LIMNOLOGICAL FEATURES AND SUCCESSIONAL CHANGES
OF LAKE CARL BLACKWELL, OKLAHOMA

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By

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INTRODUCTION

This paper concerns the limnology of a man-made impoundment in central Oklahoma. The objectives of the investigation were two-fold: an overall view of general limnological conditions was the goal and no attempt was made to find minute relationships and intricacies arising from ephemeral chemical phenomena and the resulting waxing and waning of aquatic populations: further, it was a study of limnological factors that change following a lapse of time. A volumetric method of measuring plankton is presented.

Limnological literature concerning large southwestern impoundments is sparse. Harris and Silvey (1940) studied four Texas reservoirs of varying ages existing on different geological formations. Irwin (1941) published some spring and summer records of physical and chemical features of Grand Lake, Oklahoma. Cheatum, et. al. (1942) investigated an East Texas reservoir that had been built about twenty years previous to their work.

The literature concerning annual lentic relationships is also limited. The only outstanding papers in this country containing physical, chemical, and plankton data are those of Birge and Juday (1922), Chandler (1940, 1942a, 1942b, 1944), Chandler and Weeks (1945), Cheatum et. al. (1942), Harris and Silvey (1940), Pennak (1949), Scheffer and Robinson (1939), and Scott (1927). The works of Chandler, and Chandler and Weeks are particularly notable in that they are an extended study of several years.

The present study is unique because it includes two investigations, separated by a nine year interval, on Lake Carl Blackwell, a 3300 acre impoundment in Payne County, Oklahoma. The first investigation (conducted by W. H. Irwin) began in 1940 shortly after impoundment, before the lake had completely filled and while its productivity was high. The second began in 1949 after the basin had filled and the productivity showed a definite yearly decline.

Southwestern impoundments appear to metamorphose soon after impoundment changing from biologically productive biomes to unproductive ones as they age (Moore, 1937; Irwin, 1945, 1948). Limnological data which support this idea are limited and mostly unpublished (Irwin, unpublished data on Lake McAlester, Yost Lake, and Sanborn Lake in Oklahoma: Oklahoma Game and Fish Commission, unpublished, numerous Oklahoma impoundments; Loomis and Poole, unpublished, Lake Carl Blackwell; Leonard and Stevenson, unpublished, Oklahoma ponds).

SITUATIONS STUDIED AND METHODS USED

Situations Studied

Lake Carl Blackwell is located nine miles west of Stillwater, Oklahoma, on Permian red bed soil. It drains a watershed fourteen times the size of the lake surface, has many shallow arms, which present a long shore line. The lake lies with the long axis (east-west) at right angles to the prevailing winds which are from the south.

The dam was completed in 1937, but the basin did not completely fill until 1945. Typical of reservoirs, the deepest part is near the dam.

1940-41

Investigations of the 1940-41 study were conducted monthly. The collection of samples began in October, 1940, and continued through September 20, 1941. Original plans included four stations, but other duties of the investigator necessitated partial abandonment of three. However, the data available for these stations are included as Table II. These stations were located in the shallow margins near the lake shore. Station I, from which most of the 1940-41 data were derived was located just west of the dam over a pit formed by the excavation of clay for the dam core. The pit was the deepest part of the lake and later became filled with silt since it could not be found during the 1949-50 study. Station II was in the first arm west of the dam on the north side of the lake in the northeast corner of section 9. The water depth in 1940 was about five feet. Station III was on the first arm west of the dam on the south side of the lake in about $3\frac{1}{2}$ feet of water. Station IV was in the main body of the lake in section 7, two and one-half miles west of Station I in about 8 feet of water. This area was surrounded by inundated trees.

1949-50

The four stations selected for sampling in the 1949-50 study were located in the approximate region of the same 1940-41 stations. Two, Stations I and IV, were in the main body of the lake, and two, Stations II and III were in the arms nearest the dam. Each station site represented the deepest water of that particular area of the lake. Station 1 (1949-50), which had the greatest depth, was near the dam west of the outlet tower over the stream bed instead of over the clay pit as in 1940-41.

Each station was visited twice monthly at approximately two-week intervals. An exception to this being in May when only one series of samples was taken. The 1949-50 part of the study began on March 3, 1949, and continued through February 25, 1950.

Methods Used

Physical

Temperature All temperature determinations were made with an H'B reversing thermometer. The 1940-41 study readings were taken at the surface, eight meters, and bottom. The 1949-50 readings were taken at the surface, five meters, and bottom. Exceptions to these were during thermal stratification when readings were also made throughout the thermocline.

Turbidity Turbidity was determined by the use of a Jackson turbidimeter.

Chemical

Samples for chemical determinations were collected by means of a three-liter Kemmerer bottle. Depths at which samples were taken were the same as those given for temperature.

The methods used were those given in the current editions of Standard Methods for the Examination of Water and Sewage and Welch's Limnological Methods.

Dissolved oxygen The Rideal-Stewart modification of the Winkler method was used for dissolved oxygen determinations.

Carbon dioxide Free carbon dioxide was determined by the titration of a 100 ml. water sample with N/44 NaOH. These determinations were made in the field immediately after samples were taken.

Bound and half-bound carbon dioxide determinations were made by titrating 100 ml. samples of water with N/50 H_2SO_4, employing phenolphtlalein and methyl orange as indicators.

Hydrogen-ion concentration The Hellige comparator employing color discs was used throughout the study. This method of hydrogen-ion concentration determination is considered accurate to within 0.1 pH units.

Plankton

Plankton collections from the surface, eight meters (1940-41), five meters (1949-50), and bottom were obtained by concentrating 30 liters of water using a Wisconsin plankton net with number 25 bolting silk. The concentrates were preserved in five per cent formalin.

Examination of the plankton involved two methods: (1) a numerical analysis, and (2) a volumetric analysis. Data derived by the first method are presented for Stations I only. Counts were made with the aid of a compound microscope equipped with a 10X ocular and a 16 mm. objective, a Whipple ocular micrometer, and a 1 ml. Sedgwick-Rafter counting chamber. Counts were made from the concentrate by selecting ten ocular fields at random, the numbers in the fields averaged and the necessary computations made to determine the number of organisms or colonies per liter.

A qualitative survey of each concentrate was made before counting to identify the genera present. Identification was carried only to genus.

The data obtained by the volumetric method, introduced in this paper, were secured by reducing each concentrate to 3 ml. The re-concentrate was placed in a 3 ml. cerebrospinal protein centrifuge tube which was graduated in 0.004 ml. subdivisions and centrifuged at 3,000 rpm for two minutes. The volume of plankton obtained was divided by 30. The quotient thus obtained is the volume of centrifuged plankton per liter of lake water.

Repeated examination of the supernatent showed it to be free of microscopic organisms. Throughout the study an occasional Chaoborus from the bottom samples could not be thrown down in centrifuging, but no adjustment in recording the volume was made for these floating organisms.

PHYSICAL FEATURES

Thermal Data

1940-41

Surface temperatures varied from a minimum of 3.2° C. on December 19, 1940, to a maximum of 28.4° C. on July 10, 1941 (Table I). Little vertical temperature difference occurred throughout the year, except for the thermal stratification period.

Thermal stratification had developed by May 31, 1941, continued throughout the summer, and was present when readings were made on September 20. The thermocline began at the eight-meter level on May 31, and continued to the bottom of the lake. On July 10, 1941, the thermocline began at four meters and extended downward for at least two meters. On this date all vertical determinations were not made since strong winds stopped operations on the lake. By August 29, the upper reaches of the thermocline had dropped to the seven-meter level and extended to the bottom. On September 20, a depth of ten meters marked the beginning of thermal stratification which extended downward for one meter only. A hypolimnion existed only when the September 20 readings were made. This hypolimnion, beginning at eleven meters, was one and one-half meters deep.

1949-50

Thermal data for the 1949-50 study are presented in Table III. During this period vertical differences, except during stratification, were slight, but somewhat more pronounced than those of 1941. The maximum temperature recorded, 28.5° C., occurred on June 25, 1949, at Station II. Temperatures

TABLE I

TEMPERATURE 1940-41 EXPRESSED AS DEGREES CENTIGRADE

Station I

Meters	0	4	5	6	7	8	9	10	10½	11	12	12½	13½	14
Oct. 24	18.4		17.8			17.2				17.1				
Nov. 21	8.3					8.2			8.4					
Dec. 19	3.2					3.2						3.6		
Jan. 9	5.2					5.0						5.0		
31	5.6					4.2						4.4		
March 9	7.0					5.9								5.9
April 9	13.0					12.9				12.6				
May 31	24.8		23.1			21.8				17.4	16.3			
July 10	28.4	28.3	26.7	25.1	24.1	23.6								
Aug. 29	27.4		26.3		25.2	21.4	19.8	18.2		15.2				
Sept. 20	25.4					24.1	23.9	18.1		16.2		16.1		

TABLE II

PHYSICAL, CHEMICAL, AND PLANKTON DATA STATIONS II, III, AND IV 1940-41

Station II

Date	Centrifuged Plankton	Temp. °C.	O_2	pH	CO_2 ppm	PH-TH ppm	M.O. ppm	Turbidity ppm
Jan. 31	.0019	5.6	12.5	7.8	2.0	0.0	144.0	25-
Mar. 9	.0017	6.2	11.5	8.3	0.0	0.0	138.0	25-
Apr. 9	.0032	13.2	9.8	8.1	0.0	3.5	149.0	25-
May 9	.0064	21.7	7.5	7.9	2.0	0.0	115.0	88
May 31	.0029	23.9	4.7	7.5	4.0	0.0	97.0	148

Station III

Date	Centrifuged Plankton	Temp. °C.	O_2	pH	CO_2 ppm	PH-TH ppm	M.O. ppm	Turbidity ppm
Oct. 24		19.5	8.8	8.2	0.0	1.0	142.0	25-
Jan. 31	.0019	18.0	12.7	8.0	0.0	1.5	145.0	25-
Mar. 9	.0037	8.2	12.4	8.2	0.0	3.5	139.0	25-
Apr. 9	.0042	13.3	7.2	8.1	0.0	3.5	144.0	25-
May 9	.0037	20.2	7.4	7.5	2.0	0.0	124.5	135
May 31	.0067	27.0	5.2	7.6	4.0	0.0	99.0	107

Station IV

Date	Centrifuged Plankton	Temp. °C.	O_2	pH	CO_2 ppm	PH-TH ppm	M.O. ppm	Turbidity ppm
Oct. 24	.0035	18.6	8.0	8.2	0.0	0.5	146.0	25-
Jan. 31	.0026	7.1	12.7	8.0	0.0	2.0	140.0	25-
Mar. 9	.0030	12.5	8.8	8.1	0.0	3.0	144.0	25-
Apr. 9	.0026	14.1	8.6	8.4	0.0	3.5	140.0	25-
May 9	.0037	20.7	5.1	7.7	2.0	0.0	123.0	64
May 31	.0104	26.9	7.7	7.7	4.0	0.0	109.0	110

from the other three stations on the same date were 0.1 to 1.0° C. less. The minimum temperature (3.5° C.) was recorded January 30, 1950.

