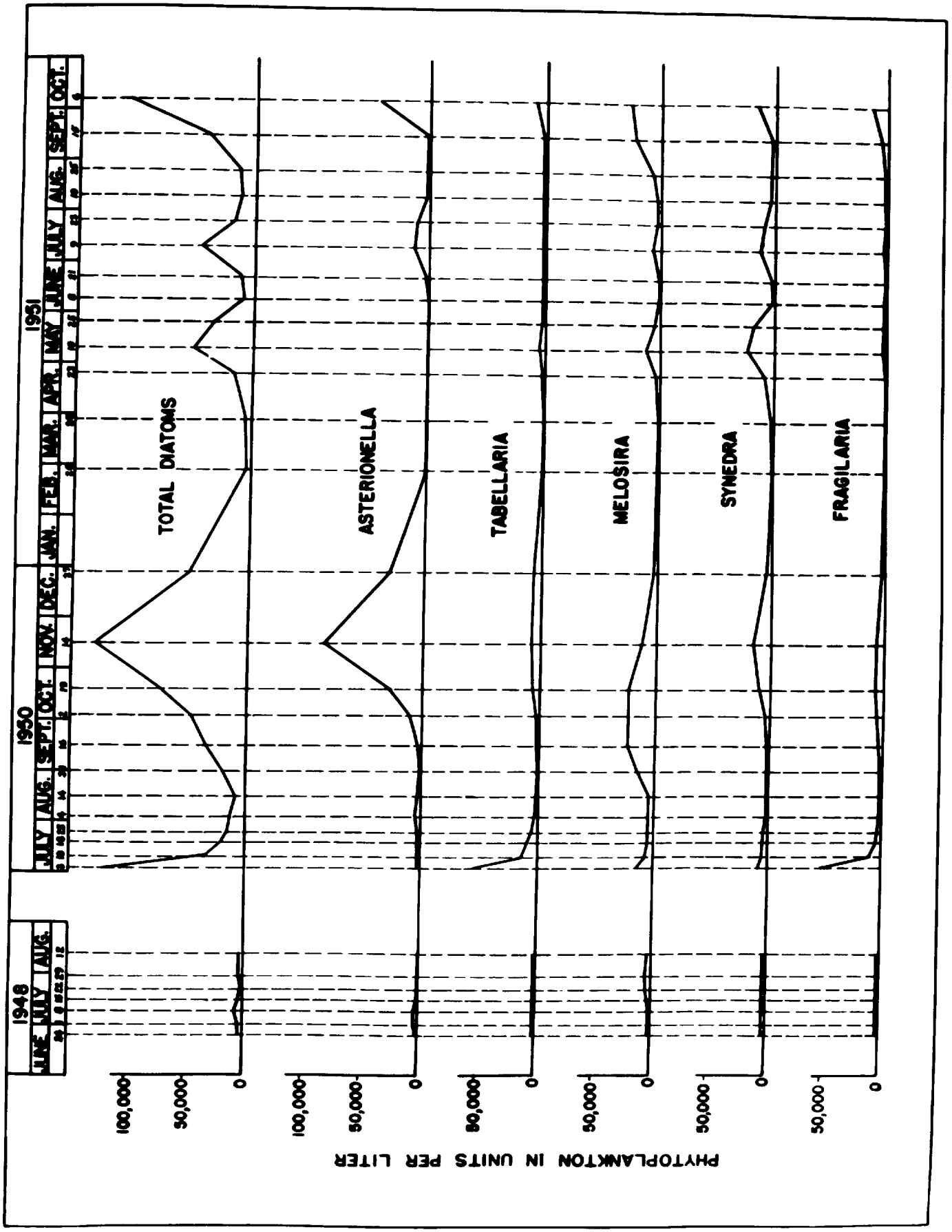

1948
JUNE JULY AUG.
1950
JULY AUG. SEPT. OCT. NOV. DEC.
1951
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.
TOTAL DIATOMS
ASTERIONELLA
TABELLARIA
MELOSIRA
SYNEDRA
FRAGILARIA
100,000
50,000
0
PHYTOPLANKTON IN UNITS PER LITER

FIG. 10

induced by continuing wind action. It is, in other words, a typical plankton drift. In the open water where the collecting station was located, such increases were not very marked and those that did occur, appeared and disappeared in a very few days. These increases were not observed in the weekly quantitative samples that were collected for enumeration. Evidently the blooms must have appeared and disappeared during the interval when samples were not taken.

The Chlorophyceae and Dinophyceae made up the remainder of the crop. Together they constituted an average of about 7 per cent of the population. They, too, were consistent in their paucity and hence played no part in any of the pulses.

Figure 11 shows the vertical distribution of total phytoplankton, Bacillariophyceae and Chrysophyceae during the period of investigation. In general, it can be seen that each of the pulses first reached its maximum in the upper waters, but soon afterward, due to the stirring action in the water, the populations tended to be distributed almost uniformly from surface to bottom.

A detailed description of the population trends of each of the genera observed in the phytoplankton of Douglas Lake will be found on pages 104 - 117. The results of the actual counts of these genera are contained in Tables 18 - 64 (Appendix). In addition these tables contain the calculated populations of the various classes of algae composing the total phytoplankton together with percentages of the total which each class represents.

Fig. 11 - Vertical Distribution of Total Phytoplankton and the Major Classes of Algae in Douglas Lake During the Summer of 1948 and from July 3, 1950, to October 6, 1951

Explanation of Fig. 11

(a) Fall overturn began between Sept. 16 and Oct. 2, 1950

(b) Ice appeared Nov. 24, 1950

(c) Ice disappeared April 13, 1951

(d) Thermal stratification began between May 10 and May 25, 1951

(e) Fall overturn began between Sept. 15 and Oct. 6, 1951

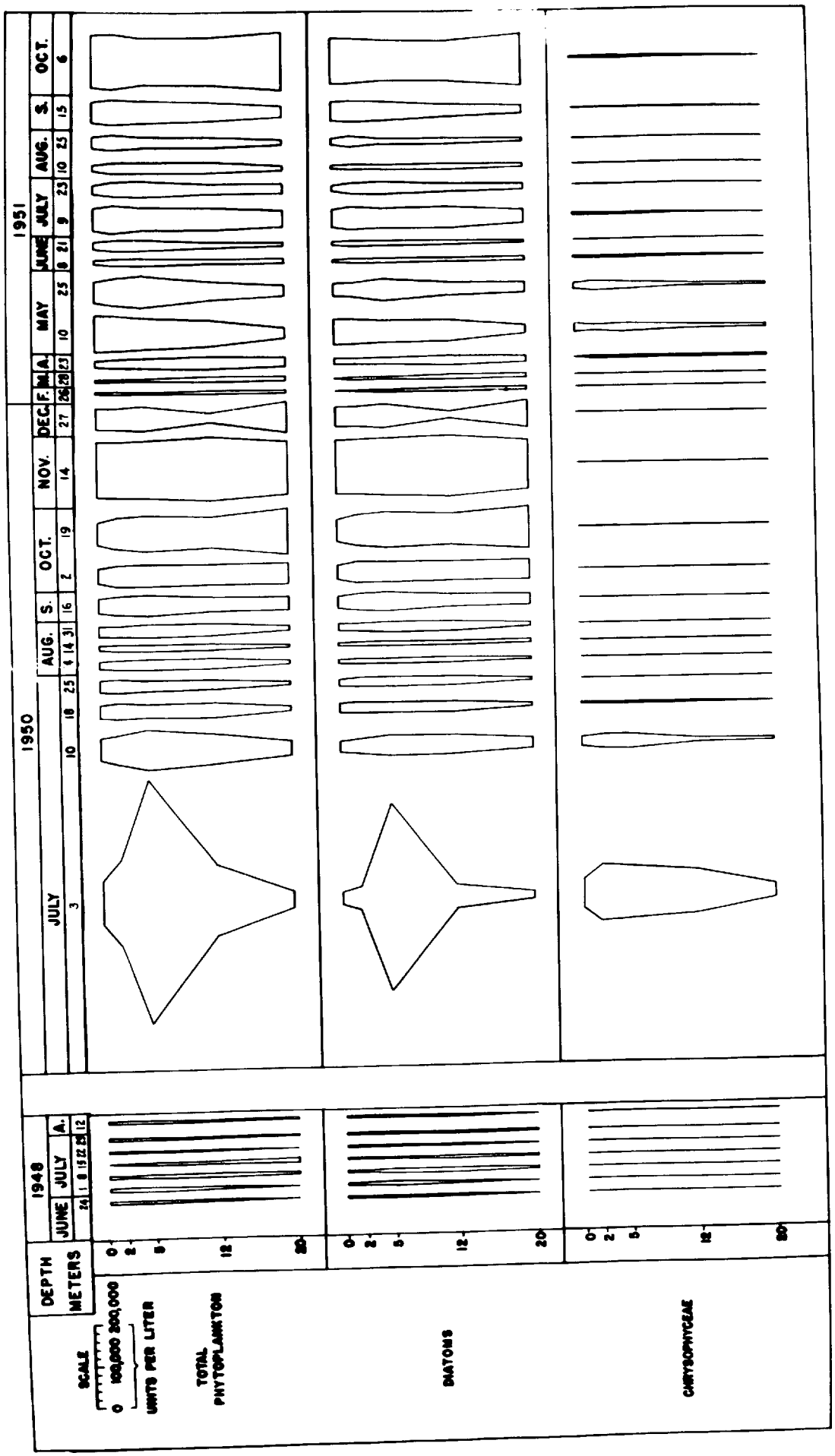

1948
JUNE
JULY
A.
24
1
8
15
22
29
12
DEPTH METERS
SCALE
0 100,000 200,000
UNITS PER LITER
TOTAL PHYTOPLANKTON
DIATOMS
CHRYSOPHYCEAE
0
2
5
12
20
50
1950
JULY
3
10
18
25
AUG.
1
8
14
21
31
S.
16
OCT.
2
19
NOV.
14
DEC.
27
F.
26
M.
28
A.
23
MAY
10
25
JUNE
8
21
JULY
9
23
AUG.
10
25
S.
15
OCT.
6
1951

FIG. 11

Fig. 12 - Seasonal Variation in Standing Crops of Total Phytoplankton and Their Percentage Composition in Douglas Lake During the Summer of 1948 and from July 3, 1950, to October 6, 1951

Explanation of Fig. 12

(a) Fall overturn began between Sept. 16 and Oct. 2, 1950

(b) Ice appeared Nov. 24, 1950

(c) Ice disappeared April 13, 1951

(d) Thermal stratification began between May 10 and May 25, 1951

(e) Fall overturn began between Sept. 15 and Oct. 6, 1951

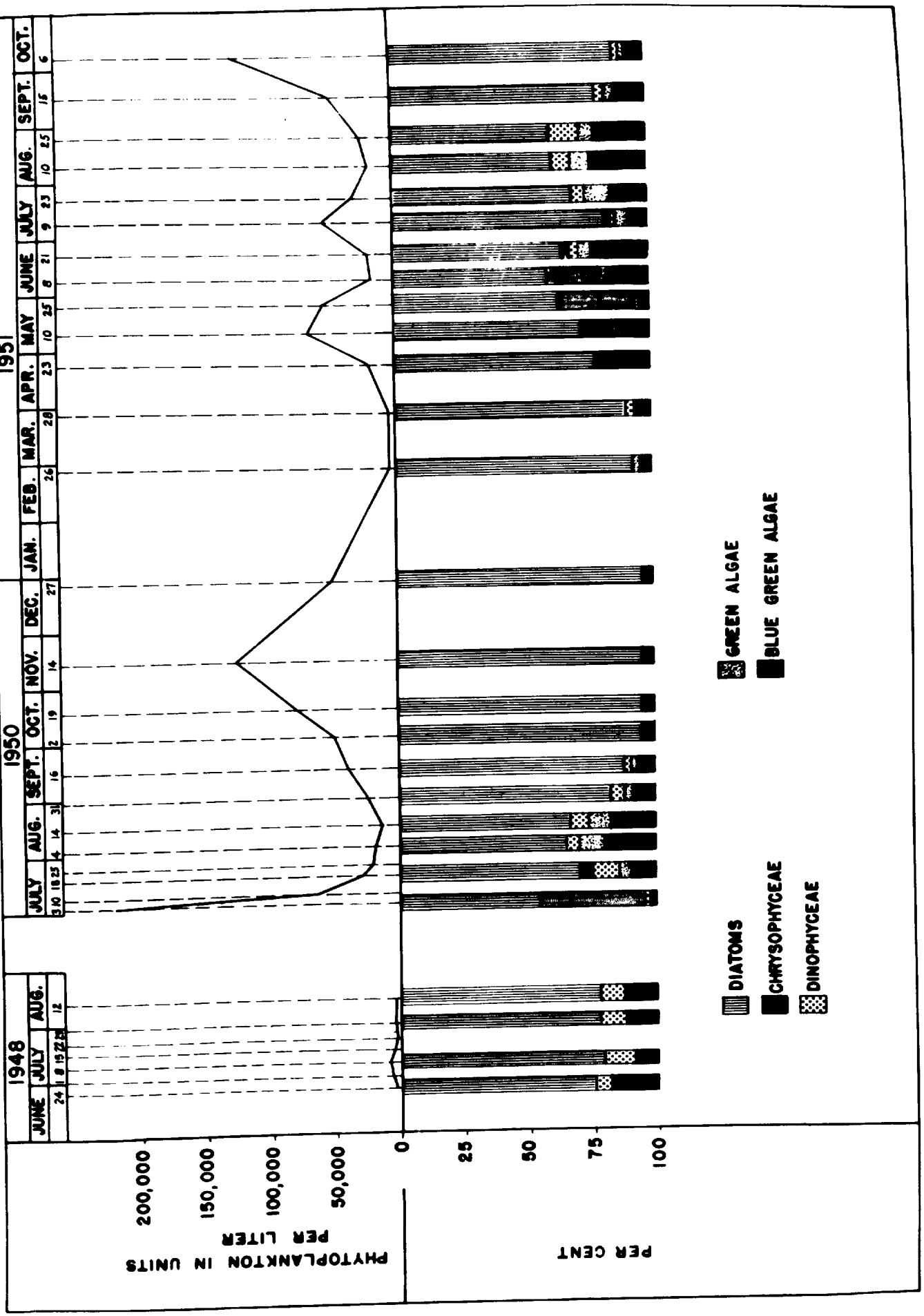

1948
JUNE
24
JULY
1 8 15 22 29
AUG.
12
1950
JULY
30 10 18 25
AUG.
4 14 31
SEPT.
16
OCT.
2 19
NOV.
14
DEC.
27
1951
JAN.
FEB.
26
MAR.
20
APR.
23
MAY
10 25
JUNE
8 21
JULY
9 23
AUG.
10 25
SEPT.
15
OCT.
6
PHYTOPLANKTON IN UNITS PER LITER
200,000
150,000
100,000
50,000
0
PER CENT
0
25
50
75
100
DIATOMS
CHRYSOPHYCEAE
DINOPHYCEAE
GREEN ALGAE
BLUE GREEN ALGAE

FIG. 12

Phytoplankton of Lancaster Lake

In none of the three summers when samples were collected did the standing crop reach a population equivalent to a pulse, that is an amount of at least 50,000 units per liter (Table 65, Appendix). As was mentioned previously in a description of the physico-chemical conditions of this lake, thermal stratification was very marked and the epilimnion usually occupied only the upper three meters. It can be seen from Table 65 and Figure 13 that in the epilimnion there were sufficient phytoplankton, at least on two occasions, July 20, 1950, and August 16, 1951, to warrant the population in this stratum being called a pulse. In spite of these minor pulses occurring in the epilimnion during the summers mentioned, it is probable that had a year-round study been made of the phytoplankton populations in Lancaster Lake, these summer crops would have appeared small in comparison to the yields which immediately follow the spring and fall overturns.

Five vertical series of plankton samples were collected at different times during the summer of 1948, and the standing crop at each of these was calculated (Tables 65, 66, Appendix). The largest yield contained 7,610 and the smallest 2,538 units per liter. The Chrysophyceae, consisting mostly of Synura, made up between 58 and 86 per cent in four of the crops and only 13 per cent in the other. Bacillariophyceae made up the next most abundant class averaging between 5 and 36 per cent of the total. Dinophyceae

and Cyanophyceae together made up the remainder. Chlorophyceae occurred in very small numbers being less than one per cent of the population (Table 67, Appendix).

During the summer of 1950, only two vertical series were collected, one on July 20 and the other on August 8. The standing crop on the first day was 42,791 and on the second day only 10,119 units per liter. On the first day (July 20), diatoms were the most abundant phytoplankters in the population contributing 88 per cent. Chrysophyceae, again composed mainly of Synura, constituted 7.4 per cent while the Dinophyceae and Cyanophyceae, together with a negligible number of Chlorophyceae, made up the remainder. On the second day (August 8) the Chrysophyceae were in the majority contributing 56.1 per cent while the Bacillariophyceae made up 23.5 per cent. The remainder of the phytoplankton was composed of Cyanophyceae and Dinophyceae. Again the Chlorophyceae appeared in negligible quantities.

Two vertical series of samples were collected during the summer of 1951, one on July 20 and the other on August 16. These were approximately the same dates of collection as in the previous summer. The first of these series showed a yield of 20,213 and the second 30,936 units per liter. In both, Chrysophyceae were the most abundant constituting 56.1 and 82.6 per cent respectively. In the first crop, Bacillariophyceae contributed 36 per cent and in the second only 8.0 per cent. The remainder consisted of Cyanophyceae and Dinophyceae.

Fig. 13 - Vertical Distribution and Percentage Composition of Phytoplankton Crops in Lancaster Lake During the Summers of 1948, 1950 and 1951

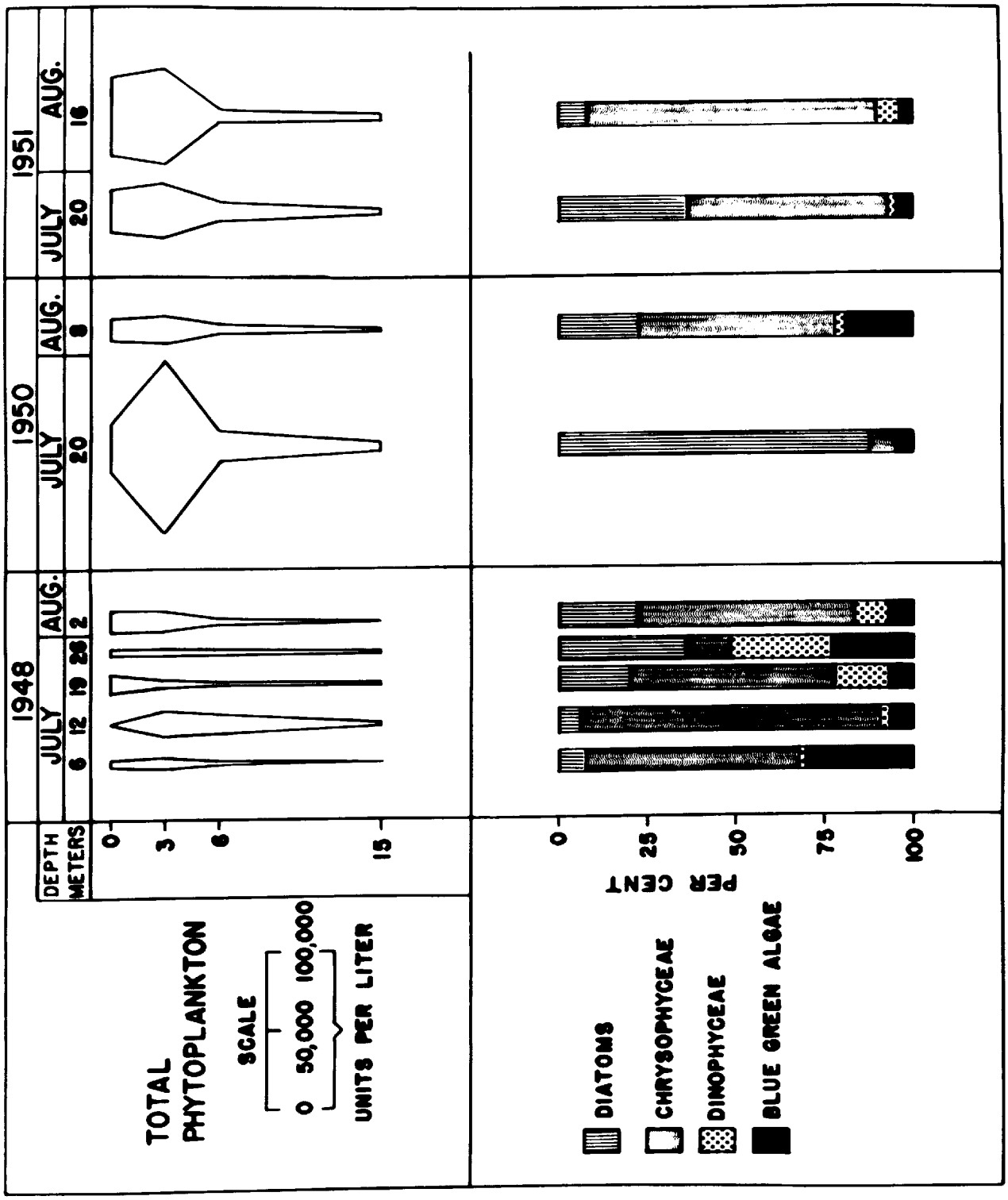

1948
JULY
AUG.
6 12 19 26 2
1950
JULY
AUG.
20 8
1951
JULY
AUG.
20 16
DEPTH METERS
0
3
6
15
TOTAL PHYTOPLANKTON
SCALE
0 50,000 100,000
UNITS PER LITER
PER CENT
0
25
50
75
100
DIATOMS
CHRYSOPHYCEAE
DINOPHYCEAE
BLUE GREEN ALGAE

FIG. 13

Considering all of the standing crops appearing during three summers, the Chrysophyceae were the most abundant, constituting an average of 53.5 per cent of the total. Bacillariophyceae were second making up an average of 27.4 per cent. Cyanophyceae and Dinophyceae were third and fourth contributing 30.5 and 28.6 per cent respectively.

Figure 13 demonstrates the vertical distribution and percentage composition of the phytoplankton in Lancaster Lake. Most of the phytoplankton occurred in the epilimnial layer during the period of thermal stratification. This illustrates the decided effect of thermal stratification on vertical distribution of phytoplankton.

A more detailed discussion of population studies of the individual genera found in this lake will appear on pages 104 - 117. The results of the actual counts of these genera are contained in Tables 73 through 91 (Appendix).

Phytoplankton of Munro Lake

Because this lake is shallow and susceptible to wind action, it would be expected that the phytoplankton would be distributed uniformly from top to bottom. Generally speaking, this was the case. Five vertical series of samples were collected at different times during the summer of 1948 and two during each of the summers of 1950 and 1951. At none of the times in 1948 and 1950 when samples were collected, was there a pulse. The smallest standing crop during these two summers amounted to 2,549 and the largest to

37,353 units per liter, the latter occurring in 1950 (Table 92, Appendix). During the summer of 1951, the first vertical series of samples taken did not give evidence of a pulse but the second series, collected on August 15, represented a small pulse amounting to 82,867 units per liter.

From the standpoint of the various classes of algae comprising the total population of phytoplankton and considering the three summers as a whole (Tables 93, 94, Appendix) Cyanophyceae were most abundant, making up an average of 58.5 per cent. Bacillariophyceae were the next most abundant with 21.4 per cent. Only in one series, collected on July 27, 1950, were the Bacillariophyceae more abundant than the Cyanophyceae; the Bacillariophyceae constituting 58.5 per cent and the Cyanophyceae only 21.3 per cent. The third largest contributors were the Chrysophyceae (consisting exclusively of Dinobryon) with 14.4 per cent. The Dinophyceae amounted to 4.8 per cent and the Chlorophyceae only one per cent.

Welch (1938) enumerated phytoplankton samples taken from Munro Lake during the summers of 1932 and 1936. Interestingly enough, the standing crops occurring during each of those two summers were very similar quantitatively and qualitatively to those analysed during the present study. Cyanophyceae were the most abundant and Chlorophyceae the least abundant during those two summers also.

Counts of the individual genera are contained in Tables 100 - 117 (Appendix) and a more detailed description of their abundance appears on pages 104 - 117.

Phytoplankton of Vincent Lake

Vertical series of plankton samples were also collected from Vincent Lake during the summers of 1948, 1950 and 1951 and with the same frequency as from Munro Lake; that is, five series were collected in 1948 and two during each of the summers of 1950 and 1951. Vincent Lake, like Munro Lake, is relatively shallow and thermal stratification, when it occurs, persists for only short periods of time. Thus, as would be expected, the phytoplankton were distributed fairly uniformly from surface to bottom (Table 118, Appendix). The standing crops during these three summers varied in amounts ranging between 22,613 and 48,875 units per liter, none of them being large enough to be called a pulse.

In Vincent, as in Munro Lake, the Cyanophyceae were the most abundant, averaging 66.9 per cent of the total (Table 120, Appendix). The Dinophyceae, composed only of Peridinium, contributed an average of 17.3 per cent while the Chlorophyceae made up 13.5 per cent. The Bacillariophyceae were very poorly represented in this lake making up only 1.7 per cent and the Chrysophyceae occurred in negligible amounts composing less than one per cent of the population.

Phytoplankton counts of samples collected from Vincent Lake during the summer of 1936 were reported by Welch (1938). During that summer, the largest group of phytoplankters was the Chlorophyceae composed mainly of a certain species of Staurastrum. This single species appeared in amounts ranging between 250,000 and 460,000 organisms per liter.

Cyanophyceae were the least abundant, occurring in very small numbers. It is apparent that there are considerable quantitative differences between those crops and these observed some fourteen summers later. The Chlorophyceae have certainly decreased in number while the Cyanophyceae have increased to become the greatest contributors to the phytoplankton populations.

The genera of this lake are discussed individually on pages 104 - 117 and their actual populations are contained in Tables 126 through 139 (Appendix).

Phytoplankton of Lake Lansing

Five vertical series of plankton samples were collected from this lake at different times during the fall season of 1950. The standing crops during this period of time occurred in amounts ranging between 15,831 and 39,819 units per liter, never reaching the status of a pulse.

