INFLUENCE OF SEDIMENT CYCLING ON PRIMARY PRODUCTIVITY IN LAKE CARL BLACKWELL, OKLAHOMA

By

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CARL BLACKWELL, OKLAHOMA

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PREFACE

The objectives of this study were (1) to determine the influence of sediment cycling on primary productivity in Lake Carl Blackwell, Oklahoma from October 1968 to October 1969, (2) to determine the effect of sediment cycling on turbidity, and (3) demonstrate longitudinal variation for sediment depth, turbidity, dissolved oxygen and temperature, primary productivity, and chlorophyll a.

Dr. Robert C. Summerfelt served as major adviser. Drs. Troy C. Dorris and William A. Drew served on the advisory committee. I am grateful for the help of my advisory committee in outling my study program, data sampling design and analysis, and editorial assistance in preparation of this manuscript. I am especially thankful to Dr. Summerfelt for the assistance given in completing my thesis while I was off-campus. I was assisted in field collections by members of the Oklahoma Cooperative Fishery Unit, Messrs. Robert Tafanelli, Paul Turner, and Paul Zweiacker, and my undergraduate employees, Russell Givens, Tom Sanders, and Wesley Holley.

Statistical analysis were performed with assistance of personnel from the Statistics Department, Oklahoma State University.

I am grateful to my wife, Wanda, and other members of my family, Bill, Larry, Jennifer, and John, for their enduring patience and encouragement throughout this study. I am especially grateful to my wife for typing the earlier drafts of this manuscript.

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CHAPTER I

INTRODUCTION

Sediment accumulation in impoundments reduces water storage capacity, and may adversely affect recreational values, aesthetic qualities, and fish production. The present study attempts to relate the effects of sediment resuspension and the resulting increase in turbidity to primary productivity in Lake Carl Blackwell, Oklahoma.

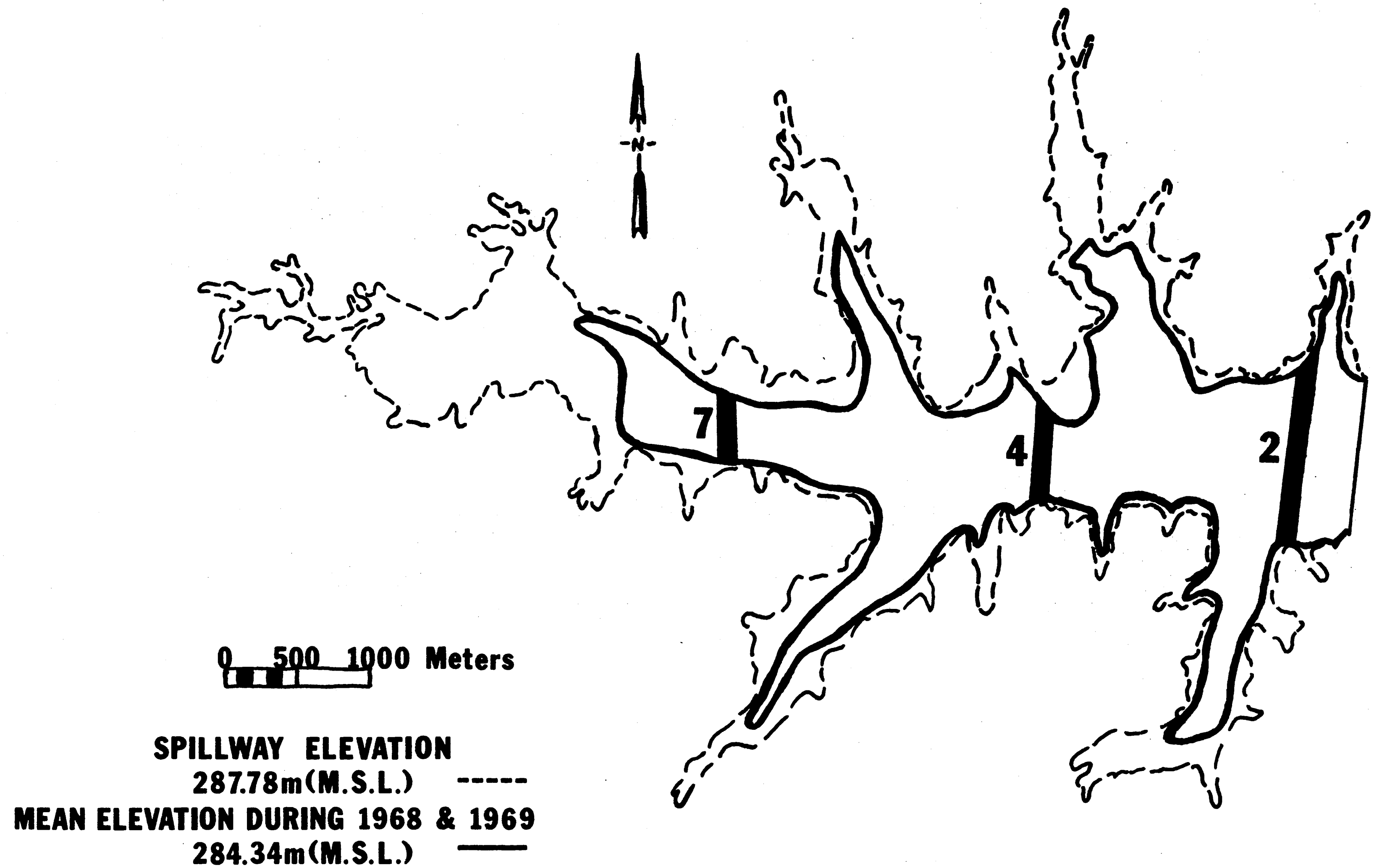
One objective of this study is to describe areal or longitudinal variation in sediment depth, turbidity, dissolved oxygen, temperature, primary productivity, and chlorophyll at three transects, transverse to the long axis of the reservoir. Other objectives are to test the hypotheses that turbidity in Lake Carl Blackwell is directly related to wind induced sediment cycling, and that primary productivity is limited by turbidity. The dynamics of sedimentation-resuspension is the focal point of this thesis because it seems to have a profound effect on turbidity and primary production.

Exceptionally high turbidity of some impoundments in central Oklahoma has been reported numerous times. Irwin (1945) attributed the turbidity problem in impounded waters of central Oklahoma to colloidal particles of montmorillonite clay. These particles range from 0.5 to 5 microns in diameters and are flattened and disc-like in shape (Irwin and Stevenson 1951). Colloidal clay particles are maintained in suspension by virtue of their small size and electrical potential, which is directly proportional to the degree of ionization of compounds present in the medium (Mathis 1965, Butler 1964, van Olpen 1963, and Irwin and Stevenson 1951).

The main source of turbidity in Lake Carl Blackwell does not seem to be the result of colloidal particles, in fact, most turbidity is removed by simply reducing the turbulence. A sample of raw water from Lake Carl Blackwell, when left undisturbed overnight will clear considerably because of sedimentation. When the larger particles have settled by gravity, it appears that only a dingy color remains which is due to colloidal matter. These observations suggest that the major turbidity problem in Lake Carl Blackwell is the result of resuspension of unconsolidated sediments by wind induced turbulence. If turbidity is strongly affected by wind, then seasonal variation in wind velocity will create a cycle of suspension and sedimentation. Norton (1968) reported on distribution, character, and abundance of sediments and how they influenced the abundance of certain benthos in Lake Carl Blackwell, Oklahoma. Sias (1974) examined the distribution of certain heavy metals in sediments in Lake Carl Blackwell.

Harris and Silvey (1940) pointed out that clay in silt ladened waters entering reservoirs in North Central Texas will settle out, if "undisturbed by winds". They also point out that even light wind action may "stir" silt accumulations near the bottom and cause a rise in turbidity. Harris and Silvey reported that lakes Dallas and Fort Worth become turbid in a "few minutes" when disturbed by high winds. The relationship between wind and turbidity in artificial impoundments and natural lakes has not been given the coverage it seems to warrant, but studies by Norton (1968), Butler (1964), Jackson and Starrett (1959),

Figure 1. Lake Carl Blackwell, Oklahoma showing lake outline at spillway (broken line) elevation (287.78 m, msl), and lake outline October 1968 through September 1969 (solid, inner line) when the lake's elevation averaged 284.34 m, msl. Heavy vertical bars are the three transects used for data collection to study areal variation along the longitudinal (east-west) axis.


N
2
4
7
0 500 1000 Meters
SPILLWAY ELEVATION
287.78m(M.S.L.) -----
MEAN ELEVATION DURING 1968 & 1969
284.34m(M.S.L.) ——

Irwin and Stevenson (1951), Andrews (1948), and Chandler (1942) include useful observations. Jackson and Starrett (1959) found a "false bottom", composed of finely divided and loose-textured material, covering the original floor of Lake Chautauqua; wind resuspended the unconsolidated bottom materials, however, where the water was deep, or where rooted vegetation was present, the influence of wind action on sediment was negligible. Johnson and Starrett suggested that rooted vegetation would reduce currents and maintain the stability of the sediment.

Turbidity reduces light penetration, and since light is essential to photosynthesis, it is assumed that an increase in turbidity will decrease photosynthesis. Buck (1956) reported eight times more plankton in clear water than in water of intermediate turbidity in impoundments in Oklahoma. Claffey (1955), found three to ten times as many phytoplankters per liter in several Oklahoma ponds and reservoirs of turbidity less than 25 ppm, when compared to numerical density of plankters in ponds with turbidity from 25 to 35 ppm; the clear ponds had six to sixteen times as many phytoplankters as were counted in pond turbidity of 51-350 ppm. Butler (1964) found that summer productivity in a clear Oklahoma pond (12 g O_2 m^{-2} day^{-1}) exceeded productivity in a turbid pond (4 g O_2 m^{-2} day^{-1}). Production per unit area is greatest in very shallow clear water and least in turbid deeper water where turbidity is due to inorganic matter (Odum and Hoskin 1958).