A thermocline was first noted on June 25, 1949, at Stations I and IV. Its upper limit began at five meters and extended through the next four meters. This upper limit remained at the five-meter level until thermal stratification disappeared between August 16 and September 3, 1949.

At Station I a hypolimnion beginning at ten meters was found on June 25, and July 8, 1949. No hypolimnion was found at Station IV. Thermal stratification was not found at Stations II and III.

Turbidity

Turbidities recorded in both the 1940-41 and 1949-50 studies were due mainly to silt as is shown by the paucity of plankton populations.

1940-41

These data are characterized by pronounced changes. Readings at Station I ranged from clear to 132 ppm at the surface and from clear to 198 ppm at a depth of eight meters. A bottom reading was not recorded when the eight-meter record of 132 ppm was made, but in other instances of increased turbidity the value of the bottom readings exceeded those of the surface and the eight-meter levels.

Turbidities were due mainly to silt carried by run-off water following rains. Previous to the December 19, 1940, readings, a rainy period occurred which increased the lake depth two and one-half feet and the turbidity from less than 25 ppm at all levels to 35 ppm at the surface, 32 ppm at the eight-meter level, and 55 ppm at the bottom.

Normally Oklahoma received its heaviest rainfall in the spring months. This was the case in 1941 since, in the interval between May 9 and May 31

TABLE III

TEMPERATURE 1949-50

Station I

Meters		0	5	6	7	8	9	10	11	11½	12	12½
March	3	9.2	9.2						9.2			
	28	10.5	10.5						10.2			
April	8	13.0	12.5						12.4			
	22	17.0	13.2						13.0			
May	20	21.0	21.0						20.0			
June	10	27.0	23.0								21.0	
	25	27.0	25.0	24.0	23.0	23.0	21.5	20.5	20.2			
July	8	28.2	27.5	26.2	26.2	24.0	22.5	21.2	21.0			
	21	28.5	28.0	27.5	26.0	24.0	22.0	21.0	21.0			
Aug.	2	27.5	27.0	27.0	26.5	24.7	22.0	21.0	19.0			
	16	28.4	27.3	27.0	27.0	25.0	24.5	23.3				20.0
Sept.	3	25.0	24.0						22.2			
	20	22.5	22.0						21.0			
Oct.	10	21.2	20.5						20.0			
	26	16.0	16.0						16.5			
Nov.	14	13.2	13.2						13.2			
	28	10.7	10.7							11.2		
Dec.	5	7.2	7.2						7.2			
	30	5.5	5.5							5.5		
Jan.	17	4.6	4.4						4.4			
	30	3.5	3.5							3.5		
Feb.	16	5.6	5.6						5.6			
	25	7.5	7.2						7.0			

TABLE III (Continued)

TEMPERATURE 1949-50

		Station II				Station III			
Meters		0	5	6	6½	0	5	6	6½
March	3	9.2	9.2			9.2	9.2		
	28	10.5	10.5			10.5	10.5		
April	8	13.5	12.5			13.0	12.5		
	22	17.2		13.2		17.0	13.0		
May	20	21.0		21.0		21.0	21.0		
June	10	27.2			23.0	27.0	23.0		
	25	28.6		25.5		27.9		25.8	
July	8	28.0	26.0			28.0		25.2	
	21	28.5		27.5		27.0	25.0		
Aug.	2	27.5	27.0			27.5	26.5		
	16	28.2		27.0		28.0	27.0		
Sept.	3	25.0	24.0			25.0	25.0		
	20	22.0	21.0			22.0	21.0		
Oct.	10	21.2		20.5		21.2	21.0		
	26	16.0	16.0			16.0	16.0		
Nov.	14	13.2	13.2			13.2	13.2		
	28	10.7	10.7			10.7	10.7		
Dec.	5	7.0	7.0			7.0	7.0		
	30	5.5	5.5			5.5	5.5		
Jan.	17	4.6	4.6			4.6	4.4		
	30	3.5	3.5			3.5		3.5	
Feb.	16	5.6	5.6			5.6	5.6		
	25	7.5	7.2			7.6	7.2		

TABLE III (Continued)

TEMPERATURE 1949-50

Station IV

Meters		0	4	5	6	6½	7	7½	8
March	3	9.2					9.2		
	28	10.5					10.3		
April	8	13.5					13.2		
	22	17.2		13.2			13.0		
May	20	21.0		21.0				21.0	
June	10	27.0		23.0			23.0		
	25	28.3		27.2	26.6		24.2		22.7
July	8	28.0		27.7	26.2		24.0		22.5
	21	28.5		28.0	27.5		25.0		24.0
Aug.	2	28.0		27.0	27.0		26.5		25.0
	16	28.0	27.0	24.2	24.2		24.0		24.0
Sept.	3	25.0		24.2			24.0		
	20	22.3		21.0				20.5	
Oct.	10	21.2		21.2				21.0	
	26	16.0		16.0			16.2		
Nov.	14	13.2					13.2		
	28	10.7						11.0	
Dec.	5	7.1					7.0		
	30	5.5				5.4			
Jan.	17	4.6				4.6			
	30	3.5					3.5		
Feb.	16	5.6				5.6			
	25	7.5			7.2				

the water level of the lake rose five feet and seven inches. This rise represents the greatest amount of run-off water received in a like period during the 1940-41 investigations. Turbidities rose from less than 25 ppm at all levels on May 9 to 132 ppm at the surface and 198 ppm at the eight-meter level on May 31.

Turbidities nearly as great in magnitude as those of May 31 were found at eight meters (99 ppm) and the bottom (143 ppm) on September 20. Low surface turbidity (less than 25 ppm) at this time indicated that either the run-off water was colder than the surface water, thus forming a density current beginning somewhere between the surface and eight meters, or decomposition of the organic material in the run-off water neutralized the negatively charged clay particles near the surface causing them to floculate. The latter seems more logical in view of data on increased free carbon dioxide and hydrogen-ions, and decreased methyl orange alkalinity and dissolved oxygen content. If this were the case the greater turbidity at the bottom was probably due to concentration of silt particles as they settled. The influx of this run-off water was not enough to upset thermal and chemical stratification.

Turbidities at other stations (Table II) varied slightly from those found at Station I. Shallowness and proximity to shore combined with wind action probably account for these differences.

1949-50

Turbidity data are presented for Station I only, since the reading at all stations were similar. Variations undoubtedly occurred due to run-off water, but were not found because of the sampling schedule which did not always allow observations to be made immediately following rains.

When the study began (March 3, 1949) turbidities at all levels were 40 ppm. These gradually increased to 53 ppm on April 22 at all levels. Readings made on May 20 showed a decrease at the surface to 38 ppm. The reading at five meters had increased to 84 ppm and at the bottom to 94 ppm. Turbidities at the surface, five meters, and bottom were nearly equal on June 10 being 37 to 44 ppm. By late June readings were identical at all levels and continued so throughout the remainder of the investigation. Turbidity was less than 25 ppm on June 25 and remained so until July 21 when it was 40 ppm. Turbidity increased to 58 ppm on August 16 and then a gradual decrease occurred to less than 25 ppm on December 30 where it remained throughout the remainder of the investigation.

CHEMICAL FEATURES

Dissolved Oxygen

1940-41

Surface differences of dissolved oxygen content (Tables II and IV) varied from 12.9 ppm on January 31, 1941, to 3.2 ppm on September 20, 1941. Bottom readings showed a maximum of 12.4 in December 1940, and a minimum of 0.0 ppm which existed from May 31 through September 20, 1941.

Variations from top to bottom were quite constant during the winter circulation period which existed from November through March. The greatest variation found in any one series was 0.5 ppm.

Oxygen depletion had begun when the April readings were made. At this time the surface waters held 9.8 ppm, those of the eight-meter level 8.4 ppm, and the bottom waters 8.3 ppm. One month later surface and eight-meter level readings were 7.7 ppm and 3.6 ppm respectively. There was no record of a bottom reading. Dissolved oxygen content at the surface remained high and fairly uniform from May until September 20 when it fell to 3.2 ppm. Conversely, however, values at the eight-meter level and bottom continued to decrease until absent or a fraction of one part per million remained.

Readings at the surface, excluding the reading of September 20, show that dissolved oxygen concentrations at all times were near saturation. Chandler (1940) in his study of western Lake Erie found that sudden increases and decreases of dissolved oxygen content seemed related to the abundance of organic material, either plankton or detritus, present. This appears to be the reason for the low amount present September 20 when the

TABLE IV

DISSOLVED OXYGEN EXPRESSED AS PPM 1940-41

Station I

Meters	0	5	8	10½	11	12	12½	13	13½	14
Oct. 24	9.0		7.8		5.9					
Nov. 21	10.2		10.3	10.1						
Dec. 19	12.4		12.4				12.4			
Jan. 9	11.9		11.9				11.9			
31	12.9		12.4						12.3	
March 9	12.1		12.1							11.8
April 9	9.8		8.4		8.3					
May 9	7.7		3.6							
31	6.9		1.1			0.0				
July 10	8.1	4.5	0.0							
Aug. 29	6.7	3.1	.9		0.0					
Sept. 20	3.2	1.4	.5		0.0		0.0			

data on turbidity and rainfall are considered.

1949-50

Dissolved oxygen (Table V) at the surface showed a variation during the study of 5.8 ppm at Station I, 5.6 ppm at Station II, 5.8 ppm at Station III, and 5.9 ppm at Station IV.

The maximum surface content recorded was 11.6 ppm. This determination was made on March 3, 1949, at Station I. Readings at the same time for Station II, III and IV were 11.2 ppm, 11.3 ppm, and 11.5 ppm respectively. These differences are characteristic of those found throughout the insuing year.

Minimum bottom readings at Stations I and IV were 0.0 ppm, which in both cases occurred August 16, 1949; at Station II 0.3 ppm on July 21, 1949; and at Station III 3.2 ppm on July 8, 1949.

Oxygen depletion at levels lower than five meters had become apparent by June 25, 1949, at Station I and to a lesser degree at Station IV. On this date no marked change was noted at Station II. The determination at Station III on the same date was 3.4 ppm only .2 ppm above its lowest reading of 3.2 ppm.

Determinations made on September 3, 1949, showed that turnover had been in progress long enough to nearly equalize oxygen concentrations at all levels.