The first series was taken on August 28 and it represented the smallest yield which was observed during this entire season. On that day, thermal stratification, although not very marked, was still present, and examination of the vertical distribution of the phytoplankton indicated that most of the population was in the epilimnial region (Figure 14). The second series was collected one week later on September 4. At that time the fall overturn was in progress and the phytoplankton as a whole had begun to increase, even though their populations had been distributed almost uniformly

from surface to bottom. The remaining series of samples indicated a general increase in the populations of the phytoplankters as the season progressed in addition to their fairly uniform vertical distribution.

The phytoplankton of this lake, during the fall season, was composed mainly of Bacillariophyceae, Cyanophyceae and Dinophyceae of which average contributions to the total were 51; 34.4; and 13.7 per cent respectively (Table 142, Appendix). The Chlorophyceae and Chrysophyceae together constituted less than one per cent. Those series which were collected during August and September showed that for those two months, each of the three classes contributed approximately equal percentages to the population (Figure 15; Table 142, Appendix). Those series collected during October and November, however, included hardly any Dinophyceae. The crops during the latter two months contained between 70 and 75 per cent Bacillariophyceae and between 25 and 30 per cent Cyanophyceae.

A discussion of the genera occurring in this lake appears on pages 104 - 117. Counts of the different genera composing the total population are contained in Tables 148 through 164 (Appendix).

Fig. 14 - Vertical Distribution of Phytoplankton in Lake Lansing During the Fall of 1950

Fig. 15 - Variation in Standing Crops of Phytoplankton and Their Percentage Composition in Lake Lansing During the Fall of 1950

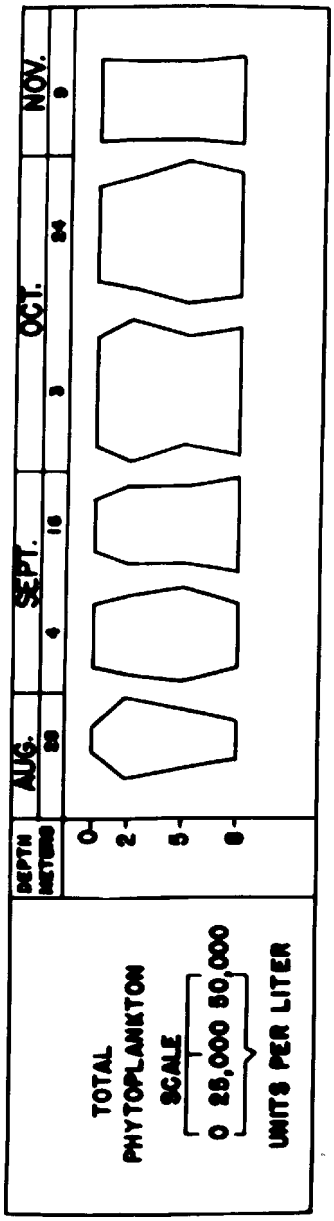

AUG.
SEPT.
OCT.
NOV.
DEPTH METERS
0
2
5
8
TOTAL PHYTOPLANKTON SCALE
0 25,000 50,000
UNITS PER LITER

FIG. 14

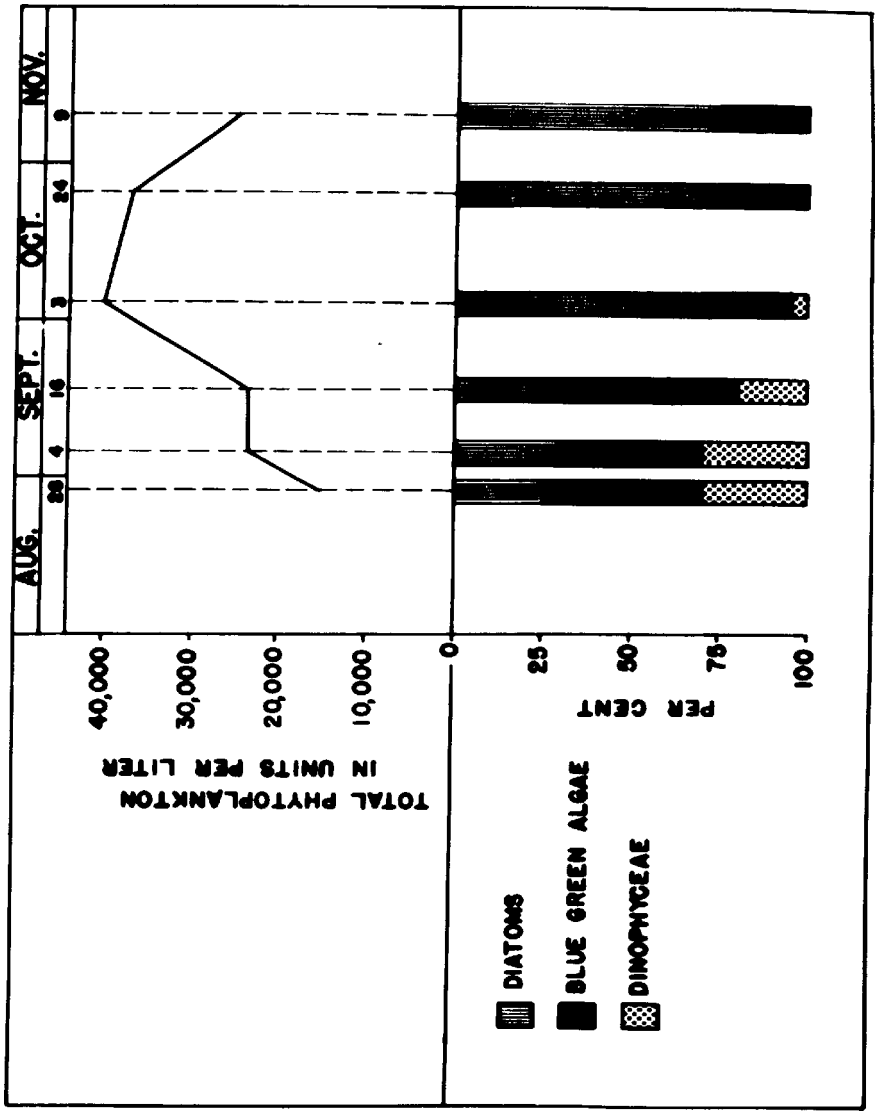

AUG.
SEPT.
OCT.
NOV.
TOTAL PHYTOPLANKTON IN UNITS PER LITER
40,000
30,000
20,000
10,000
0
PER CENT
25
50
75
100
DIATOMS
BLUE GREEN ALGAE
DINOPHYCEAE

FIG. 15

Comparison of Phytoplankton Populations in the Five Lakes

Although plankton samples were taken from Douglas Lake through 16 consecutive months, nevertheless, the summer seasons of 1948, 1950 and 1951 were the only times during which samples were collected from all four of the northern lakes namely, Douglas, Lancaster, Munro and Vincent. It is for this reason that only the summer production of phytoplankton from these lakes will be compared. An average of the mean summer standing crops of phytoplankton for the three summers was calculated for each lake, these values being derived for the total phytoplankton and each of its major groups (Table 15). It is these values for the different lakes which will be used in the comparison just mentioned.

Vincent Lake produced, on the average, the largest number of phytoplankters, having 36,010 units per liter. Douglas Lake ranked second with 32,742 units per liter whereas Munro and Lancaster came third and fourth with 23,166 and 14,310 units per liter respectively.

Douglas Lake yielded 20,726 units of Bacillariophyceae per liter which was the largest diatom production for these lakes. In Douglas Lake it was 63.3 per cent of the entire crop. Both Lancaster and Munro each produced about 6,000 units per liter; however in Lancaster Lake, this amount was 41.8 per cent of the total, whereas in Munro Lake it was only 29.6 per cent. Vincent Lake was the poorest diatom producer of all, yielding only 661 units per liter, a mere 1.8 per cent of the crop.

TABLE 15

AVERAGE OF THE THREE MEAN SUMMER STANDING CROPS OF PHYTOPLANKTON AND THEIR PERCENTAGE COMPOSITION FOR 1948, 1950 AND 1951 IN DOUGLAS, LANCASTER, MUNRO AND VINCENT LAKES

Lakes	Phytoplankton										
	Diatoms		Green algae		Blue-green algae		Dinophyceae		Chrysophyceae		Total
	count	percentage	count	percentage	count	percentage	count	percentage	count	percentage	count*
Douglas	20,726	63.3	1,094	3.3	2,808	8.6	1,390	4.2	6,724	20.6	32,742
Lancaster	5,983	41.8	18	0.1	929	6.5	556	3.9	6,824	47.7	14,310
Munro	6,854	29.6	175	0.8	13,646	58.9	675	2.9	1,816	7.8	23,166
Vincent	661	1.8	5,158	14.3	23,200	64.4	6,758	18.8	233	0.6	36,010

* Count in units per liter

The Chlorophyceae did not seem to be abundant in any of the lakes. Vincent produced the largest number which was 5,158 units per liter, but this amount constituted only 14.3 per cent of the total. In Douglas Lake there were 1,094 units per liter constituting 3.3 per cent. Lancaster and Munro produced even fewer, but in neither of the latter lakes did the Chlorophyceae comprise more than 0.1 per cent of the total.

Vincent Lake, in addition to producing the greatest number of Chlorophyceae also ranked first in the production of Cyanophyceae. The average summer yield of Cyanophyceae in this lake was 23,200 units per liter, an amount equal to 64.4 per cent of the total. The second largest production of Cyanophyceae was 13,646 units per liter, which occurred in Munro Lake. This amount comprised 58.9 per cent of all the phytoplankton in Munro. Douglas Lake yielded 2,808 units per liter which was 8.6 per cent of the entire population and Lancaster Lake contained only 929 units per liter which was only 6.5 per cent.

The Dinophyceae were not present abundantly in any of the lakes, the lake producing the greatest number being Vincent with 6,758 units per liter. This amount made up 18.8 per cent of Vincent's total crop. Douglas Lake contained 1,390 units per liter which amounted to only 4.2 per cent. Both Lancaster and Munro, each produced about 600 units per liter and in both cases, this number comprised between three and four per cent of their totals.

In respect to the Chrysophyceae, Lancaster and Douglas Lakes each yielded about 6,800 units per liter; however, in Lancaster this amount equalled 47.7 per cent of the total whereas in Douglas it constituted only 20.6 per cent. Another difference was that in Lancaster this group was composed almost entirely of Synura whereas in Douglas Lake it was made up exclusively of Dinobryon. Munro Lake contained 1,816 units per liter which was 7.8 per cent of the total and Vincent Lake contained 233 units per liter which was only 0.6 per cent.

By way of summary, then, Douglas Lake produced the largest population of Bacillariophyceae while Vincent Lake was responsible for the largest number of Chlorophyceae, Cyanophyceae and Dinophyceae. Both Lancaster and Douglas Lakes shared equally the ability to yield the greatest number of Chrysophyceae although Lancaster produced about 100 more units per liter than did Douglas Lake. The poorest producer of both Bacillariophyceae and Chrysophyceae was Vincent Lake.

Plankton samples were collected from Lake Lansing during the fall of 1950 and hence it is possible to compare the mean fall standing crop of Lake Lansing with that of Douglas Lake for the year 1950 (Table 16). Douglas Lake was the greater phytoplankton producer, yielding 57,581 units per liter as compared to 27,775 units per liter from Lake Lansing.

Bacillariophyceae appeared as the largest group in both lakes amounting to 52,868 units per liter in Douglas and 15,821 units per liter in Lake Lansing. In the former lake,

TABLE 16

COMPARISON OF THE MEAN FALL STANDING CROPS OF PHYTOPLANKTON AND THEIR PERCENTAGE COMPOSITION FOR 1950 IN DOUGLAS LAKE AND LAKE LANSING

Lakes	Phytoplankton										
	Diatoms		Green algae		Blue-green algae		Dinophyceae		Chrysophyceae		Total
	count	percentage	count	percentage	count	percentage	count	percentage	count	percentage	count*
Douglas	52,868	91.8	887	1.5	3,236	5.6	540	0.9	50	0.1	57,581
Lansing	15,821	57.0	106	0.4	8,864	31.9	2,972	10.7	12	0.0	27,775

* Count in units per liter

this amount constituted 91.8 per cent and in the latter 57.0 per cent of their respective totals. The Chlorophyceae occurred in very small numbers in both lakes, 887 in Douglas and 106 units per liter in Lake Lansing, neither number comprising more than 1.5 per cent in either lake. The Cyanophyceae were more abundant in Lake Lansing with 8,864 units per liter, an amount which equalled 31.9 per cent of the total crop of that body of water. Douglas Lake on the other hand, contained only 3,236 units of Cyanophyceae per liter which made up 5.6 per cent. Lake Lansing ranked first in the production of Dinophyceae, yielding 2,972 units per liter which amounted to 10.7 per cent of the total. The population of Dinophyceae in Douglas Lake was so small that it might be considered negligible both in actual units of count per liter and from the standpoint of percentage of the total population. The production of Chrysophyceae was negligible in both lakes.

In general, then, Douglas Lake produced the greater number of Bacillariophyceae although they were the most abundant group in each of the lakes. Lake Lansing yielded more Cyanophyceae and more Dinophyceae than did Douglas Lake. Both lakes were poor producers of Chlorophyceae and Chrysophyceae.

Discussion of the Individual Genera of Phytoplankton

Asterionella was found in all the lakes except Vincent. During the summer of 1948 this genus appeared in all the standing crops from Douglas Lake, ranging in amounts from

300 to 3,410 units per liter (Table 26, Appendix). During the summer of 1950 in the same lake the number of Asterionella in the standing crops varied between 940 and 5,565 units per liter. Shortly after the beginning of the fall overturn, which occurred sometime between September 16 and October 2, they started to increase and reached their maximum peak on November 14 at which time they were present in the amount of 85,920 units per liter. This Asterionella-peak constituted the largest part of the phytoplankton pulse at that time. By February 26, 1951, their number had decreased to 290 units per liter. From that date to June 21, their numbers did not exceed 4,010 units per liter. On July 9 a more abundant yield of Asterionella was noted amounting to 16,570 units per liter, but this abundance did not persist and on July 23 it had decreased to 1,260 units per liter. The remainder of the summer saw variations between 30 and 1,140 units per liter, but on October 6, shortly after the beginning of the fall overturn of 1951, their number had increased to 46,380 units per liter. (Table 46, Appendix) Field work was terminated on that day, so it is not known whether their numbers continued to increase or whether this amount was the maximum in that particular peak. In Douglas Lake, then, Asterionella had one main bloom in each of the years 1950 and 1951, occurring shortly after the fall overturn (Figure 10).

Lancaster produced practically no Asterionella during the summer of 1948, but in the summers of 1950 and 1951 the

standing crops contained this genus in amounts ranging between 375 and 6,525 units per liter (Table 73, Appendix), approximately the same range as in Douglas Lake for the same periods. In Munro Lake, Asterionella appeared only twice during three summers and its number in each of the crops in which it appeared did not exceed 225 units per liter (Table 100, Appendix). During the fall of 1950, the Lake Lansing phytoplankton contained this genus in amounts ranging from 450 to 9,163 units per liter (Table 148, Appendix) while Douglas Lake for the same period of time produced Asterionella in amounts ranging from 735 to 85,920 units per liter.

Fragilaria occurred in all of the lakes except Vincent. In Douglas Lake during the summer of 1948, the numbers of this genus varied from 229 to 775 units per liter (Table 27, Appendix). Except for two dates in the 16-month period of investigation carried on in Douglas Lake between July 3, 1950, and October 6, 1951, all of the yields of Fragilaria contained amounts varying between 35 and 8,960 units per liter. The two dates referred to were July 3, 1950, at which time this genus occurred in the amount of 52,520 units per liter and October 6, 1951, the crop that day being 14,050 units per liter. The former of the two crops probably represented the ending of a peak whereas the latter was part of a general pulse beginning at about that time. Although the yields of the majority of the crops of Fragilaria from Douglas Lake during the 16-month period of investigation are included in the range previously mentioned, it should be

added that the yields, which occurred shortly after each of the overturns, tended to equal amounts near the upper part of the range (Table 47, Appendix; Figure 10, page 82).

During the three summers of 1948, 1950 and 1951, Fragilaria occurred in all of the standing crops observed in Lancaster Lake in amounts varying between 125 and 1,913 units per liter except on one occasion in 1950 at which time Fragilaria consisted of 31,288 units per liter (Table 74, Appendix). In Munro Lake, this genus appeared only twice during the entire three summers and at neither of these times did it exceed 18 units per liter (Table 101, Appendix). During the fall of 1950 the number of Fragilaria appearing in the crops of Lake Lansing, varied between 1,038 and 3,394 units per liter (Table 149, Appendix). In Douglas Lake during the same period this genus occurred in amounts ranging between 1,800 and 8,340 units per liter, the majority of the crops containing amounts near the higher end of the range (Table 47, Appendix).

Melosira was present in all of the lakes. In Douglas Lake, during the summer of 1948, it occurred in amounts ranging from 266 to 1,237 units per liter (Table 28, Appendix). During the 16-month period of investigation in Douglas Lake, including the summers of 1950 and 1951, the population of this genus varied quantitatively from 39 to 24,880 units per liter (Table 48, Appendix). The general trend of these population changes followed that of the quantitative changes in the total diatoms (Figure 10). The greatest number of

Melosira occurred shortly after the inception of the spring and fall overturns whereas the smallest amounts occurred during the midsummer periods and during midwinter under the ice cover.

In Lancaster Lake, Melosira appeared in only one series of samples during the three summers. That was on July 20, 1950, and the amount was 38 units per liter (Table 75, Appendix). Munro Lake contained this genus in most of the series taken during the summers of 1948, 1950 and 1951, however, there were three series in which it did not appear. Even when it occurred, it did so in small amounts varying between 50 and 250 units per liter (Table 102, Appendix). Melosira appeared only three times in Vincent Lake during the three summers and in quantities between 50 and 100 units per liter (Table 126, Appendix). In Lake Lansing during the fall of 1950, its population varied between 875 and 3,850 units per liter (Table 150, Appendix), whereas in Douglas Lake for the same period, this genus occurred in amounts ranging between 2,490 and 22,890 units per liter (Table 48, Appendix). Melosira occurring in Douglas Lake during the fall of 1950, however, were present in amounts more closely resembling those in the upper end of the range.

Navicula appeared in the phytoplankton yields from each of the lakes, however never abundantly. It occurred consistently in Douglas, Munro and Lake Lansing, but only rarely in Lancaster and Vincent Lakes (Tables 29, 49, 76, 103, 127, 151, Appendix). In Munro Lake it appeared in amounts between

100 and 2,300 units per liter. Considering all of the crops from each of the other four lakes, only once did Navicula occur in an amount exceeding 460 units per liter; that being in Douglas Lake on May 10, 1951, at which time its population consisted of 2,634 units per liter.

Stephanodiscus occurred in most of the crops from each of the lakes. Although the yields in Douglas Lake were highest after the spring and fall overturns, they never exceeded 3,354 units per liter at any time. None of the crops from any of the other four lakes contained this genus in amounts greater than 775 units per liter (Tables 30, 50, 77, 104, 128, 152, Appendix).

Synedra was found in plankton samples from all of the lakes. In Douglas Lake during the summer of 1948, its numbers never exceeded 800 units per liter (Table 31, Appendix). During the 16-month period of investigation, the population changes of Synedra simulated the population changes of the total diatoms and contributed noticeably to the diatom pulses (Figure 10, page 82). On July 3, 1950, this genus was present in the amount of 5,860 units per liter. This number gradually decreased and on September 16 the phytoplankton contained only 990 units of this phytoplankton per liter. The fall overturn of 1950 started a few days later and at the same time the population of Synedra began to increase. On November 14, its maximum peak consisting of 14,010 units per liter was observed. Following this a gradual decrease

occurred and the numbers remained small under the ice, reaching a low of 2,120 units per liter. After the break up of the ice and during the spring overturn, the crop began to increase in size. Two peaks then occurred, one on May 10, 1951, with 23,300 units per liter and the other on July 9 with 12,995 units per liter. These two peaks were separated by small crops occurring in June whose amounts varied between 2,760 and 3,020 units per liter. After the second peak the number of Synedra began to decrease and continued to do so until on September 15 it was only 4,360 units per liter. On October 6, shortly after the beginning of the fall overturn of 1951, there were sufficient numbers of Synedra in the standing crop to indicate the beginning of another peak. On that day Douglas Lake contained 14,010 units of this genus per liter (Table 51, Appendix).

Lancaster and Vincent Lakes appeared to be poor producers of Synedra. None of the crops observed in either of these lakes during the three summers contained more than 1,500 units per liter (Tables 78, 129, Appendix). Very few Synedra were observed in Munro Lake during the summer of 1948; only between 50 and 300 units per liter. In the summers of 1950 and 1951, however, several of the crops from that lake were quite large ranging from 675 to 32,775 units per liter (Table 105, Appendix). Lake Lansing during the fall of 1950 produced Synedra in amounts varying between 713 and 23,725 units per liter (Table 153, Appendix). Douglas Lake during the same period of time produced this genus in

amounts ranging from 750 to 14,010 units per liter (Table 51, Appendix).

Tabellaria occurred in all of the lakes with the exception of Lake Lansing. In Douglas Lake during the summer of 1948 it appeared in amounts ranging between 330 and 1,280 units per liter (Table 32, Appendix). During the first two weeks of July, 1950, the standing crop of Tabellaria in Douglas Lake decreased from 55,470 to 8,488 units per liter. From that time until October 6, 1951, the crops contained quantities of this genus ranging from 660 to 8,950 units per liter. Those yields of phytoplankton appearing after the fall and spring overturns contained the largest number of Tabellaria, whereas those occurring during midsummer and midwinter contained the least number (Table 52, Appendix). Lancaster, Munro and Vincent Lakes often did not contain this genus. However, there were at least two crops from each lake that did contain it, but never in amounts exceeding 250 units per liter (Tables 79, 106, 130, Appendix).

Anabaena was found in all of the lakes except Vincent but never in great abundance. In Douglas and Lancaster Lakes it occurred on occasion but in neither lake did it exceed 231 units per liter (Tables 23, 53, 80, Appendix). The yields from Munro Lake contained between 24 and 1,275 units of Anabaena per liter (Table 107, Appendix), whereas Lake Lansing contained slightly larger numbers ranging from 738 to 3,375 units per liter (Table 154, Appendix).

Aphanizomenon was observed only in Munro Lake. It appeared once during the summer of 1948 and once during the summer of 1950; neither time did it exceed 10 units per liter (Table 108, Appendix).

Chroococcus appeared only in Lancaster, Munro and Vincent Lakes, and not regularly. None of the crops from either Lancaster or Vincent Lake contained more than 663 units per liter (Tables 81, 131, Appendix). Munro Lake, on the other hand, contained this genus in amounts ranging from 250 to 19,800 units per liter (Table 109, Appendix).

Coelosphaerium occurred in all of the lakes except Munro. In Lancaster and Vincent Lakes it appeared in only a few instances, never exceeding 100 units per liter (Tables 82, 132, Appendix). In Douglas Lake, it occurred in all the series of samples except in those taken in the winter under the ice cover. The summer and fall crops from Douglas Lake contained Coelosphaerium in amounts varying between 360 and 1,680 units per liter (Table 54, Appendix). Lake Lansing contained it in quantities varying between 206 and 2,250 units per liter (Table 155, Appendix).

Merismopedia occurred in all of the lakes except Lancaster. Douglas Lake contained it only in the summer when it occurred in amounts ranging from 1 to 240 units per liter (Table 55, Appendix). Only a few of the crops from each of the other three lakes contained Merismopedia and in amounts

never exceeding 89 units per liter (Tables 110, 133, 156, Appendix).

Microcystis appeared in all of the five lakes. Douglas Lake contained quantities varying between 117 and 8,280 units per liter; the larger crops occurring shortly after the fall and spring overturns and the smaller ones during midsummer and midwinter (Tables 34, 56, Appendix). In Lancaster Lake, the phytoplankton contained this genus in amounts ranging from 181 to 1,319 units per liter (Table 83, Appendix). Munro and Vincent Lakes produced Microcystis more abundantly than did the other lakes with amounts ranging from 1,200 to 41,600 units per liter in Munro and 14,250 to 33,475 units per liter in Vincent (Tables 111, 134, Appendix). Lake Lansing contained quantities varying between 4,888 and 7,200 units per liter (Table 157, Appendix).

Oscillatoria was observed only in Douglas Lake and Lake Lansing. In the former it occurred infrequently, never exceeding 120 units per liter (Tables 35, 57, Appendix). In Lake Lansing, only a few of the crops contained Oscillatoria and in amounts never larger than 150 units per liter (Table 158, Appendix).

Arthrodesmus was observed in Douglas, Lancaster and Vincent Lakes. In the first two, it appeared only two or three times during each summer and in amounts not greater than 150 units per liter (Tables 58, 84, Appendix). In Vincent Lake, however, it appeared consistently in amounts

ranging from 150 to 3,675 units per liter (Table 135, Appendix).

Cosmarium occurred in several of the crops from Douglas Lake in quantities between 20 and 520 units per liter (Table 59, Appendix). It appeared once in Lancaster Lake during the three summers in the amount of 38 units per liter and once in Lake Lansing during the fall of 1950 in the amount of 75 units per liter (Tables 85, 159, Appendix).

Dictyosphaerium was found only in the Lake Lansing samples. It occurred twice during the fall of 1950, each time in the amount of 19 units per liter (Table 160, Appendix).

Eudorina was present in Lancaster, Munro and Lake Lansing. It appeared in only one or two crops from each of these lakes and never exceeded 158 units per liter (Tables 86, 112, 161, Appendix).

Pediastrum was present in each of the five lakes. Douglas Lake contained it in nearly every crop in numbers varying between 20 and 600 units per liter. It occurred only once or twice in each of the other lakes, never exceeding 200 units per liter (Tables 60, 87, 113, 136, 162, Appendix).

Scenedesmus was found in Douglas, Munro and Vincent Lakes but it appeared seldom in any of them and in amounts not greater than 150 units per liter (Tables 36, 61, 114, 137, Appendix).

Staurastrum appeared in all of the lakes except Lancaster. In Douglas Lake it occurred in most of the crops but only exceeded 2,660 units per liter once. That was on July 3, 1950, at which time the yield was 8,020 units per liter (Tables 37, 62, Appendix). In Munro and Lansing Lakes it occurred rarely, and never in amounts larger than 100 units per liter (Tables 115, 163, Appendix). Vincent Lake seemed to be the greatest producer of this genus. It was present consistently in amounts ranging from 150 to 9,150 units per liter (Table 138, Appendix). During the summer of 1936, according to Welch (1938), this genus occurred in Vincent Lake in amounts ranging from 200,000 to 460,000 phytoplankters, and was the most abundant of all the genera in the lake.