Although most evidence suggests an inverse relationship between turbidity and phytoplankton densities, in Keystone Reservoir, Oklahoma a large standing crop of plankton sometimes occurred with high turbidity, and sometimes low plankton crops coincided with low turbidity

(Spangler 1965). This would be the expected finding if most of the turbidity was due to algae. In western Lake Erie, turbidity did not appear to be a factor limiting phytoplankton standing crop (Verduin 1954). Harris and Silvey (1940) observed direct and inverse relationships between turbidity and algae cell counts in four reservoirs in north-central Texas. In Lakes Dallas and Eagle Mountain, the maximum plankton standing crop was found during maximum turbidity, but in Lakes Dallas and Bridgeport, maximum plankton numbers were found during the time of minimum turbidity. Lowest gravimetric measurements of plankton in Lake Dallas were observed when conditions were described as extremely turbid due to "excessive" wind and rain. In contrast, in Lake Fort Worth the greatest amount of plankton appeared in January when the lake had the lowest monthly turbidity, whereas in Lake Bridgeport, a blue-green algae bloom produced the highest turbidity previously recorded on a Texas lake. The somewhat contradictory observations regarding the influence of turbidity on phyloplankton relates to the persistent problem of distinguishing between turbidity caused by phytoplankton and turbidity related to suspended inorganic solids.

CHAPTER II

DESCRIPTION OF STUDY AREA

Lake Carl Blackwell (Figure 1), under jurisdiction of the Oklahoma State University, is located 12.8 km west of Stillwater, Oklahoma. Construction was begun in 1936 and completed in 1938 by the Works Progress Administration. As initially conceived, the purpose of the reservoir was to provide residents of north-central Oklahoma a facility for water based outdoor recreation (General Description and Justification for Job No. 226, Central Oklahoma Development Project, LD-OK1). In 1950, the City of Stillwater and Oklahoma State University began using the reservoir for municipal water.

The main axis of the reservoir is 8.5 km long and has an east-west orientation with several arms extending north and south. In 1948, the initial spillway height of 288.37 m, mean sea level (msl) was lowered to 287.78 m, msl. At 287.78 m msl, the area of the reservoir is 1400 ha with a volume of 67.80×10^6 m^3, discounting loss of storage due to sedimentation. The reservoir level reached the new spillway elevation on several occasions 1957 through 1961. Disregarding accumulated sediment, average depth of the reservoir at spillway elevation is 4.84 m.

Below average rainfall, high evaporative loss, and increasing municipal water consumption, resulted in steadily decreasing lake levels from 1962 through 1969.

In 1968, the average water level was 283.99 m msl, 3.79 m below spillway elevation, and area of the reservoir was 877 ha, or 63.4% of the maximum area. The average water level in 1969 was 284.57 m msl, 3.21 m below spillway elevation, and the average area was 1017.8 ha, or 72.7% of the maximum area.

The reservoir watershed is contained within the Redbeds Plains physiographic region and has soils derived from Permian clays and shale. The rolling hills surrounding Lake Carl Blackwell are partially wooded, but pastures of native grasses prevail. The relatively low and unprotected shoreline, shallow depth, and east-west orientation of the main reservoir allow extensive vertical and horizontal water circulation due to wind-driven wave action. Even in mid-summer, when ambient air temperatures often exceeds 35°C, the wind intensity is sufficient to allow wave-generated circulation to maintain relatively uniform vertical water temperature and dissolved oxygen over most of the reservoir. Thermal stratification and its associated oxygen depletion of the hypolimnion is emphermeral, occurring irregularly during the summer months with coincidence of high ambient temperature and decreased wind velocity. Under those conditions, the thermocline is deep, and stratification is mainly restricted to the main pool near the dam and to the inundated stream channels present in the middle portion of the reservoir and major coves.

CHAPTER III

METHODS AND MATERIALS

Experimental Design

Transects 2, 4, and 7 (Figure 1) were selected as sampling sites because they were used in previous projects (Norton 1968, Schrieber 1959) and because they represent areas of different reservoir morphology: transect 2, located across the main pool, had an average depth of 10 m; transect 4, located approximately 1750 m upstream from transect 2, had an average depth of 9.7 m; and transect 7, located approximately 2250 m upstream from transect 4, had an average depth of 2.6 m. Three buoys, positioned approximately 6.1 m apart along each transect in mid-reservoir served as replicate sample sites for each transect. Turbidity, dissolved oxygen, temperature, and chlorophyll _a_ were sampled at each buoy on all sampling dates.

Sediment Depth

Sediment depth was measured by the use of a spud bar (Norton 1968). It is a steel bar 3.05 m in length, with grooves spaced 0.03 m apart. It was dropped vertically into the water at the desired location and retrieved with an attached line. Sediment depth was determined by visual inspection of the substrate material retained in the grooves.

Monthly measurements were taken along each transect at 152.4 m intervals beginning 152.4 m from the shoreline and ending 152.4 m from the opposite shoreline. Six measurements were observed at transects for each of the ten collection dates except 2-28-69 when only five measurements were taken; four measurements were observed at transect 4 on all dates except 11-12-68; at transect 7, one to three measurements were taken on each date.

Turbidity

Water samples for turbidity analysis were collected from the surface. Turbidity was measured photometrically in the laboratory; turbidity (ppm SiO_2) was calculated from a standard curve from the optical density of the sample.

Primary Productivity

Net primary productivity (Pn) was determined by the modified diurnal oxygen curve method (Welch 1968 and McConnell 1962). Dissolved oxygen (DO) and temperature were measured, at the surface and at 1 m intervals to the bottom, with a galvanic cell, oxygen analyzer. Measurements were made at sunset, the following sunrise, and the following sunset, all within a 24-hour period. Respiration (Rt) was calculated from the decrease in DO between sunset to sunrise. Gross primary productivity (Pg) was calculated from the increase in DO from sunrise to the following sunset. An oxygen diffusion correction (Eley 1970) was applied, and the difference between Pg and Rt was regarded as a measure of Pn. Sampling was done only on clear days to eliminate light intensity as a variable.

Chlorophyll *a*

Water samples for chlorophyll *a* (Ch *a*) analysis were collected from the surface and placed in 1-liter plastic bottles; the bottles were placed on ice for transport to the laboratory. The amount of Ch *a* was determined by filtering 500 ml of water through a millipore filter and extracting the pigments with acetone (Creitz and Richards 1955). Light absorption of the acetone extract was measured at selected wave lengths with a spectrophotometer according to the methods of Richards with Thompson (1952), except that a correction factor derived from measurement of light absorption of a 90% acetone blank was applied to each sample. Chlorophyll *a* (mg m^{-3}) was calculated by the equations of Parsons and Strickland (1963).

Wind Velocity

Wind velocity for the interval October 1968 through September 1969 was obtained from the Agronomy Research Station, Oklahoma State University, located at the western edge of Stillwater. Because the influence of wind velocity on other parameters would not necessarily be apparent from the single measurement on the sampling date, average wind velocity was computed from records from the three days preceding the sampling date and the sampling date. Wind velocity also was measured at each transect on each sampling date using a hand-held anemometer (Appendix, Table 9). On site wind velocity was not used to compute the statistical relationships between wind velocity and other parameters measured to avoid mixing field measurements with the Agronomy Research Station records.

CHAPTER IV

RESULTS AND DISCUSSION

Sediment Depth

Spatial Variation

A total of 116 individual measurements, ranging from 1 to 6 per transect, were made of sediment depth on 10 sampling dates in the 12-month interval October 1968 through September 1969. The maximum monthly mean transect sediment depth was 1.5 m at transect 4 in February 1969 (Table 1). Annual mean sediment depth was greatest at transect 4 (0.84 m), followed by 0.75 m and 0.65 m at transects 2 and 7, respectfully (Table 2). The difference in annual average sediment depth among transects (Table 3) was nonsignificant ($P > .05$) when tested with a "t" test for independent means. Under the null hypothesis, the lack of a difference between the transect means of the .05 level indicate that the inter-transect differences in annual means can be attributable to sampling variation not real difference between transects. This finding is obviously the result of having large monthly variation within transects but inadequate number of samples were obtained within months to allow a monthly analysis of differences in transects means.

Table 1. Monthly means of sediment depth, turbidity, chlorophyll *a*, and wind velocity at Transects 2, 4, and 7 in Lake Carl Blackwell, October 1968 through September 1969.

Month	Sediment Depth (m)				Turbidity (ppm, SiO_2)				Chlorophyll *a* (mg m^3)				Wind Velocity (Km/hr)-4 day
	2	4	7	$\bar{x}$	2	4	7	$\bar{x}$	2	4	7	$\bar{x}$	$\bar{x}$
1968													
October	0.2	0.4	0.7	0.43	31.0	37.5	42.0	36.8	4.59	5.57	7.02	5.73	9.78
November	0.7	0.7	0.3	0.57	25.0	25.0	30.0	26.7	5.45	6.97	7.36	6.59	5.45
December	0.5	0.7	0.5	0.57	-	-	-	-	-	-	-	-	6.37
1969													
January	1.0	0.9	0.5	0.80	25.0	25.0	25.0	25.0	-	-	-	-	8.54
February	1.2	1.5	0.4	1.03	21.3	21.8	27.3	23.5	4.46	4.18	4.77	4.47	8.03
March	-	-	-	-	28.8	30.4	53.6	37.6	4.12	5.35	4.32	4.60	8.67
April	0.8	0.5	0.7	0.67	43.7	46.1	68.5	52.8	5.04	4.41	3.29	4.25	8.67
May	-	-	-	-	43.5	51.8	82.0	59.1	-	-	-	-	8.85
June	0.8	0.7	0.7	0.73	30.7	34.9	54.1	39.9	12.20	8.75	8.89	9.95	4.96
July	0.6	0.5	0.8	0.63	27.7	36.4	54.3	39.1	9.29	10.35	13.24	10.96	4.50
August	1.0	1.3	1.0	1.10	49.7	54.8	79.3	61.3	6.55	9.81	12.93	9.76	5.34
September	0.7	1.2	0.9	0.93	39.4	42.9	63.1	48.5	7.54	10.98	16.99	11.84	4.13
Overall Means	0.75	0.84	0.65	0.74	33.67	37.53	56.16	40.93	7.03	8.07	9.85	7.57	6.94

