Some Observations on the Limnology of Greenleaf Lake[1]

I. EUGENE WALLEN, Oklahoma A. & M. College, Stillwater

Very few papers have been presented concerning the general limnology of Oklahoma waters. Turbidity has been recognized as an important characteristic in central Oklahoma (2,3,8,11,15). Temperature of Oklahoma waters has been studied by a few authors (1,4,11,14,15). Plankton studies include papers on Crustacea (6,7), on algae (4,9,10), and on plankton populations (5,12). The United States Geological survey has many records of the routine analyses of the more or less permanent chemical features of Oklahoma waters.

Observations on the temperature and general features of Greenleaf Lake during the summer of 1950, including an outline map showing the collecting stations, were given in another paper (14). These data are concerned with the physical, chemical, and biological features of Greenleaf Lake as recorded during June and July of both 1950 and 1951.

Data were collected with the use of physical equipment and methods described by Welch (16) with the exception that temperatures were taken with a Whitney direct reading thermometer of the resistance type.

TEMPERATURE

During 1951, the temperature data show some differences from the data collected in 1950 (14). There was a gradual increase (approximately 3.5° F.) at each level below the 16 foot depth during 1951. The temperatures at 13 feet and above, were mostly close to the surface temperature. Table I is a list of temperature readings at four stations on the lake with data given in degrees F. by foot depths.

The thermocline level in the lake was fairly uniform (Table II) with no decline in level as was shown in 1950 (14). The air temperatures in June were cooler and the air temperatures in July were warmer in 1951 than at each corresponding time in 1950. Slight differences in thermocline level at the different stations were attributed to wind direction and activity.

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TABLE I

Water Temperatures of Greenleaf Lake, 1951, in Degrees F. by Foot Depths at Four Stations on the Lake.

Depth in Feet	Station I								Station II						Station III						Station IV					
	June				July				June			July			June			July			June			July		
	4	11	18	26	3	10	17	28	4	11	26	10	17	28	4	11	26	10	17	28	4	11	26	10	17	28
0	75.2	74.0	84.0	82.0	77.5	84.5	90.5	88.0	75.0	74.0	83.0	85.0	91.0	89.5	74.5	74.0	83.0	85.5	91.0	89.5	75.0	73.5	84.5	87.5	90.5	88.0
3.0	75.2	73.5	80.5	81.5	77.0	84.5	87.0	88.0	75.0	73.5	83.0	85.0	89.0	88.5	74.5	73.0	83.0	85.5	90.0	88.5	75.0	72.0	84.5	86.0	90.0	88.0
6.5	75.0	73.0	73.5	78.5	76.0	83.5	86.0	87.5	75.0	73.0	83.0	85.0	86.5	87.5	74.5	72.5	82.5	85.0	87.0	87.5	74.5	72.0	84.0	85.5	88.0	86.0
10.0	75.0	71.5	71.0	75.0	73.5	82.0	85.0	86.0	75.0	71.5	82.5	81.5	85.0	85.5	74.5	72.0	82.0	83.0	84.0	86.0	74.0	71.5	84.0	85.0	85.0	85.5
13.0	74.5	70.0	69.5	71.0	71.5	76.5	81.5	84.0	74.5	69.0	78.5	78.5	81.0	83.0	74.5	70.0	81.5	78.0	80.5	85.0	71.0	70.5	83.5	80.5	82.0	85.0
16.0	74.5	69.0	68.5	68.5	70.5	73.0	73.0	76.5	74.5	68.5	70.0	71.0	73.5	75.5	74.0	69.0	70.5	73.5	75.5	75.0	69.0	69.0	82.0	73.0	74.5	75.0
19.5	74.0	68.0	67.5	67.5	68.5	69.0	69.0	70.5	67.0	67.5	68.5	69.5	70.0	70.5	66.5	68.0	68.5	71.0	70.5	70.5	65.5	68.0	73.0	70.5	70.5	70.5
23.0	64.5	66.5	67.5	67.0	67.0	67.5	67.5	68.0	64.5	67.0	67.0	68.5	68.0	68.0	64.0	67.0	67.0	68.5	68.0	68.0	64.5	68.0	67.5	70.0	68.0	68.0
26.0	63.5	65.0	66.0	66.0	66.5	66.5	67.0	67.0	63.0	65.5	66.5	68.0	67.0	66.5	63.0	65.5	66.5	67.5	67.0	67.0	64.0			69.0	67.0	67.5
29.5	62.5	64.0	65.0	65.0	66.0	66.0	66.0	66.0	62.5	64.0	65.0	66.5	66.0	66.0	62.5	65.0	65.5	66.5	66.0	66.0				67.5		
33.0	62.0	63.5	64.0	64.5	65.5	65.5	65.5	65.5	62.0	63.5	64.5	66.0	66.0	65.5	62.0	64.0	65.0	66.0	66.0	65.5						
36.0	62.0	63.0	63.5	64.0	65.0	65.0	65.0	65.0	62.0	63.0	64.5	65.5	65.5	65.0	62.0	63.0	64.5	65.5	65.5	65.0						
39.0	61.5	62.5	62.5		64.5	64.5	65.0	64.5	62.0	63.0	64.0	65.5	65.0	65.0	61.5		63.5	65.0	64.5	65.0						
42.5	61.0	62.0	62.5		63.5	64.0	64.0	64.0	61.5	62.5	63.5	65.0	64.5	64.5												
46.0		61.5	62.0		63.0	63.0	63.5	63.5		62.0	63.5	64.5	64.5													
49.0		61.5	61.5		62.5	62.5	62.5	63.0																		