Hydrogen-ion Concentration

1940-41

Tables II and VI show pH variations for this period. Readings at the surface varied from 7.6 on May 31 and September 20, 1941, to 8.3 on August 29. Eight-meter and bottom variations closely coincided with those of the

TABLE V

DISSOLVED OXYGEN EXPRESSED AS PPM 1949-50

Station I

Meters		0	5	6	7	8	9	10	11	11½	12	12½
March	3	11.6	11.2						11.0			
	28	11.1	11.1						10.8			
April	8	10.4	8.9						8.8			
	22	9.0	8.5						8.3			
May	20	10.0	7.7						7.7			
June	10	8.1	6.1								5.8	
	25	6.2	5.9	3.3	2.2	1.9	0.7	0.7	0.5			
July	8	6.0	5.1	1.4	0.5	0.3	0.1	0.1	0.1			
	21	7.4	4.9	3.8	1.9	1.9	1.1	0.6	0.5			0.0
Aug.	2	6.5	5.2			3.2	1.4	1.2	0.2			
	16	5.8	4.9			1.7	0.6					
Sept.	3	5.9	5.8						5.8			
	20	6.2	6.0						5.9			
Oct.	10	6.8	6.5						6.1			
	26	7.6	7.5						6.5			
Nov.	14	8.8	8.5						8.3			
	28	8.2	8.1							7.6		
Dec.	5	9.3	9.1						9.0			
	30	10.5	10.3							9.5		
Jan.	17	11.2	11.0						10.6			
	30	10.6	10.4							9.9		
Feb.	16	9.8	9.5						9.4			
	25	9.9	9.4						9.2			

TABLE V (Continued)

DISSOLVED OXYGEN EXPRESSED AS PPM 1949-50

	Station II					Station III				
Meters	0	5	5½	6	6½	0	5	5½	6	6½
March 3	11.2				11.0	11.3			11.2	
28	11.4				11.1	11.1			11.1	
April 8	10.2	7.9				9.3	9.0			
22	8.5				8.0	8.4			8.1	
May 20	10.0				7.6	10.6	7.0			
June 10	8.1	6.0			5.8	5.8				5.8
25	6.0	5.9			5.9	5.7				3.4
July 8	6.0				5.0	5.9			3.2	
21	7.5	5.0		1.2	0.3	7.5			5.0	
Aug. 2	7.5			4.8		6.4				4.1
16	5.8		5.7	3.8		5.5	4.4			
Sept. 3	5.8					5.8	5.7			
20	6.5				6.2	6.0			6.0	
Oct. 10	6.5				6.1	6.8		6.5		
26	7.2				6.9	7.3		6.9		
Nov. 14	8.7				8.5	8.7	8.5			
28	8.1	8.1				8.2	8.1			
Dec. 5	9.1	9.1				9.1	9.1			
30	10.1	10.2				10.6				10.5
Jan. 17	11.0				10.8	11.0				10.8
30	10.6	10.2				11.0	10.4			
Feb. 16	9.5	9.5				9.5	9.5			
25	9.6	9.3				9.6	9.4			

TABLE V (Continued)

DISSOLVED OXYGEN EXPRESSED AS PPM 1949-50

Station IV

Meters		0	5	6	6½	7	7½	8
March	3	11.5				11.0		
	28	11.0				10.9		
April	8	9.9				9.0		
	22	8.2				8.0		
May	20	10.0					6.1	
June	10	7.8				5.8		
	25	5.7	5.5	3.4		2.2		0.8
July	8	6.6	5.2	1.2		0.4		0.3
	21	7.5	5.0	1.2		0.4		0.3
Aug.	2	6.6	5.0	1.3		0.9		0.3
	16	5.6	4.4			0.0		0.0
Sept.	3	5.8				5.6		
	20	6.7	5.9				6.0	
Oct.	10	6.7					6.7	
	26	7.4				6.8		
Nov.	14	8.7				8.5		
	28	8.0					7.9	
Dec.	5	9.2				9.0		
	30	10.4			9.9			
Jan.	17	11.4			10.9			
	30	11.1				10.5		
Feb.	16	9.5			9.4			
	25	10.0		9.2				

surface. The pH reading at eight meters varied from 8.2 on October 24, 1940, to 7.1 (seven meters) on July 10, 1941. Bottom readings varied from 8.2 on October 24, 1940, to 7.2 on May 31 and September 20, 1941.

The vertical profile of pH remained nearly constant throughout the study except during stratification. The greatest vertical variation, excluding the period of stratification, was 0.4 pH units which occurred on May 31 and September 20, 1941.

The greatest change in pH noted occurred between August 29 and September 20, 1941, when the hydrogen-ion concentration increased at the surface from a pH of 8.3 to 7.6. This apparently was due to decomposition of organic detritus brought into the lake by run-off.

1949-50

The surface range of pH variation, 8.0 to 8.4, during this period was slightly less than that for 1940-41. Five-meter pH values ranged from 7.6 to 8.4 and the bottom values from 7.2 to 8.4. The greatest variations of hydrogen-ion content occurred during chemical and thermal stratification. Throughout the remainder of the investigation the pH remained nearly constant (Table VII).

The greatest variations in vertical profile were found at Stations I and IV, with the differences at Station I slightly greater than those of Station IV.

A single bottom reading (pH 7.9) on August 16, was the only reading below a pH of 8.0 recorded for Station II. The minimum bottom reading for Station III was 7.6 on July 8.

TABLE VI

HYDROGEN-ION CONCENTRATION EXPRESSED AS pH 1940-41

Station I

Meters	0	5	7	8	10½	11	12	12½	13½	14
Oct. 24	8.2			8.2		8.2				
Nov. 21	7.9			7.9	7.9					
Dec. 19	8.0			8.0				8.0		
Jan. 9	8.0			8.0				8.0		
31	7.9			7.9					7.9	
March 9	8.1			8.1						8.1
April 9	8.1			8.0		8.0				
May 31	7.6			7.4			7.2			
July 10	8.2	7.5	7.1							
Aug. 29	8.3	7.6		7.4		7.4				
Sept. 20	7.6			7.4				7.2		

TABLE VII

HYDROGEN-ION CONCENTRATION EXPRESSED AS pH 1949-50

Station I

Meters	0	5	6	7	8	9	10	11	11½	12	12½
March 3	8.0	8.0						8.0			
28	8.0	8.0						8.0			
April 8	8.4	8.4						8.4			
22	8.0	8.0						8.0			
May 20	8.2	8.2						8.2			
June 10	8.1	8.1								7.9	
25	8.0	8.0	7.8	7.6	7.6	7.6	7.4	7.2			
July 8	8.2	8.0	7.6	7.6	7.6	7.6	7.6	7.4			
21	8.2	7.6	7.6	7.6	7.6	7.6	7.6	7.6			
Aug. 2	8.4	8.4	8.4	8.4	8.2	7.8	7.8	7.8			
16	8.2	8.1			7.7	7.7					7.8
Sept. 3	8.0	8.0						8.0			
20	8.0	8.0						8.0			
Oct. 10	8.2	8.2						8.2			
26	8.0	8.0						8.0			
Nov. 14	8.2	8.2						8.2			
28	8.3	8.3							8.3		
Dec. 5	8.4	8.4						8.4			
30	8.2	8.2							8.2		
Jan. 17	8.2	8.2						8.2			
30	8.2	8.2							8.2		
Feb. 16	8.2	8.2						8.2			
25	8.2	8.2						8.2			

TABLE VII (Continued)

HYDROGEN-ION CONCENTRATION EXPRESSED AS pH 1949-50

		Station II					Station III			
Meters		0	5	5½	6	6½	0	5	6	6½
March	3	8.0	8.0				8.0	8.0		
	28	8.0	8.0				8.0	8.0		
April	8	8.0					8.2	8.2		
	22	8.0				8.0	8.0	8.0		
May	20	8.2				8.2	8.2	8.2		
June	10	8.1				8.1	8.1		8.1	
	25	8.2	8.2			8.2	8.2	8.2		8.2
July	8	8.2	8.0				8.2		7.6	
	21	8.2			8.0		8.2		8.0	
Aug.	2	8.4					8.4			8.4
	16	8.2	7.9				8.2	7.8		
Sept.	3	8.0		8.0			8.2		8.1	
	20	8.0				8.0	8.0		8.0	
Oct.	10	8.2	8.2				8.2	8.2		
	26	8.0	8.0				8.0	8.0		
Nov.	14	8.2	8.2				8.2	8.2		
	28	8.3	8.3				8.3	8.3		
Dec.	5	8.4	8.4				8.4	8.4		
	30	8.2	8.2				8.2	8.2		
Jan.	17	8.2	8.2				8.2	8.2		
	30	8.2	8.2				8.2	8.2		
Feb.	16	8.2	8.2				8.2	8.2		
	25	8.2	8.2				8.2	8.2		

TABLE VII (Continued)

HYDROGEN-ION CONCENTRATION EXPRESSED AS pH 1949-50

Station IV

Meters		0	5	6	6½	7	7½	8
March	3	8.0				8.0		
	28	8.0				8.0		
April	8	8.2				8.2		
	22	8.0				8.0		
May	20	8.2					8.2	
June	10	8.1	8.1			8.1		
	25	8.2	8.2	7.8		7.6		7.6
July	8	8.4	8.2	7.6		7.6		7.6
	21	8.2	8.0	8.0		7.9		7.9
Aug.	2	8.4	8.4	8.3		8.2		7.8
	16	8.4	7.8					7.7
Sept.	3	8.0	8.0			8.0		
	20	8.0	8.0				8.0	
Oct.	10	8.2	8.2				8.2	
	26	8.0				8.0		
Nov.	14	8.2				8.2		
	28	8.3					8.3	
Dec.	15	8.4				8.4		
	30	8.2			8.2			
Jan.	17	8.2			8.2			
	30	8.2				8.2		
Feb.	16	8.2			8.2			
	25	8.2		8.2				

Free Carbon Dioxide

1940-41

Free carbon dioxide conditions are summerized in Tables II and VIII. The year-round range, including all depths, was 0.0 to 7.0 ppm. The maximum concentrations occurred in the period between May 31, and September 20, 1941. Free CO_2 was present at all levels except the surface throughout this period. Twice, July 10, and August 29, 1941, the surface waters did not contain free CO_2.

Carbon dioxide was either absent or its concentration was greatly reduced at all levels during the winter months.

1949-50

The occurrence of free carbon dioxide for Stations I and IV is given in Table IX. No tables for Stations I and III are given since carbon dioxide in the free state occurred at these locations only on August 16, 1949, at Station II. Concentrations at the surface and bottom were both 0.1 ppm.

The interval from June 25 to August 16, 1949, marked the period of free carbon dioxide occurrence at Station I. During this time concentrations at the surface ranged from 0.0 to 1.6 ppm. The stratified area, beginning at five meters, possessed 1.0 to 14.0 ppm throughout the same period. The greatest amount, 14.0 ppm, occurred at the five-meter level on July 8, 1949. On the same date readings at 6, 7, 8, 9, 10, 11, and 11.5 meters were 12.0, 9.0, 8.0, 6.0, 1.0, 10.0, and 11.0 ppm, respectively.