Table 2. Annual means for experimental parameters collected at Transects 2, 4, and 7 in Lake Carl Blackwell, October 1968 through September 1969.[1]

Transect[2]		Sediment depth	Turb.	D.O.		Temp.		Primary productivity				Ch a
				Sur.	Bot.	Sur.	Bot.	Pg	Rt	Pn	Pg/Rt	
2	$\bar{x}$	0.75	33.67	7.14	4.97	19.8	18.5	8.89	8.56	0.33	1.18	7.03
	S.D.	0.28	10.69	0.66	0.89	1.85	1.74	5.40	5.49	1.82	0.78	3.14
	C.V.	37.84	31.75	9.24	17.91	9.34	9.41	60.83	64.11	551.10	66.75	44.80
	n	10	22	11	11	22	21	11	11	11	11	12
4	$\bar{x}$	0.84	37.53	7.17	5.42	19.7	18.6	7.46	7.34	0.12	1.05	8.07
	S.D.	0.37	12.73	0.60	0.77	3.91	1.86	6.06	6.04	1.31	0.40	3.65
	C.V.	44.61	33.92	8.37	14.21	19.85	10.00	81.17	82.30	1063.33	37.86	45.22
	n	10	22	11	11	22	21	11	11	11	11	12
7	$\bar{x}$	0.65	56.16	7.21	7.00	20.0	19.6	3.24	3.37	(-)0.12	0.89	9.85
	S.D.	0.22	23.83	0.88	0.78	1.88	2.62	3.01	2.90	0.40	0.18	4.89
	C.V.	34.21	42.43	12.21	11.14	9.40	13.37	92.91	86.24	247.14	20.00	49.71
	n	10	22	11	11	22	21	11	11	11	11	12

[1]Sediment depth in m, turbidity in ppm SiO_2, D.O. in ppm, temperature in ^oC, primary productivity in $gO_2m^{-2}day^{-1}$, and chlorophyll a in mg m^{-3}.

[2]Sample n = number of monthly transect means averaged to obtain annual transect mean.

Table 3. Tests of significance (Students t) of difference of means of experimental parameters between transects in Lake Carl Blackwell, October 1968 through September 1969.

	Transects	Transect mean	-	Transect mean	Computed t	df
Sediment Depth	T2 - T4	0.75	-	0.84	0.60	18
	T2 - T7	0.75	-	0.65	0.87	18
	T4 - T7	0.84	-	0.65	1.37	18
Turbidity	T2 - T4	33.67	-	37.53	1.17	40
	T2 - T7	33.67	-	56.16	4.15**	40
	T4 - T7	37.53	-	56.16	3.38**	40
Pg	T2 - T4	8.89	-	7.46	0.56	20
	T2 - T7	8.89	-	3.24	3.02**	20
	T4 - T7	7.46	-	3.24	2.06	20
Pn	T2 - T4	0.33	-	0.12	0.30	20
	T2 - T7	0.33	-	(-)0.12	0.80	20
	T4 - T7	0.12	-	(-)0.12	0.59	20
Rt	T2 - T4	8.56	-	7.34	0.49	20
	T2 - T7	8.56	-	3.37	2.77*	20
	T4 - T7	7.34	-	3.37	1.97	20
Pg/Rt	T2 - T4	1.18	-	1.05	0.49	20
	T2 - T7	1.18	-	0.89	1.18	20
	T4 - T7	1.05	-	0.89	1.20	20
Dissolved Oxygen-Surface	T2 - T4	7.14	-	7.17	0.22	11
	T2 - T7	7.14	-	7.21	0.24	11
	T4 - T7	7.17	-	7.21	0.12	11
Dissolved Oxygen-Bottom	T2 - T4	4.97	-	5.42	0.74	10
	T2 - T7	4.97	-	7.00	3.43**	11
	T4 - T7	5.42	-	7.00	2.72*	10
Temperature-Surface	T2 - T4	19.80	-	19.70	0.05	22
	T2 - T7	19.80	-	20.00	0.15	22
	T4 - T7	19.70	-	20.00	0.14	22
Temperature-Bottom	T2 - T4	18.50	-	18.60	0.08	21
	T2 - T7	18.50	-	19.60	0.70	21
	T4 - T7	18.60	-	19.60	0.63	21
Chlorophyll a	T2 - T4	7.03	-	8.07	0.74	22
	T2 - T7	7.03	-	9.85	1.67	22
	T4 - T7	8.07	-	9.85	1.00	22

*Significant at .05 level. **Significant at .01 level.

Temporal Variation

Substantial monthly variation occurred in mean sediment depth at the same transect (Table 1). Maximum temporal variation in sediment depth at the same transect was observed at transect 2, where the monthly mean transect sediment depth varied by a factor of 6, from 0.2 m on October 1968 to 1.2 m on 28 February 1969. There was a significant positive correlation ($r = 0.75$, $P < .05$, 8 d.f.) between monthly mean sediment depth at transect 2 and 4, but a non-significant ($P > .05$) correlation between sediment depth at transects 2 and 7, and 4 and 7. Thus, temporal variation in sediment depth at transects 2 and 4 were similar, but monthly variation in sediment depth at transects 2 and 4 was distinct from monthly variation at transect 7 (Figure 2).

A lake mean sediment depth was calculated each month between October 1967 and September 1968 from the three monthly transect means (Table 1, Figure 3). The correlation between monthly mean, lake sediment depth and wind velocity was non-significant ($r = 0.26$, $P > .05$). Only two of the monthly lake means exceeded 1.0, these were 1.03 m in February and 1.10 in August.

Based on average sediment depth, the total volume of sediment in the lake was calculated for each month (Table 4). The volume of sediment in Lake Carl Blackwell varied from $4{,}377 \times 10^3$ m^3 in October 1968 to $9{,}466 \times 10^3$ m^3 in September 1969. This represents a maximum variation in 5.1×10^6 m^3 of sediment over a 10-month interval. Norton (1968) found 3.6×10^6 m^3 of sediment in June 1967, and 2.2×10^6 m^3 of sediment in October 1967. The volume of sediment varied 1.5×10^6 m^3 in Lake Carl Blackwell between June and October 1967. Between June and September 1969 (sediment was not sampled in October 1969 or June 1968),

Figure 2. Spatial and temporal variation in sediment depth in Lake Carl Blackwell, October 1968 through September 1969.

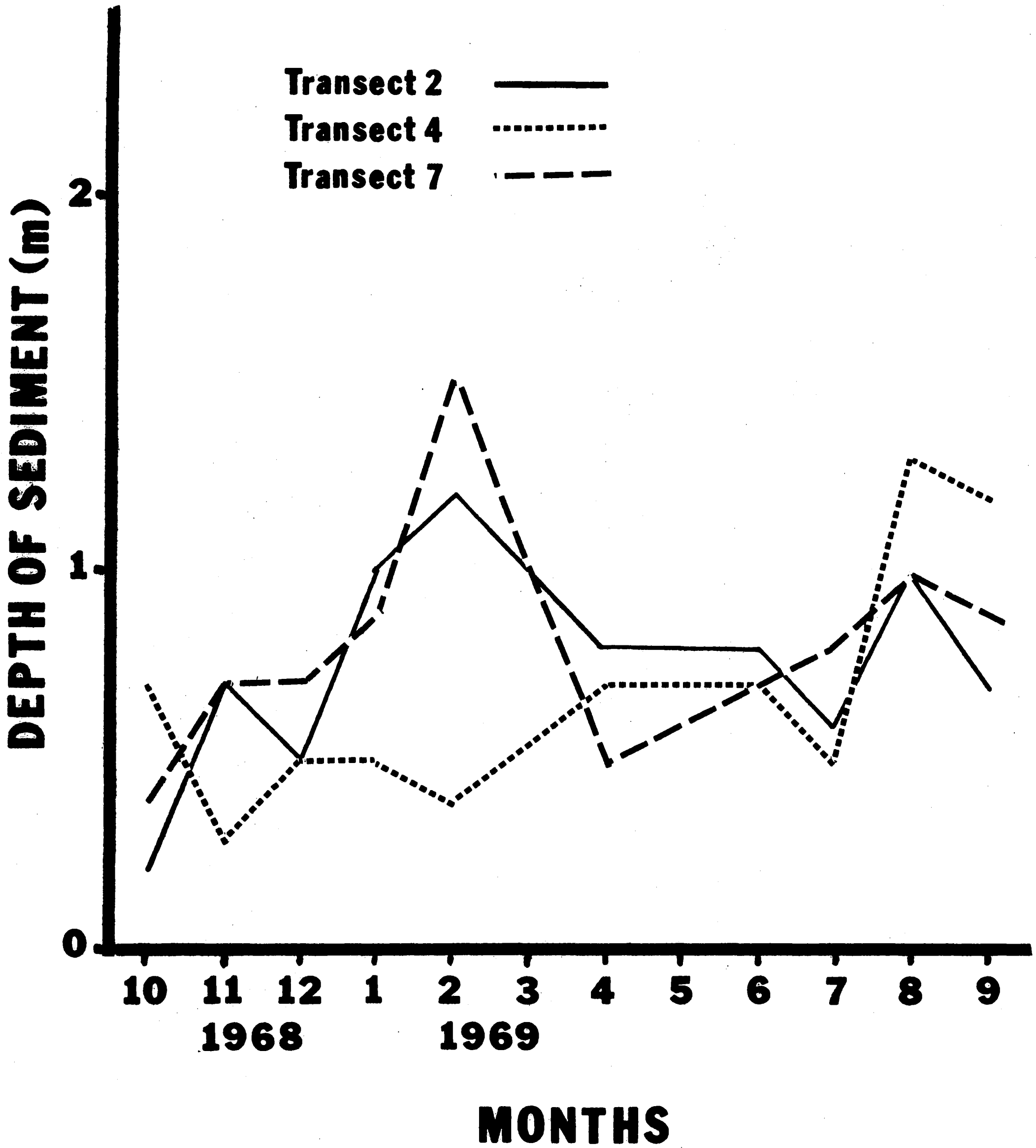

Transect 2
Transect 4
Transect 7
DEPTH OF SEDIMENT (m)
2
1
0
10
11
12
1
2
3
4
5
6
7
8
9
1968
1969
MONTHS

Figure 3. Relationship between sediment depth (solid line) and wind velocity (broken line) in Lake Carl Blackwell, October 1968 through September 1969.