Tetraedron was found only in Lake Lansing. It appeared in just two crops and in neither of these did it exceed 56 units per liter (Table 164, Appendix).

Xanthidium occurred only in Vincent Lake. It was observed in just three instances and in none of them did it exceed 300 units per liter (Table 139, Appendix).

Dinobryon was found in all of the lakes. In Douglas Lake it was the only representative of the class Chrysophyceae and appeared in amounts varying between 20 and 89,650 units per liter. The large crops of this genus occurred shortly after the spring overturns and persisted for

two or three weeks into the periods of thermal stratification, thus contributing to the major phytoplankton pulses which occurred during those times. There was not any appreciable increase in production of Dinobryon after the fall overturns. Between the times of maximum abundance this genus appeared in very small numbers; sometimes it was absent (Tables 24, 44, Appendix).

In Lancaster Lake, during the summers of 1948 and 1950, this genus appeared in amounts varying between 100 and 2,323 units per liter. In the summer of 1950, however, it occurred in much larger numbers ranging from 11,225 to 14,050 units per liter (Table 88, Appendix). Although Dinobryon appeared in nearly all of the crops from Munro Lake, still it never appeared abundantly but in amounts between 100 and 4,500 units per liter (Table 98, Appendix). The largest yield observed in Vincent Lake was 1,050 units per liter (Table 124, Appendix). In Lake Lansing it appeared only once and in the amount of 75 units per liter (Table 146, Appendix).

Synura was found only in Lancaster Lake but here it occurred more abundantly than any of the other genera; at least in the summer months during which these observations were made. It appeared in amounts ranging between 113 and 11,488 units per liter (Table 89, Appendix).

Ceratium appeared in all the lakes except Vincent. In Douglas Lake, its number varied between 30 and 3,360 units per liter. The larger amounts occurred shortly after the

overturns and persisted for several months while the smaller yields were produced during the winter months (Tables 25, 63, Appendix). Lancaster Lake produced this genus quite consistently during the summer months in small amounts ranging from 50 to 925 units per liter (Table 90, Appendix). Ceratium was also found in Munro Lake in most of the series of samples, but here, too, in small numbers from 50 to 700 units per liter except in one instance in 1950 when it was present in the amount of 2,850 units per liter (Table 116, Appendix). In Lake Lansing during the fall of 1950 this phytoplankter appeared in quantities between 50 and 7,388 units per liter. The larger numbers occurred in August and September whereas the smaller crops were produced in October and November (Table 147, Appendix).

Peridinium was found in all of the lakes except Lake Lansing. In Douglas and Munro it appeared in most of the series of samples but in neither lake did it exceed 220 units per liter (Tables 64, 117, Appendix). Lancaster also produced it in small quantities, never more than 775 units per liter (Table 91, Appendix). Vincent Lake, on the other hand, contained large numbers of Peridinium ranging between 50 and 16,950 units per liter (Table 125, Appendix).

A Comparison of the Densities of Extracted Pigment With Phytoplankton Counts of Comparable Samples

The pigment extraction technique of plankton analysis is being used by many workers at the present time because of its simplicity and rapidity in estimating phytoplankton productivity at a given time. In a previous paper I compared statistically the densities of extracted pigment with the number of units of phytoplankton in comparable samples collected from the Bay of Quinte and found the coefficient of correlation to be .83 (Tucker, 1949). In that study pigment was extracted with acetone and its density determined with the use of a visual colorimeter. In this investigation pigment was extracted with acetone as before but its density was determined by the use of a Klett-Summerson photoelectric colorimeter with a red light filter No. 66.

Duplicate series of plankton samples were collected from Douglas, Lancaster and Lansing Lakes; one for counting, the other for the purpose of extracting pigment (Tables 165, 166, 169, Appendix). Statistical comparisons of the densities of the extracted pigment with the phytoplankton counts in comparable samples indicated the coefficients of correlation to be .84, .95 and .88 for samples from Douglas, Lancaster and Vincent Lakes respectively (Table 17; Figure 16). The coefficients were higher than was found for the Bay of Quinte plankton. This difference could be due to elimination of the personal error involved in estimating color densities

TABLE 17

STATISTICAL ANALYSIS SHOWING RELATIONSHIP BETWEEN NUMBER OF UNITS OF PHYTOPLANKTON COUNTED AND DENSITY OF PIGMENT EXTRACTED*

Lakes	Figure	Number of Items	Formula of Regression Line	Standard Error of Estimate	Coefficient of Correlation	Probability of correlation as great through chance alone
Douglas	16a	40	log. Y = 4.39726 + 1.46665 log. X	± .211	.84	less than .00001
Lancaster	16b	12	log. Y = 4.11619 + 1.35441 log. X	± .118	.95	less than .00001
Lansing	16c	12	log. Y = 3.85793 + 1.32421 log. X	± .080	.88	less than .00001

*X = Density of extracted pigment in Klett units per liter
Y = Phytoplankton count in units per liter

Fig. 16 - Relation Between Density of Extracted Pigment (Measured in Klett Units per Liter) and Units of Count per Liter in Comparable 10 Liter Samples of Plankton Collected from Douglas, Lancaster and Lansing Lakes. (Displayed on Double Log. Scale)

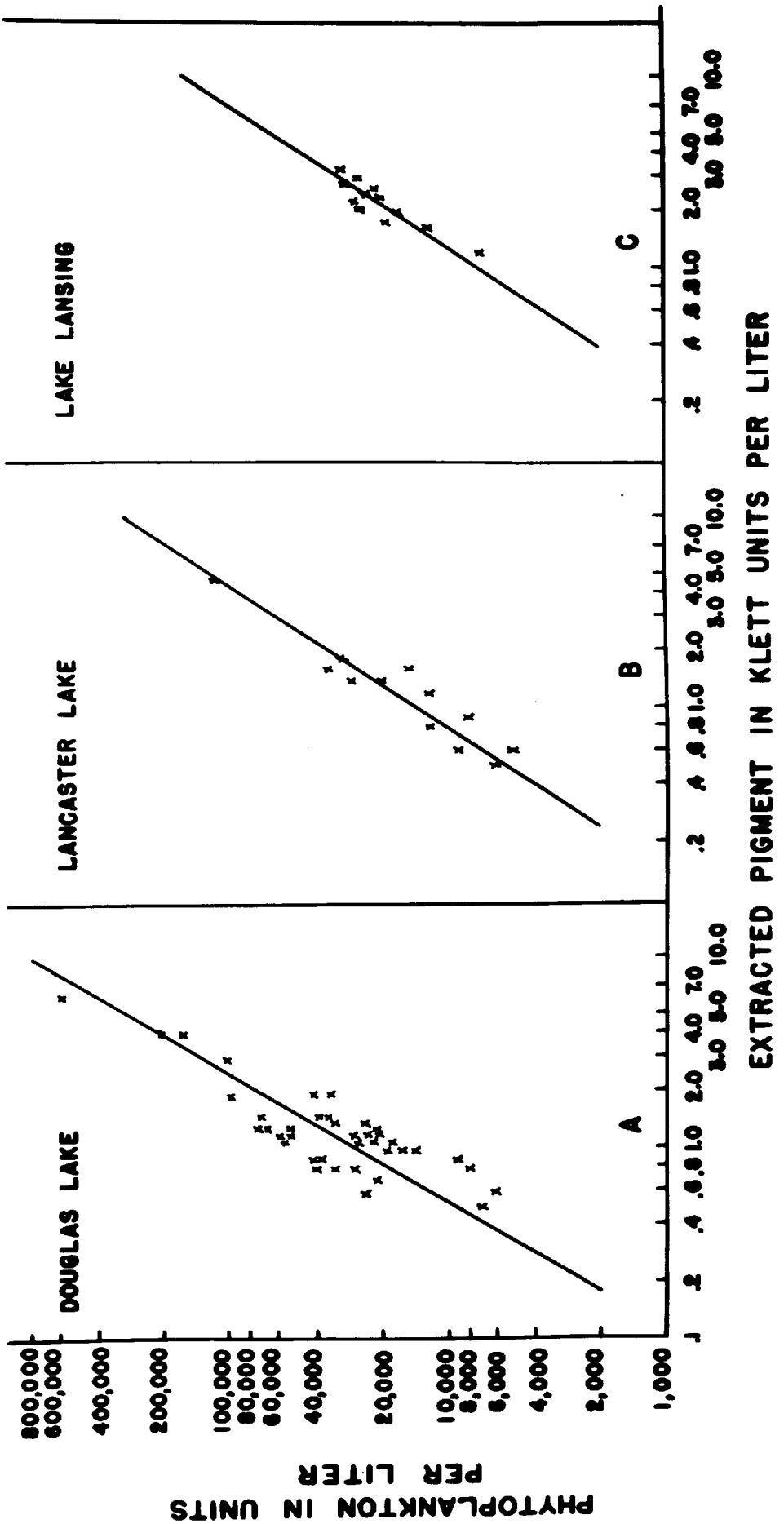

DOUGLAS LAKE
LANCASTER LAKE
LAKE LANSING
A
B
C
PHYTOPLANKTON IN UNITS PER LITER
EXTRACTED PIGMENT IN KLETT UNITS PER LITER

FIG. 16

through a visual colorimeter. In the study of the Bay of Quinte pigment densities were measured in Harvey units, that unit being the color density of an arbitrary color standard. In this study pigment densities were determined in Klett units, which is a measure of the distance that the pointer of the photoelectric colorimeter deviates from zero due to the color density of the pigment being measured.

Pigments were also extracted from the concentrates of duplicate series of plankton samples; one series concentrated by filtration through a plankton net, the other by centrifugation (Table 165, Appendix). Assuming that the centrifuge retained 100 per cent of the pigment, the net was found to retain between 12 and 28.6 per cent with an average of 17.5 per cent. This value is similar to that determined gravimetrically by Birge and Juday (1922) who found that the net was able to remove from the water only one quarter to one fifth of the organic matter that could be removed by the centrifuge.

GENERAL DISCUSSION AND CONCLUSIONS

The question of relationship between the numerical abundance of phytoplankton and the nature of their chemical environment has been the object of many investigations both in this country and abroad. Such studies have produced some tangible results and considerable basis for speculation and hypotheses pointing to the need for further investigation.

Atkins (1923) concluded that phosphorus might be a limiting factor in the production of phytoplankton in the sea. Prescott (1931) states that he has "found positive correlations between phosphorus content and productivity of plankton in Iowa lakes." He further states that "there is some evidence that the difference between one eutrophic lake and another in respect to its flora might be due to the difference in phosphate content." In some of the Wisconsin lakes, however, there was no evidence that phosphorus was a limiting factor to growth of phytoplankton populations (Juday, Birge, Kemmerer and Robinson, 1927; Tressler and Domogalla, 1931; and Juday and Birge, 1931). In Douglas Lake, which was studied quite intensively during this investigation, the soluble inorganic phosphate fluctuated irregularly in the epilimnial waters during the 16-month period of investigation (Figure 3) but these fluctuations seemed to have no relationship with the occurrence of spring and fall phytoplankton pulses.

There are some who believe that nitrates have a controlling influence on phytoplankton productivity, among them Prescott (1939) who found direct correlations between nitrogen and quantity of plankton in the various lakes which he studied. Riley (1940), on the other hand, concluded that in Linsley Pond nitrates and phosphates appeared to have no effect on productivity although they are closely related to variations in the standing crop. Still others suggest that changes in the ratio of nitrates to phosphates may be responsible for differences in the magnitudes of the phytoplankton populations (Pearsall, 1932; Cooper, 1937; and Hutchinson, 1941). Nitrates were not determined in the present investigation and hence it is not known whether nitrogen is related to changes in numbers of phytoplankters in Douglas Lake.

Both Pearsall (1932) and Hutchinson (1944) have suggested certain relationships between chemical changes in the water and the periodicity of certain phytoplankters. Pearsall maintained that in the English lakes, diatoms occur when the waters are richest in nitrate, phosphate and silica. He also postulated that diatoms cannot reproduce appreciably when the concentration of silica is less than 0.5 mg. per liter. Lund (1950) found a positive correlation between available silica and size of populations of Asterionella. He also confirmed the view of Einsele and Grim (1938) that the amount of silica per unit area of cell is constant under all conditions. In the light of these facts, he agreed with Pearsall's hypothesis pertaining to silica and concluded

that this element could very well be a limiting factor to the production of diatoms. He did not, however, make the same committment regarding phosphorus because he found that cells of Asterionella can store phosphorus in excess of immediate requirements even when the concentration in the water is one microgram per liter or less. If such is the case with other phytoplankters, then a measurement of the available soluble inorganic phosphorus in a lake would give no indication as to whether or not the plankton are starved for phosphorus. Hutchinson (1944) found the waters of Linsley Pond adequately supplied with phosphorus, nitrogen and silica but poor in diatoms and hence is doubtful of Pearsall's hypothesis.

The numbers of Dinobryon in certain English lakes (according to Pearsall, 1932) begin to grow with a rise in the ratio of nitrate to phosphate and with a decrease in the amount of silica in the water. In Linsley Pond, Hutchinson (1944) found that an increase in the number of Dinobryon was associated with a rise in the ratio of nitrate to phosphate, as pointed out by Pearsall, but not with a decrease in silica. The data of Tressler and Domogalla (1931) gave no evidence that a change in the nitrogen-phosphorus ratio had any effect on the variations of Dinobryon populations in Lake Wingra, however, a decrease of the silica content of the water was observed to occur simultaneously with an increase in the quantities of this genus.

Pearsall (1932) also noticed that a fall in calcium

seemed to favor an increase in the numbers of Dinobryon. In the present study, the data from Douglas Lake showed that a decrease in bicarbonates accompanied the reduction in the quantities of Dinobryon during the first few weeks of July, 1950, and an increase of bicarbonates occurred when numbers of this genus were increasing during the first two weeks of May, 1951. If it can be implied that variations in bicarbonates indicate similar variations in calcium, then the relationship between calcium and Dinobryon populations in Douglas Lake is the reverse of that in the English lakes and it might be inferred that in Douglas Lake it is an increase rather than a decrease of calcium that is favorable for a greater rate of reproduction among the members of this genus. Pearsall (1932) and Hutchinson (1944) found that Dinobryon did not appear until after the decline of the diatom maximum. In Douglas Lake, the diatom and Dinobryon maxima occurred simultaneously in the same spring pulse indicating, therefore, the presence of sufficient nutrients in the water at that particular time to support both populations.

The abundance of Cyanophyceae has been correlated with high concentration of organic matter (Pearsall, 1932). In the present investigation, Cyanophyceae were found to be most numerous in Vincent Lake which is a body of water rich in organic matter. Pearsall also found that large numbers of this class were maintained in the English lakes despite minimal quantities of nitrate and phosphate. Vincent Lake,

although containing more total phosphorus per liter than any of the other lakes here studied, nevertheless contained the least amount of available inorganic phosphorus, usually less than one microgram per liter.

Very little is known of the chemical factors controlling the increase of Chlorophyceae in natural waters. Pearsall (1932) concluded that more Chlorophyceae occur during periods when concentrations of nitrates and phosphates in the waters are low. He further states that in the English lakes there seems to be no general correlation between abundance of Chlorophyceae and the amount of organic matter. Certain individual species from this group (for example, Eudorina elegans) however, appear to thrive in this type of environment. In the present study, although Chlorophyceae were not found to be abundant in any of the lakes, their largest population appeared in Vincent Lake which, incidentally, was the same lake containing the largest number of Cyanophyceae.

Vincent Lake is an interesting body of water for several reasons. It will be remembered that in the description of the chemical conditions in this lake on page 58, mention was made of the fact that the hydrogen ion concentration of the water had been changing during the past 30 years. Whereas the water previously was on the acid side of the pH scale, it is now neutral and often a little on the alkaline side. This change in pH, of course, is merely an index of the occurrence of other changes in the chemical nature of the lake. During the summer of 1936, a certain species of Staurastrum

predominated the plankton populations with its large numbers. During that same summer, Cyanophyceae were in the minority. During the summer of 1951, some 15 years later, this Staurastrum appeared in very small numbers, whereas, the quantities of Cyanophyceae had increased tremendously to become the largest group in the total phytoplankton. A possible explanation for this change in the algal flora is the change in the chemical environment.

Another species found in Vincent Lake worthy of comment was Peridinium wisconsinensis. This phytoplankter comprised approximately 17 per cent of the mean summer standing crop of this lake. It did not appear in any of the other lakes in this investigation, but it was observed in Weber Lake, a small body of water in northern Michigan. The chemical characteristics of Weber Lake were similar to those of Vincent Lake with respect to the pH which was slightly on the acid side, and the bicarbonate content which was extremely low. If this species of Peridinium is found in other bodies of water having the same chemical characteristics, it might prove to be a useful biological index.

It is evident from the discussion thus far, that many inconsistencies exist between the behavior of similar phytoplankters in different lakes, and hence clear cut correlations between phytoplankton abundance and chemical factors can not be indicated. The reasons for many of these inconsistencies are still in the realm of speculation, although several of them are known. It is known, for instance, that the

physiological state of the cell at the time of analysis could have a profound influence on the results obtained. It is also realized that where a single factor in itself may not exert an influence on the reproductive rate of a cell, two or more factors might act synergistically. Another possible reason for these inconsistencies could be the degree of competition between species for the available nutrients. Still another aspect which should be considered is the effect of predators on the phytoplankton populations. All of these factors plus many more could contribute to the dynamics of a single ecological situation. The relationships and interrelationships are very complex. The ecologist is becoming increasingly aware of the fact that observations in the field can produce only limited information and that biological situations must be carried from the field to the laboratory where variables can be isolated and observations made with greater precision, through the medium of controlled experiments.

Although no clear cut correlations could be established between variations of phytoplankton numbers and changes in chemical factors of the environment, it is felt that a discussion of the sequence of events preceding each plankton pulse might express some cause-effect relationships. In Douglas Lake each pulse occurred almost immediately after the beginning of the overturns. It is certainly not a new concept that during circulation of the water, nutrients which have been accumulating at the bottom are brought to the

surface and made available to the existing plankton, and that these nutrients stimulate the phytoplankters to reproduce at a greater rate. What are the conditions in the hypolimnion of Douglas or any other temperate lake of the second order? First of all, the bottom is covered with dead plankton organisms which have descended from the upper waters (Welch,1935). These organisms are being decomposed by bacteria, and various elements such as phosphorus and nitrogen are being released (Waksman, 1941). As a result of the activity of these bacteria, the bottom of the lake eventually becomes depleted of oxygen. In Douglas Lake, toward the end of the summer, oxygen was absent in the bottom of the hypolimnion, however the phosphorus which was supposedly being released from the decomposing plankton could not be detected even at the bottom of the lake until approximately eight weeks after the oxygen had disappeared.

The logical question to ask at this time is: What happened to the phosphorus that was being released as a result of the decomposition of the dead plankton organisms at the bottom of the lake? In order to answer this question, it is necessary to have an appreciation of some of the many chemical reactions which are involved in the pelometabolism of the lake. Einsele (1938) was one of the first workers to investigate the chemical relationships which exist between the bottom mud, mud-water interphase and the free water. He found that divalent iron and phosphate can exist side by side in solution in the hypolimnetic waters only when oxygen

is absent, but if oxygen is introduced, for instance, at the fall overturn, the iron and phosphorus will combine to form an insoluble ferric phosphate precipitate which will sink to the bottom mud and become part of it. Conversely, when oxygen is removed from the water, the iron will be reduced to form ferrous phosphate which is soluble. The rates of these reactions are of course subject to the relative concentrations of the elements involved, plus various chemical factors in the environment such as hydrogen ion concentration, the presence of hydrogen sulfide and perhaps others which as yet have not been discovered. Mortimer (1941) has produced evidence that phosphorus is strongly adsorbed on ferric hydroxide or ferric hydroxide organic complexes in the oxidized surface mud layers of lake bottoms as long as oxygen is present in the overlying water. When the oxygen becomes depleted, however, these ferric complexes are reduced and phosphorus is liberated into the water. Mortimer also conducted experiments in the laboratory to see if this phenomenon would occur in artificial mud-water systems. He took samples of typical lake-bottom mud and placed portions in each of three rectangular glass tanks, to which he later added lake water. The first tank was aerated regularly, the second left undisturbed but with the water surface exposed to air, and the third sealed from air with paraffin. When the dissolved oxygen had disappeared from the water in the sealed tank, Mortimer observed considerable increases in alkalinity, conductivity, ferrous iron, manganese, turbidity,

silica and phosphorus. He also studied changes in the muds at the bottom of these tanks. In the first two tanks there were no increases in any of the elements and very little change in the composition of the muds. In the third, he found the behavior of the mud-water system very similar to those of the hypolimnial muds of certain lakes which he had studied.

Although Einsele and Mortimer describe different sets of reactions occurring in the hypolimnion at the time of oxygen depletion, it is probable that both sets of reactions are occurring simultaneously. In either case, however, none of the elements are released from the mud until the oxygen in the overlying water disappears.

In Douglas Lake, then, the dead plankton organisms decompose as a result of bacterial action releasing phosphorus, nitrogen and other elements, but these either go into combination with iron to form insoluble precipitates or become adsorbed on ferric complexes. It is interesting to note that the bacteria are not only decomposing the dead organisms at the bottom of the lake but they are using up the oxygen, the presence of which inhibits the liberation of the elements which they are freeing.

During the summer of 1950, eight weeks elapsed from the time that oxygen disappeared from the bottom of the hypolimnion and phosphorus was released. This seemed to be rather a long delay but it is really not out of proportion when compared to similar time intervals in other lakes. Mortimer

(1941) observed large-scale liberation of phosphate two or three weeks after the oxygen had fallen below one part per million. In his laboratory experiments, phosphate did not appear in large quantities until 40 to 50 days after the oxygen had fallen nearly to zero. Einsele and Vetter (1938) found that the sharp rise in phosphate occurred normally one month after the oxygen had fallen to below one part per million. The time interval between oxygen depletion evidently varies considerably from lake to lake and probably depends upon the amount of ferric complex which has to be reduced, on the reducing capacity of the mud and on the conditions of microstratification near the mud surface which again depends on water movement. All this points to the conclusion that ferric complexes are only destroyed slowly by reduction, after which they liberate the adsorbed load of phosphorus.

It seems reasonable to assume that once the mud begins to liberate soluble inorganic phosphate into the water above, it would continue to do so, and that the supply of phosphate would keep building up in the bottom waters until oxygen is introduced at the overturn. In two instances such was not the case. In Douglas Lake, after the ice cover appeared in November, 1950, the phosphorus continued to increase at the bottom and should have continued to do so until the spring overturn which occurred after the ice had broken up in April, 1951. Between February 26 and March 28, however, although the ice cover was still present, there was a decrease of phosphorus from 33 to 15 micrograms per liter. In Lancaster

Lake during the summer of 1951, after the oxygen had disappeared from the bottom, there was a continual increase of phosphorus. Between August 16 and August 25, however, while the lake was still thermally stratified, there was a decrease from 175 to 130 micrograms per liter. This is a perplexing problem and at the present time there seems to be no plausible explanation. One possible answer might be that the sampling station was not located at exactly the same place each time. Mortimer (1941) and Hutchinson (1941) have evidence that turbulence occurs in the hypolimnion. If such is the case, then a very important factor to consider would be the position of the sampling stations relative to the deep holes. It is conceivable that variations in results may occur if samples taken on successive dates are not collected at exactly the same location in the lake.

Although cyclic fluctuations of phosphorus concentrations in the bottom waters of a lake can be expected throughout successive years, the heights of the peaks may not be identical. In Douglas Lake peaks of phosphorus appeared in September of 1950 and 1951, however the former far exceeded the latter in size (Figure 4, page 39). The same factors are probably involved in the production of both of these peaks but a slight difference in their relationship to each other could very well alter the magnitude of the results. In this particular instance, however, the concentration of phosphorus occurring at the bottom on September 16, 1951, might not represent the maximum concentration during the

time of phosphorus release. The periods of maximum liberation during the fall are evidently short, lasting from two to three weeks. If samples had been collected sometime between September 16 and October 6, perhaps a higher peak might have been observed.

At the times of the overturns the lake undergoes complete circulation from surface to bottom. It would be expected that elements which have been liberated at the bottom up to this time will be distributed throughout the whole lake and become available to the phytoplankters in the upper waters, thus making it possible for them to reproduce more rapidly and form pulses. Determinations of phosphorus in the surface waters, therefore, should show a significant increase, if not in soluble inorganic phosphorus, at least in total phosphorus. The data in Douglas Lake indicate no such increase following the overturns.

A possible hypothesis which might explain these data is that although the water was being circulated vertically throughout the lake, the bottom phosphorus did not reach the upper waters. It is of interest to follow this argument through to its logical conclusion. As has already been mentioned, oxygen is absent in the hypolimnion just before the overturn. At the time of the overturn, oxygen is reintroduced into the system and ferric hydroxide again formed. Some of the phosphorus is re-adsorbed on these ferric complexes and some recombines chemically with iron to form insoluble ferric phosphate. These combinations occur near the

bottom of the lake where the elements other than oxygen have been accumulating. If these insoluble compounds are sufficiently heavy to sink to the bottom as soon as they are formed, without first being carried to the surface, they would not beome available as nutrients to the plankton in the upper waters. This being true, it is necessary, then, to seek other sources of nutrients for these organisms. One possible source involves those plankters which die in the upper waters and undergo decomposition while descending, thus releasing certain elements directly into the upper waters. A difficulty inherent in this possibility at the present time, is the lack of information as to the rate of fall of the dead phytoplankters, and the rate of decomposition under aerobic conditions, both of which have to do with the rate of phosphorus release from the organisms. It is also possible, that as a result of wave action of the water against the shore, certain elements are leached out of the soil of the slopes and are mixed into the upper waters. The supply of nutrients provided by these two sources to the epilimnial region would at least be continuous throughout the year, and if it is assumed that they provide sufficient food to maintain phytoplankton, then factors other than amounts of nutrients must control the periodicity of phytoplankton components in a lake such as Douglas. Furthermore, it would have to be admitted that it is merely coincidental that a phytoplankton pulse immediately follows an overturn, because the stirring action during an overturn is no different from that occurring

almost constantly in the epilimnion, where the reproduction of phytoplankton takes place.