Free carbon dioxide occurred in lesser amounts at Station IV than at Station I during this same period (June 25 to August 16, 1949). The range of variation was from 0.0 to 8.0 ppm. Free carbon dioxide was found in the surface water once only — August 16, 1949. The amount present was

TABLE VIII

FREE CARBON DIOXIDE EXPRESSED AS PPM 1940-41

Station I

Meters		0	5	8	10½	11	12	12½	13	13½	14
Oct.	24	0.0		0.0		0.0					
Nov.	21	2.0		6.0	2.0						
Dec.	19	0.0		0.0				0.0			
Jan.	9	0.0		0.0				0.0			
	31	2.0		2.0						2.0	
March	9	0.0		0.0							0.0
April	9	0.0		0.0		0.0					
May	31	4.0		4.0			4.0				
July	10	0.0	4.0	6.0							
Aug.	29	0.0	2.0	4.0		6.0					
Sept.	20	2.0		3.0				7.0			

TABLE IX

FREE CARBON DIOXIDE EXPRESSED AS PPM 1949-50

Station I

Meters		0	5	6	7	8	9	10	11	11½	12	12½
March	3	0.0	0.0						0.0			
	28	0.0	0.0						0.0			
April	8	0.0	0.0						0.0			
	22	0.0	0.0						0.0			
May	20	0.0	0.0						0.0			
June	10	0.0	0.0								0.0	
	25	0.0	0.0	3.0	6.0	6.0	6.0	8.0	9.0			
July	8	0.0	14.0	12.0	9.0	8.0	6.0	1.0	1.0			
	21	0.0	8.0	8.0	8.0	9.0	9.0	9.0	9.0			
Aug.	2	0.0	5.0	5.0			6.0	6.0	6.0			
	16	1.6	5.0			7.0	7.0					7.2
Sept.	3	0.0	0.0						0.0			
	20	0.0	0.0						0.0			
Oct.	10	0.0	0.0						0.0			
	26	0.0	0.0						0.0			
Nov.	14	0.0	0.0						0.0			
	28	0.0	0.0							0.0		
Dec.	5	0.0	0.0						0.0			
	30	0.0	0.0							0.0		
Jan.	17	0.0	0.0						0.0			
	30	0.0	0.0							0.0		
Feb.	16	0.0	0.0						0.0			
	25	0.0	0.0						0.0			

TABLE IX (Continued)

FREE CARBON DIOXIDE EXPRESSED AS PPM 1949-50

Station IV

Meters		0	5	6	6½	7	7½	8
March	3	0.0	0.0			0.0		
	28	0.0	0.0			0.0		
April	8	0.0	0.0			0.0		
	22	0.0	0.0			0.0		
May	20	0.0	0.0				0.0	
June	10	0.0	0.0			0.0		
	25	0.0	0.0	3.0				6.0
July	8	0.0	0.0	4.0				4.0
	21	0.0	0.0	0.0				8.0
Aug.	2	0.0	0.0	0.0	0.0			6.0
	16	0.2	1.8					5.6
Sept.	3	0.0	0.0			0.0		
	20	0.0	0.0				0.0	
Oct.	10	0.0	0.0				0.0	
	26	0.0	0.0			0.0		
Nov.	14	0.0	0.0			0.0		
	28	0.0	0.0				0.0	
Dec.	5	0.0	0.0			0.0		
	30	0.0	0.0		0.0			
Jan.	17	0.0	0.0		0.0			
	30	0.0	0.0			0.0		
Feb.	16	0.0	0.0		0.0			
	25	0.0	0.0	0.0				

0.2 ppm. The condition of greater concentration in the upper than in the lower part of the thermocline did not occur at this station as it did at Station I.

Phenolphthalein Alkalinity

1940-41

Phenolphthalein alkalinity values at all levels were nearly uniform (Tables II and X). During more than half of this year of investigation the water was characterized by the absence of bound carbon dioxide. Bound carbon dioxide was found on the following dates: October 24, 1940, 1.0 ppm. at the surface, 1.5 ppm at eight meters, and 1.0 ppm at the bottom; March 9, 1941, 3.0 ppm at the surface, 3.0 ppm at eight meters, and 0.0 ppm at the bottom; April 9, 1941, 2.5 ppm at the surface, 3.0 ppm at eight meters, and 0.0 ppm at the bottom; July 10, 1941, 5.0 ppm (the highest recorded) at the surface, and 0.0 ppm at eight meters and the bottom; August 29, 1941, 3.5 ppm at the surface, and 0.0 ppm at eight meters and the bottom.

1949-50

Phenolphthalein alkalinity was present for a longer period in 1949-50 than in 1940-41 (Table XI). With the exception of March, 1949, it was absent only during the summer months. The range was from 0.0 to 13.0 ppm at the surface, 0.0 to 13.0 ppm at the five-meter level and the bottom. The values were nearly constant at all stations and in vertical profile, except during the period of stratification.

TABLE X

PH-TH ALKALINITY EXPRESSED AS PPM 1940-41

Station I

Meters	0	5	8	10½	11	12	12½	13	13½	14
Oct. 24	1.0		1.5		1.0					
Nov. 21	0.0		0.0	0.0						
Dec. 19	0.0		0.0				0.0			
Jan. 9	0.0		0.0				0.0			
31	0.0		0.0						0.0	
March 9	3.0		3.0							0.0
April 9	2.5		3.0		3.0					
May 31	0.0		0.0			0.0				
July 10	5.0	0.0	0.0							
Aug. 29	3.5	0.0	0.0							
Sept. 20	0.0		0.0				0.0			

TABLE XI

PH-TH ALKALINITY EXPRESSED AS PPM 1949-50

Station I

Meters		0	5	6	7	8	9	10	11	11½	12	12½
March	3	0.0	0.0						0.0			
	28	0.0	0.0						0.0			
April	8	11.0	9.0						8.0			
	22	6.0	7.0						8.0			
May	20	7.0	1.0						8.0			
June	10	0.0	0.0								0.0	
	25	2.0	2.0						2.0			
July	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
	21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Aug.	2	5.0	0.0			0.0	0.0	0.0	0.0			
	16	0.0	0.0		0.0	0.0	0.0					0.0
Sept.	3	2.0	2.0						0.0			
	20	7.0	7.0						6.0			
Oct.	10	4.0	4.0						4.0			
	26	5.0	4.0						4.0			
Nov.	14	4.0	6.0						6.0			
	28	6.0	5.0							6.0		
Dec.	5	5.0	5.0						5.0			
	30	5.0	4.0							5.0		
Jan.	17	5.0	5.0						4.0			
	30	9.0	8.0							8.0		
Feb.	16	6.0	5.0						5.0			
	25	5.0	5.0						4.0			

TABLE XI (Continued)

PH–TH ALKALINITY EXPRESSED AS PPM 1949–50

		Station II				Station III			
Meters		0	5	6	6½	0	5	6	6½
March	3	0.0	0.0			0.0	0.0	0.0	
	28	0.0	0.0			0.0	0.0	0.0	
April	8	13.0	12.0			10.0	9.0		
	22	7.0	8.0			8.0	8.0		
May	20	7.0		7.0		7.0		7.0	
June	10	0.0	0.0	0.0		0.0	0.0	0.0	
	25	2.0	2.0	2.0		4.0	3.0		3.0
July	8	0.0		0.0		0.0	0.0	0.0	
	21	0.0	0.0	0.0		0.0	0.0	0.0	
Aug.	2	4.0	4.0	3.0		4.0	4.0	4.0	
	16	0.0		0.0		0.0	0.0		
Sept.	3	2.0		0.0		2.0	2.0		
	20	8.0		8.0		0.0	0.0		
Oct.	10	3.0	3.0	3.0		4.0	3.0		
	26	4.0	3.0	3.0		4.0	4.0		
Nov.	14	7.0	6.0			5.0	6.0		
	28	5.0	5.0			5.0	5.0		
Dec.	5	4.0	4.0			5.0	6.0		
	30	4.0	4.0			5.0	5.0		
Jan.	17	6.0		6.0		5.5	5.5		
	30	8.0	7.0			8.0		8.0	
Feb.	16	6.0	5.0			5.0	5.0		
	25	4.0	3.0			5.0	5.0		

TABLE XI (Continued)

PH-TH ALKALINITY EXPRESSED IN PPM 1949-50

Station IV

Meters	0	5	6	6½	7	7½	8
March 3	0.0				0.0		
28	0.0				0.0		
April 8	5.0				3.0		
22	6.0				5.0		
May 20	7.0					4.0	
June 10	0.0	0.0			0.0		
25	5.0	3.0	0.0		0.0		0.0
July 8	0.0	0.0	0.0		0.0		0.0
21	0.0	0.0	0.0		0.0		0.0
Aug. 2	6.0	5.0	4.0				0.0
16	0.0	0.0	0.0				0.0
Sept. 3	1.0	0.0			0.0		
20	2.0	0.0				0.0	
Oct. 10	5.0	4.0				4.0	
26	5.0				3.0		
Nov. 14	5.0				6.0		
28	6.0					6.0	
Dec. 5	4.0				4.0		
30	5.0			4.0			
Jan. 17	6.0			5.0			
30	8.0				7.0		
Feb. 16	6.0		0.0	6.0			
25	7.0		7.5				

Methyl Orange Alkalinity

1940-41

Annual surface variation of half-bound carbon dioxide (Tables II and VII) was 67.0 ppm; the greatest amount, 146.0 ppm being present on November 21, 1940 and the least amount, 79.0 ppm on May 31, 1941.

The annual fluctuation at eight meters was 60 ppm; the maximum concentration, 144.0 ppm occurring on October 24, 1940, and the minimum, 84.0 ppm on May 31, 1941.

The minimum bottom reading, 91.0 ppm, was obtained on May 31, 1941, and the maximum, 159.5 ppm, on September 20, 1941, showing a variation of 68.5 ppm for the year.

Vertical differences were usually slight, two to seven parts per million. Notable exceptions to this occurred on May 31, and September 20, 1941. May 31 the methyl orange alkalinity at the surface was 79.0 ppm and that at the bottom 91.0 ppm. The September surface reading was 113.0 ppm and the bottom reading 159.5 ppm.

1949-50

The annual methyl orange alkalinity values (Table XIII) were lower and more constant during 1949-50 than in 1940-41.

The minimum surface concentration was 93.0 ppm at Station IV on June 25, 1949. Surface values for Stations I, II, and III on the same date were 117.0, 116.0, and 119.0 ppm respectively. The maximum surface methyl orange alkalinity, 136.0 ppm, was found at Stations II and IV in January, 1950, while readings at Stations I and III were one or two parts per million lower. Values at the five-meter level closely approximated those of the surface.

TABLE XII

MO ALKALINITY EXPRESSED AS PPM 1940-41

Station I

Meters	0	5	8	10½	11	12	12½	13	13½	14
Oct. 24	143.0		144.0		146.0					
Nov. 21	146.0		137.0	148.0						
Dec. 19	144.0		143.0				140.0			
Jan. 9	140.0		138.0				138.0			
31	141.5		143.0						138.0	
March 9	139.0		136.0							140.0
April 9	140.0		146.0		147.0					
May 31	79.0		84.0			91.0				
July 10	80.0	85.0	90.0							
Aug. 29	119.0	124.0	124.0		121.5					
Sept. 20	113.0		121.0				159.0			

Readings from samples taken at the bottom showed an annual variation of 69.0 ppm. The minimum, 70.0 ppm, occurred at Station IV on June 25, 1949, and the maximum, 139.0 ppm, from the same station on February 16, 1950.

Vertical concentrations on any given date generally had a difference of less than 10 ppm. One outstanding exception to this being on August 16, 1949, at Station IV when the surface reading was 118.0 ppm and that of the bottom 137.0 ppm.