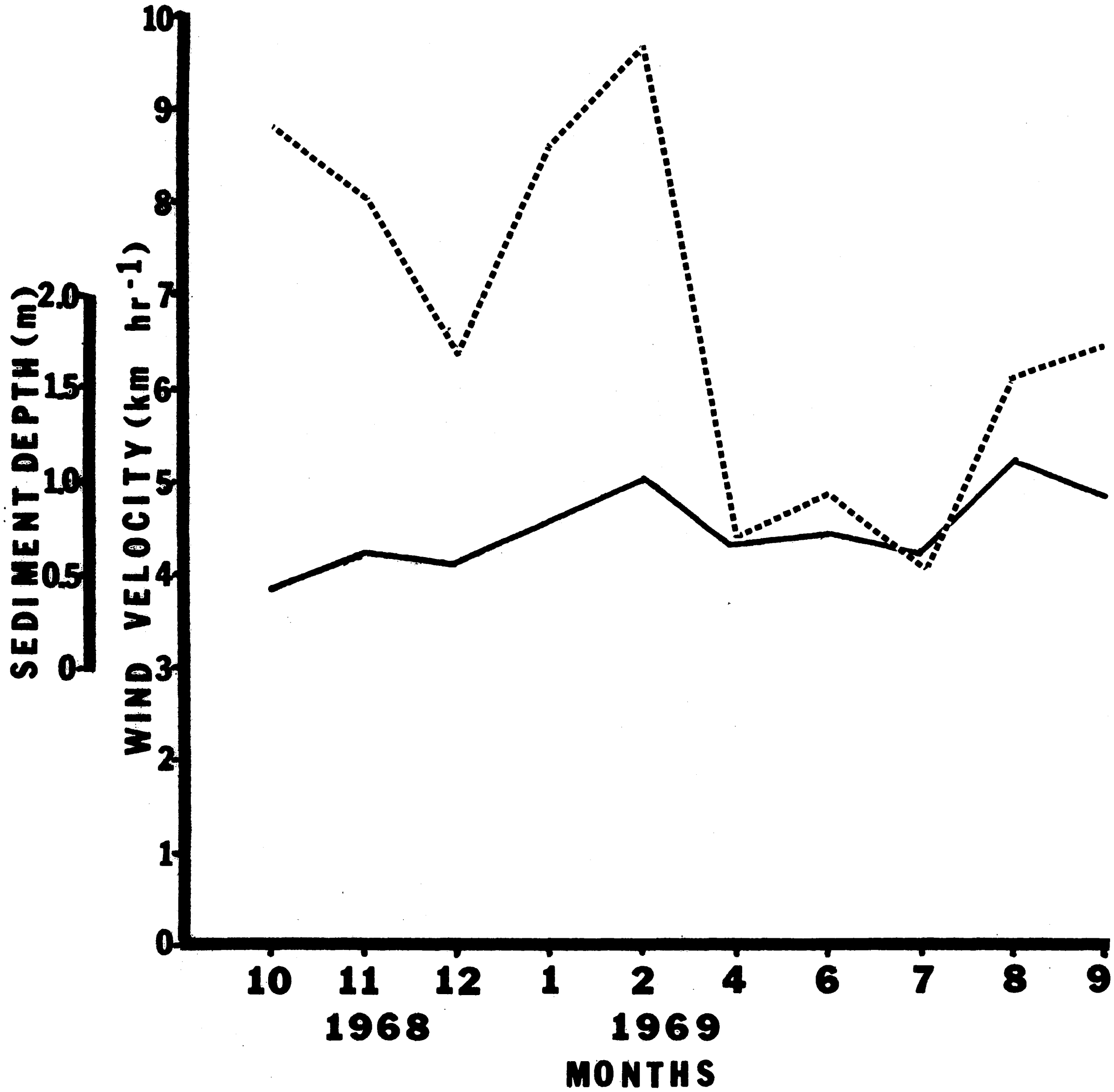

SEDIMENT DEPTH (m)
2.0
1.5
1.0
0.5
0
WIND VELOCITY (km hr^{-1})
10
9
8
7
6
5
4
3
2
1
0
10
11
12
1
2
4
6
7
8
9
1968
1969
MONTHS

Table 4. Volume of sediment ($m^3 \times 10^3$) at a water level of 284.57 m msl based on an estimated 1017.8 ha in Lake Carl Blackwell, 4 October 1968 through 8 September 1969.

Date	Sediment volume ($m^3 \times 10^3$)	Change in sediment depth from previous month[1] (Volume $m^3 \times 10^3$)
10-4-68	4,377	-
11-12-68	5,802	+1,425
12-17-68	5,802	0
1-23-69	8,143	+2,341
2-28-69	10,484	+2,341
4-25-69	6,819	-3,665
6-5-69	7,430	+ 611
7-18-69	6,412	-1,018
8-13-69	11,196	+4,784
9-8-69	9,466	-1,730

[1]Positive values (+) suggest deposition; negative (-) values suggest resuspension.

the lake average of sediment depth was 0.73 and 0.93, respectively. Thus, in 1969 sediment increased between June and September.

Relationship Between Sediment Depth, Ch *a* and Primary Production

The correlation between sediment depth and net productivity (Pn) at transect 2 was highly significant ($r = 0.77$, $p < .01$) (Table 5) but correlations between Pn and sediment depth at transects 4 and 7 were nonsignificant (Tables 6 and 7). The correlation between sediment depth and Ch *a*, Pg, and community metabolism (Pg/Rt) were non-significant ($P > .05$) at all three transects (Tables 5, 6, and 7) with one exception where a significant positive correlation was obtained between Ch *a* and sediment depth at transect 7. The lack of similar correlation at other transects suggests that algal blooms at station 7 are more light-limited by the suspended solids than at other station. The amount of Ch *a* at all transects was directly related to wind velocity (r was significant at all transects, $p < .05$).

Turbidity

Spatial Variation

During this study, 207 water samples were analyzed for turbidity; the sample turbidities ranged from 17.0 to 109.7 ppm SiO_2 (Appendix, Table 10) with an overall mean value of 42.5 ppm.

The mean of the monthly means (annual mean) for turbidity was highest (56.16 ppm SiO_2) at transect 7, least (33.67 ppm SiO_2) at transect 2 (Table 2) and intermediate at transect 4 (Table 2). Differences in turbidity between transects 2 and 7, and 4 and 7 were significant

Table 5. Correlation matrix of sediment depth, turbidity, primary productivity, chlorophyll a and wind velocity for Transect 2 in Lake Carl Blackwell, October 1968 through September 1969.

	Sediment Depth	Turbidity	Primary Productivity				Chlorophyll a
			Pg	Rt	Pn	Pg/Rt	
Turbidity	0.69						
Pg	0.15	0.47					
Rt	0.26	0.40	0.94**				
Pn	0.77**	0.18	0.12	-0.20			
Pg/Rt	0.38	0.13	-0.01	-0.30	0.89**		
Chlorophyll a	0.05	0.03	-0.21	-0.55	0.37	0.26	
Wind Velocity	0.14	0.64**	0.73*	0.75**	0.09	0.65*	0.73**

*Significant at the .05 level.

**Significant at the .01 level.

Table 6. Correlation matrix of sediment depth, turbidity, primary productivity, chlorophyll a, and wind velocity for Transect 4 in Lake Carl Blackwell, October 1968 through September 1969.

	Sediment Depth	Turbidity	Primary Productivity Pg	Rt	Pn	Pg/Rt	Chlorophyll a
Turbidity	0.01						
Pg	0.52	0.21					
Rt	0.48	0.24	0.98**				
Pn	-0.10	-0.10	0.08	-0.13			
Pg/Rt	0.27	0.02	0.10	-0.11	-.93**		
Chlorophyll a	0.36	0.29	0.50	-0.50	-0.18	0.24	
Wind Velocity	0.39	0.68*	0.57	0.58	-0.01	0.71*	0.73**

*Significant at the .05 level.

**Significant at the .01 level.

Table 7. Correlation matrix of sediment depth, turbidity, primary productivity, chlorophyll a, and wind velocity for Transect 7 in Lake Carl Blackwell, October 1968 through September 1969.

	Sediment Depth	Turbidity	Primary Productivity: Pg	Rt	Pn	Pg/Rt	Chlorophyll a
Turbidity	0.60						
Pg	0.19	0.48					
Rt	0.34	0.43	0.99**				
Pn	-0.07	0.47	0.33	0.20			
Pg/Rt	0.13	0.47	0.59	0.48	0.86**		
Chlorophyll a	0.73*	-0.02	0.32	-0.28	0.21	0.35	
Wind Velocity	-0.56	0.63**	0.68*	0.71*	-0.45	0.78**	0.69*

*Significant at the .05 level.

**Significant at the .01 level.

($P < .01$), but the difference between transects 2 and 4 was not significant (Table 3). The lack of significant variation between transects 2 and 4 may be attributed to their having similar average water depth (10.0 m and 9.7 m, respectively).