TABLE II

Thermocline Levels by Foot Depths in Greenleaf Lake, 1951, at the Four Stations.

	June				July			
	4	11	18	26	3	10	17	28
Sta. 1	19-23	10-13	0-10	3-16	7-13 16-20	10-20	0-3 10-20	10-23
Sta. 2	16-23	10-13		10-16		6-20	3-23	10-23
Sta. 3	16-23	10-13		13-20		6-23	3-23	13-23
Sta. 4	10-20			16-23		10-20	6-23	3-6 13-23

Visibility. The transparency of the water was measured at each visit with a Secchi's disk to indicate the relative amount of visible light penetration. The depth at which Secchi's disk was visible averaged 3.5 feet during each summer, and the maximum was 6 feet for each summer. There was a gradual, but slight, increase in visibility as each summer progressed.

Free Carbon Dioxide. The amounts of free carbon dioxide varied much more with depth than with progression of dates during the two summers. The lake had relatively high concentrations of free carbon dioxide on most of the occasions when it was visited. The average amounts of carbon dioxide in parts per million are shown in Table III as computed from the 1950 and 1951 data. They vary from 1.4 to 26.5 ppm. in 1950 and from 1.0 to 13.1 ppm. in 1951.

TABLE III.

Average Free Carbon Dioxide Content in Parts per Million Computed at Feet Depths in Greenleaf Lake.

	Depths in feet							
	0	10	15	20	25	30	35	40
1950	1.4	4.3	5.3	8.1	10.1	16.4	16.0	26.5
1951	1.0	6.0	7.2	10.3	10.9	11.7	10.0	13.1

*p*H. The hydrogen ion concentration as expressed by *p*H values was found to vary from the surface to the bottom of the lake. The *p*H data show a decrease from the surface to near 30 feet and then usually shows an increase to near neutral at the bottom (Table IV). Readings of *p*H above 8.0 were rare. The average *p*H was 7.8 at the surface, slightly under 7.0 at 20 feet and slightly over 7.0 at the 40 foot depth.

Dissolved oxygen. Dissolved oxygen was less abundant at similar depths in 1951 than in 1950. This is believed to be related to the stronger winds during the warmer, earlier part of 1950. Less wind was estimated at most of the 1951 data collection dates than at corresponding times in 1950. Table V shows the dissolved oxygen in parts per million in Greenleaf Lake at the dates of visits in 1950 and 1951. During both years, oxygen was usually lacking below 30 foot depths, often lacking at the 25 foot level and on one occasion, entirely gone at the 17 foot depth level. At two visits in 1950, and one in 1951, a small amount of oxygen was found at the lowest depth tested under upper oxygenless waters.

Phenolphthalein Alkalinity. The alkalinity represented by titration with phenolphthalein was zero with one exception when 0.14 ml. was used to neutralize surface water in July, 1950.

METHYL ORANGE ALKALINITY. The methyl orange alkalinity titrations ranged between 3.9 and 8.0 ml. equivalent. The data shows a small gradual increase in readings toward the bottom with one exception to be discussed later.

TABLE IV

The Hydrogen Ion Concentration in Greenleaf Lake as Represented by pH at Feet Depths.