TABLE XIII

MO ALKALINITY EXPRESSED AS PPM 1949-50

Station I

Meters		0	5	6	7	8	9	10	11	11½	12	12½
March	3	115.0	117.0						119.0			
	28	114.0	118.0						118.0			
April	8	122.0	121.0						125.0			
	22	123.0	122.0						125.0			
May	20	129.0	126.0						136.0			
June	10	103.0	117.0								115.0	
	25	117.0	125.0	120.0	121.0	122.0	123.0	121.0	124.0			
July	8	115.0	110.0	117.0	123.0	123.0	122.0	122.0	124.0			
	21	114.0	113.0	117.0	123.0	122.0	124.0	124.0	126.0			
Aug.	2	127.0	130.0			125.0	132.0	128.0	127.0			
	16	125.0	128.0			124.0	126.0					135.0
Sept.	3	123.0	126.0						128.0			
	20	128.0	132.0						133.0			
Oct.	10	126.0	120.0					132.0	132.0			
	26	128.0	126.0						130.0			
Nov.	14	124.0	130.0					131.0	131.0			
	28	128.0	128.0							132.0		
Dec.	5	127.0	128.0						130.0			
	30	127.0	128.0							129.0		
Jan.	17	131.0	132.0						134.0			
	30	135.0	134.0							133.0		
Feb.	16	134.0	135.0						137.0			
	25	130.0	132.0						132.0			

TABLE XIII (Continued)

MO ALKALINITY EXPRESSED AS PPM 1949-50

		Station II				Station III			
Meters		0	5	6	6½	0	5	6	6½
March	3	118.0	120.0			114.0	118.0		
	28	114.0	119.0			116.0	117.0		
April	8	125.0	127.0			120.0	125.0		
	22	125.0		126.0		126.0	127.0		
May	20	130.0		127.0		129.0	130.0		
June	10	101.0	115.0	108.0		105.0	116.0	118.0	
	25	116.0	125.0		125.0	119.0	124.0	126.0	
July	8	115.0	118.0			116.0	119.0	119.0	
	21	116.0	113.0	117.0		113.0	111.0	118.0	
Aug.	2	127.0	128.0	129.0		125.0	131.0	131.0	
	16	116.0		122.0		120.0	122.0		
Sept.	3	123.0	125.0			127.0	127.0		
	20	133.0			132.0	120.0		124.0	
Oct.	10	125.0	125.0		131.0	129.0		131.0	
	26	128.0	127.0	129.0		127.0		129.0	
Nov.	14	130.0	131.0			130.0		134.0	
	28	128.0	130.0			128.0		128.0	
Dec.	5	125.0	129.0			128.0		131.0	
	30	126.0	128.0			125.0		130.0	
Jan.	17	132.0		137.0		124.0	128.0		
	30	136.0	132.0			134.0		132.0	
Feb.	16	135.0	137.0			132.0	136.0		
	25	134.0	134.0			129.0	132.0		

TABLE XIII (Continued)

MO ALKALINITY EXPRESSED IN PPM 1949-50

Station IV

Meters		0	5	6	6½	7	7½	8
March	3	115.0				117.0		
	28	115.0				119.0		
April	8	112.0				116.0		
	22	123.0				124.0		
May	20	129.0					129.0	
June	10	103.0	116.0			110.0		
	25	93.0	86.0	73.0		73.0		70.0
July	8	116.0	116.0	118.0		124.0		123.0
	21	115.0	111.0	117.0		118.0		124.0
Aug.	2	126.0	132.0	132.0		131.0		129.0
	16	118.0	121.0					137.0
Sept.	3	128.0				129.0		
	20	121.0	122.0				124.0	
Oct.	10	125.0	133.0				132.0	
	26	129.0	128.0			130.0		
Nov.	14	127.0				130.0		
	28	129.0					130.0	
Dec.	5	127.0				129.0		
	30	126.0			127.0			
Jan.	17	128.0			136.0			
	30	136.0				133.0		
Feb.	16	136.0			139.0			
	25	134.0		136.0				

PLANKTON

Phytoplankton

1940-41

General features of seasonal distribution and relative abundance of genera are shown in Table XIV. These data were derived from collections at Station I.

The following list shows the classes and genera of phytoplankton found during a qualitative study.

Bacillarieae
    Fragillaria
    Gyrosigma
    Melosira
    Synedra

Chrysophyceae
    Mallomonas

Dinophyceae
    Ceratium

Chlorophyceae
    Closterium
    Cosmarium
    Pandorina
    Pediastrum
    Scenedesmus
    Staurastrum
    Ulothrix

Myxophyceae
    Anabaena
    Aphanotheca
    Coeloapharium
    Microcystis
    Oscillatoria

Five classes and eighteen genera were identified. Some of the forms occurred too infrequently to influence total counts. The discussion following presents information concerning relative abundance, seasonal, and vertical distribution of the classes and the dominant forms of each class.

BACILLARIEAE. Representatives of both orders were present. *Melosira*. Collectively the whole Pennales group found were not

TABLE XIV

PLANKTON COUNTS IN NUMBERS PER LITER 1940-41

Surface

	Oct. 24	Nov. 21	Dec. 19	Jan. 9	Jan. 31	March 9	April 9	May 9	May 31	July 10	Aug. 29
Myxophyceae	39800	97100	5500								11700
Chlorophyceae		200	6800	1600	2100	2700	23400	200			
Bacillarieae		900		600	700	800	700	400			
Chrysophyceae			1300	4100	2000	500	700		200		800
Dinophyceae											
Protozoa				200	200						
Rotifera			200	600	600		700		200		3300
Cladocera					100				200		300
Copepoda				200	300		300	400	200		
Total	39800	98200	13800	7300	6000	4000	25800	1000	800		16100

Eight Meters

	Oct. 24	Nov. 21	Dec. 19	Jan. 9	Jan. 31	March 9	April 9	May 9	May 31	July 10	Aug. 29
Myxophyceae	32800	99800	5200	4100			1200				5500
Chlorophyceae		500	600	400		6000	18800				200
Bacillarieae	300	300	100	300		300	600	100			200
Chrysophyceae			400	600		1200	1200	300			400
Dinophyceae											
Protozoa	500	100	300	200			300	100			400
Rotifera		100	500	200		1200	2400	400	200		
Cladocera	400		100	400			300				
Copepoda			100	100							
Total	34000	20800	2300	6300		8700	24800	900	200		6700

TABLE XIV (Continued)

PLANKTON COUNTS IN NUMBERS PER LITER 1940-41

<u>Bottom</u>

	Oct. 24	Nov. 21	Dec. 19	Jan. 9	Jan. 31	March 9	April 9	May 9	May 31	July 10	Aug. 29
Myxophyceae	3000	106300	3800	4500	5200	5100					
Chlorophyceae	200	500	700	1000	3100	8600	22200	100			900
Bacillarieae		300			300	200	300				300
Chrysophyceae			400	400	300	500	500	200			
Dinophyceae		300									
Protozoa	200	400		200	300						
Rotifera	400	100	400	200	300	1200		500			300
Cladocera							300	100			
Copepoda	900	100			200	200	300				
Total	4700	108000	5300	6300	9700	15800	23600	900			1500

There seems to be only a slight correlation between occurrance of Chlorophyceae and depth of water. Considering the study as a whole, the counts showed a slightly larger number of organisms in the surface samples, but counts from the bottom more often contain sufficient numbers of this group to influence the total count.

Closterium. This genus ranked second in number of times present as well as in total organisms per liter, and it appeared more consistantly during the interval between November 1940 and April 1941 than at any other like interval during the study. The maximum peak noted, 1000 cells per liter, occurred on April 9, 1941, from a sample taken at the surface. Counts at other times were usually about 200 cells per liter.

Cosmarium. This form did not occur in numbers sufficient to be included in any of the counts.

Pandorina. A sample from the eight-meter level on March 21, 1941, yielded a count of 100 colonies per liter. This was the only time this genus was encountered.

Pediastrum. This genus ranked third in occurrance and in numbers per liter. It was found throughout the year in the qualitative surveys of the plankton, but it rarely contributed to the total count. The maximum concentration found, 600 per liter, was from the bottom on August 8, 1941.

Scenedesmus. This form was found once only, November 1941. It was not prevelant enough to influence the total plankton count.

Staurastrum. Staurastrum was quantitatively and seasonally the most important genus of the green algae. It was present in all collections and greatly influenced Chlorophyceae counts throughout the study. With the exception of August 8, 1941, bottom sample mentioned in connection with Pediastrum, it was the dominant green algae genus in all the quantitatively equal to Melosira whose maximum abundance was 1100 organisms per liter.

Fragillaria, with a maximum count of 800 organisms per liter, ranked second to Melosira in quantitative numbers.

Gryrosigma ranked third with a maximum peak of 300 organisms per liter.

Synedra was relatively rare.

The diatoms were not an outstanding constituent of the plytoplankton found in 1940-41.

Surface counts usually showed a greater number of diatoms per liter than did the other levels. One outstanding exception to this occurred on September 20, 1941, when the surface count totaled 500 per liter, the eight-meter level 100 per liter, and the bottom 1400 per liter.

Data are not available to allow a statement concerning the seasonal maxima of the genera, but the total diatom counts were greater from November 21, 1940, to March 9, 1941. The previously mentioned count of September 20 was the largest of the 1940-41 period.

CHLOROPHYCEAE. Seven genera of this class were found in the 1940-41 study. This group had the most genera but their maxima counts were not as great as were those of the blue-greens.

Data on seasonal distribution of total Chlorophyeae show that this group produced its peak on April 9, 1941. On this date the surface had 23,400 organisms per liter, and the bottom 22,200. They were not encountered when counting samples taken in October 1940, and May 31, 1941, however in the qualitative surveys, Staurastrum and Closterium were usually found. On other dates the counts, except in the pulse previously mentioned, ranged from 200 to 8500 organisms per liter.

collections. Its maximum peaks for all levels appeared on April 9, 1941. The surface concentration was 22,400, the eight meter 18,500, and the bottom 21,900 organisms per liter.

Ulothrix. This genus was found only in the October 9, 1941, surface sample. It was not present in quanities great enough to influence the total Chlorophyceae count.

CHRYSOPHYCEAE. Mallamonas was the sole representative of this group. It was generally present throughout the study, although, as with the diatoms, at times in insufficient numbers to be included in the counts. Its maximum peak occurred on January 9, 1941, when the surface count was 4100 per liter. The maximum at eight meters occurred on March 9 and May 9, 1941, when the counts were 1200 organisms per liter in each case. The above is also true of samples from the bottom except the number was 500 organisms per liter.

DINOPHYCEAE. This group numerically unimportant, seldom influenced quantitative surveys. The one genus, Ceratium, appeared in one count with 300 organisms per liter from the bottom on November 21, 1940.

MYXOPHYCEAE. This class was of numerical importance in October, November, and December of 1940 and from August to September of 1941. At these times it was responsible for the pulses shown in Table XIV.

Coelospharium was the only genus that occurred in sufficient numbers to influence the total count of blue-green algae. Data from the October 24, 1940, samples showed 39,800 organisms per liter at the surface, 32,800 at eight meters, and 3,000 at the bottom. On November 21, 1940, the values had risen to 97,000, 99,800, and 106,300 for surface, eight meters and the bottom, respectively. These figures represent the largest pulse noted in the 1940-41 study.