It seems unreasonable to assume that bottom phosphorus was not brought to the surface during the overturn. Water samples collected from the upper region of the lake while it was turning over, contained particles of bottom mud. Eggleton (private communication) has also observed particles of bottom mud in the surface water of a lake while it was in the process of an overturn. If the vertical stirring action of the water is capable of bringing these mud particles to the surface, surely it must be capable of carrying up molecules of ferric complexes which are much lighter. If it is postulated that bottom phosphorus was brought to the surface, then a different line of reasoning must be followed to account for the fact that data from Douglas Lake did not show an increase of this element following the overturn.

When oxygen is reintroduced into the system, it is true that the phosphorus becomes part of the newly formed ferric complexes and quite possibly some of these complexes do go back into the mud. The remainder is probably stirred vertically throughout the lake. As has been noted in Figure 5 (page 53) the phosphorus released from the bottom mud of Douglas Lake does not diffuse very far upward into the hypolimnion. The data collected just a short time before the overturn indicated that the high concentration of phosphorus had not risen beyond one meter above the bottom of the lake.

Considering the total phosphorus in Douglas Lake, and

assuming that on September 16, 1950, its enormous concentration of 641 micrograms per liter was contained in a layer of water one meter thick at the bottom of the hypolimnion (Table 4, page 34), certain rough calculations can be made to determine how much should have reached the upper waters during the overturn. The depth of the lake at the collecting station is 20 meters. If calculations are made for a hypothetical vertical column of water 1 meter square by 20 meters high, with a concentration of 641 micrograms per liter of total phosphorus in the water between 19 and 20 meters, then a uniform distribution of the contents of the bottom layer of water throughout the column should increase the concentration of total phosphorus at all depths by 32 micrograms per liter. This value would be high if applied to Douglas Lake for several reasons. First, the surface area of the lake is greater than the area of that part of the bottom covered by deoxygenated water, thus resulting in greater dilution, and second, the bottom layer of water at lesser depths would contain less phosphorus than was found in the bottom layer of water at this station because according to Mortimer (private communication) horizontal turbulence causes the denser bottom waters to accumulate in the deeper holes.

For the sake of argument, suppose that the amount of total phosphorus in the upper waters of Douglas Lake was increased by 32 micrograms per liter during the overturn. This together with the amount already there would make a total of approximately 42 micrograms per liter. The fact remains,

however, that on October 2, 1950, when the lake was in the process of complete circulation, the concentration of total phosphorus in the upper waters was not significantly different from the concentration prior to the overturn. When the station was visited about two weeks earlier, September 16 to be exact, thermal stratification was still in existence and the phosphorus which had been accumulating at the bottom of the lake was still undisturbed. In other words, sometime during this 16-day period during which no observations were made the overturn began, and the phosphorus which was supposedly brought to the surface as a result of the vertical stirring action in the water must have disappeared.

The problem as to where and how phosphorus disappears from lake water is one that is puzzling many workers. Barrett (unpublished manuscript) observed that the surface waters of certain northern Michigan lakes lost as much as 70 per cent of the total phosphorus in only three days. This figure coincides with the theoretical loss of total phosphorus in the surface water of Douglas Lake if it is assumed that phosphorus reached the surface waters in the first place.

Of the 641 micrograms per liter of total phosphorus present in the lower waters of the hypolimnion on September 16, the fraction represented by soluble inorganic phosphorus was 460 micrograms per liter. At the overturn, it would be expected that this soluble inorganic phosphorus, coming into contact with oxygen during the circulation, might be stirred

into the upper waters as part of the ferric complexes. Hutchinson (1941) also suggests that during an overturn, part of the phosphate normally determined as soluble, might really be in a suspended but acid soluble form. He found this to be true during the autumnal overturn in Linsley Pond.

A logical question at the present time would be: Can the algae utilize the phosphorus in this insoluble form? Harvey (1937) has evidence that marine diatoms can make use of suspended ferric compounds. There is a strong possibility, therefore, that other phytoplankters might also utilize them.

The introduction of phosphorus from the hypolimnion into the upper waters at the time of the overturn, may be compared to the artificial addition of phosphorus fertilizer to the lake. Many investigators who have experimented with artificial fertilization of lakes have noticed extreme losses of the added phosphorus but have been unable to trace its disappearance. Einsele (1941) describes how large quantities of superphosphate added to a certain lake disappeared within a few weeks after which time the phosphate content of the lake water was the same as before the addition of the fertilizer. He claimed that the phosphorus was stored by the phytoplankton but, despite this, no increase in phytoplankton occurred. Hayes et al (1951) introduced radioactive phosphorus into the lake in an attempt to trace its disappearance. On the basis of this work Hayes (1951) suggests:"..... that what seems to be a great deal of nutrient material (in terms of water) is really only a small fraction of an equilibrated

system of water and solids." When nutrient material is added to the lake it does not disappear but rather it will partition itself between water and solids so that neither phase will be much richer than before. He claims that there is ". . . . a continuous exchange of phosphorus going on between the water and solids in the lake, solids referring to plants and animals as well as a thin layer of participating mud, perhaps one mm. thick." He further concludes that if nutrient salts are added to a lake as fertilizer, within a few weeks 90 per cent of them would be expected to enter the water-and-solid phase and hence would not be detected by ordinary analyses. The remaining 10 per cent is likely to remain in the water and contribute to the initiation of the algal growth.

The discussion thus far appears to strengthen the inference that phosphorus might have been brought to the upper waters of Douglas Lake during the fall overturn and had disappeared by October 2. It is unfortunate that, due to practical difficulties, daily analyses could not be carried out during the critical period between September 16 and October 2, 1950. Had this been possible, the question as to whether phosphorus was brought to the upper waters could be answered by fact rather than speculation.

One fraction of the total phosphorus which has not yet been mentioned is the organic sestonic phosphorus which is part of the protoplasm of plankton cells. In Douglas Lake during the fall overturn, there was no increase in organic

sestonic phosphorus yet a phytoplankton pulse did occur. This could mean that the phytoplankton as a group absorbed very little, if any, of the phosphorus which was supposedly available to them at the overturn, even while they were increasing in number. Much interesting work has been done on the relationship of available phosphorus and Asterionella. Mackereth (in press) has shown that populations of Asterionella can grow in certain lakes containing as little phosphate phosphorus as one microgram per liter. Furthermore he found that they will continue to grow until there is only 0.06 micrograms of phosphorus per million cells. In other words even one microgram per liter of phosphorus is sufficient to support over 16 million cells per liter providing other nutrients, such as silicates, are not lacking. This concentration of cells is much greater than was ever found in Douglas Lake. Mackereth (loc. cit.) also has been able to demonstrate that Asterionella can take phosphorus into store from media containing this element and partition it out to daughter cells down to a very low irreducible minimum, if the phosphate in the external medium becomes completely exhausted. This raises the whole question of how far phosphate is really a limiting factor in lakes and it would be of the greatest interest to know whether other algae including planktonic diatoms possess this property.

These facts help to explain how it could have been possible for the phytoplankton in Douglas Lake to increase in number without a simultaneous increase in organic sestonic

phosphorus. The phytoplankton probably parcelled out their phosphorus content to daughter cells resulting in less phosphorus per individual cell but the same amount in the population as a whole.

This study provides no evidence that phosphorus is a limiting factor in the reproductive rate of phytoplankton in spite of the fact that phytoplankton pulses follow the overturns which supposedly distribute the bottom phosphorus throughout the lake (Figure 17). It is felt that because plankton pulses always occur immediately after the inception of an overturn, there is probably some cause-effect relationship. Perhaps during the overturn, certain other nutrients which may have a more profound influence on population growths than phosphorus are made available to the plankton.

The sequence of events which leads up to the development of a phytoplankton pulse is essentially as follows: Dead plankton organisms decompose at the bottom of the lake simultaneously with a decrease in oxygen in the hypolimnion. The nutrient elements which are liberated from the decomposing plankton become tied up in ferric complexes in the bottom muds. As soon as oxygen is depleted from the bottom, these nutrients are liberated due to the reduction of the ferric complexes. These liberated nutrients are made available to the phytoplankton in the upper waters during the overturn. It is possible that the magnitude and duration of each of the phytoplankton pulses which occurs after an overturn may depend upon the magnitude and duration of nutrient liberation

Fig. 17 - Seasonal Variation of Standing Crop of Total Phytoplankton and Soluble Inorganic Phosphorus at 20-meter Depth in Douglas Lake. Years 1950-1951

Explanation of Fig. 17

(a) Fall overturn began between Sept. 16 and Oct. 2, 1950

(b) Ice appeared Nov. 24, 1950

(c) Ice disappeared April 13, 1951

(d) Thermal stratification began between May 10 and May 25, 1951

(e) Fall overturn began between Sept. 15 and Oct. 6, 1951

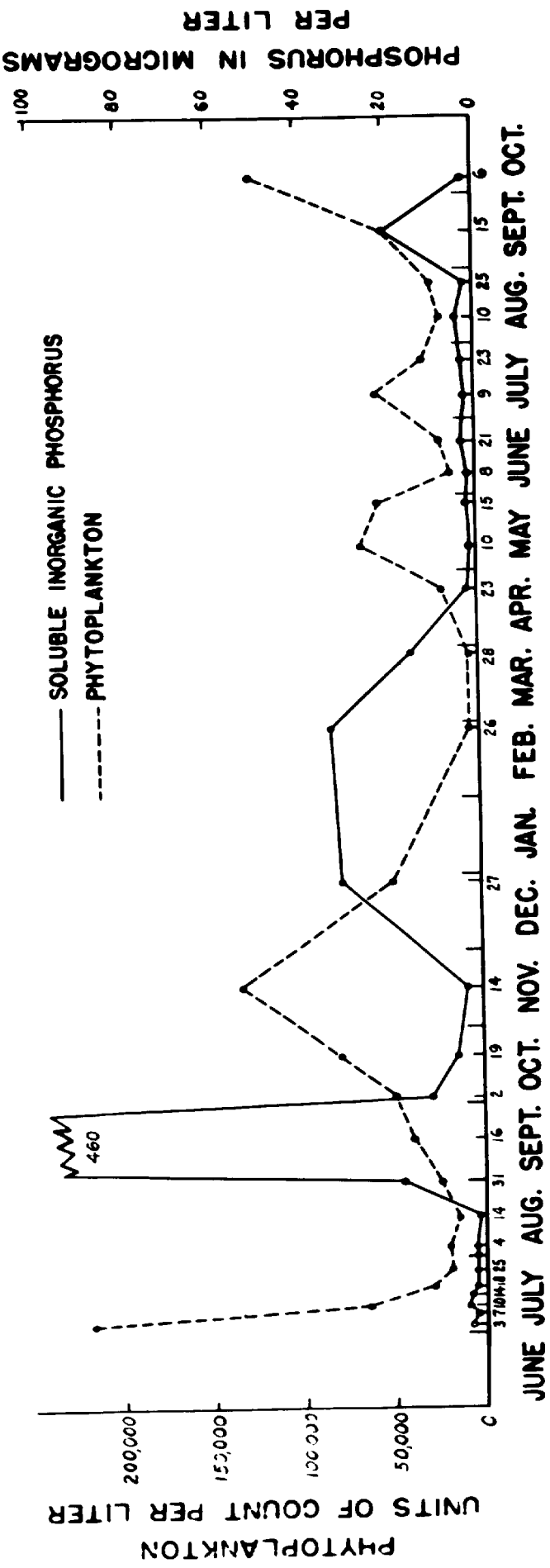

PHOSPHORUS IN MICROGRAMS PER LITER
100
80
60
40
20
0
SOLUBLE INORGANIC PHOSPHORUS
PHYTOPLANKTON
460
200,000
150,000
100,000
50,000
0
PHYTOPLANKTON UNITS OF COUNT PER LITER
JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.

FIG.16

from the mud, which, in turn, depends upon how soon before the overturn the bottom becomes depleted of oxygen.

The question is raised regarding the factors involved in the production of phytoplankton pulses in shallow unprotected lakes having no outlets or inlets. The water in these lakes would presumably be in circulation most of the time and any thermal stratification occurring would be slight and of short duration. There would never be an oxygen depletion and hence no accumulation of nutrients at the bottom. The nutrients would probably be distributed uniformly most of the time. In a lake such as this it is probable that there would always be an adequate supply of nutrients available to the plankton. The productivity of phytoplankton in such a lake throughout the year should constantly be as great from the standpoint of nutrients as peak productions in thermally stratified lakes such as Douglas Lake. These small lakes, however, do show evidence of pulses but, according to Pennak (1949), the times of these pulses cannot be predicted. Also the number of pulses occurring in these lakes varies from lake to lake and from year to year in the same lake. If nutrients are not the limiting factor, then other factors must be involved. It is suggested that most of these factors do not stimulate the organisms to greater production but rather inhibit the production already in operation. These inhibitory factors might be the cause of the troughs in a graph depicting seasonal variations of phytoplankton populations in this type of lake.

SUMMARY

1. This investigation was undertaken in an attempt to discover relationships which may exist between the seasonal and vertical distribution of phytoplankton and changes in physico-chemical conditions in five Michigan Lakes.

2. Plankton samples and physico-chemical data were collected from Douglas Lake in northern Michigan during the summer of 1948 and during 16 consecutive months from July 3, 1950, to October 6, 1951. In addition, plankton samples and physico-chemical data were collected during the summers of 1948, 1950 and 1951 from Munro, Vincent and Lancaster Lakes in northern Michigan and during the fall of 1950 from Lake Lansing in southern Michigan.

3. Morphometric data are presented for each of the lakes. The four lakes in northern Michigan are only a few miles from each other, nevertheless, they differ markedly in their morphometric, physico-chemical and biological conditions.

4. Plankton samples were collected with a 10-liter Birge and Juday plankton trap. During the summer of 1950 duplicate vertical series of plankton samples were collected; one for identification and enumeration, the other for pigment extraction. In addition, several vertical series of

water samples were collected with a Kemmerer sampler. These samples were centrifuged and pigment extracted from the concentrates with a view to comparing the density of their pigment with that extracted from the concentrates of filtered samples.

5. With the exception of phosphorus, all chemical determinations were made according to procedures described in Standard Methods of Water Analyses, 9th edition. Phosphorus concentrations were determined colorimetrically with a Klett-Summerson photoelectric colorimeter. The techniques employed to bring out the blue color of the phosphorus ions were modified from Denige (1920) and Robinson and Kemmerer (1930).

6. The various fractions of phosphorus; soluble inorganic, soluble organic, organic sestonic and acid soluble sestonic are discussed. Methods for their determination and calculation are outlined.

7. Douglas is the largest of the five lakes studied. It shows typical thermal and chemical stratification with a gradual depletion of oxygen in the hypolimnion during the summer.

8. Munro Lake is shallow with no thermal or chemical stratification. It is second largest of the four northern lakes. Its chemical conditions resemble those of the epilimnion of Douglas Lake.

9. Lancaster Lake is deeper than Munro Lake but has a smaller area. It has a very marked thermal and chemical stratification during the summer. The epilimnion is very

shallow and most of the volume of the lake is contained by the hypolimnion. The water in this lake is highly colored.

10. Douglas, Munro and Lancaster Lakes are all slightly alkaline.

11. Vincent is a small shallow lake having soft water which is low in dissolved substances. It very seldom stratifies thermally. Its pH fluctuates but never varies greatly from 7.0. Comparison of these data with those of previous workers indicates that the water of this lake is gradually changing from acid to alkaline.

12. Lake Lansing in southern Michigan is a little smaller and deeper than Munro, however it has two depressions in which thermal stratification occurs. It is a hard water lake with the pH always on the alkaline side.

13. Concentration of total phosphorus in Munro Lake and in the epilimnial waters of Douglas and Lancaster Lakes ranged between 6 and 13 micrograms per liter. In Vincent and in the epilimnion of Lake Lansing, the total phosphorus varied between 13 and 18 micrograms per liter, the latter two bodies of water containing more organic matter than any of the former three.

14. In the bottom waters of the hypolimnion of Douglas and Lancaster Lakes, the phosphorus concentration increased tremendously soon after the oxygen had disappeared. In Douglas Lake, approximately two weeks after the inception of the overturn, the amount of phosphorus in the upper waters was no greater than before the overturn. This is contrary

to what might be expected since it would seem that the stirring action in the water would have carried it to the surface.

15. Facts are presented to support the hypothesis that some of the accumulated phosphorus from the bottom waters actually was brought to the surface after the inception of the overturn but had disappeared before water samples were collected from the lake several days after the overturn had begun. Evidently, phosphorus reaching the upper waters can disappear in a matter of days because on September 16, 1950, the overturn had not yet begun and phosphorus was still concentrated in the lower waters of the hypolimnion, whereas 16 days later, complete vertical circulation was in progress and an increase in the phosphorus content of the upper water was not indicated.

16. Phosphorus at the bottom of the lake which is introduced into the upper waters at the time of the overturn is compared to artificial fertilizer added to a lake and the resulting chemical and biological conditions would be expected to be similar in both instances.

17. The chemistry pertaining to the release of phosphorus from the bottom muds to the overlying water is discussed. In the presence of oxygen, iron and phosphorus combine to form insoluble ferric complexes. When oxygen disappears from the bottom waters as a result of decomposition, the ferric complexes are reduced forming ferrous complexes which are soluble. When oxygen is reintroduced at

the overturn, ferric complexes are once again formed.

18. The phytoplankton were counted only by genera due to the impossibility of placing the high power objective over the Sedgewick-Rafter cell. Members of those genera which appeared in the samples in sufficiently large numbers were identified to species where possible.

19. During the 16-month period of investigation in Douglas Lake, the numbers of phytoplankton varied between 3,809 and 219,352 units per liter. Five separate pulses were observed; the first and second being the spring and fall pulses of 1950 occurring after the spring and fall overturn respectively, the third and fourth making up a double spring pulse in 1951 and occurring after the spring overturn, the fifth representing the beginning of the fall pulse of 1951 following the fall overturn.

20. Douglas Lake is a diatom lake. Bacillariophyceae comprised an average of 76.2 per cent of the entire phytoplankton production for the 16 months. The genera most abundant in this class during each of the fall pulses were Asterionella, Melosira and Synedra, whereas the fall pulses contained mostly Tabellaria, Melosira, Synedra and Fragilaria. The Chrysophyceae represented exclusively by Dinobryon made up between 30 and 40 per cent of each of the spring pulses. The other classes of algae together made up about 17 per cent of the phytoplankton populations.

21. In Lancaster Lake, the summer standing crops never exceeded 42,791 units per liter. Chrysophyceae composed of

Synura made up an average of 53.5 per cent of the total. Bacillariophyceae were second, comprising 27.4 per cent, whereas Cyanophyceae and Dinophyceae were third and fourth contributing 30.5 and 28.6 per cent respectively. Chlorophyceae were quantitatively insignificant.

22. During the summer months Munro Lake contained phytoplankton crops in amounts ranging between 2,549 and 82,867 units per liter. Cyanophyceae were most abundant making up an average of 58.5 per cent of the total. Bacillanophyceae produced 24.4 per cent. Chrysophyceae contributed 14.4 per cent whereas the Dinophyceae and Chlorophyceae together amounted to about 6 per cent.

23. During the summer months the standing crops in Vincent Lake varied between 22,613 and 48,875 units per liter. Cyanophyceae were most numerous averaging 66.9 per cent of the total. The Dinophyceae, composed only of Peridinium, contributed an average of 17.3 per cent while the Chlorophyceae made up 13.5 per cent. Bacillariophyceae and Chrysophyceae together comprised about 2 per cent.

24. The standing crops of phytoplankton in Lake Lansing during the fall of 1950 occurred in amounts ranging between 15,831 and 39,819 units per liter. These crops were composed mainly of Bacillariophyceae, Cyanophyceae and Dinophyceae whose average contribution to the total were 51, 34.4 and 13.7 per cent respectively.

25. The average of the three mean summer standing crops for each of the northern lakes was computed. These

averages show that Vincent produced the largest number of phytoplankton. Douglas Lake ranked second while Munro and Lancaster Lakes came third and fourth.

26. Bacillariophyceae was the most dominant group in Douglas Lake whereas the Chrysophyceae made up the largest part of the population in Lancaster Lake. Cyanophyceae were the dominant group both in Munro and Vincent Lakes.

27. Chlorophyceae and Dinophyceae contributed the least to the populations of both Douglas and Munro Lakes. Chlorophyceae were the smallest group in Lancaster whereas Bacillariophyceae and Chrysophyceae were the least important groups in Vincent Lake.

28. In the four lakes, Bacillariophyceae were most abundant in Douglas, next most numerous in Munro, less common in Lancaster and least numerous in Vincent. Chlorophyceae occurred most abundantly in Vincent Lake with Douglas, Munro and Lancaster following in order. Vincent Lake also produced the largest number of Cyanophyceae with Munro, Douglas and Lancaster ranking second, third and fourth. Dinophyceae appeared in greatest numbers in Vincent Lake followed by Douglas, Munro and Lancaster; the latter two lakes producing approximately equal numbers. The numbers of Chrysophyceae in Douglas and Lancaster Lakes were approximately equal with Munro producing fewer and Vincent hardly any.

29. In comparing the mean fall standing crops of Douglas Lake and Lake Lansing, it was found that Douglas produced the larger population. Douglas Lake produced the

larger number of Bacillariophyceae whereas Lake Lansing produced the larger number of Cyanophyceae and Dinophyceae. Neither lake produced many Chlorophyceae or Chrysophyceae.

30. Discussions are presented of the individual genera of phytoplankton appearing in these lakes from the standpoint of their quantitative differences in the various lakes and at different times in the same lake.

31. The densities of pigment extracted from plankton samples taken from Douglas, Lancaster and Lansing Lakes were compared statistically to quantities of phytoplankton in analagous samples. The coefficients of correlation were .84, .95 and .88. These coefficients of correlation were slightly higher than those calculated for samples from the Bay of Quinte and Lake Erie (Tucker, 1949). This difference might be due to the fact that in the present investigation a photoelectric colorimeter was used to measure the densities of the pigment whereas in the previous studies a visual colorimeter was used. A photoelectric colorimeter eliminates some personal error.

32. Pigments were extracted from the concentrates of duplicate series of plankton; one series having been concentrated by filtration through a plankton net, the other by centrifugation. The net retained an average of 17.5 per cent of the pigment that was retained by the centrifuge from the corresponding series of samples. This value is similar to that determined gravimetrically by Birge and Juday (1922) who found that the net removed from the water only one

quarter to one fifth of the organic matter that could be removed by the centrifuge.

33. There is no evidence in this study that the phosphorus liberated from the mud and brought to the surface waters during the overturn has any controlling influence over the reproductive rate of the phytoplankters in Douglas Lake probably because there is always a sufficient minimum present.

34. It is suggested that other nutrient elements which are combined with the ferric complexes and released at approximately the same time of the year as phosphorus, are responsible for the phytoplankton pulses occurring after each overturn.

35. The hypothesis is presented that the magnitude and duration of each of the phytoplankton pulses which occurs after an overturn may depend upon the magnitude and duration of nutrient liberation from the mud, which in turn depends upon how soon before the overturn the bottom becomes depleted of oxygen.

36. In shallow unprotected lakes which are undergoing almost constant circulation, there would probably always be an adequate supply of nutrients available to the plankton. Factors other than nutrients may control the formation of plankton pulses in these lakes. It is suggested that these factors do not stimulate the organisms to greater production but rather inhibit the production already in operation. These inhibitory factors might be the cause of the troughs in the graphs illustrating seasonal variation of phytoplankton populations in this type of lake.