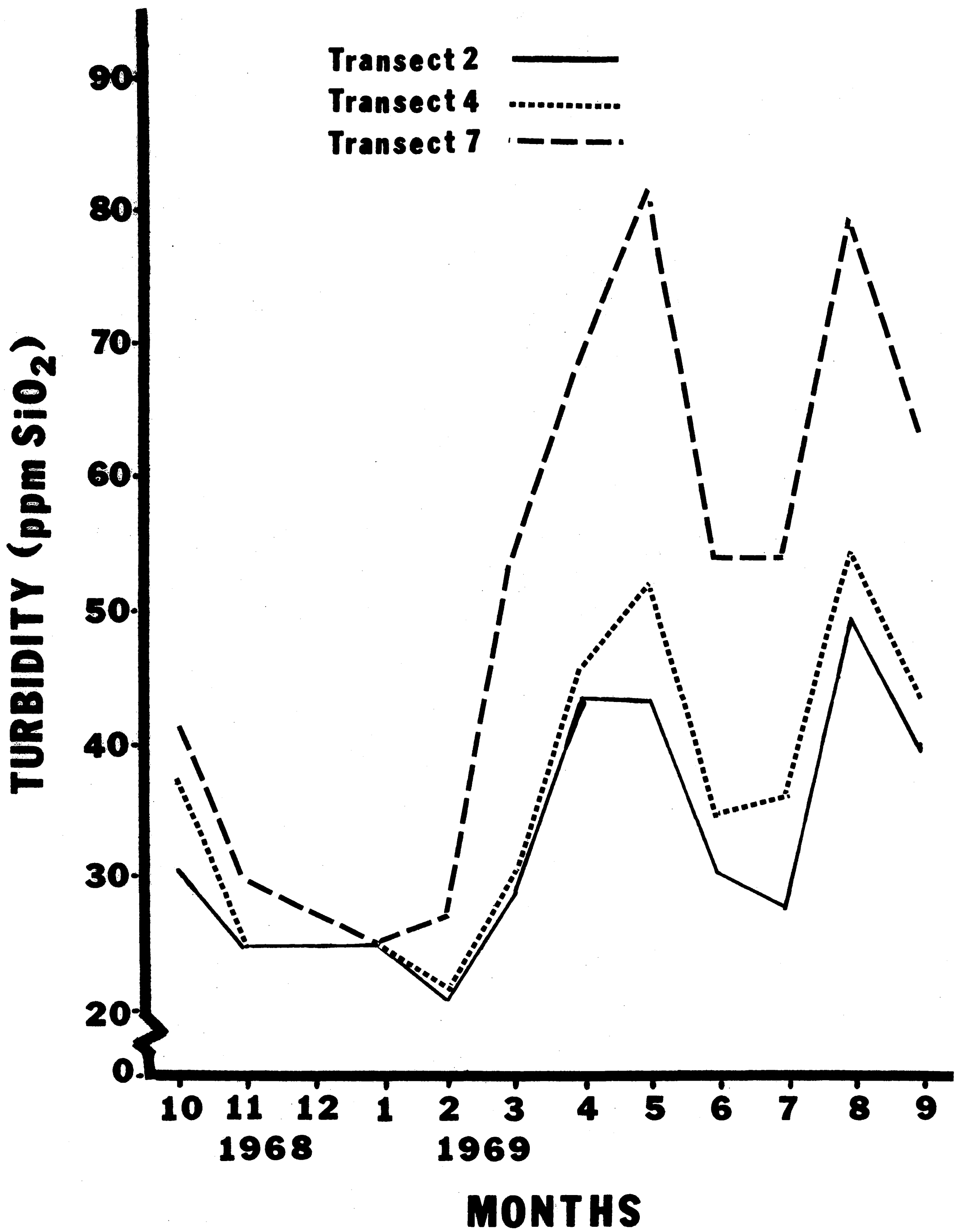
High turbidity at transect 7 is attributable to its shallow depth (2.6 m) because runoff was almost negligible during this study. The major cause of high turbidity at transect 7 would appear to be wind-induced turbulence agitating bottom material.

Turbidity was lower at transects 2 and 4 (10.0 m and 9.7 m, respectively) than transect 7 (2.6 m), probably because they are of similar and of greater depth than transect 7. Turbidity in deep water would be least affected by wind-induced water turbulence because effect of water turbulence on agitating sediment decreased with increasing depth. Water particles travel under waves in almost circular orbits in a vertical plane, the amplitude decreases with depth, becoming negligible when depth exceeds one half of the wave length or distance between wave crests (Saunders 1974).

Temporal Variation

Monthly mean turbidity at all three transects varied seasonally (Figure 4). Low turbidity was prevalent throughout the winter months, but increased rapidly with the onset of spring; turbidity decreased during June and July but increased again during late summer. There was a highly significant ($P < .01$) correlation between monthly mean turbidities at transects 2 and 4 ($r = 0.96$), 2 and 7 ($r = 0.91$), and 4 and 7 ($r = 0.94$). Thus, in spite of significant differences in mean turbidity between transects 2 and 7 and 4 and 7, monthly variation in turbidity

Figure 4. Spatial and temporal variation in monthly mean turbidity in Lake Carl Blackwell, October 1968 through September 1969.


Transect 2
Transect 4
Transect 7
TURBIDITY (ppm SiO_2)
90
80
70
60
50
40
30
20
0
10 11 12 1 2 3 4 5 6 7 8 9
1968
1969
MONTHS

followed the same pattern at all transects. This suggests a common factor effects turbidity over the entire reservoir. The most likely factor is wind; turbidity at all three transects was highly correlated ($P < .01$) with wind velocity (Tables 5, 6, and 7). The correlation coefficients were $r = 0.64$, 0.68, and 0.63 for transects 2, 4, and 7, respectively.

Dissolved Oxygen

Spatial Variation

Dissolved oxygen at the surface and bottom was sampled on 33 occasions between 18 October 1968 and 25 September 1969 (Appendix, Table 10). The DO at the surface ranged from 3.72 to 11.81 ppm; DO on the bottom ranged from 1.03 to 11.69 ppm. Anoxic conditions were not observed. Annual mean dissolved oxygen, surface and bottom, was highest (7.21 and 7.00 ppm) at transect 7 and lowest (7.14 and 4.97 ppm) at transect 2 (Table 2). Variation between transect mean DO from the surface was trivial, but significant differences ($P < .05$) occurred in the annual mean bottom DO between transects 2 and 7 and 4 and 7, but not between 2 and 4. Once again, the similarity between 2 and 4 probably arises from similarity in depth. The highest annual mean DO was at transect 7, which demonstrates the effect of total water column mixing as a result of wind-reduced water turbulence.

Temporal Variation

Dissolved oxygen was consistently low during the fall (3.00 to 4.00 ppm), high during the spring (10.00 to 11.00 ppm), and intermediate (5.00 to 8.00 ppm) during the summer and winter (Table 1). The bottom

DO at transect 2, the deepest transect, dropped to an average of 2.13 ppm during the summer.

Temperature

Spatial Variation

A total of 66 measurements of water temperature were made at the surface and bottom between 18 October 1968 and 25 September 1969 (Appendix, Table 10). In this interval, the maximum range was from 3.4 to 31.9°C; overall means show trivial differences between transects for the surface or bottom measurements. While between transect differences in surface and bottom water temperatures were not significantly different ($P > .05$) there was a greater difference in surface and bottom water temperatures at transects 2 and 4 than at transect 7 (Table 3). This This corroborates similar findings with DO and illustrates the fact that while the water column at transects 7 was nearly always homothermal at transects 2 and 4, which were deeper, sometimes showed some stratification and clinograde variation in DO (Figures 5 and 6). Temperature and thermal stratification occurred at transects 2 and 4 June through August but there were only a few isobars (few distinct strata). A decrease in turbidity coincided with thermal stratification. Inconsistency in the relationship between sediment depth and turbidity may be explained by the effects of transient thermal stratification, because the thermocline would not permit mixing of epilimnetic and hypolimnetic waters. A turbidity inversion concurrent with thermal stratification was observed by Hooper et al. (1953). Since turbidity samples for this study were collected at the surface, this phenomenon would not have been observed.

Figure 5. Temperature (C) profile for Transect 2, Lake Carl Blackwell, October 1968 through September 1969.

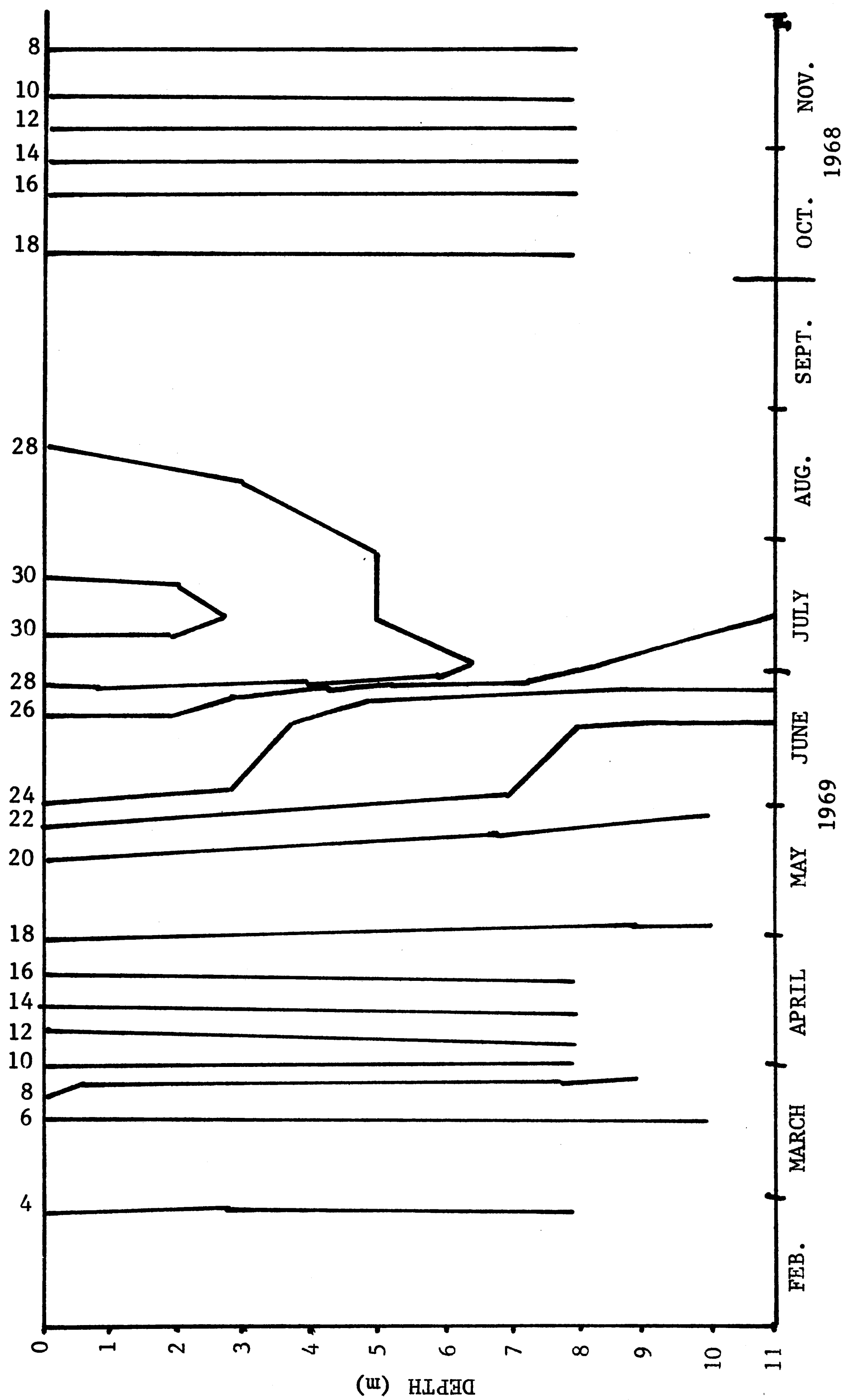

DEPTH (m)
0 1 2 3 4 5 6 7 8 9 10 11
FEB. MARCH APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV.
1969
1968
4 6 8 10 12 14 16 18 20 22 24 26 28 30 30 28
18 16 14 12 10 8

Figure 6. Temperature (C) profile for Transect 4, Lake Carl Blackwell, October 1968 through September 1969.