1949-50

Total number of individuals and occurrence of the various classes are shown in Table XV. These data were derived from collections made at Station I.

Two maxima occurred during the 1949-50 study; one in August 1949, and one, of longer duration, in November 1949, which extended into February 1950. The August maximum was due to an increase of plankton in the surface water only, while that of the winter period was due to organisms found at all depths with their surface values generally lower than those of the five-meter level, and only slightly higher than those of the bottom. Bottom counts were greater than those of the surface in two instances and the February 16, 1950, sample with 8400 organisms per liter provided the largest count of the 1949-50 study.

The classes and genera found during 1949-50 are given below.

Bacillarieae
- *Amphipleura*
- *Cymbella*
- *Gomphonema*
- *Melosira*
- *Navicula*
- *Synedra*

Dinophyceae
- *Ceratium*
- *Glenodinium*
- *Peridinium*

Chlorophyceae
- *Chlamydomonas*
- *Closterium*
- *Coelastrum*
- *Cosmarium*
- *Hydrodicton*
- *Pediastrum*
- *Spirotaenia*
- *Staurastrum*
- *Tetraspora*

Myxophyceae
- *Anabaena*
- *Oscillatoria*

There was little difference in the seasonal frequency, both were present throughout the study, but in numbers of organisms per liter the diatoms exceeded the green algae.

The Myxophyceae were found at the surface on June 10 and August 16, 1949, at five meters on July 21 and September 20, 1949, and at the bottom

TABLE XV

PLANKTON COUNTS IN NUMBERS PER LITER 1949-50

Surface

	March 3	March 28	April 8	April 22	May 20	June 10	June 25	July 8	July 21	Aug. 2	Aug. 16	Sept. 3
Myxophyceae						100						
Chlorophyceae	1200	1000		300	300	100	200	500				500
Baccillarieae	1400	1300			2100	100	400	3700		4300	4800	3000
Chrysophyceae												
Dinophyceae												
Protozoa		600	1100			100	100					
Rotifera	200	200			200			200		100	100	300
Cladocera	500	200	200	100							100	300
Copepoda				100	200	400						
Total	3300	3300	1300	500	2800	800	700	4400		4400	5000	4100

Surface (Continued)

	Sept. 20	Oct. 10	Oct. 26	Nov. 14	Nov. 28	Dec. 5	Dec. 30	Jan. 17	Jan. 30	Feb. 16	Feb. 25
Myxophyceae											
Chlorophyceae	200	200		100	900	300	1500	1700	1300	1900	1200
Baccillarieae		200	400	400	1600	1400	3100	2000	1700	2600	1500
Chrysophyceae											
Dinophyceae											
Protozoa											
Roterifera					300	800		800	700	400	300
Cladocera		200	100								
Total	200	600	500	500	2800	2500	4600	4500	3700	4900	3000

TABLE XV (Continued)

PLANKTON COUNTS IN NUMBERS PER LITER 1949-50

5 Meters

	March 3	March 28	April 8	April 22	May 20	June 10	June 25	July 8	July 21	Aug. 2	Aug. 16	Sept. 3
Myxophyceae									100			
Chlorophyceae	400	100	100	200		100		100	3600		100	
Bacillarieae	2300	1300	300	200	1400	100	200	2500		2200	1000	700
Chrysophyceae												
Dinophyceae												
Protozoa		300	100				100		100			
Rotifera	400	300	400		100			100				
Cladocera		100		200					100			
Copepoda			200	500					400	100		
Total	3100	2100	1100	1100	1500	200	300	2700	4300	2300	1100	700

5 Meters (Continued)

	Sept. 20	Oct. 10	Oct. 26	Nov. 14	Nov. 28	Dec. 5	Dec. 30	Jan. 17	Jan. 30	Feb. 16	Feb. 25
Myxophyceae	100										
Chlorophyceae		200	300		500	200	800	2600	2800	1100	1000
Bacillarieae	300		100	500	900	3900	4100	3200	2800	3600	2700
Chrysophyceae											
Dinophyceae											
Protozoa						200			800		
Rotifera					100	800	1200	500		700	700
Cladocera		200	300	200					400		300
Copepoda							200				
Total	400	400	700	700	1500	5100	6300	6300	6800	5400	4700

1.
2.
Bacillariophyceae = Diatoms (Yellow Green Algae) - Chrysophyta
3.
4.
5.

TABLE XV (Continued)

PLANKTON COUNTS IN NUMBERS PER LITER 1949-50

Bottom

Dates	March 3	March 28	April 8	April 22	May 20	June 10	June 25	July 8	July 21	Aug. 2	Aug. 16	Sept. 3
Myxophyceae				100								
Chlorophyceae		400	300	200			200					
Bacillarieae	1300	700	600	500	2000		400	800	500	500	200	
Chrysophyceae												
Dinophyceae												
Protozoa		200				100						
Rotifera	700	700	300	100	300					200		200
Cladocera	100											
Copepoda					200					200		
Total	2100	2000	1200	900	2500	100	600	800	500	900	200	200

Bottom (Continued)

	Sept. 20	Oct. 10	Oct. 26	Nov. 14	Nov. 28	Dec. 5	Dec. 30	Jan. 17	Jan. 30	Feb. 16	Feb. 25
Myxophyceae											
Chlorophyceae		100					300	200	1200	2400	1800
Bacillarieae		300	300	100	1100	2900	900	1800	2400	6100	3100
Chrysophyceae											
Dinophyceae											
Protozoa				300			200	100			200
Rotifera			100			500	600	400	300		200
Cladocera		100	100		200						
Copepoda											
Total	000	500	500	400	1300	3400	2000	2500	3900	8500	5300

on April 22, 1949. Total numbers counted for these dates did not exceed 100 per liter except when 600 were found on the surface on August 16, 1949. *Anabaena* alone occurred in countable numbers.

DINOPHYCEAE. Three genera were encountered in the qualitative surveys but were not found in the quantitative counts.

BACILLARIEAE. The Pennales group was represented by five genera but only Synedra occurred in sufficient numbers to be counted and then not exceeding 100 organisms per liter.

Melosira was the only Centrales genus encountered.

The diatoms were the outstanding group of the 1949-50 phytoplankton, *Melosira* being the numerically dominant genus. This genus was absent from only a few collections. In nearly all instances it occurred in numbers greater than any other.

The numerical analyses show the five-meter and bottom values exceeded those of the surface about half of the time. The maximum count for the year occurred at the bottom on February 16, 1950, with 6100 organisms per liter. Surface and five-meter values on the same date were 2600 and 3600 organisms per liter.

The 1949-50 maxima of *Melosira* account for the August and November - February phytoplankton maxima previously mentioned. A general statement only can be given concerning minima concentrations. *Melosira* was absent from a few counts, but in qualitative surveys it was always present. It appears from the data that summer and fall are the times of lowest concentration.

CHLOROPHYCEAE. Nine genera were found, the largest number for any one phytoplankton class in the 1949-50 study.

Closterium was the only genus that occurred in numbers great enough to influence the count. Quantitatively it was exceeded only by the diatoms, its maximum reaching 3600 organisms per liter at five meters on July 21, 1949. It was present in the qualitative surveys of each concentrate although at times its numbers were not significant. The period between April and November 14, 1949, marked its lowest ebb at all levels with the exception of the previously mentioned count of 3600 organisms found at five meters on July 21. At other times during this period surface and five-meter levels did not exceed 500 organisms per liter. Winter concentrations were greater, the winter maxima being 3100 organisms per liter at the surface and 2800 at five meters. Green algae were absent from counts made from bottom collections in the period between July and October 10, 1949.

Zooplankton

1940-41

Data on the seasonal distribution and relative abundance of genera (Table XV) were derived from collections taken at Station I.

Listed below are the various groups and their genera found during the 1940-41 period. All the genera listed except *Chaoborus* larvae were present in sufficient numbers to be included in the counts at some time throughout the study; many were sporadic in occurrence and will be treated as groups rather than separate genera.

- Protozoa
  - *Codonella*
- Copepoda
  - *Cyclops*
  - *Diaptomus*
  - *Nauplii*
- Rotifera
  - *Asplanchna*
  - *Keratella*
  - *Notholca*
  - *Notops*
  - *Pedalion*
  - *Pleosome*
  - *Polyarthra*
  - *Rotifer*

Cladocera	Insects
Bosmina	Chaoborus
Ceriodaphnia	
Daphnia	

Fifteen genera were found in the 1940-41 study excluding the contracted rotifers and larval forms of the Copepods.

PROTOZOA. The genus Codonella was the only protozoan found in the concentrates. This form was present throughout the year at all levels, but it occurred in greater numbers and a greater number of times at the eight-meter level.

The counts made from the surface concentrates show that Codonella was present only on January 9 and 31, 1941, in quantities of 200 per liter. It was present eight times in the counts from the eight-meter level concentrates. The maximum numbers per liter occurred in the fall of 1940 and summer of 1941. The greatest number counted (October 9, 1940) was 500 per liter. Bottom occurrence and concentrations were similar to the eight-meter level with the maximum being 400 per liter.

COPEPODA. The Copepoda, represented by two genera and nauplii, occurred in the surface counts in greatest concentrations in the late winter and early spring (January 31 to May 9, 1941). The maximum number per liter was 400. They were absent from many of the counts.

Numbers from the eight-meter level were somewhat less than those given for the surface. They were present in counts three times during the study. These occurred during the late winter--early spring interval previously mentioned. The maximum count at this level was 300 per liter on May 9, 1941.

Copepods were most numerous in samples taken from the bottom, the maximum count of 900 per liter on October 9, 1940, being the greatest of the study. The late winter — early spring period represented the most prolonged concentration of these planktors in the bottom waters.

CLADOCERA. Cladocera were present in each concentration throughout the year, but in quantitative counts they were present only a few times at any of the levels studied. No pulse of these plankters appeared; maxima were 800 per liter at the surface and bottom and 400 at eight meters. Usually the counts were 100 to 200 per liter.

ROTIFERA. This group was represented by the largest number of zooplankton genera. Six genera were recognized. Some rotifers were contracted beyond recognition by the formalin.

Rotifers were counted in the surface samples seven times, the eight-meter samples seven times, and the bottom samples nine times. Keratella and Polyarthra were the most numerous.

The greatest abundance of rotifers at eight-meters and the bottom occurred during March and May, 1941. The surface maximum was somewhat later, occurring in August, 1941. The maximum was 3300 per liter at the surface, 2400 at eight meters, and 1200 at the bottom. Throughout the study surface concentrations were usually greatest and those of the bottom least.

Chaoborus. These larval forms were present in a great many of the samples, but none were encountered when counting.

1949-50

The seasonal distribution and relative abundance of genera found in collections taken at Station I are shown in Table XV.

The following list gives the various groups and their genera found during the 1949-50 period. All the forms except *Chaoborus* larvae and *Vorticella* were present in sufficient numbers to be included in the counts at various times, but, as with the 1940-41 study, many were sporadic in occurrence making it advantageous to discuss them as groups rather than genera.