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A P P E N D I X

(Tables 18 - 169)

TABLE 18

ABUNDANCE OF TOTAL PHYTOPLANKTON IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates		Count in units per liter				Total	Mean
1948	June 24	5,590	4,080	3,935	2,667	985	17,257	3,451
	July 1	4,780	8,500	11,260	7,530	1,135	32,705	6,541
	July 8	8,226	6,541	11,333	11,249	4,030	41,379	8,276
	July 15	1,941	2,636	4,450	6,766	8,375	24,168	4,833
	July 22	4,130	2,246	3,143	3,700	810	14,029	2,806
	July 29	6,913	6,176	5,460	4,283	2,166	24,998	5,000
	Aug. 12	5,700	5,750	4,815	2,933	1,500	20,698	4,140

TABLE 19

*COMPOSITION OF PHYTOPLANKTON IN DOUGLAS LAKE DURING THE SUMMER OF 1948

	Diatoms	Chryso-phyceae	Dino-phyceae	Green algae	Blue-green algae	Total
Dates		Count in units per liter				
1948 June 24	2,630	0	220	0	601	3,451
July 1	4,824	60	680	80	897	6,541
July 8	6,491	20	1,080	20	665	8,276
July 15	2,636	0	440	60	1,697	4,833
July 22	1,838	0	580	0	388	2,806
July 29	3,857	0	500	100	543	5,000
Aug. 12	3,215	0	380	80	465	4,140

*Each value represents the mean of the counts in units per liter of the vertical series of samples collected on a particular day

TABLE 20

PERCENTAGE COMPOSITION OF PHYTOPLANKTON IN DOUGLAS LAKE DURING THE SUMMER OF 1948

		Diatoms	Chryso-phyceae	Dino-phyceae	Green algae	Blue-green algae
1948	June 24	76.2	0	6.4	0	17.4
	July 1	73.8	0.9	10.4	1.2	13.7
	July 8	78.4	0.2	13.0	0.2	8.0
	July 15	54.5	0	9.1	1.2	35.1
	July 22	65.5	0	20.7	0	13.8
	July 29	77.1	0	10.0	2.0	10.9
	Aug. 12	77.7	0	9.2	1.9	11.2
Mean		71.9	0.2	11.3	0.9	15.7
Extremes	Max.	78.4	0.9	20.7	2.0	35.1
	Min.	65.5	0	6.4	0	8.0

TABLE 21

ABUNDANCE OF DIATOMS IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

Depth Meters	0	3	5	10	18		
Dates	Count in units per liter					Total	Mean
1948 June 24	4,440	3,220	2,455	2,500	535	13,150	2,630
July 1	2,980	6,700	8,680	5,225	535	24,120	4,824
July 8	6,913	4,541	8,533	9,833	2,630	32,453	6,491
July 15	1,425	1,816	1,950	5,416	2,575	13,182	2,636
July 22	2,700	1,430	1,683	2,800	575	9,188	1,838
July 29	5,280	4,810	3,810	3,733	1,650	19,283	3,857
Aug. 12	4,400	4,700	3,240	2,533	1,200	16,073	3,215

TABLE 22

ABUNDANCE OF BLUE-GREEN ALGAE IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

Depth Meters	0	3	5	10	18		
Dates	Count in units per liter					Total	Mean
1948 June 24	950	160	1,280	167	450	3,007	601
July 1	600	800	1,280	1,205	600	4,485	897
July 8	510	700	400	516	1,200	3,326	665
July 15	213	220	1,600	750	5,700	8,483	1,697
July 22	730	216	730	100	135	1,941	388
July 29	633	666	850	150	416	2,715	543
Aug. 12	600	550	875	100	200	2,325	465

TABLE 23

ABUNDANCE OF GREEN ALGAE IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates		Count in units per liter				Total	Mean
1948	June 24	0	0	0	0	0	0	0
	July 1	100	300	0	0	0	400	80
	July 8	0	0	100	0	0	100	20
	July 15	0	0	200	100	0	300	60
	July 22	0	0	0	0	0	0	0
	July 29	200	100	100	100	0	500	100
	Aug. 12	100	100	100	100	0	400	80

TABLE 24

ABUNDANCE OF CHRYSOPHYCEAE (MADE UP WHOLLY OF DINOBRYON) IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates		Count in units per liter				Total	Mean
1948	June 24	0	0	0	0	0	0	0
	July 1	0	100	200	0	0	300	60
	July 8	0	100	0	0	0	100	20
	July 15	0	0	0	0	0	0	0
	July 22	0	0	0	0	0	0	0
	July 29	0	0	0	0	0	0	0
	Aug. 12	0	0	0	0	0	0	0

TABLE 25

ABUNDANCE OF DINOPHYCEAE (MADE UP WHOLLY OF CERATIUM) IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates			Count in units per liter			Total	Mean
1948	June 24	200	700	200	0	0	1,100	220
	July 1	600	600	1,100	1,100	0	3,400	680
	July 8	800	1,200	2,300	900	200	5,400	1,080
	July 15	300	600	700	500	100	2,200	440
	July 22	700	600	700	800	100	2,900	580
	July 29	800	600	700	300	100	2,500	500
	Aug. 12	600	400	600	200	100	1,900	380

TABLE 26

ABUNDANCE OF ASTERIONELLA IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates			Count in units per liter			Total	Mean
1948	June 24	700	750	1,000	650	200	3,300	666
	July 1	1,550	3,350	4,000	2,800	450	12,150	2,430
	July 8	3,500	2,750	4,600	5,300	900	17,050	3,410
	July 15	250	450	600	1,550	350	3,200	640
	July 22	150	200	650	400	100	1,500	300
	July 29	700	950	600	850	250	3,350	670
	Aug. 12	600	1,050	400	600	200	2,850	570

TABLE 27

ABUNDANCE OF FRAGILARIA IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates		Count in units per liter				Total	Mean
1948	June 24	100	360	25	500	100	1,145	229
	July 1	400	500	800	925	25	2,650	530
	July 8	1,350	75	1,050	1,200	200	3,875	775
	July 15	25	100	200	350	675	1,330	270
	July 22	550	150	400	550	250	1,900	380
	July 29	600	600	450	1,000	800	3,450	690
	Aug. 12	500	700	400	600	500	2,700	540

TABLE 28

ABUNDANCE OF MELOSIRA IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates		Count in units per liter				Total	Mean
1948	June 24	1,530	760	630	200	160	3,280	656
	July 1	230	500	930	800	60	2,520	504
	July 8	266	166	333	733	530	2,028	406
	July 15	200	166	0	366	600	1,332	266
	July 22	600	530	33	300	100	1,563	313
	July 29	1,530	1,660	1,660	933	400	6,183	1,237
	Aug. 12	1,200	1,400	1,340	633	300	4,873	975

TABLE 29

ABUNDANCE OF NAVICULA IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates		Count in units per liter				Total	Mean
1948	June 24	100	0	0	0	0	100	20
	July 1	0	0	100	0	0	100	20
	July 8	0	0	100	0	0	100	20
	July 15	0	0	100	0	200	300	60
	July 22	0	0	100	0	0	100	20
	July 29	0	0	0	0	0	0	0
	Aug. 12	0	0	0	0	0	0	0

TABLE 30

ABUNDANCE OF STEPHANODISCUS IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates		Count in units per liter				Total	Mean
1948	June 24	100	100	100	0	0	300	60
	July 1	0	100	0	0	0	100	20
	July 8	300	0	100	0	100	500	100
	July 15	200	100	100	100	100	600	120
	July 22	0	0	100	0	0	100	20
	July 29	200	0	100	200	0	500	100
	Aug. 12	0	100	100	100	0	300	60

TABLE 31

ABUNDANCE OF SYNEDRA IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates	Count in units per liter					Total	Mean
1948	June 24	1,400	300	100	0	0	1,800	360
	July 1	200	300	400	100	0	1,000	200
	July 8	500	300	800	600	300	2,500	500
	July 15	300	400	0	700	400	1,800	360
	July 22	500	300	200	600	100	1,700	340
	July 29	1,800	1,200	600	300	100	4,000	800
	Aug. 12	1,700	1,100	700	200	100	3,800	760

TABLE 32

ABUNDANCE OF TABELLARIA IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates	Count in units per liter					Total	Mean
1948	June 24	450	950	600	1,150	75	3,225	645
	July 1	600	1,950	2,450	600	0	5,600	1,120
	July 8	1,000	1,250	1,550	2,000	600	6,400	1,280
	July 15	450	600	950	2,350	250	4,600	920
	July 22	900	250	200	950	25	2,325	465
	July 29	450	400	400	450	100	1,800	360
	Aug. 12	400	350	300	400	100	1,550	330

TABLE 33

ABUNDANCE OF ANABAENA IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates		Count in units per liter				Total	Mean
1948	June 24	0	0	30	17	0	47	9
	July 1	0	100	30	30	0	160	32
	July 8	10	0	0	166	0	176	35
	July 15	66	20	400	0	0	486	97
	July 22	530	166	460	0	0	1,156	231
	July 29	433	266	100	0	66	865	173
	Aug. 12	300	300	175	0	0	775	155

TABLE 34

ABUNDANCE OF MICROCYSTIS IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates		Count in units per liter				Total	Mean
1948	June 24	950	160	1,250	150	450	2,960	592
	July 1	600	700	1,250	1,175	600	4,325	865
	July 8	500	700	400	350	1,200	3,150	630
	July 15	150	100	800	750	5,700	7,500	1,500
	July 22	200	50	200	100	35	585	117
	July 29	200	400	650	150	350	1,750	350
	Aug. 12	300	250	700	100	200	1,550	310

TABLE 35

ABUNDANCE OF OSCILLATORIA IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates	Count in units per liter					Total	Mean
1948	June 24	0	0	0	0	0	0	0
	July 1	0	0	0	0	0	0	0
	July 8	0	0	0	0	0	0	0
	July 15	0	100	400	0	0	500	100
	July 22	0	0	100	0	100	200	40
	July 29	0	0	100	0	0	100	20
	Aug. 12	0	0	0	0	0	0	0

TABLE 36

ABUNDANCE OF SCENEDESMUS IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

	Depth Meters	0	3	5	10	18		
	Dates	Count in units per liter					Total	Mean
1948	June 24	0	0	0	0	0	0	0
	July 1	0	0	0	0	0	0	0
	July 8	0	0	100	0	0	100	20
	July 15	0	0	0	0	0	0	0
	July 22	0	0	0	0	0	0	0
	July 29	0	0	0	0	0	0	0
	Aug. 12	0	0	0	0	0	0	0

TABLE 37

ABUNDANCE OF *STAURASTRUM* IN DOUGLAS LAKE AT VARIOUS DEPTHS DURING THE SUMMER OF 1948

Depth Meters	0	3	5	10	18		
Dates	Count in units per liter					Total	Mean
1948 June 24	0	0	0	0	0	0	0
July 1	100	300	0	0	0	400	80
July 8	0	0	0	0	0	0	0
July 15	0	0	200	100	0	300	60
July 22	0	0	0	0	0	0	0
July 29	200	100	100	100	0	500	100
Aug. 12	100	100	100	100	0	400	80

TABLE 38

SEASONAL AND VERTICAL DISTRIBUTION OF TOTAL PHYTOPLANKTON AT VARIOUS DEPTHS FROM JULY, 1950 THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	100,500	204,120	580,660	170,420	41,060	1,096,760	219,352
July 10	52,460	73,882	98,600	67,940	37,560	330,442	66,088
July 18	33,373	39,149	34,268	35,544	7,438	149,772	29,954
July 25	26,227	27,450	23,265	22,627	6,165	105,734	21,147
Aug. 4	18,510	21,345	23,388	24,275	9,375	96,893	19,379
Aug. 14	13,740	16,202	17,559	17,550	7,850	72,901	14,580
Aug. 31	23,275	24,125	29,275	30,965	14,925	122,565	24,513
Sept.16	34,050	45,915	48,900	37,650	33,300	199,815	39,963
Oct. 2	39,750	52,400	53,250	49,950	51,900	247,250	49,450
Oct. 19	55,250	76,725	83,550	77,550	109,650	402,725	80,545
Nov. 14	133,050	135,075	138,675	150,450	124,950	682,200	136,440
Dec. 27	50,625	48,875	57,900	20,225	74,900	252,525	50,505
1951							
Feb. 26	900	2,150	3,450	6,041	6,505	19,046	3,809
March 28	1,675	5,000	5,300	6,800	6,630	25,405	5,081
April 23	16,550	20,650	21,900	27,850	21,800	108,750	21,750
May 10	85,457	83,210	78,750	64,150	23,950	335,517	67,103
May 25	51,050	63,250	78,700	45,600	30,500	269,100	53,820
June 8	13,550	16,400	19,100	15,750	15,350	80,150	16,030
June 21	18,682	24,093	23,949	17,150	8,699	92,573	18,515
July 9	52,650	66,466	58,125	57,400	40,533	275,174	55,035
July 23	20,499	32,883	39,866	27,033	24,400	144,681	28,936
Aug. 10	15,900	24,933	23,349	23,933	15,266	103,381	20,676
Aug. 25	27,666	35,183	23,516	26,916	13,500	126,781	25,356
Sept.15	51,866	61,100	54,383	45,800	25,200	238,349	47,670
Oct. 6	125,700	133,050	114,100	116,850	138,050	627,750	125,550

TABLE 39

COMPOSITION* OF PHYTOPLANKTON IN DOUGLAS LAKE FROM JULY, 1950, THROUGH OCTOBER, 1951

Dates	Diatoms	Chryso-phyceae	Dino-phyceae	Green algae	Blue-green algae	Total
	Count in units per liter					
1950						
July 3	120,626	89,650	2,650	1,440	4,986	219,352
July 10	35,856	21,200	3,360	1,820	3,852	66,088
July 18	20,013	1,330	3,010	1,715	3,885	29,954
July 25	15,958	300	1,080	1,620	2,189	21,147
Aug. 4	12,388	0	960	1,800	4,231	19,379
Aug. 14	9,735	0	840	1,200	2,805	14,580
Aug. 31	20,210	0	1,350	810	2,143	24,513
Sept. 16	34,800	120	840	870	3,333	39,963
Oct. 2	46,545	0	90	630	2,185	49,450
Oct. 19	75,750	0	90	975	3,730	80,545
Nov. 14	130,170	180	30	840	5,220	136,440
Dec. 27	48,125	90	0	120	2,170	50,505
1951						
Feb. 26	3,504	20	0	80	205	3,809
March 28	4,646	0	180	40	215	5,081
April 23	17,120	1,140	30	240	3,220	21,750
May 10	49,254	14,210	120	570	2,947	67,101
May 25	34,630	16,420	280	480	2,010	53,820
June 8	9,740	3,060	180	600	2,450	16,030
June 21	12,323	540	350	880	4,422	18,515
July 9	45,495	1,490	725	2,250	5,075	55,035
July 23	20,460	80	1,600	2,860	3,936	28,936
Aug. 10	13,037	60	1,440	1,640	4,500	20,677
Aug. 25	15,700	120	2,960	1,100	5,476	25,356
Sept. 15	38,740	320	1,780	1,680	5,150	47,670
Oct. 6	110,200	1,570	1,380	2,450	9,950	125,550

*Each value represents the mean of the counts in units per liter of the vertical series of samples collected on a particular day

TABLE 40

PERCENTAGE COMPOSITION OF PHYTOPLANKTON IN DOUGLAS LAKE FROM JULY, 1950, THROUGH OCTOBER, 1951

	Diatoms	Chryso-phyceae	Dino-phyceae	Green algae	Blue-green algae
1950					
July 3	54.9	40.9	1.2	0.7	2.3
July 10	54.3	32.1	5.1	2.7	5.8
July 18	66.8	4.4	10.0	5.7	12.9
July 25	75.5	1.4	5.1	7.7	10.4
Aug. 4	63.9	0	5.0	9.3	21.8
Aug. 14	66.8	0	5.8	8.2	19.2
Aug. 31	82.4	0	5.5	3.3	8.7
Sept. 16	87.1	0.3	2.1	2.2	8.3
Oct. 2	94.1	0	0.2	1.3	4.2
Oct. 19	94.0	0	0.1	1.2	4.6
Nov. 14	95.4	0.1	0	0.6	3.8
Dec. 27	95.3	0.2	0	0.2	4.3
1951					
Feb. 26	92.0	0.5	0	2.1	5.4
March 28	91.4	0	3.5	0.8	4.2
April 23	78.7	5.2	0.1	1.1	14.8
May 10	73.4	21.2	0.2	0.8	4.4
May 25	64.3	30.5	0.5	0.9	3.7
June 8	60.8	19.1	1.1	3.7	15.3
June 21	66.6	2.9	1.9	4.8	23.9
July 9	82.7	2.7	1.3	4.1	9.2
July 23	70.7	0.3	5.5	9.9	13.6
Aug. 10	63.1	0.3	7.0	7.9	21.8
Aug. 25	61.9	0.5	11.7	4.3	21.4
Sept. 15	81.2	0.7	3.7	3.5	10.8
Oct. 6	87.8	1.2	1.1	2.0	7.9
Mean	76.2	6.6	3.1	3.6	10.5
Extremes Max.	95.4	40.9	11.7	9.9	23.9
Min.	54.3	0	0	0.2	2.3

TABLE 41

SEASONAL AND VERTICAL DISTRIBUTION OF DIATOMS AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	30,250	55,960	442,600	55,660	18,660	603,130	120,626
July 10	25,700	33,820	48,600	45,000	26,160	179,280	35,856
July 18	20,563	25,463	23,625	25,078	5,338	100,067	20,013
July 25	18,725	20,550	18,225	17,325	4,965	79,790	15,958
Aug. 4	11,370	13,095	15,575	16,575	5,325	61,940	12,388
Aug. 14	7,800	9,225	12,375	12,900	6,375	48,675	9,735
Aug. 31	19,425	18,825	25,650	25,750	11,400	101,050	20,210
Sept.16	31,500	39,900	43,125	32,325	27,150	174,000	34,800
Oct. 2	37,800	49,725	49,500	46,800	48,900	232,725	46,545
Oct. 19	52,200	71,850	80,550	73,800	100,350	378,750	75,750
Nov. 14	126,300	129,450	133,050	142,800	119,250	650,850	130,170
Dec. 27	48,750	48,275	56,625	19,875	67,100	240,625	48,125
1951							
Feb. 26	750	2,100	2,950	5,766	5,955	17,521	3,504
March 28	750	4,950	4,800	6,600	6,130	23,230	4,646
April 23	13,300	15,500	16,700	22,500	17,600	85,600	17,120
May 10	60,920	59,900	54,650	51,800	19,000	246,270	49,254
May 25	29,500	35,300	51,400	33,800	23,150	173,150	34,630
June 8	6,450	8,550	11,150	10,550	12,000	48,700	9,740
June 21	12,366	16,633	15,633	11,600	5,383	61,615	12,323
July 9	41,650	54,300	47,125	49,500	34,900	227,475	45,495
July 23	14,100	22,150	28,000	20,300	17,750	102,300	20,460
Aug. 10	9,700	13,050	15,383	16,500	10,550	65,183	13,036
Aug. 25	17,800	21,550	13,000	17,650	8,500	78,500	15,700
Sept.15	44,350	46,700	44,800	34,900	20,950	193,700	38,740
Oct. 6	111,400	115,650	99,700	97,200	127,050	551,000	110,200

TABLE 42

SEASONAL AND VERTICAL DISTRIBUTION OF BLUE-GREEN ALGAE AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	3,250	7,260	5,260	6,960	2,200	24,930	4,986
July 10	3,360	3,262	6,400	3,740	2,500	19,262	3,852
July 18	5,810	5,286	4,518	2,935	875	19,424	3,885
July 25	2,552	2,400	2,190	3,202	600	10,944	2,189
Aug. 4	4,740	3,900	4,963	4,850	2,700	21,153	4,231
Aug. 14	2,940	4,127	3,084	3,000	875	14,026	2,805
Aug. 31	2,050	1,700	1,675	2,965	2,325	10,715	2,143
Sept. 16	1,650	3,015	3,675	2,775	5,550	16,665	3,333
Oct. 2	1,050	2,075	2,850	2,400	2,550	10,925	2,185
Oct. 19	2,225	3,075	2,550	2,250	8,550	18,650	3,730
Nov. 14	6,150	4,725	5,025	6,000	4,200	26,100	5,220
Dec. 27	1,425	600	975	200	7,650	10,850	2,170
1951							
Feb. 26	50	50	400	175	350	1,025	205
March 28	325	50	100	100	500	1,075	215
April 23	3,000	3,250	3,400	3,650	2,800	16,100	3,220
May 10	2,437	4,400	3,300	3,150	1,450	14,737	2,947
May 25	1,650	2,350	3,300	2,000	750	10,050	2,010
June 8	2,500	2,150	2,550	2,700	2,350	12,250	2,450
June 21	4,516	5,560	5,266	4,150	2,616	22,108	4,422
July 9	4,400	6,466	5,375	5,000	4,133	25,374	5,075
July 23	2,699	4,833	5,166	3,033	3,950	19,681	3,936
Aug. 10	4,100	6,183	5,066	3,833	3,316	22,498	4,500
Aug. 25	6,366	7,333	5,216	5,666	2,800	27,381	5,476
Sept. 15	3,516	6,900	5,883	6,500	2,950	25,749	5,150
Oct. 6	8,600	10,950	8,850	13,650	7,700	49,750	9,950

TABLE 43

SEASONAL AND VERTICAL DISTRIBUTION OF GREEN ALGAE AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	500	1,500	1,800	2,200	1,200	7,200	1,440
July 10	2,000	2,000	1,600	2,200	1,300	9,100	1,820
July 18	1,925	2,450	1,050	3,150	0	8,575	1,715
July 25	2,250	1,950	1,800	1,650	450	8,100	1,620
Aug. 4	750	2,250	2,100	2,700	1,200	9,000	1,800
Aug. 14	1,200	2,100	1,050	1,050	600	6,000	1,200
Aug. 31	300	750	600	1,800	600	4,050	810
Sept. 16	300	1,350	1,200	1,200	300	4,350	870
Oct. 2	600	600	750	750	450	3,150	630
Oct. 19	875	1,350	450	1,350	900	4,875	975
Nov. 14	600	900	450	1,050	1,200	4,200	840
Dec. 27	0	0	300	150	150	600	120
1951							
Feb. 26	0	0	100	100	200	400	80
March 28	0	0	100	100	0	200	40
April 23	0	200	400	300	300	1,200	240
May 10	850	800	500	500	200	2,850	570
May 25	100	600	1,300	400	0	2,400	480
June 8	300	1,200	200	800	500	3,000	600
June 21	700	900	900	1,300	600	4,400	880
July 9	2,700	2,300	2,250	2,500	1,500	11,250	2,250
July 23	1,800	3,900	4,000	2,800	1,800	14,300	2,860
Aug. 10	700	2,400	2,000	2,200	900	8,200	1,640
Aug. 25	200	1,500	1,800	1,000	1,000	5,500	1,100
Sept. 15	1,400	2,500	2,000	1,900	600	8,400	1,680
Oct. 6	2,200	2,100	2,100	2,550	3,300	12,250	2,450

TABLE 44

SEASONAL AND VERTICAL DISTRIBUTION OF CHRYSOPHYCEAE (COMPOSED WHOLLY OF DINOBRYON) AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	65,250	135,000	125,600	104,400	18,000	448,250	89,650
July 10	21,400	31,400	36,600	10,200	6,400	106,000	21,200
July 18	1,750	1,925	1,575	1,050	350	6,650	1,330
July 25	300	750	450	0	0	1,500	300
Aug. 4	0	0	0	0	0	0	0
Aug. 14	0	0	0	0	0	0	0
Aug. 31	0	0	0	0	0	0	0
Sept.16	0	0	0	600	0	600	120
Oct. 2	0	0	0	0	0	0	0
Oct. 19	0	0	0	0	0	0	0
Nov. 14	0	0	0	600	300	900	180
Dec. 27	450	0	0	0	0	450	90
1951							
Feb. 26	100	0	0	0	0	100	20
March 28	0	0	0	0	0	0	0
April 23	200	1,600	1,400	1,400	1,100	5,700	1,140
May 10	21,250	18,000	20,300	8,700	2,800	71,050	14,210
May 25	19,800	24,300	22,200	9,300	6,500	82,100	16,420
June 8	4,200	4,500	4,700	1,400	500	15,300	3,060
June 21	800	0	1,900	0	0	2,700	540
July 9	2,500	2,200	2,750	0	0	7,450	1,490
July 23	400	0	0	0	0	400	80
Aug. 10	0	200	0	100	0	300	60
Aug. 25	300	300	0	0	0	600	120
Sept.15	200	900	0	500	0	1,600	320
Oct. 6	1,700	2,550	1,500	2,100	0	7,850	1,570

TABLE 45

SEASONAL AND VERTICAL DISTRIBUTION OF DINOPHYCEAE AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	1,250	4,400	5,400	1,200	1,000	13,250	2,650
July 10	0	3,400	5,400	6,800	1,200	16,800	3,360
July 18	3,325	4,025	3,500	3,325	875	15,050	3,010
July 25	2,400	1,800	600	450	150	5,400	1,080
Aug. 4	1,650	2,100	750	150	150	4,800	960
Aug. 14	1,800	750	1,050	600	0	4,200	840
Aug. 31	1,500	2,850	1,350	450	600	6,750	1,350
Sept. 16	600	1,650	900	750	300	4,200	840
Oct. 2	300	0	150	0	0	450	90
Oct. 19	0	450	0	0	0	450	90
Nov. 14	0	0	150	0	0	150	30
Dec. 27	0	0	0	0	0	0	0
1951							
Feb. 26	0	0	0	0	0	0	0
March 28	600	0	300	0	0	900	180
April 23	50	100	0	0	0	150	30
May 10	0	100	0	0	500	600	120
May 25	0	700	500	100	100	1,400	280
June 8	100	0	500	300	0	900	180
June 21	300	1,000	250	100	100	1,750	350
July 9	1,400	1,200	625	400	0	3,625	725
July 23	1,500	2,000	2,700	900	900	8,000	1,600
Aug. 10	1,400	3,100	900	1,300	500	7,200	1,440
Aug. 25	3,000	4,500	3,500	2,600	1,200	14,800	2,960
Sept. 15	2,400	2,100	1,700	2,000	700	8,900	1,780
Oct. 6	1,800	1,800	1,950	1,350	0	6,900	1,380

TABLE 46

SEASONAL AND VERTICAL DISTRIBUTION OF ASTERIONELLA AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	375	1,000	1,400	1,600	600	4,975	995
July 10	900	1,700	1,200	800	100	4,700	940
July 18	1,400	1,488	1,050	875	175	4,988	998
July 25	3,755	3,450	3,375	2,475	825	13,880	2,776
Aug. 4	5,325	5,475	7,275	7,350	2,400	27,825	5,565
Aug. 14	1,125	1,050	2,400	3,750	2,100	10,425	2,085
Aug. 31	600	750	1,050	750	525	3,675	735
Sept. 16	2,250	3,225	4,200	2,625	2,400	14,700	2,940
Oct. 2	9,600	15,900	12,750	12,150	10,200	60,600	12,120
Oct. 19	20,400	28,650	30,600	25,800	33,150	138,600	27,720
Nov. 14	86,250	82,950	85,800	96,450	78,150	429,600	85,920
Dec. 27	32,700	36,750	41,250	13,350	32,700	156,750	31,350
1951							
Feb. 26	150	300	400	250	350	1,450	290
March 28	200	800	1,100	350	450	2,900	580
April 23	550	650	1,200	1,400	1,300	5,100	1,020
May 10	3,810	1,050	1,500	1,700	900	8,960	1,792
May 25	2,000	1,900	2,000	2,600	1,050	9,550	1,910
June 8	300	0	1,350	150	550	2,350	470
June 21	4,150	6,850	5,600	2,650	800	20,050	4,010
July 9	14,900	17,400	16,250	18,800	15,500	82,850	16,570
July 23	1,550	1,150	1,800	1,150	650	6,300	1,260
Aug. 10	100	150	700	400	1,200	2,550	510
Aug. 25	150	0	0	0	0	150	30
Sept. 15	2,700	750	1,200	700	350	5,700	1,140
Oct. 6	45,300	45,450	54,450	48,300	38,400	231,900	46,380