DEPTH IN FEET	1950 JUNE 12	20	27	JULY 4	11	18	19	25	27	AUG. 1	11	1951 JUNE 15	18	26	JULY 3	10	17	24	28
0	8.0	8.0	7.8	7.8	7.6	7.4	7.5	8.4	8.2	7.3	8.0	8.4	8.5	7.4	7.3	7.8	7.8	7.9	7.8
1																			
2																			
3												8.2							
4												7.8							
5																			
6																			
7												7.6							
8																			
9										7.2									
10				7.5					8.2		7.5		7.3	7.0		7.4			
11																			
12										7.2									
13																			
14		7.3																	
15		7.5						7.7	8.1	7.0				6.8	6.8	7.0	7.4	7.3	6.9
16			7.4						8.0										
17				7.4					7.6					6.7					
18		6.8	7.0				7.0	7.3	7.2	5.9									
19																			
20			7.3	7.3				7.0	7.2		7.2		6.8	6.7	6.8	6.7	6.8	6.8	6.9
21							7.0			5.7									
22									7.0										
23		7.0		7.1	7.2			6.9											
24							6.8		7.0	5.7									
25				7.0				6.8			7.2		6.7	6.8	6.8	6.8	6.8	6.8	6.8
26					7.2				6.8										
27								7.0		5.7									
28									7.0										
29																			
30		7.0	6.8	7.0	7.0	7.2		7.3	7.0	5.6	7.0		6.7	6.8	6.8	6.9	6.9	6.7
31																			
32																			
33																			
34																			
35									7.2	5.8	7.0		6.8	6.9					
36																			
37																			
38																			
39																			
40																			
41			7.0		7.2	6.8		7.3		7.0		7.0			7.0	6.9	7.0	7.0	6.7
42																			
43																			
44																			
45							7.2												
										7.3									

TABLE V

Dissolved Oxygen in Parts per Million by Feet Depths in Greenleaf Lake, 1950 and 1951.

Depth in Feet	1950									1951							
	June			July					Aug.	June			July				
	12	20	27	4	11	18	19	25	1	11	18	26	3	10	17	24	28
0	5.7	5.4	6.4	6.5	5.1	5.6	5.4	8.4	6.1	7.3	7.7	5.4	6.2	7.2	7.6	7.4	7.4
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10				5.9						6.4		4.1					
11																	
12																	
13																	
14		3.9															
15			6.4									0.2	2.0	6.2	4.4	4.2	1.4
16				5.7													
17					4.5							0.0					
18		1.02	1.02				3.1		2.0								
19																	
20				3.3	4.8			2.9		3.7	1.3	0.0	0.5	2.6	0.2	0.2	0.6
21							1.9		2.5								
22																	
23			0.0		3.7	4.0		0.6									
24							0.0		1.7								
25					.12			0.5		2.8	1.2	0.0	0.4	0.1	0.0	0.0	0.0
26						0.5											
27								0.0	2.6								
28																	
29																	
30		0.0	0.0	0.0	0.0	0.0		0.0	1.8	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31																	
32																	
33																	
34																	
35									0.4	0.0	0.0	0.0					
36																	
37																	
38																	
39																	
40				0.0		0.8	0.0			0.4	0.0		0.0	0.0	0.0	0.0	0.0
41																	
42																	
43																	
44																	
45								0.1	0.0								

Turbidity. The lake was visited on February 23 and 24, 1951, and found to be turbid after heavy rains. On the two successive days after the rain, turbidity dropped from 210 ppm. to 140 ppm. On only one occasion, to be discussed later, was turbid water due to soil found during the two

summers (14). All waters with less than 25 ppm. of turbidity were considered clear since only a Jackson turbidimeter was available.

DENSITY CURRENT. The data for August 1, 1950 are shown in Table VI. The data show a layer of turbid water between two clearer layers. The *p*H values are unusual in revealing especially low *p*H (5.6-5.9) in the middle level readings while dissolved oxygen data and methyl orange alkalinity data are erratic. This is believed to indicate a density current passing through the reservoir from heavy rains on July 31 and in progress when the data were secured.

TABLE VI

Physical and Chemical Data on Greenleaf Lake Taken in the Afternoon of August 1, 1950.

DEPTH IN FEET	TEMP.	TURBIDITY	*p*H	FREE CO_2	DISS. O_2	ALK. PHTH.	ALK. M.O.
0	79.5	>25	7.3	5	5.95	0.0	4.5
15	77.5	>25	7.0	15			
18	75.0	>25	5.9	14	1.9	0.0	4.4
21	73.5	30	5.7	13.5	2.4	0.0	4.4
24	72.5	40	5.7	14	1.7	0.0	4.6
27	72.0	90	5.7	12	2.5	0.0	3.7
30	71.5	105	5.6	14	1.8	0.0	3.4
35	67.0	80	5.8	16	0.4	0.0	4.0
45	64.5	40	7.3	10	0.0	0.0	1.9

PLANKTON. Surface plankton collections were taken during eleven visits to the lake in June and July of 1950. Collections were also taken from water at 30 feet on the latter eight of the dates. It is interesting to note that the sky was clear to 0.2 overcast on all visits in June, no less than 0.8 overcast to completely overcast during July, and the August collections were made during a rainstorm.