- Protozoa
  - *Codonella*
  - *Vorticella*

- Copepoda
  - *Cyclops*
  - *Diaptomus*
  - Nauplii

- Cladocera
  - *Bosmina*
  - *Ceriodaphnia*
  - *Daphnia*

- Insects
  - *Chaoborus*

- Rotifera
  - *Asplanchna*
  - *Brachionus*
  - *Keratella*
  - *Noteus*
  - *Pedetes*
  - *Ploesoma*
  - *Pterodina*
  - *Rattulus*
  - *Rotifer*
  - *Simocephalus*
  - *Synchaeta*
  - *Triarthra*
  - Contracted rotifers

Twenty genera were found in the 1949-50 study excluding the contracted rotifers and larval Copepoda.

PROTOZOA. *Vorticella* and *Codonella* were the only Protozoa found in the surveys of the plankton concentrate.

Vorticella was found once in these surveys. It was not present in any of the counts.

Codonella was present throughout the year at all levels. Numbers sufficient to influence the surface counts occurred four times. These larger populations were found in the period from March 3 to June 25, 1949. A count of 600 per liter was found in the March 28 sample, 1100 (the greatest number encountered at any level) on April 8, while the other counts were 100 each on June 10 and June 25.

Codonella were present in the five-meter level counts six times. Occurrence was similar to that of the surface except for the maximum of 800 per liter which occurred on January 30, 1950. Other counts were from 100 to 300 per liter.

Counts for the bottom samples were usually greater than for the other levels although the maximum was not so pronounced.

COPEPODA. Genera were the same as those of the 1940-41 study.

Copepoda were present at the surface in quantities great enough to count three times. These occurred in concentrates taken during the spring. Four hundred per liter was the maximum in the surface samples. This count was made on June 10, 1949. The other counts were 100 and 200 per liter.

Concentrations at five meters were somewhat greater than those at the surface. The maximum number, 500 per liter, occurred earlier in the spring (April 22). The summer maximum was 400 per liter. Throughout the remainder of the study the Copepoda were absent from counts.

Copepoda were found in the bottom samples only twice in sufficient numbers to count. On May 20 and August 2, 1949, 200 per liter were found.

CLADOCERA. The surface concentrates provided numbers great enough to count during spring and late summer — early autumn. The maximum number, 500 per liter, was from the March 3, 1949, concentrate.

Populations great enough to count occurred at five-meters at similar periods as those given for the surface. The maximum count, 400 per liter, was made from the January 30, 1950, concentrate. The spring maximum was 200 per liter and the summer — fall maximum was 300 per liter.

The Cladocera were not as abundant at the bottom as at other levels. During the spring they were encountered once. At that time the number per liter was 100. They were present in three samples in October and November, 1949. The maximum number per liter for this fall period was 200.

ROTIFERA. Twelve genera of rotifera were found in the 1949-50 study. This comprised the largest number of genera of any zooplankter group encountered. Some forms were contracted beyond recognition. The rotifers occurred more frequently and more abundantly in the surface concentrates taken during the winter months. The maximum number at this level, 800 per liter, was collected on December 5, 1949, and January 17, 1950. Other samples taken during the winter period had 300, 400, and 700 per liter. The maximum summer count of 200 was from the July 8, 1949, concentrate.

In the winter five-meter and bottom counts differed from the surface in size and time of peak occurrence with 1200 per liter at five meters and 600 at the bottom on December 30, 1949. It is of interest to note that Rotifera were absent from the surface on this date when maximum occurrence appeared at five meters.

Centrifuged Plankton

1940-41

Results obtained from centrifuged plankton concentrates are given in Tables II and XVI as ml. per liter of lake water.

Three surface maxima were found during the study. The first, November 21, 1940, showed a volume of 0.0048 ml.; the second and third, April 9 and August 29, 1941, each a volume of 0.0053 ml.

The only notable peak found at the eight-meter level occurred on April 9, 1941 with a volume of 0.0066 ml. This was the second largest volume found at any level.

TABLE XVI

CENTRIFUGED PLANKTON EXPRESSED AS CUBIC MILLILITERS PER LITER 1940-41

Station I

	Oct. 24	Nov. 21	Dec. 19	Jan. 9	Jan. 31	March 9	April 9	May 9	May 31	Aug. 29	Sept. 20
Surface	.0035	.0028	.0020	.0032	.0024	.0012	.0053	.0029	.0037	.0053	.0017
8 Meters	.0040	.0044	.0026	.0037	.0000	.0019	.0066	.0009	.0029	.0019	.0019
Bottom	.0500	.0029	.0035	.0027	.0059	.0015	.0048	.0007	.0000	.0016	.0012

Three maxima were noted in the bottom concentrates. The first in October with a volume of 0.05 ml. This was the greatest volume recorded. The second maximum recorded was 0.0059 ml. from the sample taken on January 31, 1941. The third peak, the smallest, was 0.0048 ml. collected April 9, 1941.

It can be noted from Table XVI that these maxima at the various levels did not occur simultaneously even though their rise and decline are similar and that minima volumes are associated with increased turbidity.

When the volume of centrifuged plankton, 0.05 ml., for October 24, 1940, and the quantitative count of the same sample with 900 copepoda per liter are compared the profound effect of these zooplankters on volume can be seen. Peaks of volume and peaks of total numbers of plankton do not coincide in all cases, although, with rare exceptions, they do show similar fluctuations.

1949-50

The centrifuged plankton volumes in the 1949-50 study were not outstandingly large and the concentrate values were nearly equal (Table XVII) thus presenting a somewhat undulating aspect. Centrifuge data agree more closely with total quantitative counts in 1949-50 than in 1940-41.

Volumes of centrifuged plankton in 1949-50 were considerably less than in 1940-41. The maxima at the surface and bottom were 0.0036 ml. and at the five-meter level 0.0034 ml. (Station I) and occurred in the spring of 1949. Minima volumes occurred during the summer and fall. Plamkton volumes for all stations are quite similar.

Plankton volume change as associated with turbidity fluctuation was not so apparent as in 1940-41. Still, plankton volumes were greater in early spring of 1949 and winter of 1949-50 when the turbidity was less.

TABLE XVII

CENTRIFUGED PLANKTON EXPRESSED AS CUBIC MILLILITERS PER LITER 1949-50

Station I

	March 3	March 28	April 8	April 22	May 20	June 10	June 25	July 8	July 21	Aug. 2	Aug. 16	Sept. 3
Surface	.0036	.0034	.0016	.0027	.0019	.0007	.0008	.0009	.0009	.0010	.0012	.0010
5 Meters	.0030	.0029	.0025	.0025	.0016	.0008	.0009	.0018	.0010	.0012	.0013	.0009
Bottom	.0034	.0039	.0019	.0020	.0021	.0005	.0015	.0017	.0008	.0009	.0009	.0007

	Sept. 20	Oct. 10	Oct. 26	Nov. 14	Nov. 28	Dec. 5	Dec. 30	Jan. 17	Jan. 30	Feb. 16	Feb. 25
Surface	.0004	.0004	.0005	.0004	.0009	.0016	.0012	.0012	.0009	.0012	.0015
5 Meters	.0012	.0008	.0009	.0016	.0019	.0019	.0025	.0019	.0014	.0015	.0019
Bottom	.0004	.0008	.0008	.0012	.0023	.0016	.0016	.0020	.0016	.0026	.0020

Station II

	March 3	March 28	April 8	April 22	May 20	June 10	June 25	July 8	July 21	Aug. 2	Aug. 16	Sept. 3
Surface	.0034	.0026	.0026	.0020	.0015	.0005	.0013	.0003	.0007	.0008	.0008	.0009
Bottom	.0036	.0034	.0025	.0025	.0017	.0007	.0015	.0024	.0020	.0010	.0030	.0008

	Sept. 20	Oct. 10	Oct. 26	Nov. 14	Nov. 28	Dec. 5	Dec. 30	Jan. 17	Jan. 30	Feb. 16	Feb. 25
Surface	.0004	.0007	.0004	.0003	.0007	.0019	.0011	.0010	.0002	.0018	.0011
Bottom	.0005	.0008	.0007	.0005	.0017	.0011	.0015	.0012	.0019	.0019	.0017

TABLE XVII (Continued)

CENTRIFUGED PLANKTON EXPRESSED AS CUBIC MILLILITERS PER LITER 1949-50

Station III

	March 3	March 28	April 8	April 22	May 20	June 10	June 25	July 8	July 31	Aug. 2	Aug. 16	Sept. 3
Surface	.0032	.0030	.0011	.0025	.0016	.0007	.0007	.0017	.0008	.0008	.0006	.0010
Bottom	.0034	.0032	.0020	.0019	.0015	.0004	.0011	.0013	.0021	.0012	.0011	.0011

	Sept. 20	Oct. 10	Oct. 26	Nov. 14	Nov. 28	Dec. 5	Dec. 30	Jan. 17	Jan. 30	Feb. 16	Feb. 25
Surface	.0005	.0004	.0005	.0005	.0009	.0013	.0013	.0011	.0001	.0019	.0011
Bottom	.0005	.0013	.0009	.0007	.0002	.0015	.0016	.0015	.0002	.0020	.0020

Station IV

	March 3	March 28	April 8	April 22	May 20	June 10	June 25	July 8	July 21	Aug. 2	Aug. 16	Sept. 3
Surface	.0029	.0020	.0015	.0017	.0020	.0007	.0019	.0011	.0007	.0007	.0012	.0010
5 Meters						.0007	.0008	.0013	.0016	.0009	.0015	
Bottom	.0015	.0018	.0018	.0017	.0025	.0016	.0011	.0016	.0015	.0010	.0011	.0009

	Sept. 20	Oct. 10	Oct. 26	Nov. 14	Nov. 28	Dec. 5	Dec. 30	Jan. 17	Jan. 30	Feb. 16	Feb. 25
Surface	.0003	.0009	.0004	.0005	.0008	.0009	.0010	.0011	.0012	.0022	.0020
5 Meters	.0006	.0002									
Bottom	.0005	.0004	.0008	.0016	.0016	.0013	.0013	.0019	.0020	.0017	.0022

DISCUSSION

Thermal data of 1940-41 and 1949-50 were similar and differences found were in all probability due to climatic variations. The greatest difference between the two years studied was the behavior of thermal stratification. Stratification occurred earlier in the spring of 1941 than it did in 1949. The upper limits of the 1941 thermocline began at eight meters, changed later to four meters, and still later descended to ten meters. These differences were more than likely due to the relatively small amount of water in the lake and high winds and rains in autumn. The thermocline in the summer of 1949 remained constant at five meters indicating that the influence of climatic factors had less effect on the larger area of water present.

The winters included by the two investigations produced no ice cover and circulation was continuous from early fall to early spring.

The lack of thermal stratification in the summer of 1949 at Stations II and III whose depths were greater than the upper reaches of the thermocline found at Stations I and IV was probably due to the obtuse V-shaped bottom, the relatively small amount of water below the five-meter level, and the fact that these stations are in arms that lie parallel to the prevailing winds. It is hardly probable that shore line and bottom contours could have produced depression individuality as described by Welch (1935).