TABLE 47

SEASONAL AND VERTICAL DISTRIBUTION OF FRAGILARIA AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	9,000	17,800	216,000	13,600	6,200	262,600	52,520
July 10	4,600	6,400	11,400	10,600	11,800	44,800	8,960
July 18	2,975	4,900	3,675	6,125	2,188	19,863	3,973
July 25	3,450	3,000	1,950	1,800	1,650	11,850	2,370
Aug. 4	2,175	2,100	1,350	1,350	525	7,500	1,500
Aug. 14	1,800	1,950	2,850	1,650	750	9,000	1,800
Aug. 31	2,850	3,150	5,400	1,950	1,350	14,700	2,940
Sept. 16	3,600	4,350	4,200	3,750	5,100	21,000	4,200
Oct. 2	3,900	6,600	6,750	4,500	7,050	28,800	5,760
Oct. 19	6,600	9,900	7,350	7,200	10,650	41,700	8,340
Nov. 14	6,450	8,850	6,900	8,550	7,350	38,100	7,620
Dec. 27	4,200	1,350	675	150	6,600	12,975	2,595
1951							
Feb. 26	0	0	0	0	175	175	35
March 28	0	100	200	0	0	300	60
April 23	400	850	550	1,150	1,000	3,950	790
May 10	2,870	2,450	2,750	2,500	1,700	12,270	2,454
May 25	2,700	2,700	4,400	3,300	2,750	15,850	3,170
June 8	1,300	1,600	3,300	3,600	1,750	11,550	2,310
June 21	700	1,200	1,000	500	400	3,800	760
July 9	2,850	4,100	2,250	5,300	3,050	17,550	3,510
July 23	2,300	2,900	2,200	2,200	1,500	11,100	2,220
Aug. 10	2,200	2,600	3,300	3,300	0	11,400	2,280
Aug. 25	3,300	4,200	3,600	3,500	2,100	16,700	3,340
Sept. 15	4,700	8,900	7,200	5,400	4,200	30,400	6,080
Oct. 6	12,200	14,400	12,450	13,350	17,850	70,250	14,050

TABLE 48

SEASONAL AND VERTICAL DISTRIBUTION OF *MELOSIRA* AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	8,125	11,660	20,600	12,260	4,660	57,305	11,461
July 10	2,200	5,520	7,000	7,800	6,660	29,180	5,836
July 18	4,025	4,550	4,725	3,028	700	17,028	3,406
July 25	3,795	3,300	3,450	4,650	690	15,885	3,177
Aug. 4	1,545	1,095	1,850	4,650	1,050	10,190	2,038
Aug. 14	2,100	2,100	1,800	3,900	2,550	12,450	2,490
Aug. 31	13,200	12,000	14,850	18,400	8,100	66,550	13,310
Sept. 16	22,050	26,550	28,950	22,050	14,850	114,450	22,890
Oct. 2	19,800	18,150	20,700	21,900	25,350	105,900	21,180
Oct. 19	14,400	17,550	18,300	22,800	34,350	107,400	21,580
Nov. 14	11,700	12,300	11,850	13,200	9,900	58,950	11,790
Dec. 27	0	50	150	150	6,050	6,400	1,280
1951							
Feb. 26	0	0	0	60	130	196	39
March 28	0	0	0	0	630	630	126
April 23	2,300	2,300	1,950	4,600	2,600	13,750	2,750
May 10	16,750	12,400	13,400	11,900	2,800	57,250	11,450
May 25	3,200	4,400	3,000	5,400	5,400	21,400	4,280
June 8	800	1,100	1,200	1,200	1,200	5,500	1,100
June 21	1,466	1,733	2,033	2,500	733	8,465	1,693
July 9	6,400	7,700	5,750	7,900	6,700	34,450	6,890
July 23	2,200	4,900	4,800	3,800	3,700	19,400	3,880
Aug. 10	600	3,300	3,633	5,300	4,100	16,933	3,387
Aug. 25	6,100	11,400	6,400	5,700	3,100	32,700	6,540
Sept. 15	27,300	28,500	27,100	20,300	13,400	116,600	23,320
Oct. 6	30,700	24,900	10,750	11,700	46,350	124,400	24,880

TABLE 49

SEASONAL AND VERTICAL DISTRIBUTION OF NAVICULA AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	0	0	0	0	0	0	0
July 10	0	0	0	200	0	200	40
July 18	175	350	175	175	0	875	175
July 25	0	150	0	0	0	150	30
Aug. 4	0	0	600	150	450	1,200	240
Aug. 14	0	0	0	0	0	0	0
Aug. 31	0	0	0	0	0	0	0
Sept. 16	300	300	300	450	300	1,650	330
Oct. 2	0	0	0	0	0	0	0
Oct. 19	0	150	150	0	150	450	90
Nov. 14	450	750	150	300	300	1,950	390
Dec. 27	0	0	0	0	300	300	60
1951							
Feb. 26	0	0	0	0	0	0	0
March 28	0	0	0	0	100	100	20
April 23	200	100	800	500	400	2,000	400
May 10	3,370	4,100	2,900	2,100	700	13,170	2,634
May 25	300	500	800	300	300	2,200	440
June 8	200	0	0	0	0	200	40
June 21	600	400	500	500	300	2,300	460
July 9	600	500	0	300	600	2,000	400
July 23	0	0	0	300	0	300	60
Aug. 10	0	0	0	200	0	200	40
Aug. 25	0	200	100	300	0	600	120
Sept. 15	0	0	100	300	0	400	80
Oct. 6	0	300	0	0	0	300	60

TABLE 50

SEASONAL AND VERTICAL DISTRIBUTION OF *STEPHANODISCUS* AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	0	1,400	1,600	200	800	4,000	800
July 10	1,200	1,600	1,800	2,200	1,200	8,000	1,600
July 18	875	1,225	1,575	700	0	4,375	875
July 25	150	600	900	450	300	2,400	480
Aug. 4	150	600	750	600	150	2,250	450
Aug. 14	450	300	600	900	300	2,550	510
Aug. 31	600	600	1,050	1,650	600	4,500	900
Sept. 16	750	1,800	1,800	600	2,400	7,350	1,470
Oct. 2	750	1,200	1,350	1,350	1,500	6,150	1,230
Oct. 19	300	1,800	3,900	3,450	5,100	14,550	2,910
Nov. 14	1,650	4,800	3,450	3,300	3,300	16,500	3,300
Dec. 27	150	750	1,200	1,350	2,400	5,850	1,170
1951							
Feb. 26	0	0	100	300	400	800	160
March 28	0	400	100	200	0	700	140
April 23	100	800	500	1,400	1,300	4,100	820
May 10	3,870	3,200	4,900	3,800	1,000	16,770	3,354
May 25	600	1,600	2,700	1,100	1,200	7,200	1,440
June 8	100	1,500	1,600	1,400	700	5,300	1,060
June 21	800	1,400	2,000	1,000	800	6,000	1,200
July 9	1,700	1,800	3,000	2,900	500	9,900	1,980
July 23	0	500	2,200	600	300	3,600	720
Aug. 10	1,400	700	500	600	400	3,600	720
Aug. 25	1,500	900	200	400	0	3,000	600
Sept. 15	1,900	2,000	1,700	1,400	300	7,300	1,460
Oct. 6	1,700	1,800	750	1,650	3,450	9,350	1,870

TABLE 51

SEASONAL AND VERTICAL DISTRIBUTION OF SYNEDRA AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	1,500	8,400	8,000	8,600	2,800	29,300	5,860
July 10	3,400	4,200	7,400	3,000	2,600	20,600	4,120
July 18	2,450	3,325	1,575	2,625	525	10,500	2,100
July 25	1,350	2,550	2,550	1,650	150	8,250	1,650
Aug. 4	450	900	1,350	600	300	3,600	720
Aug. 14	600	1,200	750	900	300	3,750	750
Aug. 31	750	450	1,350	1,050	150	3,750	750
Sept. 16	1,200	1,350	1,050	900	450	4,950	990
Oct. 2	1,650	4,350	4,500	3,300	2,700	16,500	3,300
Oct. 19	7,350	7,500	15,450	9,150	9,150	48,600	9,720
Nov. 14	14,400	11,100	17,250	14,250	13,050	70,050	14,010
Dec. 27	5,700	5,250	4,650	2,400	10,500	28,500	5,700
1951							
Feb. 26	300	1,300	1,800	4,500	3,700	11,600	2,120
March 28	500	3,000	3,000	4,800	4,600	15,900	3,180
April 23	8,000	9,100	9,000	11,200	8,700	46,000	9,200
May 10	26,000	31,900	25,200	24,900	8,500	116,500	23,300
May 25	17,700	21,200	33,000	17,100	9,400	98,400	19,680
June 8	1,700	2,600	2,400	2,300	6,100	15,100	3,020
June 21	3,100	3,300	3,000	2,800	1,600	13,800	2,760
July 9	11,900	18,600	16,875	10,800	6,800	64,975	12,995
July 23	6,400	10,500	15,200	10,200	9,200	51,500	10,300
Aug. 10	3,900	4,300	5,100	3,900	2,500	19,700	3,940
Aug. 25	4,000	2,000	1,000	4,300	1,500	12,800	2,560
Sept. 15	4,700	7,200	4,800	4,200	900	21,800	4,360
Oct. 6	15,900	19,200	9,900	11,700	13,350	70,050	14,010

TABLE 52

SEASONAL AND VERTICAL DISTRIBUTION OF TABELLARIA AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950 July 3	11,250	15,700	195,000	19,400	3,600	277,350	55,470
July 10	13,400	14,400	19,800	20,400	3,800	71,800	14,360
July 18	8,663	9,625	10,850	11,550	1,750	42,438	8,488
July 25	6,225	7,500	6,000	6,300	1,350	27,375	5,475
Aug. 4	1,725	2,925	2,400	1,875	450	9,375	1,875
Aug. 14	1,725	2,625	3,975	1,800	375	10,500	2,100
Aug. 31	1,425	1,875	1,950	1,950	675	7,875	1,575
Sept. 16	1,350	2,325	2,625	1,950	1,650	9,900	1,980
Oct. 2	2,100	3,525	3,450	3,600	2,100	14,775	2,955
Oct. 19	3,150	6,300	4,800	5,400	7,800	27,450	5,490
Nov. 14	5,400	8,700	7,650	6,750	7,200	35,700	7,140
Dec. 27	6,000	4,125	8,700	2,475	8,550	29,850	5,970
1951 Feb. 26	300	500	650	650	1,200	3,300	660
March 28	50	650	400	1,250	350	2,700	540
April 23	1,750	1,700	2,700	2,250	2,300	10,700	2,140
May 10	4,250	4,800	4,000	4,900	3,400	21,350	4,270
May 25	3,000	3,000	5,500	4,000	3,050	18,550	3,710
June 8	2,050	1,750	1,300	1,900	1,700	8,700	1,740
June 21	1,550	1,750	1,500	1,650	750	7,200	1,440
July 9	3,300	4,200	3,000	3,500	1,750	15,750	3,150
July 23	1,650	2,200	1,800	2,050	2,400	10,100	2,020
Aug. 10	1,500	2,000	2,150	2,800	2,350	10,800	2,160
Aug. 25	2,750	2,850	1,700	3,450	1,800	12,550	2,510
Sept. 15	3,050	1,350	2,700	2,600	1,800	11,500	2,300
Oct. 6	5,600	9,600	11,400	10,500	7,650	44,750	8,950

TABLE 53

SEASONAL AND VERTICAL DISTRIBUTION OF ANABAENA AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	3,250	460	1,460	460	0	5,630	1,126
July 10	660	660	400	0	0	1,720	344
July 18	1,050	1,103	578	228	0	2,959	592
July 25	750	600	540	200	0	2,090	418
Aug. 4	600	450	200	50	0	1,300	260
Aug. 14	390	150	450	450	50	1,490	298
Aug. 31	100	200	100	100	0	500	100
Sept. 16	0	0	0	0	0	0	0
Oct. 2	0	50	0	0	0	50	10
Oct. 19	0	0	0	0	0	0	0
Nov. 14	0	0	0	0	0	0	0
Dec. 27	0	0	0	0	0	0	0
1951							
Feb. 26	0	0	0	0	0	0	0
March 28	0	0	0	0	0	0	0
April 23	0	0	0	0	0	0	0
May 10	0	0	0	0	0	0	0
May 25	0	0	0	0	0	0	0
June 8	600	1,250	300	250	0	2,400	480
June 21	1,066	1,650	966	1,200	266	5,148	1,030
July 9	1,200	1,266	1,000	600	433	4,499	900
July 23	366	633	366	133	150	1,648	330
Aug. 10	1,500	1,033	1,166	733	266	4,698	940
Aug. 25	2,966	3,133	1,366	1,266	450	9,181	1,836
Sept. 15	266	100	433	0	0	799	160
Oct. 6	700	750	450	300	0	2,200	440

TABLE 54

SEASONAL AND VERTICAL DISTRIBUTION OF COELOSPHAERIUM AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950 July 3	0	2,000	1,000	2,400	200	5,600	1,120
July 10	2,000	600	4,400	1,200	200	8,400	1,680
July 18	2,275	1,925	1,750	1,400	0	7,350	1,470
July 25	900	1,050	900	2,250	300	5,400	1,080
Aug. 4	2,100	2,100	2,700	2,550	450	9,900	1,980
Aug. 14	1,500	3,600	1,350	1,500	450	8,400	1,680
Aug. 31	600	0	150	900	450	2,100	420
Sept. 16	450	600	1,350	1,050	450	3,900	780
Oct. 2	300	900	750	150	450	2,550	510
Oct. 19	300	750	300	300	150	1,800	360
Nov. 14	1,050	900	300	150	300	2,700	540
Dec. 27	0	0	0	0	0	0	0
1951 Feb. 26	0	0	0	0	0	0	0
March 28	0	0	0	0	0	0	0
April 23	0	0	0	0	0	0	0
May 10	875	1,200	800	300	0	3,175	635
May 25	0	0	0	0	0	0	0
June 8	600	400	900	900	400	3,200	640
June 21	500	200	300	200	400	1,600	320
July 9	1,100	800	625	300	400	3,225	645
July 23	500	1,300	1,100	400	500	3,800	760
Aug. 10	500	1,500	800	200	300	3,300	660
Aug. 25	600	1,100	700	200	100	2,700	540
Sept. 15	300	300	600	800	600	2,600	520
Oct. 6	700	900	1,500	1,650	1,200	5,950	1,190

TABLE 55

SEASONAL AND VERTICAL DISTRIBUTION OF MERISMOPEDIA AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	0	0	0	200	0	200	40
July 10	200	2	0	40	800	1,042	208
July 18	35	70	352	0	0	457	91
July 25	2	0	0	2	0	4	1
Aug. 4	15	0	38	0	0	53	11
Aug. 14	0	2	9	0	0	11	2
Aug. 31	225	75	225	15	0	540	108
Sept. 16	75	165	0	0	0	240	48
Oct. 2	0	0	0	0	0	0	0
Oct. 19	50	0	0	0	0	50	10
Nov. 14	0	0	0	0	0	0	0
Dec. 27	0	0	0	0	0	0	0
1951							
Feb. 26	0	0	50	0	0	50	10
March 28	0	0	0	0	0	0	0
April 23	0	0	0	0	0	0	0
May 10	0	0	0	0	0	0	0
May 25	0	0	0	0	0	0	0
June 8	0	0	0	0	0	0	0
June 21	0	10	0	0	0	10	2
July 9	0	0	0	0	0	0	0
July 23	300	0	0	0	0	300	60
Aug. 10	0	0	0	0	0	0	0
Aug. 25	700	0	0	200	300	1,200	240
Sept. 15	100	0	50	0	0	150	30
Oct. 6	0	0	0	0	200	200	40

TABLE 56

SEASONAL AND VERTICAL DISTRIBUTION OF MICROCYSTIS AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950 July 3	0	4,800	2,800	3,900	2,000	13,500	2,700
July 10	500	2,000	1,600	2,500	1,500	8,100	1,620
July 18	2,450	2,188	1,838	1,313	875	8,664	1,733
July 25	900	750	750	750	300	3,450	690
Aug. 4	2,025	1,350	2,025	2,250	2,250	9,900	1,980
Aug. 14	1,050	375	1,275	1,050	375	4,125	825
Aug. 31	975	1,275	1,200	1,950	1,575	6,975	1,395
Sept. 16	1,125	2,250	2,325	1,725	5,100	12,525	2,505
Oct. 2	750	1,125	2,100	2,250	2,100	8,325	1,665
Oct. 19	1,875	2,325	2,250	1,950	8,400	16,800	3,360
Nov. 14	5,100	3,825	4,725	5,850	3,900	23,400	4,680
Dec. 27	1,425	600	975	200	7,650	10,850	2,170
1951 Feb. 26	50	50	350	175	350	975	195
March 28	325	50	100	100	500	1,075	215
April 23	3,000	3,250	3,400	3,650	2,800	16,100	3,220
May 10	1,562	3,200	2,500	2,850	1,450	11,562	2,312
May 25	1,650	2,350	3,300	2,000	750	10,050	2,010
June 8	1,300	500	1,350	1,550	1,950	6,650	1,330
June 21	2,950	3,700	3,900	2,750	1,850	15,150	3,030
July 9	2,100	4,400	3,750	4,100	3,300	17,650	3,530
July 23	1,400	2,900	3,700	2,500	3,300	13,800	2,760
Aug. 10	2,100	3,650	3,100	2,900	2,750	14,500	2,900
Aug. 25	2,100	3,100	3,150	4,000	1,950	14,300	2,860
Sept. 15	2,850	6,500	4,800	5,700	2,350	22,200	4,440
Oct. 6	7,200	9,300	6,900	11,700	6,300	41,400	8,280

TABLE 57

SEASONAL AND VERTICAL DISTRIBUTION OF OSCILLATORIA AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	0	0	0	0	0	0	0
July 10	0	0	0	0	0	0	0
July 18	0	0	0	0	0	0	0
July 25	0	0	0	0	0	0	0
Aug. 4	0	0	0	0	0	0	0
Aug. 14	0	0	0	0	0	0	0
Aug. 31	150	150	0	0	300	600	120
Sept. 16	0	0	0	0	0	0	0
Oct. 2	0	0	0	0	0	0	0
Oct. 19	0	0	0	0	0	0	0
Nov. 14	0	0	0	0	0	0	0
Dec. 27	0	0	0	0	0	0	0
1951							
Feb. 26	0	0	0	0	0	0	0
March 28	0	0	0	0	0	0	0
April 23	0	0	0	0	0	0	0
May 10	0	0	0	0	0	0	0
May 25	0	0	0	0	0	0	0
June 8	0	0	0	0	0	0	0
June 21	0	0	100	0	100	200	40
July 9	0	0	0	0	0	0	0
July 23	133	0	0	0	0	133	27
Aug. 10	0	0	0	0	0	0	0
Aug. 25	0	0	0	0	0	0	0
Sept. 15	0	0	0	0	0	0	0
Oct. 6	0	0	0	0	0	0	0

TABLE 58

SEASONAL AND VERTICAL DISTRIBUTION OF ARTHRODESMUS AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	0	0	0	0	0	0	0
July 10	0	0	0	0	0	0	0
July 18	0	0	0	0	0	0	0
July 25	0	0	0	0	0	0	0
Aug. 4	0	0	0	0	0	0	0
Aug. 14	0	0	0	0	0	0	0
Sept. 16	0	0	0	0	0	0	0
Oct. 2	0	0	0	0	0	0	0
Oct. 19	0	0	0	0	0	0	0
Nov. 14	0	0	0	0	0	0	0
Dec. 27	0	0	0	0	0	0	0
1951							
Feb. 26	0	0	0	0	0	0	0
March 28	0	0	0	100	0	100	20
April 23	0	0	0	0	0	0	0
May 10	0	0	0	0	0	0	0
May 25	0	0	0	0	0	0	0
June 8	0	0	0	0	0	0	0
June 21	0	0	0	0	0	0	0
July 9	0	0	0	0	0	0	0
July 23	0	0	0	0	0	0	0
Aug. 10	0	0	0	0	0	0	0
Aug. 25	0	0	0	0	0	0	0
Sept. 15	0	0	0	0	0	0	0
Oct. 6	0	600	150	0	0	750	150

TABLE 59

SEASONAL AND VERTICAL DISTRIBUTION OF COSMARIUM AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	0	0	0	0	0	0	0
July 10	0	0	0	0	0	0	0
July 18	0	0	0	0	0	0	0
July 25	0	0	0	0	0	0	0
Aug. 4	0	0	0	0	0	0	0
Aug. 14	0	0	0	0	0	0	0
Aug. 31	0	0	0	0	150	150	30
Sept. 16	0	0	0	0	0	0	0
Oct. 2	0	0	150	0	0	150	30
Oct. 19	150	300	0	150	0	600	120
Nov. 14	150	0	150	150	150	600	120
Dec. 27	0	0	0	0	0	0	0
1951							
Feb. 26	0	0	0	0	0	0	0
March 28	0	0	0	0	0	0	0
April 23	0	0	100	0	0	100	20
May 10	600	800	500	500	200	2,600	520
May 25	0	0	100	0	0	100	20
June 8	100	0	0	0	0	100	20
June 21	0	0	0	100	0	100	20
July 9	500	100	0	0	0	600	120
July 23	0	0	200	0	0	200	40
Aug. 10	0	0	500	0	0	500	100
Aug. 25	0	0	0	0	0	0	0
Sept. 15	0	0	0	0	0	0	0
Oct. 6	0	0	300	450	0	750	150

TABLE 60

SEASONAL AND VERTICAL DISTRIBUTION OF PEDIASTRUM AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	0	200	800	1,200	800	3,000	600
July 10	200	200	600	800	300	2,100	420
July 18	175	175	0	350	0	700	140
July 25	150	150	150	0	0	450	90
Aug. 4	0	300	300	450	150	1,200	240
Aug. 14	0	150	150	0	150	450	90
Aug. 31	0	150	0	600	300	1,050	210
Sept. 16	150	0	300	600	0	1,050	210
Oct. 2	450	300	300	150	150	1,350	270
Oct. 19	375	600	300	600	450	2,325	465
Nov. 14	450	900	150	750	750	3,000	600
Dec. 27	0	0	150	0	150	300	60
1951							
Feb. 26	0	0	0	100	200	300	60
March 28	0	0	100	0	0	100	20
April 23	0	200	300	200	100	800	160
May 10	0	0	0	0	0	0	0
May 25	100	600	300	400	0	1,400	280
June 8	0	500	0	600	500	1,600	320
June 21	300	200	500	200	300	1,500	300
July 9	200	300	0	400	500	1,400	280
July 23	0	0	400	300	0	700	140
Aug. 10	0	200	200	400	0	800	160
Aug. 25	200	0	300	300	300	1,100	220
Sept. 15	200	1,100	500	400	100	2,300	460
Oct. 6	0	0	300	450	450	1,200	240

TABLE 61

SEASONAL AND VERTICAL DISTRIBUTION OF SCENEDESMUS AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	0	100	0	0	0	100	20
July 10	0	0	0	0	0	0	0
July 18	0	0	0	0	0	0	0
July 25	0	0	0	0	0	0	0
Aug. 4	0	0	0	0	0	0	0
Aug. 14	0	0	0	0	0	0	0
Aug. 31	150	0	0	0	0	150	30
Sept. 16	0	0	0	0	0	0	0
Oct. 2	0	0	0	0	0	0	0
Oct. 19	0	0	0	0	0	0	0
Nov. 14	0	0	0	150	0	150	30
Dec. 27	0	0	0	0	0	0	0
1951							
Feb. 26	0	0	0	0	0	0	0
March 28	0	0	0	0	0	0	0
April 23	0	0	0	0	0	0	0
May 10	0	0	0	0	0	0	0
May 25	0	0	0	0	0	0	0
June 8	0	0	0	0	0	0	0
June 21	0	0	0	0	0	0	0
July 9	0	0	125	0	100	225	45
July 23	0	0	0	100	0	100	20
Aug. 10	0	0	0	0	0	0	0
Aug. 25	0	0	0	0	0	0	0
Sept. 15	0	0	100	0	0	100	20
Oct. 6	0	0	0	300	0	300	60

TABLE 62

SEASONAL AND VERTICAL DISTRIBUTION OF STAURASTRUM AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	500	1,200	1,000	1,000	400	4,100	8,020
July 10	1,800	1,800	1,000	1,400	1,000	7,000	1,400
July 18	1,750	2,275	1,050	2,800	0	7,875	1,575
July 25	2,100	1,800	1,650	1,650	450	7,650	1,530
Aug. 4	750	1,950	1,800	2,250	1,050	7,800	1,562
Aug. 14	1,200	1,950	900	1,050	450	5,550	1,110
Aug. 31	150	600	600	1,200	150	2,700	540
Sept. 16	150	1,350	900	600	300	3,300	660
Oct. 2	150	300	300	600	300	1,650	330
Oct. 19	300	450	150	600	450	1,950	390
Nov. 14	0	0	150	0	300	450	90
Dec. 27	0	0	150	150	0	300	60
1951							
Feb. 26	0	0	100	0	0	100	20
March 28	0	0	0	0	0	0	0
April 23	0	0	0	100	200	300	60
May 10	250	0	0	0	0	250	50
May 25	0	0	900	0	0	900	180
June 8	200	700	200	200	0	1,300	260
June 21	400	700	400	1,000	300	2,800	560
July 9	2,000	1,900	2,125	2,100	900	9,025	1,805
July 23	1,800	3,900	3,400	2,400	1,800	13,300	2,660
Aug. 10	700	2,200	1,300	1,800	900	6,900	1,380
Aug. 25	0	1,500	1,500	700	700	4,400	880
Sept. 15	1,200	1,400	1,400	1,500	500	6,000	1,200
Oct. 6	2,200	1,500	1,350	1,350	2,850	9,250	1,850

TABLE 63

SEASONAL AND VERTICAL DISTRIBUTION OF CERATIUM AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	1,250	4,400	5,400	1,200	1,000	13,250	2,650
July 10	0	3,400	5,400	6,800	1,200	16,800	3,360
July 18	3,325	4,025	3,500	3,325	875	15,050	3,010
July 25	2,400	1,800	600	450	150	5,400	1,080
Aug. 4	1,650	2,100	750	150	150	4,800	960
Aug. 14	1,500	600	1,050	600	0	3,750	750
Aug. 31	1,500	2,850	1,350	450	450	6,600	1,320
Sept. 16	600	1,650	750	600	300	3,900	780
Oct. 2	300	0	150	0	0	450	90
Oct. 19	0	450	0	0	0	450	90
Nov. 14	0	0	0	0	0	0	0
Dec. 27	0	0	0	0	0	0	0
1951							
Feb. 26	0	0	0	0	0	0	0
March 28	0	0	100	0	0	100	20
April 23	0	0	0	0	0	0	0
May 10	0	100	0	0	0	100	20
May 25	0	200	0	0	100	300	60
June 8	100	0	500	0	0	600	120
June 21	300	1,000	150	0	0	1,450	290
July 9	1,400	1,200	625	400	0	3,625	725
July 23	1,400	1,700	2,700	900	900	7,600	1,520
Aug. 10	1,400	3,100	900	1,300	500	7,200	1,440
Aug. 25	2,300	4,500	3,400	2,600	1,200	14,000	2,800
Sept. 15	2,400	2,100	1,600	2,000	700	8,800	1,760
Oct. 6	1,800	1,650	1,800	1,050	0	6,300	1,260