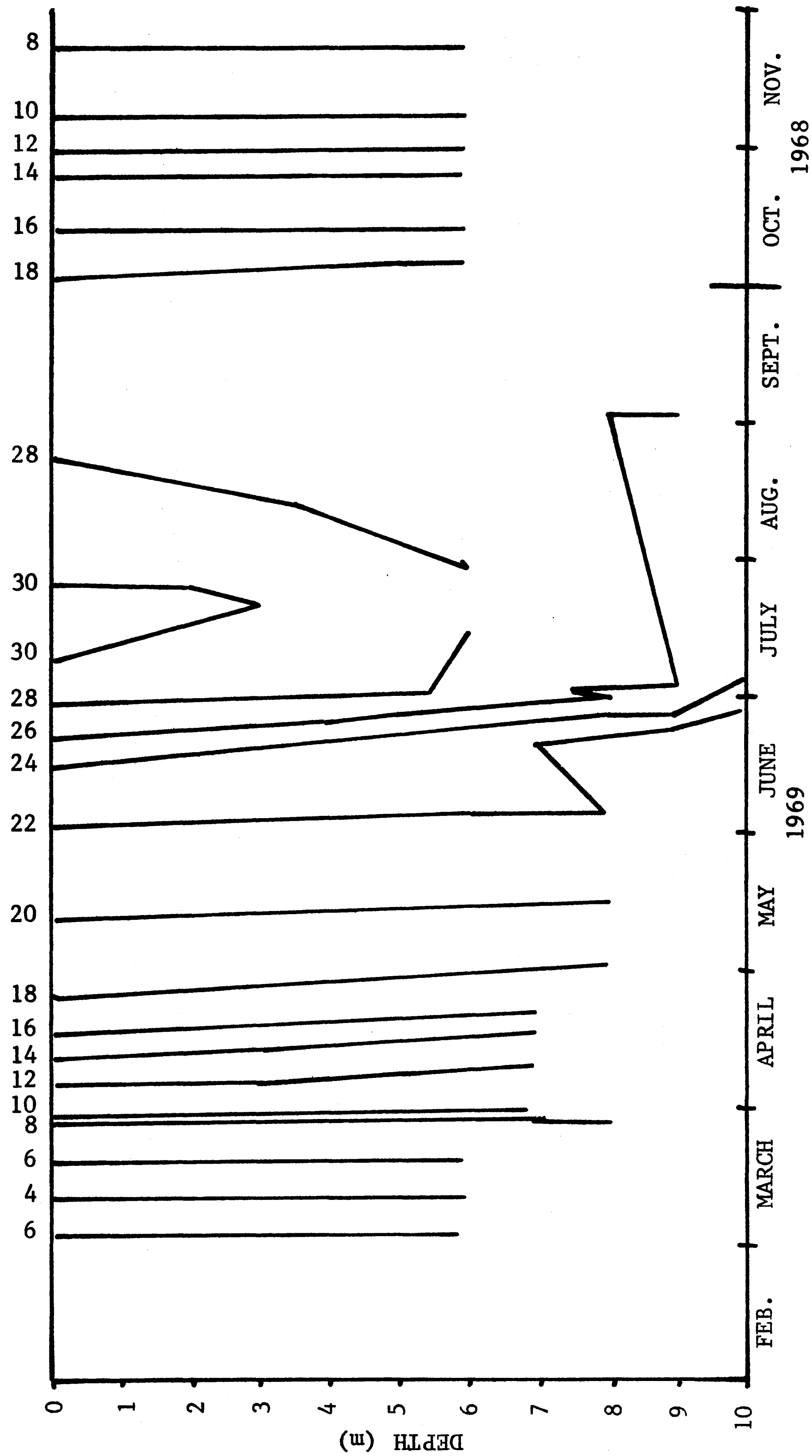
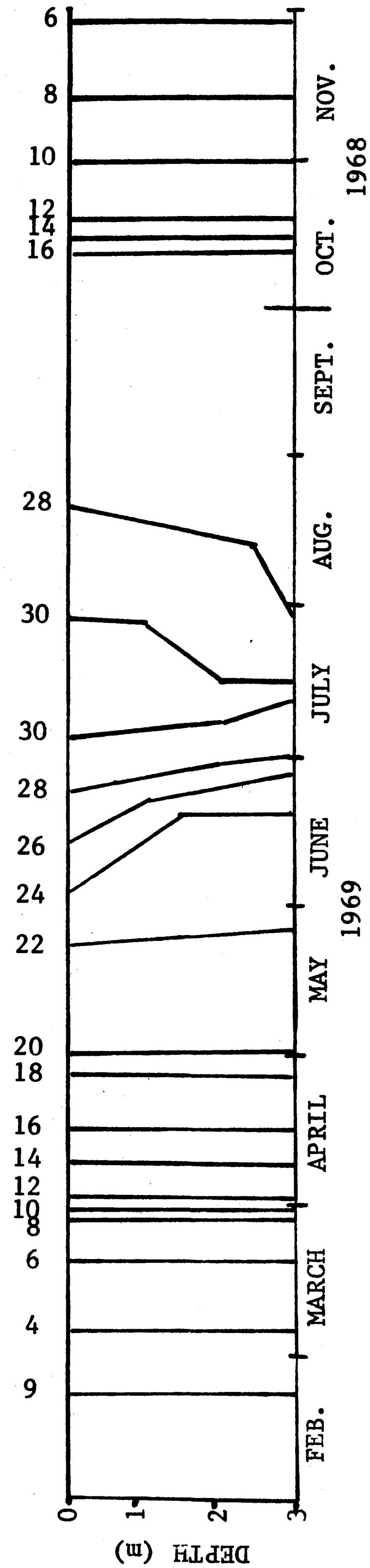

8
10
12
14
16
18
28
30
30
28
26
24
22
20
18
16
14
12
10
8
6
4
6
NOV.
1968
OCT.
SEPT.
AUG.
JULY
JUNE
1969
MAY
APRIL
MARCH
FEB.
0
1
2
3
4
5
6
7
8
9
10
DEPTH (m)

Figure 7. Temperature (C) profile for Transect 7, Lake Carl Blackwell, October 1968 through September 1969.


6
8
10
12
14
16
28
30
30
28
26
24
22
20
18
16
14
12
10
8
6
4
9
NOV.
OCT.
1968
SEPT.
AUG.
JULY
JUNE
1969
MAY
APRIL
MARCH
FEB.
0
1
2
3
DEPTH (m)

Primary Productivity

A total of 33 diurnal oxygen curves were obtained from 18 October 1968 to 25 September 1969 (Appendix, Table 10); gross productivity (Pg) ranged from 0.28 to 23.56 g O_2 m^{-2} day^{-1} (Appendix, Table 11). Annual transect means for Pg ranged from 3.24 g O_2 m^{-2} day^{-1} to 8.89 g O_2 m^{-2} day^{-1} (Table 2). Annual Pg in Lake Carl Blackwell was low when compared to Keystone Reservoir Oklahoma where annual means at several sample sites ranged from 11.34 to 49.00 g O_2 m^{-2} day^{-1} (Eley 1970). Pg in Lake Carl Blackwell was higher than Canyon Ferry Reservoir with an annual mean range of 2.22 to 3.02 g O_2 m^{-2} day^{-1} (Wright 1961). Pg in Lake Carl Blackwell was similar to Pg (4 to 12 g O_2 m^{-2} day^{-1}) obtained in selected farm ponds of Central Oklahoma (Butler 1964).

Total Community Respiration (Rt) ranged from 0.38 to 23.76 g O_2 m^{-2} day^{-1} (Appendix, Table 11). Annual mean Rt ranged from 3.37 g O_2 m^{-2} day^{-1} to 8.56 g O_2 m^{-2} day^{-1} (Table 2). Annual mean Rt in Lake Carl Blackwell was low compared to Keystone Reservoir which had an annual sample site mean range of 11.04 to 54.12 g O_2 m^{-2} day^{-1} (Eley 1970); Rt in Lake Carl Blackwell was high compared to Canyon Ferry Reservoir with an annual mean range of 1.44 to 2.01 g O_2 m^{-2} day^{-1} (Wright 1961), and high compared to the annual mean range of 0.4 to 9.9 g O_2 m^{-2} day^{-1} in Central Oklahoma farm ponds (Butler 1964).

Net Productivity (Pn) ranged from -2.13 to 4.86 g O_2 m^{-2} day^{-1} (Appendix, Table 11). Annual mean Pn ranged from -0.12 g O_2 m^{-2} day^{-1} to 0.33 g O_2 m^{-2} day^{-1} (Table 3). Annual mean Pn ranged from -5.03 to 0.30 g O_2 m^{-2} day^{-1} in Keystone Reservoir (Eley 1970) and -3.1 to 7.8 g O_2 m^{-2} day^{-1} in Central Oklahoma farm ponds (Butler 1964).