Turbidity differences of 1940-41 and 1949-50 were great. Those of 1940-41 were characterized by great variations and comparatively long periods of clarity while those of 1949-50 did not show great variations but remained more or less stable, lacking clarity most of the time, and especially at the times ordinarily assigned as the periods of greatest phytoplankton production.

It has been stated that clay (Welch, 1935), and specifically montmorillonite clay (Irwin, 1945), belong to a group of non-settling turbidity producing agents. The turbidities found in Lake Carl Blackwell are due to clay of the latter type. Irwin (1945) stated further that this non-settling clay can be floculated in impoundments by employing plant manures to increase the hydrogen-ion concentration. The clarity thus produced remains until water exchange in the basin or/and inflowing mud decreased the hydrogen-ion concentration by the buffer effect of dispersed clay particles. This seems to have happened in Lake Carl Blackwell. The vegetation inundated by impoundment, decayed, released hydrogen-ions and clarified the water, although turbidities following rains were great in 1940-41. As the years passed, this floculating ability was lost due to inflowing mud, and water exchange. The turbidities became more constant creating the condition found in 1949-50." The possibility seems great that Lake Carl Blackwell will remain turbid unless remedial measures are taken.

Turbidity and temperature readings are insufficient to prove the presence or absence of density currents.

The dissolved oxygen differences of the two periods studied were negligable, climatic conditions being the governing factor in the oxygen values. Oxygen values of each investigation were nearly equal in vertical profile except during stratification. Super-saturation of dissolved oxygen was not found.

Hydrogen-ion concentration differed considerable regardless of a similar range during both years. Fluctuations of pH values in 1940-41 were more pronounced than those of 1949-50. The fluctuations of pH from surface to bottom in both investigations during the months of thermal and chemical stratification was in keeping with what might be expected in a stratified lake.

None of the readings in either study indicated a condition of acidity as the minimum pH recorded was 7.1.

The relationships between pH and carbon dioxide as well as the fluctuations of carbon dioxide in its free, bound, and half-bound states (Tables II, VI, VII, VIII, IX, X, XI, XII, and XIII) show a substantial difference in the two studies.

At times these relationships resemble those found by other investigators, but at other times there was no explainable reason for these changes except as given by Stevenson (1950, unpublished doctoral thesis, Oklahoma A. and M. College) who stated that a rough correlation exists between the occurrence of carbon dioxide, either in the free state or as bicarbonates, and the precipitation of colloidal clay, each of these being utilized in floculating the clay. If one examines the turbidity, pH, and bicarbonate data of this paper this correlation can be seen. This is especially true in the case of 1949-50 data. Too, it should be noted that bicarbonate concentrations were greater in 1940-41 when turbidities were low, than in 1949-50. This is true also in the data of Harris and Silvey (1940) although they did not mention it except in connection with the density current found in Lake Bridgeport.

In the light of past research on the effects of silting and turbidity on aquatic organisms (Chandler, 1937, 1940, 1942a, 1942b, 1944;

Chandler and Weeks, 1945; Doan, 1941, 1942; Ellis, 1936; Harris and Silvey, 1940; Irwin, 1945, 1948; Meyer and Heritage, 1941; Moore, 1937; Welch, 1935; Whipple, et. al., 1927; and unpublished data from Oklahoma A. and M. College) it appears that clay turbidity rather than chemical conditions as found in Lake Carl Blackwell are responsible for plankton paucity and succession. It seems doubtful that the turbidity producing clay in Lake Carl Blackwell would produce direct injury as noted by Chandler (1937).

Plankton succession was from a more or less typical myxophycean-chlorophycean phytoplankton population in 1940-41 to one in 1949-50 characterized by an almost complete absence of blue-greens, relatively few greens, quantitatively, and dominated in numbers by a diatom (Melosira) population. The succession corresponded to that found by Chandler (1942b) in Lake Erie when its waters were turbid. The same succession is suggested in Chandler's (1940) work as well as that of Harris and Silvey (1940).

Myxophyceae pulses occurred in the fall of 1940 and to a lesser extent in August of 1941. The blue-greens were not important constituents of the plankton at other times of the year. The fall pulse approximated 100,000 organisms per liter at all levels. Coelosphaerium was the dominant organism in numbers. The August pulse was small in comparison to that of the preceding fall, being only 11,700 organisms per liter. Whether or not this concentration was the forerunner of a pulse comparable with that of 1940 is not known due to the profound effect of physical-chemical phenomena that occurred between August 20 and September 20, 1941.

The Chlorophyceae were most abundant during the spring months of 1941. The greatest concentrations noted were from the April 9 collections.

The surface count was the highest with 23,400 organisms per liter. Staurastrum was the numerically dominant form throughout 1940-41.

The maximum diatom count of 1940-41, 800 per liter, occurred in the spring of 1941 just preceding the green algae pulse. At other times they were either absent or occurred in very small numbers.

The phytoplankton population of 1949-50 showed marked differences quantitatively from that of 1940-41. Maxima did not occur at the same time and were considerably less in numbers than were those of 1940-41. Many investigators have noted the inconsistancy of phytoplankton pulse appearances and the only significance that can be attached to phytoplankton behavior in this study is that caused by the clay turbidity of the water.

Phytoplankton maxima did not present outstanding peaks as were found in 1940-41, but were of an undulating nature in 1949-50.

Two noteable peaks occurred in August, 1949, and winter, 1949-50, They were small numerically when compared to those of 1940-41. The August pulse was apparently minimized and later decreased because of high turbidity, as September 3 concentrates yielded very low counts. The winter peak coincided with turbidity decline.

Characteristic myxophyceae peaks did not appear in this year of study, in fact, the blue-greens were unimportant in 1949-50. The numerically dominant phytoplankter was the diatom Melosira. This genus occurred throughout the study and at times of increased turbidity was the main constituent of the plankton.

Closterium was the only green alga present in quantities in 1949-50. Its maximum concentration was found at five meters on July 21, 1949, but in other samples taken during spring and summer it was scarce. The winter concentrations which began in November were much greater than those of spring and summer.

Mallomonas which occurred often in countable numbers in 1940-41 was not found in 1949-50.

The number of samples taken and the relative scarcity of the zooplankters allow little more than generalities concerning seasonal distribution in both 1940-41 and 1949-50.

The Rotifera in the two years studied were the numerically dominant zooplankters. Concentrations were greater in 1940-41, the maximum number per liter being 3300. This maximum was found in the surface water. The maximum in 1949-50, from the five-meter level, was 1200 per liter. It is noteworthy of attention that these plankters reached their maxima, or were present in greater numbers, at times that coincided with phytoplankton increase. Concentrations of rotifers in 1940-41 were greatest during spring and summer and during the winter months of 1949-50.

The only notable difference in occurrence of Protozoa in 1940-41 and 1949-50 was the greater surface concentrations of Codonella in 1949-50. This was the only protozoan found in 1940-41. In 1949-50, two, Codonella and Verticella, were present.

Cladocera were more abundant and occurred more frequently during the spring and autumn months of both years studied. Eight-meter concentrations of these plankters were the greatest in 1940-41, but they were found more often at the surface in 1949-50. Regardless of their scarcity it must be recognized that these zooplankters greatly influence plankton volume because of their size.

The volumes obtained by centrifuging the plankton concentrates were considerably larger for 1940-41 than for 1949-50.

The trends shown by volumetric and total count data resemble each other, but the seasonal peaks vary in time of occurrence in some cases. The differences of peak occurrences were due to a greater number of large plankters. The pulses of 1940-41 shown by the volumetric data are more sharply delineated than those of 1949-50 which is in keeping with the total count data.

Both volumetric and total count data show an inverse relation to turbidity readings, indicating that the zooplankters which greatly influence the centrifuged plankton volumes are reduced by clay turbidity. There is need for more research concerning this relationship.

The main advantages of the volumetric method presented lie in the relative short time required for analysis and the fact that the data obtained are based on volume of plankton present rather than numbers.

Many fisheries biologists have been prone to ignore plankton as an index of productivity in waters with which they are concerned. This attitude appears to be due to an inability to visualize the food value of large numbers of small phytoplankters when they observe fish stomachs filled with zooplankters which appear insignificant in counts.

Welch (1948) stated that in centrifuge data exuviae, wind-blown material, dead organisms remains, and silt present an incorrect measure of the living plankton. This without doubt is true, but complications arising because of adjustments to compensate for organism size in numerical counts also present inaccuracies.

The fact that organic detritus was not separated from the plankton was recognized at the beginning of the study. However, this did not cause much concern as most organic material adds to the sum total of productivity of a body of water.

Suspended silt does present a matter of vital concern. Preliminary experimentation showed that it could influence the total volume obtained even though the amount present was not concentrated but consisted merely of that in the water collected with the concentrated plankton. Since the suspended silt in Lake Carl Blackwell is of a colloidal nature and the volume of the concentrate was reduced to 3 ml., the amount centrifuged, the silt remaining in this concentrate did not influence the readings. If care is not exercised when collecting samples from the water near the bottom, or in cases of suspension from turbulence, inorganic particles too large to pass through the bolting silk will be retained.

Lake Carl Blackwell, typical of central Oklahoma impoundments, both large and small, has changed only slightly physically and chemically during the nine-year interval between the two investigations of this study. The only notable difference has been the greater constancy of clay turbidity and its direct effect on carbon dioxide in its various forms.

Plankton crops have greatly decreased numerically and volumetrically. The succession of phytoplankton has been from a myxophycean-chlorophycean population to one of diatoms. This diatom population which has been associated with intervals of increased turbidity in the studies of other workers was year-long in 1949-50. Workers have shown that plankton have been effected by great increases in turbidity, but in this study it appears also that prolonged turbidities due to clay, even though not extreme, have an even more decided effect.

SUMMARY

1. Two one-year limnological investigations, separated by a nine-year interval, on Lake Carl Blackwell, an impoundment in Payne County, Oklahoma, are presented. The first began when productivity was high; the second when productivity was on the decline.

2. Physical-chemical data show that turbidity, pH, and carbonates have increased while bicarbonates have decreased. It is strongly suspected that the negatively charged clay particles which cause the turbidity in Lake Carl Blackwell behave as a buffer producing these changes.

3. Turbidity or its cause seems to be the limiting physical factor influencing productivity of the water in Lake Carl Blackwell.

4. Quantitative surveys of the phyto-plankton revealed eighteen genera present in 1940-41 and twenty in 1949-50.

5. Succession was shown to be from a myxophycean-chlorophycean phytoplankton population with characteristic behavior in 1940 to a predominantly diatom population in 1949-50. The blue-greens had almost disappeared in 1949-50.

6. The phytoplankton, quantitatively, was greater in 1940-41 than in 1949-50.

7. Fifteen zooplankton genera were found in 1940-41 and twenty in 1949-50, the numerically dominant group being the Rotifera in both studies.

8. Zooplankton, quantitatively, was more abundant in 1940-41 than in 1949-50.

9. A volumetric method of measuring plankton was developed which was successful in analyzing the plankton in Lake Carl Blackwell and is believed to be usable by fisheries biologists.

10. Quantitative and volumetric analyses do not agree in all respects.

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