TABLE 64

SEASONAL AND VERTICAL DISTRIBUTION OF PERIDINIUM AT VARIOUS DEPTHS FROM JULY, 1950, THROUGH OCTOBER, 1951

DOUGLAS LAKE

Depth Meters	0	2	5	12	20		
Dates	Count in units per liter					Total	Mean
1950							
July 3	0	0	0	0	0	0	0
July 10	0	0	0	0	0	0	0
July 18	0	0	0	0	0	0	0
July 25	0	0	0	0	0	0	0
Aug. 4	0	0	0	0	0	0	0
Aug. 14	300	150	0	0	0	450	90
Aug. 31	0	0	0	0	150	150	30
Sept. 16	0	0	150	150	0	300	60
Oct. 2	0	0	0	0	0	0	0
Oct. 19	0	0	0	0	0	0	0
Nov. 14	0	0	150	0	0	150	30
Dec. 27	0	0	0	0	0	0	0
1951							
Feb. 26	0	0	0	0	0	0	0
March 28	600	0	200	0	0	800	160
April 23	50	100	0	0	0	150	30
May 10	0	0	0	0	500	500	100
May 25	0	500	500	100	0	1,100	220
June 8	0	0	0	300	0	300	60
June 21	0	0	100	100	100	300	60
July 9	0	0	0	0	0	0	0
July 23	100	300	0	0	0	400	80
Aug. 10	0	0	0	0	0	0	0
Aug. 25	700	0	100	0	0	800	160
Sept. 15	0	0	100	0	0	100	20
Oct. 6	0	150	150	300	0	600	120

TABLE 65

ABUNDANCE OF TOTAL PHYTOPLANKTON IN LANCASTER LAKE AT VARIOUS DEPTHS DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	2,500	6,100	1,825	630	11,055	2,764
July 12	500	16,855	11,820	1,265	30,440	7,610
July 19	10,750	4,600	1,975	1,350	18,675	4,669
July 26	3,700	3,450	1,700	1,300	10,150	2,538
Aug. 2	12,375	12,525	2,950	750	28,600	7,150
1950 July 20	30,365	111,800	20,450	8,550	171,165	42,791
Aug. 8	12,300	14,900	7,725	5,550	40,475	10,119
1951 July 20	28,350	34,800	12,150	5,550	80,850	20,213
Aug. 16	49,535	58,385	9,000	6,820	123,740	30,935

TABLE 66

COMPOSITION* OF PHYTOPLANKTON IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Diatoms	Chryso-phyceae	Dino-phyceae	Blue-green algae	Green algae	Total
Dates						
1948 July 6	206	1,664	50	844	0	2,764
July 12	396	6,575	163	476	0	7,610
July 19	913	2,738	700	319	0	4,670
July 26	919	331	725	538	25	2,538
Aug. 2	1,644	4,406	625	438	38	7,151
1950 July 20	37,650	3,185	363	1,556	38	42,792
Aug. 8	2,375	5,644	200	1,863	38	10,120
1951 July 20	7,275	11,338	475	1,100	25	20,213
Aug. 16	2,463	25,538	1,700	1,235	0	30,936

*Each value represents the mean of the counts in units per liter of the vertical series of samples collected on a particular day

TABLE 67

PERCENTAGE COMPOSITION OF PHYTOPLANKTON IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Diatoms	Chryso-phyceae	Dino-phyceae	Blue-green algae	Green algae
Dates		Count in units per liter			
1948 July 6	7.5	60.2	1.8	30.5	0
July 12	5.2	86.4	2.1	6.3	0
July 19	19.6	58.6	15.0	6.8	0
July 26	36.2	13.0	28.6	21.2	1.0
Aug. 2	23.0	61.6	8.7	6.1	0.5
1950 July 20	88.0	7.4	0.8	3.6	0.1
Aug. 8	23.5	55.8	2.0	18.4	0.4
1951 July 20	36.0	56.1	2.3	5.4	0.1
Aug. 16	8.0	82.6	5.5	4.0	0
Mean	27.4	53.5	7.4	11.4	0.3
Extremes Max.	88.0	86.4	28.6	30.5	1.0
Extremes Min.	5.2	7.4	0.8	3.6	0

TABLE 68

ABUNDANCE OF DIATOMS IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Depth Meters	0	3	6	15		
	Dates	Count in units per liter				Total	Mean
1948	July 6	100	700	25	0	825	206
	July 12	100	635	850	0	1,585	396
	July 19	1,900	1,300	250	200	3,650	913
	July 26	1,300	1,375	850	150	3,675	919
	Aug. 2	2,700	2,250	1,275	350	6,575	1,644
1950	July 20	21,750	103,900	18,875	6,075	150,600	37,650
	Aug. 8	2,100	1,400	2,100	3,900	9,500	2,375
1951	July 20	13,750	8,450	5,050	1,850	29,100	7,275
	Aug. 16	2,100	3,300	2,450	2,000	9,850	2,463

TABLE 69

ABUNDANCE OF BLUE-GREEN ALGAE IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Depth Meters	0	3	6	15		
	Dates	Count in units per liter				Total	Mean
1948	July 6	2,400	500	400	75	3,375	844
	July 12	250	170	1,370	115	1,905	476
	July 19	150	700	275	150	1,275	319
	July 26	500	250	450	950	2,150	538
	Aug. 2	475	875	175	225	1,750	438
1950	July 20	675	2,700	1,125	1,725	6,225	1,556
	Aug. 8	2,100	1,300	2,925	1,125	7,450	1,863
1951	July 20	1,300	1,350	1,000	750	4,400	1,100
	Aug. 16	935	1,585	1,250	1,170	4,940	1,235

TABLE 70

ABUNDANCE OF GREEN ALGAE IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	0	0	0	0	0
July 12	0	0	0	0	0	0
July 19	0	0	0	0	0	0
July 26	100	0	0	0	100	25
Aug. 2	0	0	150	0	150	38
1950 July 20	0	0	150	0	150	38
Aug. 8	150	0	0	0	150	38
1951 July 20	0	100	0	0	100	25
Aug. 16	0	0	0	0	0	0

TABLE 71

ABUNDANCE OF CHRYSOPHYCEAE IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1950

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	4,900	1,200	555	6,655	1,664
July 12	100	15,750	9,500	950	26,300	6,575
July 19	7,600	1,000	1,350	1,000	10,950	2,738
July 26	700	325	200	100	1,325	331
Aug. 2	8,100	8,500	950	75	17,625	4,406
1950 July 20	7,340	4,800	300	300	12,740	3,185
Aug. 8	7,650	12,000	2,400	525	22,575	5,644
1951 July 20	11,900	24,600	5,900	2,950	45,350	11,338
Aug. 16	44,300	50,100	4,600	3,150	102,150	25,538

TABLE 72

ABUNDANCE OF DINOPHYCEAE IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	0	200	0	200	50
July 12	50	300	100	200	650	163
July 19	1,100	1,600	100	0	2,800	700
July 26	1,100	1,500	200	100	2,900	725
Aug. 2	1,100	900	400	100	2,500	625
1950 July 20	600	400	0	450	1,450	363
Aug. 8	300	200	300	0	800	200
1951 July 20	1,400	300	200	0	1,900	475
Aug. 16	2,200	3,400	700	500	6,800	1,700

TABLE 73

ABUNDANCE OF ASTERIONELLA IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	0	25	0	25	6
July 12	0	0	0	0	0	0
July 19	0	0	0	0	0	0
July 26	0	0	0	0	0	0
Aug. 2	0	0	25	0	25	6
1950 July 20	6,900	9,400	1,725	525	18,550	4,638
Aug. 8	150	200	1,500	450	2,300	575
1951 July 20	12,600	7,350	4,700	1,450	26,100	6,525
Aug. 16	200	0	950	350	1,500	375

TABLE 74

ABUNDANCE OF *FRAGILARIA* IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Depth Meters	0	3	6	15		
	Dates	Count in units per liter				Total	Mean
1948	July 6	0	500	0	0	500	125
	July 12	0	335	650	0	985	246
	July 19	1,800	900	250	100	3,050	763
	July 26	1,100	1,275	750	150	3,275	819
	Aug. 2	2,400	2,250	1,100	350	6,100	1,525
1950	July 20	13,950	90,200	16,200	4,800	125,150	31,288
	Aug. 8	1,050	1,000	450	3,075	5,575	1,394
1951	July 20	850	900	350	200	2,300	575
	Aug. 16	1,900	2,700	1,500	1,550	7,650	1,913

TABLE 75

ABUNDANCE OF *MELOSIRA* IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Depth Meters	0	3	6	15		
	Dates	Count in units per liter				Total	Mean
1948	July 6	0	0	0	0	0	0
	July 12	0	0	0	0	0	0
	July 19	0	0	0	0	0	0
	July 26	0	0	0	0	0	0
	Aug. 2	0	0	0	0	0	0
1950	July 20	0	100	50	0	150	38
	Aug. 8	0	0	0	0	0	0
1951	July 20	0	0	0	0	0	0
	Aug. 16	0	0	0	0	0	0

TABLE 76

ABUNDANCE OF NAVICULA IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	0	0	0	0	0
July 12	0	0	0	0	0	0
July 19	0	0	0	0	0	0
July 26	0	0	0	0	0	0
Aug. 2	0	0	0	0	0	0
1950 July 20	150	0	150	0	300	75
Aug. 8	0	0	0	0	0	0
1951 July 20	0	0	0	100	100	25
Aug. 16	0	0	0	0	0	0

TABLE 77

ABUNDANCE OF STEPHANODISCUS IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	200	0	0	200	50
July 12	100	300	200	0	600	150
July 19	100	300	0	100	500	125
July 26	100	0	0	0	100	25
Aug. 2	200	0	100	0	300	75
1950 July 20	150	2,200	450	300	3,100	775
Aug. 8	750	200	0	0	950	238
1951 July 20	0	0	0	0	0	0
Aug. 16	0	300	0	100	400	100

TABLE 78

ABUNDANCE OF SYNEDRA IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	100	0	0	0	100	25
July 12	0	0	0	0	0	0
July 19	0	100	0	0	100	25
July 26	100	100	100	0	300	75
Aug. 2	100	0	0	0	100	25
1950 July 20	600	2,000	300	450	3,350	838
Aug. 8	150	0	150	0	300	75
1951 July 20	300	200	0	100	600	150
Aug. 16	0	300	0	0	300	75

TABLE 79

ABUNDANCE OF TABELLARIA IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	0	0	0	0	0
July 12	0	0	0	0	0	0
July 19	0	0	0	0	0	0
July 26	0	0	0	0	0	0
Aug. 2	0	0	50	0	50	13
1950 July 20	0	0	0	0	0	0
Aug. 8	0	0	0	375	375	94
1951 July 20	0	0	0	0	0	0
Aug. 16	0	0	0	0	0	0

TABLE 80

ABUNDANCE OF *ANABAENA* IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	100	0	0	100	25
July 12	100	100	70	40	310	78
July 19	0	400	0	0	400	100
July 26	50	0	100	0	150	38
Aug. 2	175	675	175	0	1,025	256
1950 July 20	150	0	0	0	150	38
Aug. 8	450	0	0	0	450	113
1951 July 20	0	0	0	0	0	0
Aug. 16	335	735	100	170	1,340	335

TABLE 81

ABUNDANCE OF *CHROOCOCCUS* IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	0	0	0	0	0
July 12	0	0	0	0	0	0
July 19	0	0	0	0	0	0
July 26	0	0	0	0	0	0
Aug. 2	0	0	0	0	0	0
1950 July 20	0	800	0	0	800	200
Aug. 8	1,200	400	750	300	2,650	663
1951 July 20	100	300	0	0	400	100
Aug. 16	0	500	200	0	700	175

TABLE 82

ABUNDANCE OF COELOSPHAERIUM IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	0	0	0	0	0
July 12	0	0	0	0	0	0
July 19	0	0	0	0	0	0
July 26	0	0	0	0	0	0
Aug. 2	0	0	0	0	0	0
1950 July 20	0	0	0	0	0	0
Aug. 8	0	0	0	0	0	0
1951 July 20	0	0	0	0	0	0
Aug. 16	0	0	200	0	200	50

TABLE 83

ABUNDANCE OF MICROCYSTIS IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	2,400	400	400	75	3,275	819
July 12	150	70	1,300	75	1,595	399
July 19	150	300	275	150	875	219
July 26	450	250	350	950	2,000	500
Aug. 2	300	200	0	225	725	181
1950 July 20	525	1,900	1,125	1,725	5,275	1,319
Aug. 8	450	900	2,175	825	4,350	1,088
1951 July 20	1,200	1,050	1,000	750	4,000	1,000
Aug. 16	600	350	950	1,000	2,900	725

TABLE 84

ABUNDANCE OF ARTHRODESMUS IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Depth Meters	0	3	6	15		
	Dates	Count in units per liter				Total	Mean
1948	July 6	0	0	0	0	0	0
	July 12	0	0	0	0	0	0
	July 19	0	0	0	0	0	0
	July 26	100	0	0	0	100	25
	Aug. 2	0	0	0	0	0	0
1950	July 20	0	0	0	0	0	0
	Aug. 8	0	0	0	0	0	0
1951	July 20	0	0	0	0	0	0
	Aug. 16	0	0	0	0	0	0

TABLE 85

ABUNDANCE OF COSMARIUM IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Depth Meters	0	3	6	15		
	Dates	Count in units per liter				Total	Mean
1948	July 6	0	0	0	0	0	0
	July 12	0	0	0	0	0	0
	July 19	0	0	0	0	0	0
	July 26	0	0	0	0	0	0
	Aug. 2	0	0	0	0	0	0
1950	July 20	0	0	150	0	150	38
	Aug. 8	150	0	0	0	150	38
1951	July 20	0	0	0	0	0	0
	Aug. 16	0	0	0	0	0	0

TABLE 86

ABUNDANCE OF EUDORINA IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	0	0	0	0	0
July 12	0	0	0	0	0	0
July 19	0	0	0	0	0	0
July 26	0	0	0	0	0	0
Aug. 2	0	0	0	0	0	0
1950 July 20	0	0	0	0	0	0
Aug. 8	0	0	0	0	0	0
1951 July 20	0	100	0	0	100	25
Aug. 16	0	0	0	0	0	0

TABLE 87

ABUNDANCE OF PEDIASTRUM IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	0	0	0	0	0
July 12	0	0	0	0	0	0
July 19	0	0	0	0	0	0
July 26	0	0	0	0	0	0
Aug. 2	0	0	150	0	150	38
1950 July 20	0	0	0	0	0	0
Aug. 8	0	0	0	0	0	0
1951 July 20	0	0	0	0	0	0
Aug. 16	0	0	0	0	0	0

TABLE 88

ABUNDANCE OF DINOBRYON IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	900	200	80	1,180	295
July 12	100	600	700	100	1,500	375
July 19	100	200	100	0	400	100
July 26	300	200	100	0	600	150
Aug. 2	2,700	2,600	200	0	5,500	1,375
1950 July 20	5,840	3,000	300	150	9,290	2,323
Aug. 8	4,950	800	150	0	5,900	1,475
1951 July 20	11,900	24,600	5,600	2,800	44,900	11,225
Aug. 16	34,500	20,500	1,200	0	56,200	14,050

TABLE 89

ABUNDANCE OF SYNURA IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	4,000	1,000	475	5,475	1,369
July 12	0	15,150	8,800	850	24,800	6,200
July 19	7,500	800	1,250	1,000	10,550	2,638
July 26	400	125	100	100	725	181
Aug. 2	5,400	5,900	750	75	12,125	3,031
1950 July 20	1,500	1,800	0	150	3,450	863
Aug. 8	2,700	11,200	2,250	525	16,675	4,169
1951 July 20	0	0	300	150	450	113
Aug. 16	9,800	29,600	3,400	3,150	45,950	11,488

TABLE 90

ABUNDANCE OF CERATIUM IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	0	200	0	200	50
July 12	50	300	100	200	650	163
July 19	1,000	1,600	100	0	2,700	675
July 26	1,000	1,500	200	100	2,800	700
Aug. 2	900	900	400	100	2,300	575
1950 July 20	600	0	0	300	900	225
Aug. 8	300	200	150	0	650	163
1951 July 20	1,400	300	200	0	1,900	475
Aug. 16	0	3,100	300	300	3,700	925

TABLE 91

ABUNDANCE OF PERIDINIUM IN LANCASTER LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	3	6	15		
Dates	Count in units per liter				Total	Mean
1948 July 6	0	0	0	0	0	0
July 12	0	0	0	0	0	0
July 19	100	0	0	0	100	25
July 26	100	0	0	0	100	25
Aug. 2	200	0	0	0	200	50
1950 July 20	0	400	0	150	550	138
Aug. 8	0	0	150	0	150	38
1951 July 20	0	0	0	0	0	0
Aug. 16	2,200	300	400	200	3,100	775

TABLE 92

ABUNDANCE OF TOTAL PHYTOPLANKTON IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Depth Meters	0	2		
	Dates	Count in units per liter		Total	Mean
1948	July 3	3,712	4,300	8,012	4,006
	July 10	2,383	2,715	5,098	2,549
	July 24	2,000	28,650	30,650	15,325
	July 31	7,500	12,917	20,417	10,209
	Aug. 12	6,190	6,625	12,815	6,408
1950	July 27	21,940	26,280	48,220	24,110
	Aug. 15	36,000	38,705	74,705	37,353
1951	July 18	18,766	32,766	51,532	25,766
	Aug. 15	96,900	68,833	165,733	82,867

TABLE 93

COMPOSITION* OF PHYTOPLANKTON IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Diatoms	Blue-green algae	Green algae	Dino-phyceae	Chryso-phyceae	Total
Dates						
1948 July 3	356	1,300	0	50	2,300	4,006
July 10	50	1,449	0	250	800	2,549
July 24	2,475	12,100	0	525	225	15,325
July 31	2,275	7,134	0	700	100	10,209
Aug. 12	1,443	3,690	350	750	175	6,408
1950 July 27	14,108	5,133	150	475	4,245	24,111
Aug. 15	2,725	27,203	975	2,850	3,600	37,353
1951 July 18	3,375	21,841	100	50	400	25,766
Aug. 15	34,875	42,967	0	525	4,500	82,867

* Each value represents the mean of the counts in units per liter of the vertical series of samples collected on a particular day.

TABLE 94

PERCENTAGE COMPOSITION OF PHYTOPLANKTON IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Diatoms	Blue-green algae	Green algae	Dino-phyceae	Chryso-phyceae
Dates		Count in units per liter			
1948 July 3	8.9	32.5	0	1.2	57.4
July 10	2.0	56.8	0	9.8	31.4
July 24	16.2	79.0	0	3.4	1.5
July 31	22.3	69.9	0	6.9	1.0
Aug. 12	22.5	57.6	5.5	11.7	2.7
1950 July 27	58.5	21.3	0.6	2.0	17.6
Aug. 15	7.3	72.8	2.6	7.6	9.6
1951 July 18	13.1	84.8	0.4	0.2	1.6
Aug. 15	42.1	51.9	0	0.6	5.4
Mean	21.4	58.5	1.0	4.8	14.4
Extremes Max.	58.5	79.0	5.5	11.7	57.4
Extremes Min.	2.0	21.3	0	0.2	1.0

TABLE 95

ABUNDANCE OF DIATOMS IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	212	500	712	356
July 10	100	0	100	50
July 24	300	4,650	4,950	2,475
July 31	2,050	2,500	4,550	2,275
Aug. 12	1,625	1,260	2,885	1,443
1950 July 27	9,300	18,915	28,215	14,108
Aug. 15	2,850	2,600	5,450	2,725
1951 July 18	3,250	3,500	6,750	3,375
Aug. 15	39,150	30,600	69,750	34,875

TABLE 96

ABUNDANCE OF BLUE-GREEN ALGAE IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	1,500	1,100	2,600	1,300
July 10	1,683	1,215	2,898	1,449
July 24	1,400	22,800	24,200	12,100
July 31	4,550	9,717	14,267	7,134
Aug. 12	3,365	4,015	7,380	3,690
1950 July 27	4,640	5,625	10,265	5,133
Aug. 15	25,950	28,455	54,405	27,203
1951 July 18	15,216	28,466	43,682	21,841
Aug. 15	52,500	33,433	85,933	42,967

TABLE 97

ABUNDANCE OF GREEN ALGAE IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	350	350	700	350
1950 July 27	0	300	300	150
Aug. 15	900	1,050	1,950	975
1951 July 18	0	200	200	100
Aug. 15	0	0	0	0

TABLE 98

ABUNDANCE OF CHRYSOPHYCEAE (COMPOSED WHOLLY OF DINOBRYON IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	2,000	2,600	4,600	2,300
July 10	200	1,400	1,600	800
July 24	0	450	450	225
July 31	100	100	200	100
Aug. 12	150	200	350	175
1950 July 27	7,200	1,290	8,490	4,245
Aug. 15	3,600	3,600	7,200	3,600
1951 July 18	300	500	800	400
Aug. 15	4,500	4,500	9,000	4,500

[redacted]

TABLE 101

ABUNDANCE OF FRAGILARIA IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	25	10	35	18
1950 July 27	0	15	15	8
Aug. 15	0	0	0	0
1951 July 18	0	0	0	0
Aug. 15	0	0	0	0

TABLE 102

ABUNDANCE OF MELOSIRA IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	200	200	100
July 10	0	0	0	0
July 24	100	0	100	50
July 31	300	0	300	150
Aug. 12	200	0	200	100
1950 July 27	0	0	0	0
Aug. 15	150	50	200	100
1951 July 18	300	200	500	250
Aug. 15	0	0	0	0

TABLE 103

ABUNDANCE OF NAVICULA IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	100	100	200	100
July 10	0	0	0	0
July 24	100	4,500	4,600	2,300
July 31	700	1,800	2,500	1,250
Aug. 12	600	400	1,000	500
1950 July 27	400	900	1,300	650
Aug. 15	1,350	1,800	3,150	1,575
1951 July 18	500	600	1,100	550
Aug. 15	1,950	900	2,850	1,425

TABLE 104

ABUNDANCE OF STEPHANODISCUS IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	600	300	900	450
Aug. 12	400	300	700	350
1950 July 27	400	750	1,150	575
Aug. 15	750	0	750	375
1951 July 18	200	100	300	150
Aug. 15	450	900	1,350	675

TABLE 105

ABUNDANCE OF SYNEDRA IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	100	200	300	150
July 10	100	0	100	50
July 24	100	150	250	125
July 31	300	300	600	300
Aug. 12	200	300	500	250
1950 July 27	8,000	17,250	25,250	12,625
Aug. 15	600	750	1,350	675
1951 July 18	1,900	2,500	4,400	2,200
Aug. 15	36,750	28,800	65,550	32,775

TABLE 106

ABUNDANCE OF TABELLARIA IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	12	0	12	6
July 10	0	0	0	0
July 24	0	0	0	0
July 31	150	100	250	125
Aug. 12	100	100	200	100
1950 July 27	500	0	500	250
Aug. 15	0	0	0	0
1951 July 18	0	0	0	0
Aug. 15	0	0	0	0

TABLE 107

ABUNDANCE OF ANABAENA IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	100	100	200	100
July 10	33	15	48	24
July 24	0	600	600	300
July 31	200	367	567	284
Aug. 12	350	200	550	275
1950 July 27	200	450	650	325
Aug. 15	1,200	1,350	2,550	1,275
1951 July 18	216	166	382	191
Aug. 15	450	333	783	392

TABLE 108

ABUNDANCE OF APHANIZOMENON IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	0	20	20	10
1950 July 27	20	0	20	10
Aug. 15	0	0	0	0
1951 July 18	0	0	0	0
Aug. 15	0	0	0	0

TABLE 109

ABUNDANCE OF CHROOCOCCUS IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	150	350	500	250
Aug. 12	100	100	200	100
1950 July 27	0	0	0	0
Aug. 15	19,500	20,100	39,600	19,800
1951 July 18	1,400	7,500	8,900	4,450
Aug. 15	1,050	900	1,950	975

TABLE 110

ABUNDANCE OF MERISMOPEDIA IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	15	15	30	15
1950 July 27	20	0	20	10
Aug. 15	0	30	30	15
1951 July 18	0	0	0	0
Aug. 15	0	0	0	0

TABLE 111

ABUNDANCE OF MICROCYSTIS IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	1,400	1,000	2,400	1,200
July 10	1,650	1,200	2,850	1,425
July 24	1,400	22,200	23,600	11,800
July 31	4,200	9,000	13,200	6,600
Aug. 12	3,000	3,600	6,600	3,300
1950 July 27	4,400	5,175	9,575	4,788
Aug. 15	5,250	6,975	12,225	6,113
1951 July 18	13,600	20,800	34,400	17,200
Aug. 15	51,000	32,200	83,200	41,600

TABLE 112

ABUNDANCE OF EUDORINA IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	0	0	0	0
1950 July 27	0	0	0	0
Aug. 15	600	750	1,350	675
1951 July 18	0	0	0	0
Aug. 15	0	0	0	0

TABLE 113

ABUNDANCE OF PEDIASTRUM IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	150	150	300	150
1950 July 27	0	150	150	75
Aug. 15	150	150	300	150
1951 July 18	0	0	0	0
Aug. 15	0	0	0	0

TABLE 114

ABUNDANCE OF SCENEDESMUS IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	100	100	200	100
1950 July 27	0	150	150	75
Aug. 15	150	150	300	150
1951 July 18	0	100	100	50
Aug. 15	0	0	0	0

TABLE 115

ABUNDANCE OF STAURASTRUM IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	100	100	200	100
1950 July 27	0	0	0	0
Aug. 15	0	0	0	0
1951 July 18	0	100	100	50
Aug. 15	0	0	0	0

TABLE 116

ABUNDANCE OF CERATIUM IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	100	100	50
July 10	400	100	500	250
July 24	300	750	1,050	525
July 31	800	600	1,400	700
Aug. 12	600	700	1,300	650
1950 July 27	800	150	950	475
Aug. 15	2,700	3,000	5,700	2,850
1951 July 18	0	0	0	0
Aug. 15	600	200	800	400

TABLE 117

ABUNDANCE OF PERIDINIUM IN MUNRO LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	8		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	100	100	200	100
1950 July 27	0	0	0	0
Aug. 15	0	0	0	0
1951 July 18	0	100	100	50
Aug. 15	150	100	250	125