Spatial Variation

Annual transect mean Pg values varied from a high of 8.89 g O_2 m^{-2} day^{-1} at transect 2 to a low of 3.24 at transect 7 (Table 8). The difference in average Pg between transects 2 and 7 was significant at the .01 level and the difference between 4 and 7 narrowly missed significance at the .05 level (P = .053) (Table 3); the difference in mean Pg at transect 2 and 4 was non-significant. Pg declined at transects 2-7, going from east to west, coinciding with a gradient in overall mean turbidity (33.7, 37.5, and 55.2 ppm SiO_2 at transects 2, 4, and 7, respectively). The correlation between the three transect means for Pg and turbidity was $r = 0.997$, which was significant at the .05 level with only one degree of freedom.

There was a significant correlation ($P < .01$) between Pg and Rt at all three transects, but the correlation between Pg and chlorophyll a was non-significant ($P > .05$) at all of the transects (Tables 5, 6, and 7). A significant ($P < .05$) positive correlation was obtained between Pg and wind velocity at transects 2 and 7, but this relationship ($r = 0.57$) was non-significant ($P > .05$) at transect 4. The direct relationship between Pg and wind velocity at transects 2 and 7 is not clear, but may be the result of an underestimate of the diffusion constant for oxygen under turbulent conditions, or the dynamic interaction between the negative aspects of turbidity on primary productivity during periods of high wind and the positive influence of nutrient recycling which would increase phytoplankton growth.

Spatial variation in Pn was greatest in July and September (Figure 8). Highest Pn was observed at transect 2 in July and at transect 4 in September. Pn was generally lower at transect 7 than Pn

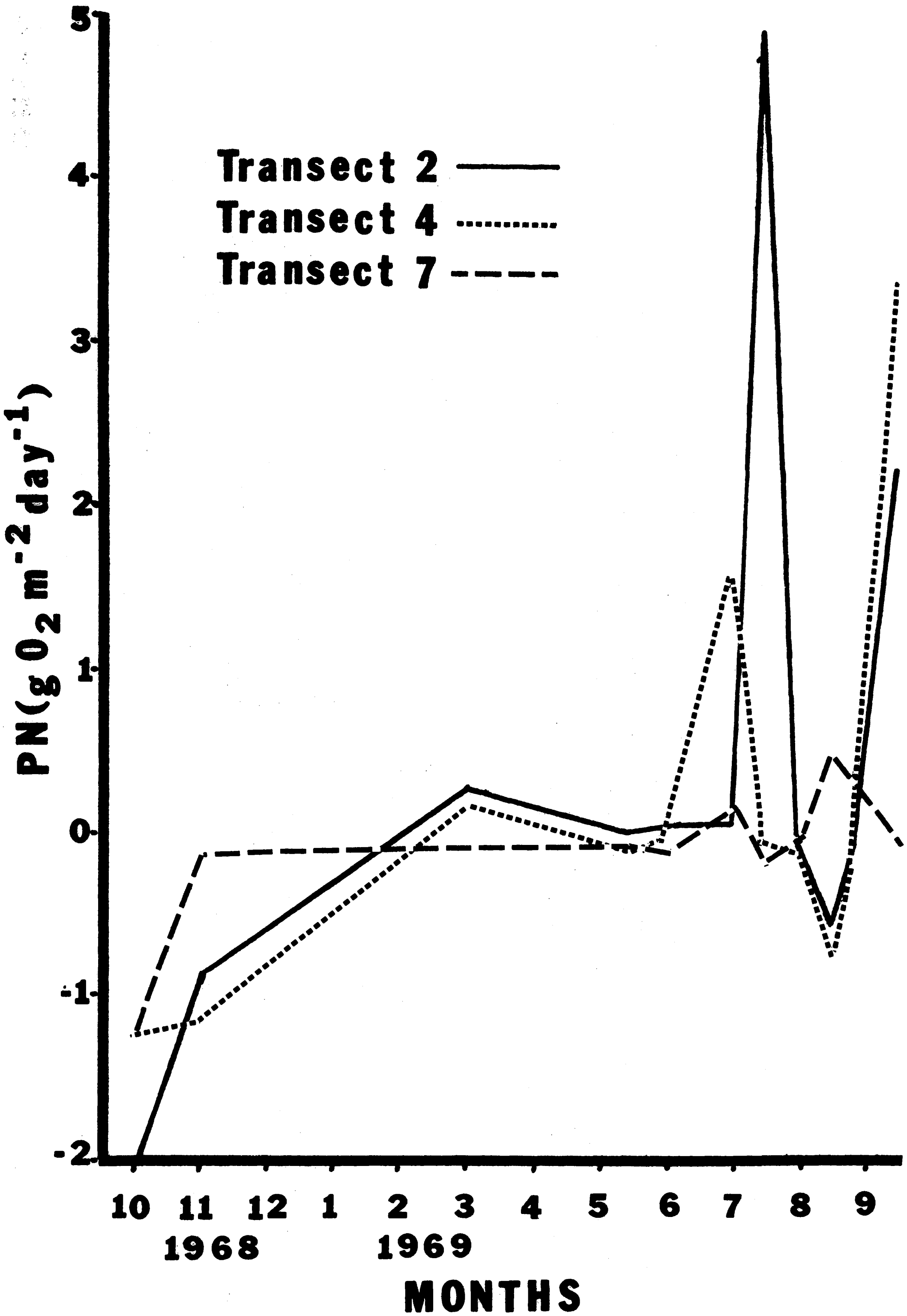
Table 8. Monthly mean values for primary productivity (g $O_2m^{-2}day^{-1}$) at Transects 2, 4, and 7 in Lake Carl Blackwell, October 1968 through September 1969.

	Pg				Rt			
Month	2	4	7	$\bar{x}$	2	4	7	$\bar{x}$
October	5.91	2.31	1.47	3.23	8.04	3.53	2.69	4.75
November	1.24	4.20	0.85	2.10	2.16	5.38	1.01	2.85
March	15.12	7.62	7.54	10.09	14.88	7.44	7.44	9.92
June	8.61	2.95	0.31	3.96	8.59	3.02	0.43	4.01
July	4.45	9.47	2.76	5.56	2.00	8.78	2.79	4.52
August	11.18	6.67	3.02	6.96	11.47	7.08	2.88	7.14
September	13.51	14.90	6.81	11.74	12.48	13.32	6.84	10.88
Annual mean[1]	8.89	7.46	3.24	6.23	8.56	7.34	3.37	6.29

	Pn				Pg/Rt			
	2	4	7	$\bar{x}$	2	4	7	$\bar{x}$
October	-2.13	-1.22	-1.22	-1.52	0.74	0.65	0.52	0.64
November	-0.92	-1.18	-0.16	-0.75	0.57	0.78	0.84	0.73
March	0.24	0.18	0.10	0.17	1.02	1.02	1.01	1.02
June	0.02	-0.07	-0.12	-0.17	1.00	0.97	0.72	0.90
July	2.45	0.77	-0.03	1.06	2.26	1.08	0.95	1.43
August	-0.28	-0.49	0.14	0.21	0.98	0.91	1.05	0.98
September	1.03	1.58	-0.03	0.86	1.08	1.58	0.99	1.22
Annual mean[1]	0.33	0.12	-0.12	-0.02	1.18	1.05	0.89	0.98

[1]Transect means are of eleven individual determinations; annual lake means are means of the monthly means.

Figure 8. Spatial and temporal variation in net productivity (Pn) in Lake Carl Blackwell, October 1968 through September 1969.


Transect 2
Transect 4
Transect 7
PN(g O_2 m^{-2} day^{-1})
5
4
3
2
1
0
-1
-2
10
11
12
1
2
3
4
5
6
7
8
9
1968
1969
MONTHS

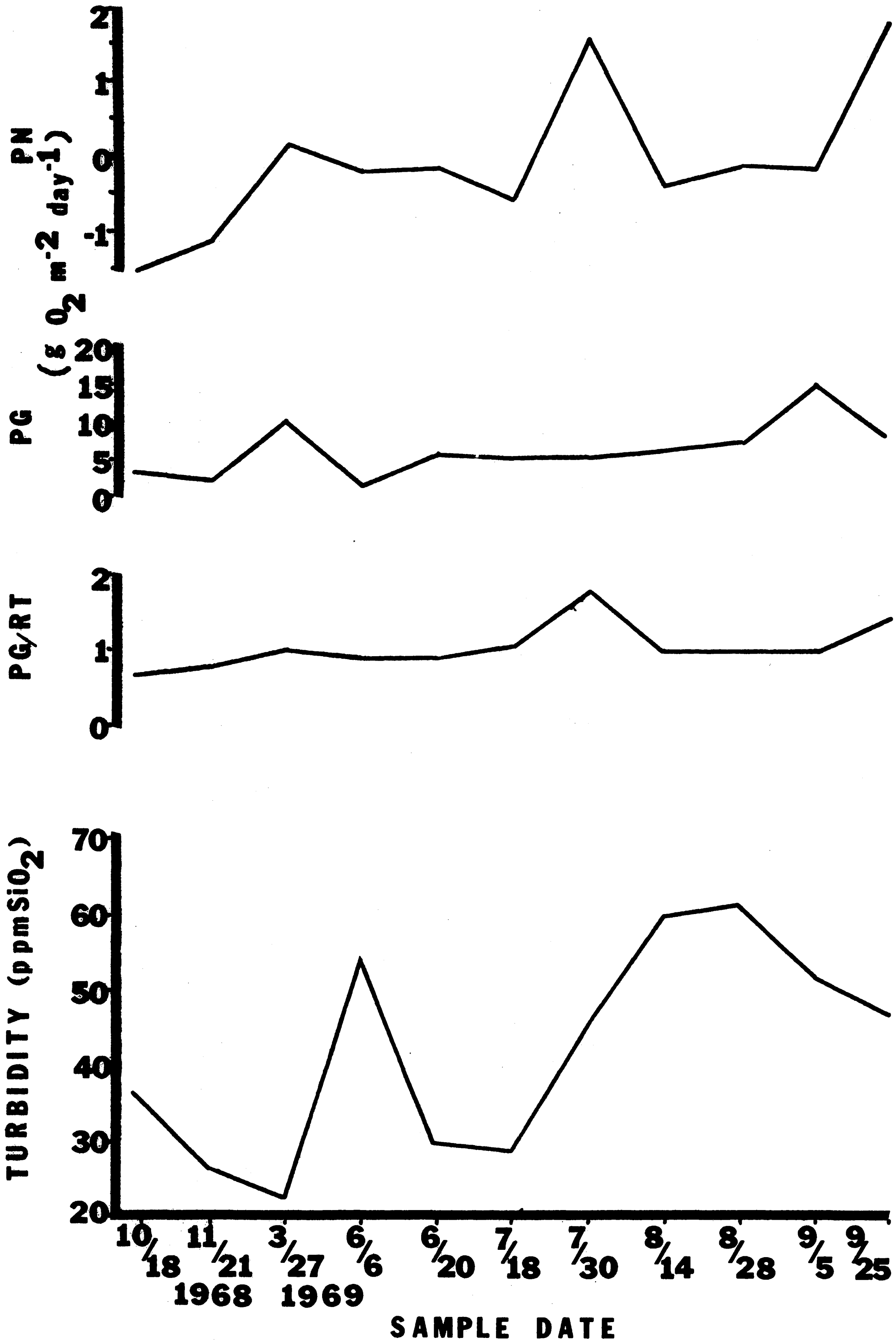
values at transects 2 and 4. Average monthly Pn (Table 8) for all three transects indicated an autotrophic condition at transects 2 and 4 and a heterotrophic condition at transect 7. The incidence of negative Pn values was highest at transect 7, decreasing at transect 4 and lowest at transect 2. The difference in Pn among transects was non-significant ($P > .05$, Table 3). Spatial variation in the P/R ratio was greatest in mid-summer and early fall with highest Pg/Rt observed at transects 2 and 4 (Figure 9). Pg/Rt values supported the conclusion that, on the average, autotrophic conditions existed at transects 2 and 4 and heterotrophic conditions existed at transect 7.