Total and generic counts were made of the number of specimens present in each collection. The total counts are given in Table VII as an indication of the productivity of the lake for plankton. Only generic determinations were attempted and the organisms were each counted as one unit regardless of size. The diatom, *Synedra*, and the chlorophycean, *Hormidium*, were the dominant algal representatives. Among the animals, *Difflugia*, *Keratella*, and *Polyarthra* were nearly always represented in the counts. A peak of numbers of species was not evident in the data.

TABLE VII

Numbers of Plankton Organisms per Liter of Water in Greenleaf Lake at Two Depths in 1950.

	JUNE					JULY					AUG.
	12	17	24	27	4	11	12	18	19	25	1
SURFACE	1938	1428	1786	47	3745	2230	1803	1004	1233	1228	1042
30 FEET				899	1057	308	648	362	108	758	259

DISCUSSION. Eastern Oklahoma has a rainfall of 40-60 inches during an average year. This results in a considerable run-off, and lakes in the area tend to stay near spillway level at all times. The inflowing waters contain leaves and detritus which aid in the flocculation of soil turbidity. Eastern Oklahoma waters are often colored due to the suspension of organic materials and this color reduces the penetration of light. Wind action is also somewhat reduced by the surrounding foothills of the Ozark Mountains.

Greenleaf Lake is a low buffered soft-water lake. The alkalinity is low in comparison to the waters of central Oklahoma, and the fluctuations in *p*H are quite pronounced from day to day (data not given) as well as varying from week to week . The volume of run-off water that passes through the reservoir keeps the fertility down. The nature of the slope of the sides, along with the climate of the area, add to the low productivity. Thermal stratification and chemical stratification reduce the usable water area during the summer to such an ebb that a high productivity of fishes should not be expected.

LITERATURE CITED

1. IRWIN, W. H. 1941. Preliminary records of physico-chemical features of Grand Lake, Oklahoma. Proc. Oklahoma Acad. Sci. 22:19-23.
2. ————. 1945. Methods of precipitating colloidal soil particles from impounded waters of Central Oklahoma. Bull. Okla. A.&M. College 13:3-16.
3. IRWIN, W. H. AND J. H. STEVENSON. 1951. Physio-chemical nature of clay turbidity with special reference to clarification and productivity of impounded waters. Bull. Okla. A. & M. College 48(*3*):1-54.
4. LEAKE, D. V. 1945. The algae of Crystal Lake, Cleveland County, Oklahoma. Am. Midland Naturalist 34:750-768.
5. LEONARD, E. M. Limnological features and successional changes of Lake Carl Blackwell, Oklahoma. Unpublished thesis, Okla. A. & M. College, July, 1950.
6. MACKIN, J. G. 1931. Studies on the Crustacea of Oklahoma. Notes on the Cladoceran fauna. Proc. Oklahoma Acad. Sci. 12:22-28.
7. ————. 1939. Key to the species of Phyllopoda of Oklahoma and neighboring states. Proc. Oklahoma Acad. Sci. 19(1938):45-47.
8. MOORE, G. A. 1950. The cutaneous sense organs of barbeled minnows adapted to life in the muddy waters of the Great Plains region. Trans. Am. Microscop. Soc. 69:69-95.
9. TAFT, C. E. 1931. Desmids of Oklahoma. Publ. Univ. Okla. Biol. Surv. 3:274-321.
10. ————. 1940. Additions to the Algae of Oklahoma. Proc. Oklahoma Acad. Sci. 20:45-54.
11. THOMPSON, WILLIAM. 1950. Investigation of the fisheries resources of Grand Lake. Fisheries Mgt. Rep. No. 18, Oklahoma Fisheries Experiment Station, 46 pp. (mimeo.)
12. WALLEN, I. E. 1949. The plankton population of a small fertile pond in Central Oklahoma. Trans. Am. Microscop. Soc. 68:200-205.
13. ————. 1951. The direct effect of turbidity on fishes. Bull. Okla. A. & M. College 48(*2*):1-27.
14. ————. 1951. Thermal stratification in some Eastern Oklahoma waters. Proc. Oklahoma Acad. Sci. 31(1950):57-64.
15. ————. 1952. The relationship of turbidity to temperature of some farm ponds. Proc. Oklahoma Acad. Sci. 32(1951):20-26.
16. WELCH, P. S. 1948. Limnological methods. Philadelphia: Blakiston Company.