TABLE 118

ABUNDANCE OF TOTAL PHYTOPLANKTON IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Depth Meters	0	2.5		
Dates		Count in units per liter		Total	Mean
1948	July 3	36,550	33,550	70,100	35,050
	July 10	24,800	28,210	53,010	26,505
	July 24	14,550	30,675	45,225	22,613
	July 31	27,250	33,600	60,850	30,425
	Aug. 12	41,010	43,980	84,990	42,495
1950	July 28	45,500	52,250	97,750	48,875
	Aug. 17	26,700	44,250	70,950	35,475
1951	July 18	42,835	42,290	85,125	42,563
	Aug. 16	47,300	34,900	82,200	41,100

TABLE 119

COMPOSITION* OF PHYTOPLANKTON IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Diatoms	Blue-green algae	Green algae	Dino-phyceae	Chryso-phyceae	Total
Dates						
1948 July 3	375	33,550	375	750	0	35,050
July 10	150	25,755	550	50	0	26,505
July 24	288	17,925	2,850	1,550	0	22,613
July 31	600	22,550	5,375	1,900	0	30,425
Aug. 12	1,700	19,495	3,950	17,100	250	42,495
1950 July 28	600	28,550	12,375	7,350	0	48,875
Aug. 17	150	14,250	8,325	11,700	1,050	35,475
1951 July 18	488	29,225	8,225	4,475	150	42,563
Aug. 16	1,600	17,500	4,400	16,950	650	41,100

* Each value represents the mean of the counts in units per liter of the vertical series of samples collected on a particular day

TABLE 120

PERCENTAGE COMPOSITION OF PHYTOPLANKTON IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

	Diatoms	Blue-green algae	Green algae	Dino-phyceae	Chryso-phyceae
Dates	Count in units per liter				
1948 July 3	1.1	95.7	1.1	2.1	0
July 10	0.6	97.2	2.1	0.2	0
July 24	1.3	79.3	12.6	6.9	0
July 31	2.0	74.1	17.7	6.2	0
Aug. 12	4.0	45.9	9.3	40.2	0.6
1950 July 28	1.2	58.4	25.3	15.0	0
Aug. 17	0.4	40.2	23.5	33.0	3.0
1951 July 18	1.1	68.7	19.3	10.5	0.4
Aug. 16	3.9	42.6	10.7	41.2	1.6
Mean	1.7	68.7	15.6	17.3	0.6
Max.	4.0	97.2	25.3	41.2	3.0
Extremes Min.	0.4	40.2	1.1	0.2	0

TABLE 121

ABUNDANCE OF DIATOMS IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	450	300	750	375
July 10	100	200	300	150
July 24	200	375	575	288
July 31	400	800	1,200	600
Aug. 12	2,000	1,400	3,400	1,700
1950 July 28	450	750	1,200	600
Aug. 17	150	150	300	150
1951 July 18	325	650	975	488
Aug. 16	1,700	1,500	3,200	1,600

TABLE 122

ABUNDANCE OF BLUE-GREEN ALGAE IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	35,350	31,750	67,100	33,550
July 10	24,400	27,110	51,510	25,755
July 24	12,750	23,100	35,850	17,925
July 31	19,400	25,700	45,100	22,550
Aug. 12	18,760	20,230	38,990	19,495
1950 July 28	30,500	26,600	57,100	28,550
Aug. 17	10,950	17,550	28,500	14,250
1951 July 18	29,710	28,740	58,450	29,225
Aug. 16	19,000	16,000	35,000	17,500

TABLE 123

ABUNDANCE OF GREEN ALGAE IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	150	600	750	375
July 10	200	900	1,100	550
July 24	1,300	4,400	5,700	2,850
July 31	5,750	5,000	10,750	5,375
Aug. 12	3,950	3,950	7,900	3,950
1950 July 28	10,350	14,400	24,750	12,375
Aug. 17	6,150	10,500	16,650	8,325
1951 July 18	8,100	8,350	16,450	8,225
Aug. 16	4,900	3,900	8,800	4,400

TABLE 124

ABUNDANCE OF CHRYSOPHYCEAE (COMPOSED WHOLLY OF DINOBRYON) IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	300	200	500	250
1950 July 28	0	0	0	0
Aug. 17	750	1,350	2,100	1,050
1951 July 18	100	200	300	150
Aug. 16	800	500	1,300	650

TABLE 125

ABUNDANCE OF DINOPHYCEAE (COMPOSED OF PERIDINIUM ONLY) IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	600	900	1,500	750
July 10	100	0	100	50
July 24	300	2,800	3,100	1,550
July 31	1,700	2,100	3,800	1,900
Aug. 12	16,000	18,200	34,200	17,100
1950 July 28	4,200	10,500	14,700	7,350
Aug. 17	8,700	14,700	23,400	11,700
1951 July 18	4,600	4,350	8,950	4,475
Aug. 16	20,900	13,000	33,900	16,950

TABLE 126

ABUNDANCE OF MELOSIRA IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	100	0	100	50
July 31	0	0	0	0
Aug. 12	50	100	150	75
1950 July 28	0	0	0	0
Aug. 17	0	0	0	0
1951 July 18	0	0	0	0
Aug. 16	100	100	200	100

TABLE 127

ABUNDANCE OF NAVICULA IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	200	200	100
July 31	100	300	400	200
Aug. 12	0	0	0	0
1950 July 28	0	0	0	0
Aug. 17	0	0	0	0
1951 July 18	50	100	150	75
Aug. 16	0	200	200	100

TABLE 128

ABUNDANCE OF STEPHANODISCUS IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	100	0	100	50
1950 July 28	150	0	150	75
Aug. 17	0	150	150	75
1951 July 18	50	150	200	100
Aug. 16	0	0	0	0

TABLE 129

ABUNDANCE OF SYNEDRA IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	450	150	600	300
July 10	0	200	200	100
July 24	100	100	200	100
July 31	300	500	800	400
Aug. 12	1,800	1,200	3,000	1,500
1950 July 28	300	750	1,050	525
Aug. 17	150	0	150	75
1951 July 18	200	400	600	300
Aug. 16	1,600	1,200	2,800	1,400

TABLE 130

ABUNDANCE OF TABELLARIA IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	150	150	75
July 10	0	0	0	0
July 24	0	75	75	38
July 31	0	0	0	0
Aug. 12	50	100	150	75
1950 July 28	0	0	0	0
Aug. 17	0	0	0	0
1951 July 18	25	0	25	13
Aug. 16	0	0	0	0

TABLE 131

ABUNDANCE OF CHROOCOCCUS IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	100	50	150	75
July 10	0	0	0	0
July 24	50	100	150	75
July 31	100	200	300	150
Aug. 12	50	30	80	40
1950 July 28	50	50	100	50
Aug. 17	0	0	0	0
1951 July 18	60	40	100	50
Aug. 16	0	0	0	0

TABLE 132

ABUNDANCE OF COELOSPHAERIUM IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	100	100	200	100
1950 July 28	150	0	150	75
Aug. 17	0	0	0	0
1951 July 18	0	0	0	0
Aug. 16	100	0	100	50

TABLE 133

ABUNDANCE OF MERISMOPEDIA IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	10	10	5
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	10	0	10	5
1950 July 28	0	0	0	0
Aug. 17	0	0	0	0
1951 July 18	0	0	0	0
Aug. 16	0	0	0	0

TABLE 134

ABUNDANCE OF MICROCYSTIS IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	35,250	31,700	66,950	33,475
July 10	24,400	27,100	51,500	25,750
July 24	12,700	23,000	35,700	17,850
July 31	19,300	25,500	44,800	22,400
Aug. 12	18,600	20,100	38,700	19,350
1950 July 28	30,300	26,550	56,850	28,425
Aug. 17	10,950	17,550	28,500	14,250
1951 July 18	29,650	28,700	58,350	29,175
Aug. 16	18,900	16,000	34,900	17,450

TABLE 135

ABUNDANCE OF ARTHRODESMUS IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	300	300	150
July 10	100	700	800	400
July 24	900	2,800	3,700	1,850
July 31	1,800	1,500	3,300	1,650
Aug. 12	2,400	2,200	4,600	2,300
1950 July 28	2,550	3,600	6,150	3,075
Aug. 17	2,400	4,950	7,350	3,675
1951 July 18	2,050	1,850	3,900	1,950
Aug. 16	3,200	2,200	5,400	2,700

TABLE 136

ABUNDANCE OF PEDIASTRUM IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	200	200	100
July 31	50	0	50	25
Aug. 12	0	0	0	0
1950 July 28	0	150	150	75
Aug. 17	0	0	0	0
1951 July 18	50	150	200	100
Aug. 16	100	300	400	200

TABLE 137

ABUNDANCE OF SCENEDESMUS IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	50	100	150	75
1950 July 28	0	150	150	75
Aug. 17	150	0	150	75
1951 July 18	0	0	0	0
Aug. 16	0	0	0	0

TABLE 138

ABUNDANCE OF STAURASTRUM IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	150	300	450	225
July 10	100	200	300	150
July 24	400	1,600	2,000	1,000
July 31	3,900	3,500	7,400	3,700
Aug. 12	1,400	1,600	3,000	1,500
1950 July 28	7,800	10,500	18,300	9,150
Aug. 17	3,300	5,250	8,550	4,275
1951 July 18	6,000	6,300	12,300	6,150
Aug. 16	1,600	1,400	3,000	1,500

TABLE 139

ABUNDANCE OF XANTHIDIUM IN VINCENT LAKE DURING THE SUMMERS OF 1948, 1950 AND 1951

Depth Meters	0	2.5		
Dates	Count in units per liter		Total	Mean
1948 July 3	0	0	0	0
July 10	0	0	0	0
July 24	0	0	0	0
July 31	0	0	0	0
Aug. 12	100	50	150	75
1950 July 28	0	0	0	0
Aug. 17	300	300	600	300
1951 July 18	0	50	50	25
Aug. 16	0	0	0	0

TABLE 140

ABUNDANCE OF TOTAL PHYTOPLANKTON IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	6,900	25,425	18,525	12,475	[illegible]	15,851
Sept. 4	20,550	24,675	28,955	20,475	[illegible]	23,664
Sept. 16	16,850	25,700	23,450	29,350	[illegible]	23,885
Oct. 3	36,875	45,350	35,600	41,450	159,275	39,819
Oct. 24	30,500	34,525	45,175	40,575	150,775	37,694
Nov. 9	26,400	24,825	24,450	27,375	103,050	25,763

TABLE 141

COMPOSITION* OF PHYTOPLANKTON IN LAKE LANSING DURING THE FALL OF 1950

	Diatoms	Green algae	Blue-green algae	Chryso-phyceae	Dino-phyceae	Total
Dates						
Aug. 28	4,106	169	6,888	0	4,669	15,832
Sept. 4	6,789	131	9,356	0	7,388	23,664
Sept.16	7,450	200	11,858	0	4,375	23,883
Oct. 3	28,025	138	10,231	75	1,350	39,819
Oct. 24	29,019	0	8,625	0	50	37,694
Nov. 9	19,538	0	6,225	0	0	25,763

* Each value represents the mean of the counts in units per liter of the vertical series of samples collected on a particular day

Sept. 4 [illegible]
Sept. 16 [illegible]
Oct. 3 24,350
Oct. 24 23,650 [illegible]
Nov. 9 20,650 [illegible]

TABLE 142

PERCENTAGE COMPOSITION OF PHYTOPLANKTON IN LAKE LANSING DURING THE FALL OF 1950

		Diatoms	Green algae	Blue-green algae	Chryso-phyceae	Dino-phyceae
Dates		Count in units per liter				
Aug. 28		25.9	1.1	43.5	0	29.4
Sept. 4		28.7	0.6	39.5	0	31.2
Sept. 16		31.2	0.8	49.7	0	18.3
Oct. 3		70.4	0.3	25.7	0.2	3.4
Oct. 24		77.0	0	22.9	0	0.1
Nov. 9		75.8	0	24.2	0	0
	Mean	51.5	0.5	34.4	0.03	13.7
	Max.	77.0	1.1	49.7	0.2	31.2
Extremes	Min.	25.9	0	22.9	0	0

TABLE 143

ABUNDANCE OF DIATOMS IN LAKE LANSING DURING THE FALL OF 1950

	Depth Meters	0	2	5	8		
Dates		Count in units per liter				Total	Mean
Aug. 28		1,650	4,275	5,325	5,175	16,425	4,106
Sept. 4		6,225	6,825	7,880	6,225	27,155	6,789
Sept. 16		5,800	7,550	6,300	10,150	29,800	7,450
Oct. 3		24,580	30,350	27,150	30,050	112,100	28,025
Oct. 24		25,650	24,650	35,700	32,075	116,075	29,019
Nov. 9		20,650	17,075	19,250	21,175	78,150	19,538
Oct. 3		0					
Oct. 24		0					
Nov. 9		0					

TABLE 144

ABUNDANCE OF BLUE-GREEN ALGAE IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	3,450	9,750	9,375	4,975	27,550	6,888
Sept. 4	7,500	9,975	11,775	8,175	37,425	9,356
Sept. 16	9,250	10,900	14,100	13,180	47,450	11,858
Oct. 3	10,525	13,300	7,050	10,050	40,925	10,231
Oct. 24	6,850	9,875	9,475	8,300	34,500	8,625
Nov. 9	5,750	7,750	5,200	6,200	24,900	6,225

TABLE 145

ABUNDANCE OF GREEN ALGAE IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	150	300	150	75	675	169
Sept. 4	150	75	300	0	525	131
Sept. 16	100	350	50	300	800	200
Oct. 3	0	100	300	150	550	138
Oct. 24	0	0	0	0	0	0
Nov. 9	0	0	0	0	0	0

TABLE 146

ABUNDANCE OF CHRYSOPHYCEAE (COMPOSED ONLY OF DINOBRYON) IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	0	0	0	0	0	0
Sept. 4	0	0	0	0	0	0
Sept. 16	0	0	0	0	0	0
Oct. 3	0	300	0	0	300	75
Oct. 24	0	0	0	0	0	0
Nov. 9	0	0	0	0	0	0

TABLE 147

ABUNDANCE OF DINOPHYCEAE (COMPOSED ONLY OF CERATIUM) IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	1,650	11,100	3,675	2,250	18,675	4,669
Sept. 4	6,675	7,800	9,000	6,075	29,550	7,388
Sept. 16	1,700	6,900	3,000	5,900	17,500	4,375
Oct. 3	1,800	1,300	1,100	1,200	5,400	1,350
Oct. 24	0	0	0	200	200	50
Nov. 9	0	0	0	0	0	0

TABLE 148

ABUNDANCE OF ASTERIONELLA IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	300	600	600	300	1,800	450
Sept. 4	1,125	900	675	600	3,300	825
Sept. 16	1,050	2,050	1,250	1,950	6,300	1,575
Oct. 3	9,500	9,500	10,700	6,950	36,650	9,163
Oct. 24	400	3,100	2,700	1,950	8,150	2,038
Nov. 9	500	600	950	1,000	3,050	763

TABLE 149

ABUNDANCE OF FRAGILARIA IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	675	1,875	1,950	1,350	5,850	1,463
Sept. 4	2,025	3,450	4,950	3,150	13,575	3,394
Sept. 16	1,350	2,100	1,250	1,250	5,950	1,488
Oct. 3	2,150	3,350	5,950	2,700	12,150	3,038
Oct. 24	1,250	1,650	1,200	1,150	5,250	1,313
Nov. 9	850	1,275	1,050	975	4,150	1,038

TABLE 150

ABUNDANCE OF MELOSIRA IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	0	825	2,025	3,000	5,850	1,463
Sept. 4	1,950	750	1,275	1,125	5,100	1,275
Sept. 16	1,800	1,900	1,300	2,750	7,750	1,938
Oct. 3	1,900	1,300	4,100	7,300	14,600	3,650
Oct. 24	700	1,000	2,300	2,275	6,475	1,619
Nov. 9	500	800	1,200	1,000	3,500	875

TABLE 151

ABUNDANCE OF NAVICULA IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	0	0	0	75	75	19
Sept. 4	150	0	0	0	150	[illegible]
Sept. 16	200	0	0	200	400	[illegible]
Oct. 3	0	200	0	500	[illegible]	[illegible]
Oct. 24	50	300	100	100	[illegible]	[illegible]
Nov. 9	100	200	0	100	400	100

TABLE 152

ABUNDANCE OF STEPHANODISCUS IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	0	0	0	0	0	0
Sept. 4	0	0	0	0	0	0
Sept. 16	100	0	400	200	700	175
Oct. 3	200	300	300	400	1,200	300
Oct. 24	100	500	0	200	800	200
Nov. 9	100	200	0	0	300	75

TABLE 156

ABUNDANCE OF [illegible] IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	675	975	750	450	2,850	713
Sept. 4	975	1,725	900	1,350	5,850	1,463
Sept. 16	1,500	1,500	2,100	3,900	8,800	2,200
Oct. 3	10,800	15,700	8,100	12,200	46,800	11,700
Oct. 24	21,200	18,100	29,200	26,400	94,900	23,725
Nov. 9	18,600	14,000	16,050	18,100	66,750	16,688

TABLE 154

ABUNDANCE OF ANABAENA IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	1,050	1,800	675	600	4,125	1,031
Sept. 4	1,200	2,250	2,250	1,950	7,650	1,913
Sept. 16	2,550	2,700	3,700	4,350	13,500	3,375
Oct. 3	4,875	5,450	800	1,250	12,375	3,094
Oct. 24	750	775	975	900	3,400	850
Nov. 9	600	750	700	900	2,950	738

TABLE 155

ABUNDANCE OF COELOSPHAERIUM IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	150	0	300	375	825	206
Sept. 4	0	0	0	0	0	0
Sept. 16	1,600	1,900	2,200	230	5,930	1,483
Oct. 3	2,400	2,300	2,800	1,500	9,000	2,250
Oct. 24	200	1,200	3,600	1,400	6,400	1,600
Nov. 9	300	600	800	500	2,200	550

TABLE 156

ABUNDANCE OF MERISMOPEDIA IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	0	0	0	0	0	0
Sept. 4	0	0	0	375	375	89
Sept.16	0	0	0	0	0	0
Oct. 3	0	0	0	0	0	0
Oct. 24	0	0	0	0	0	0
Nov. 9	0	0	0	0	0	0

TABLE 157

ABUNDANCE OF MICROCYSTIS IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	2,250	7,875	8,400	3,975	22,500	5,625
Sept. 4	5,850	7,725	9,525	5,700	28,800	7,200
Sept.16	5,100	6,300	8,200	8,400	28,000	7,000
Oct. 3	3,250	5,550	3,450	7,300	19,550	4,888
Oct. 24	5,900	7,900	4,900	6,000	24,700	6,175
Nov. 9	4,850	6,400	3,700	4,800	19,750	4,938

TABLE 158

ABUNDANCE OF OSCILLATORIA IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	0	75	0	25	100	25
Sept. 4	450	0	0	150	600	150
Sept. 16	0	0	0	0	0	0
Oct. 3	0	0	0	0	0	0
Oct. 24	0	0	0	0	0	0
Nov. 9	0	0	0	0	0	0

TABLE 159

ABUNDANCE OF COSMARIUM IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	0	0	0	0	0	0
Sept. 4	0	0	0	0	0	0
Sept. 16	0	150	50	100	300	75
Oct. 3	0	0	0	0	0	0
Oct. 24	0	0	0	0	0	0
Nov. 9	0	0	0	0	0	0

TABLE 160

ABUNDANCE OF DICTYOSPHAERIUM IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	0	75	0	0	75	19
Sept. 4	0	0	75	0	75	19
Sept. 16	0	0	0	0	0	0
Oct. 3	0	0	0	0	0	0
Oct. 24	0	0	0	0	0	0
Nov. 9	0	0	0	0	0	0

TABLE 161

ABUNDANCE OF EUDORINA IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	150	75	0	0	225	56
Sept. 4	75	0	0	0	75	19
Sept. 16	0	0	0	0	0	0
Oct. 3	0	0	0	0	0	0
Oct. 24	0	0	0	0	0	0
Nov. 9	0	0	0	0	0	0

TABLE 162

ABUNDANCE OF PEDIASTRUM IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	0	0	0	0	0	0
Sept. 4	75	75	75	0	225	56
Sept. 16	0	0	0	200	200	50
Oct. 3	0	0	0	150	150	38
Oct. 24	0	0	0	0	0	0
Nov. 9	0	0	0	0	0	0

TABLE 163

ABUNDANCE OF STAURASTRUM IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	0	150	0	0	150	38
Sept. 4	0	0	75	0	75	19
Sept. 16	100	200	0	0	300	75
Oct. 3	0	100	300	0	400	100
Oct. 24	0	0	0	0	0	0
Nov. 9	0	0	0	0	0	0

TABLE 164

ABUNDANCE OF TETRAEDRON IN LAKE LANSING DURING THE FALL OF 1950

Depth Meters	0	2	5	8		
Dates	Count in units per liter				Total	Mean
Aug. 28	0	0	150	75	225	56
Sept. 4	0	0	75	0	75	19
Sept. 16	0	0	0	0	0	0
Oct. 3	0	0	0	0	0	0
Oct. 24	0	0	0	0	0	0
Nov. 9	0	0	0	0	0	0

Average Pigment from determined samples

TABLE 165

A COMPARISON OF DENSITIES OF PIGMENT EXTRACTED FROM THE CONCENTRATES OF FILTERED AND CENTRIFUGED WATER SAMPLES FROM DOUGLAS LAKE

Dates	Depth Meter	Plankton Count units per liter	Pigment Extracted Trap Net	Pigment Extracted Centrifuged	Percentage Pigment Retained by Net*
		Measured in Klett units per liter			
1950					
July 3	0	100,500	5.0	13	38.1
	2	204,120	4.1	17	24.1
	5	580,660	6.4	23	27.8
	12	170,420	4.0	16	25.0
	20	41,060	2.0	7	28.6
	Average	219,352	3.9	15	25.7
July 10	0	52,460	1.3	7	18.6
	2	73,882	1.3	7	18.6
	5	98,800	1.9	10	19.0
	12	67,940	1.3	8	16.8
	20	37,560	0.9	7	12.9
	Average	66,088	1.4	8	17.8
July 18	0	33,373	1.4	9	15.6
	2	39,149	1.5	10	15.0
	5	34,268	1.5	9	16.7
	12	35,544	1.5	8	18.8
	20	7,458	0.5	4	12.5
	Average	29,954	1.3	8	15.7
July 25	0	26,227	1.1	6	18.3
	2	27,450	1.2	6	20.0
	5	23,265	1.2	7	17.1
	12	22,627	1.1	5	22.0
	20	6,165	0.6	4	15.0
	Average	21,147	1.0	6	18.5
Aug. 4	0	18,510	1.0	8	12.5
	2	21,345	1.3	10	13.0
	5	23,388	1.2	10	12.0
	12	24,275	1.4	11	12.7
	20	9,375	0.9	7	12.9
	Average	19,379	1.2	9	13.0
Aug. 14	0	13,948	1.0		
	2	16,202	1.0		
	5	17,559	1.1		
	12	17,550	1.1		
	20	7,850	0.8		
	Average	14,580	1.0		
1951					
July 9	0	52,650	1.2	7	17.1
	2	66,466	1.3	8	16.3
	5	58,125	1.2	7	17.1
	12	57,400	1.1	5	22.0
	20	40,533	0.9	7	12.9
	Average	55,035	1.1	5	17.1
July 25	0	20,499	0.0	4	17.5
	2	32,885	8.0	6	13.3
	5	39,866	8.0	5	16.0
	12	27,033	8.0	5	16.0
	20	24,400	6.0	5	12.0
	Average	28,956	7.0	5	15.0

* Percentage Pigment Retained by Net = $\frac{\text{Pigment from Net Sample}}{\text{Pigment from Centrifuged Sample}} \times 100$

TABLE 166

A COMPARISON OF PLANKTON COUNTS WITH DENSITIES OF EXTRACTED PIGMENT FROM SIMILAR SAMPLES FROM LANCASTER LAKE

	Depth Meters	Plankton Count units per liter	Pigment Extracted klett units per liter
Dates			
1950			
July 20	0	30,365	1.8
	3	111,800	4.6
	6	20,450	1.4
	15	5,550	.4
	Average	42,791	2.1
Aug. 8	0	18,000	1.2
	3	14,900	1.6
	6	7,725	.9
	15	5,550	.6
	Average	10,119	1.1
1951			
July 20	0	28,350	1.4
	3	34,800	1.6
	6	12,150	.8
	15	5,550	.5
	Average	20,212	1.1

TABLE 167

A COMPARISON OF PLANKTON COUNTS WITH DENSITIES OF EXTRACTED PIGMENT FROM SIMILAR SAMPLES FROM MUNRO LAKE

	Depth Meters	Plankton Count units per liter	Pigment Extracted klett units per liter
Dates			
1950			
July 27	0	21,240	.6
	2	26,250	1.0
	Average	24,118	.8
Aug. 15	0	36,000	.8
	2	39,705	.8
	Average	37,352	.8
1951	0	18,766	.6
July 18	2	32,766	1.0
	Average	25,766	.8

TABLE 168

A COMPARISON OF PLANKTON COUNTS WITH DENSITIES OF EXTRACTED PIGMENT FROM SIMILAR SAMPLES FROM VINCENT LAKE

	Depth Meters	Plankton Count units per liter	Pigment Extracted klett units per liter
Dates 1950			
July 28	0	45,500	1.3
	2.5	52,250	1.7
	Average	48,875	1.5
Aug. 17	0	26,700	1.2
	2.5	44,250	1.6
	Average	35,475	1.4

TABLE 169

A COMPARISON OF PLANKTON COUNTS WITH DENSITIES OF EXTRACTED PIGMENT FROM SIMILAR SAMPLES FROM LAKE LANSING

	Depth Meters	Plankton Count units per liter	Pigment Extracted klett units per liter
Dates 1950			
Aug. 28	0	6,900	1.2
	2	25,425	2.0
	5	18,525	1.7
	8	12,475	1.6
	Average	15,851	1.6
Sept. 4	0	20,550	2.6
	2	24,675	2.9
	5	28,955	2.7
	8	20,475	2.3
	Average	23,664	2.6
Sept. 16	0	16,850	1.9
	2	25,700	2.2
	5	23,450	2.4
	8	29,550	3.1
	Average	23,885	2.4

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