Relation Between Measures of Productivity and Wind Speed

There was significant correlation ($P < .05$) between Pg/Rt and wind velocity at all three transects (Tables 5, 6, and 7). The difference in magnitude of these correlations suggest longitudinal variation in the effects of wind on Pg/Rt. Although the difference in Pg/Rt among transects was non-significant ($P > .05$) (Table 3), the highest correlation coefficient between wind and velocity was at transect 7 ($r = 0.78$) and least affected by wind velocity at transect 2 ($r = 0.65$). The relationship between Pg, Pn, and Pg/Rt and turbidity (Figure 9) indicated an increase in Pn and Pg/Rt during late fall corresponded to a decrease in turbidity. Pg decreased during late fall. During the summer months Pn and Pg/Rt were inversely related to turbidity.

The difference in Rt between transects 2 and 7 (Table 8) was highly significant ($P < .01$) (Table 3). There was significant ($P < .01$ and $P > .05$) correlation of Rt to wind velocity at transects 2 and 7

Figure 9. Relationship between Pg, Pn, and Pg/Rt and turbidity in Lake Carl Blackwell, October 1968 through September 1969.


PN
(g O2 m-2 day-1)
2
1
0
-1
PG
20
15
10
5
0
PG/RT
2
1
0
TURBIDITY (ppmSiO2)
70
60
50
40
30
20
10/18
11/21
1968
3/27
1969
6/6
6/20
7/18
7/30
8/14
8/28
9/5
9/25
SAMPLE DATE

(r = 0.75 and 0.71, Tables 5 and 7). Correlation of Rt and wind velocity at transect 4 was non-significant (Table 6).

Temporal Variation

Monthly variation mean Pg values (Figure 9) indicates an early spring (3-27-69) and early fall (9-5-69) phytoplankton bloom (Table 8, Figure 8). Without exception, the monthly mean Pg at transect 7 was always lower than the Pg monthly means at the other transects (Table 5); mean values of Rt followed the same seasonal trend as Pg. Pg/Rt (P/R) monthly means ranged from 0.64 to 1.43 (Table 8). Spatial variation in the P/R ratio was greatest in mid-summer and early fall with highest Pg/Rt observed at transects 2 and 4. Pg/Rt values indicated that, on the average, autotrophic conditions existed at transects 2 and 4 and heterotrophic conditions existed at transect 7.

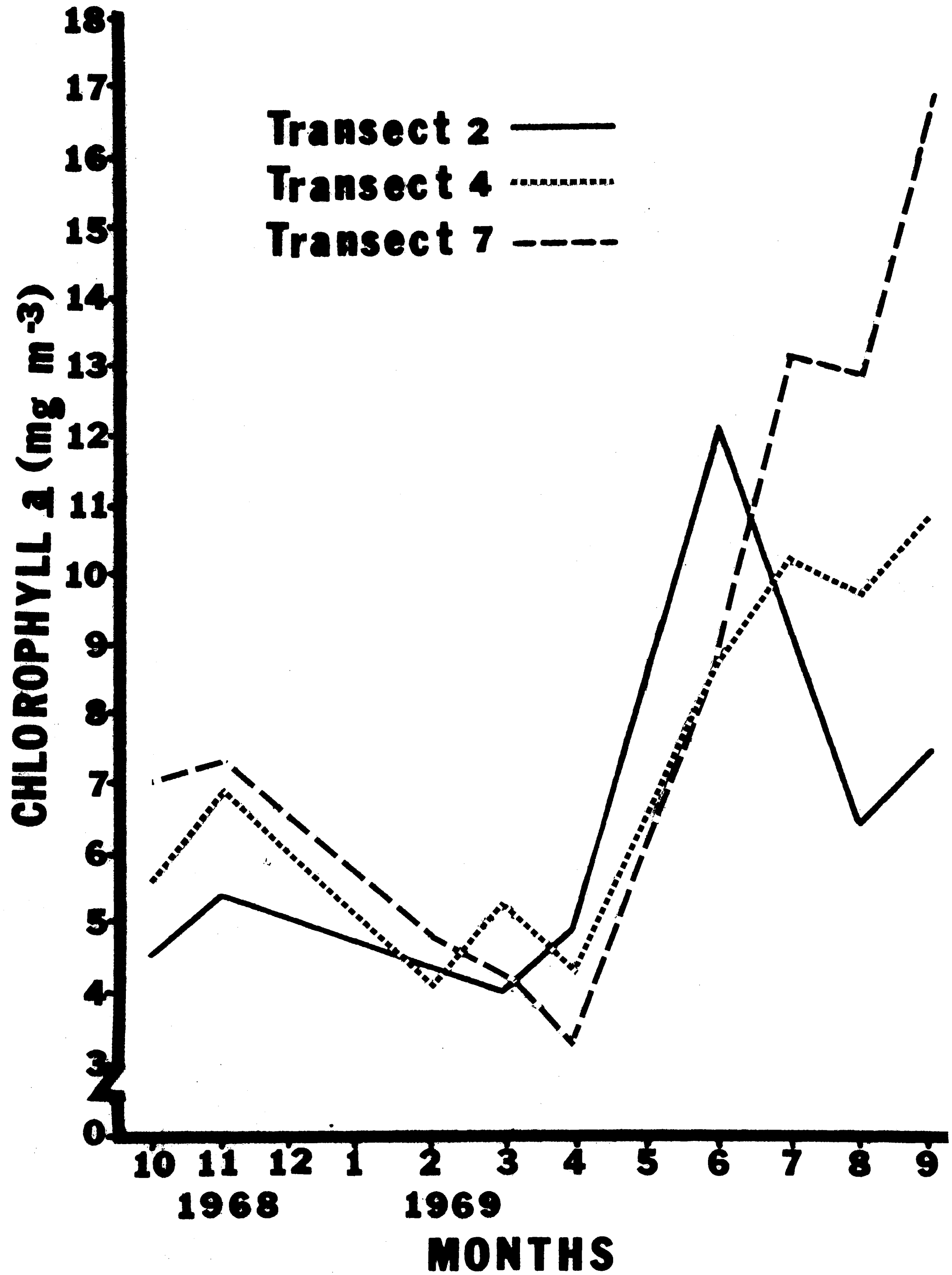
Chlorophyll *a*

Individual measurements of Ch *a* ranged from 3.29 to 17.57 mg m^{-3} (Appendix, Table 10); transect means varied from 7.03 to 9.85 (Table 2). Chlorophyll samples in Lake Carl Blackwell were generally lower than in Keystone Reservoir which had a range of 6 to 478 mg m^{-3} (Eley 1970) and 33 to 59 mg m annual mean for all Ch *a* measurements was 7.03 mg m^{-3} (Spangler 1969).

Spatial Variation

Intertransect variation in Ch *a* was maximum in September 1969 and least during May and June (Figure 10). Differences in chlorophyll *a* among transects was non-significant ($P > .05$, Table 2). Spatial

Figure 10. Spatial and temporal variation in Chlorophyll *a* in Lake Carl Blackwell, October 1968 through September 1969.


Transect 2
Transect 4
Transect 7
CHLOROPHYLL a (mg m-3)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
0
10
11
12
1
2
3
4
5
6
7
8
9
1968
1969
MONTHS

variation in chlorophyll a was reverse to spatial variation in primary productivity; primary productivity was highest at transect 2 and lowest at transect 7, but Ch a was highest at transect 7 and lowest at transect 2. Chlorophyll a was most variable at transect 7 where values ranged from 3.29 to 16.99 mg m (Table 1).

Monthly mean chlorophyll a values ranged from 4.25 to 11.84 mg m^{-3} (Table 1) and indicated seasonal variation, but the seasonal pattern in Ch a did not parallel that of Pn or Pg.

Relationship Between Ch a and Turbidity, and Ch a and Wind Velocity

A significant correlation ($P < .05$) was obtained for all transects of the relationship between abundance of Ch a and wind velocity. This correlation was contrary to the expected inverse relationship. Although phytoplankton biomass, determined by Ch a analysis, was apparently more abundant at transect 7 than 2 and 4, primary productivity was lowest at transect 7.

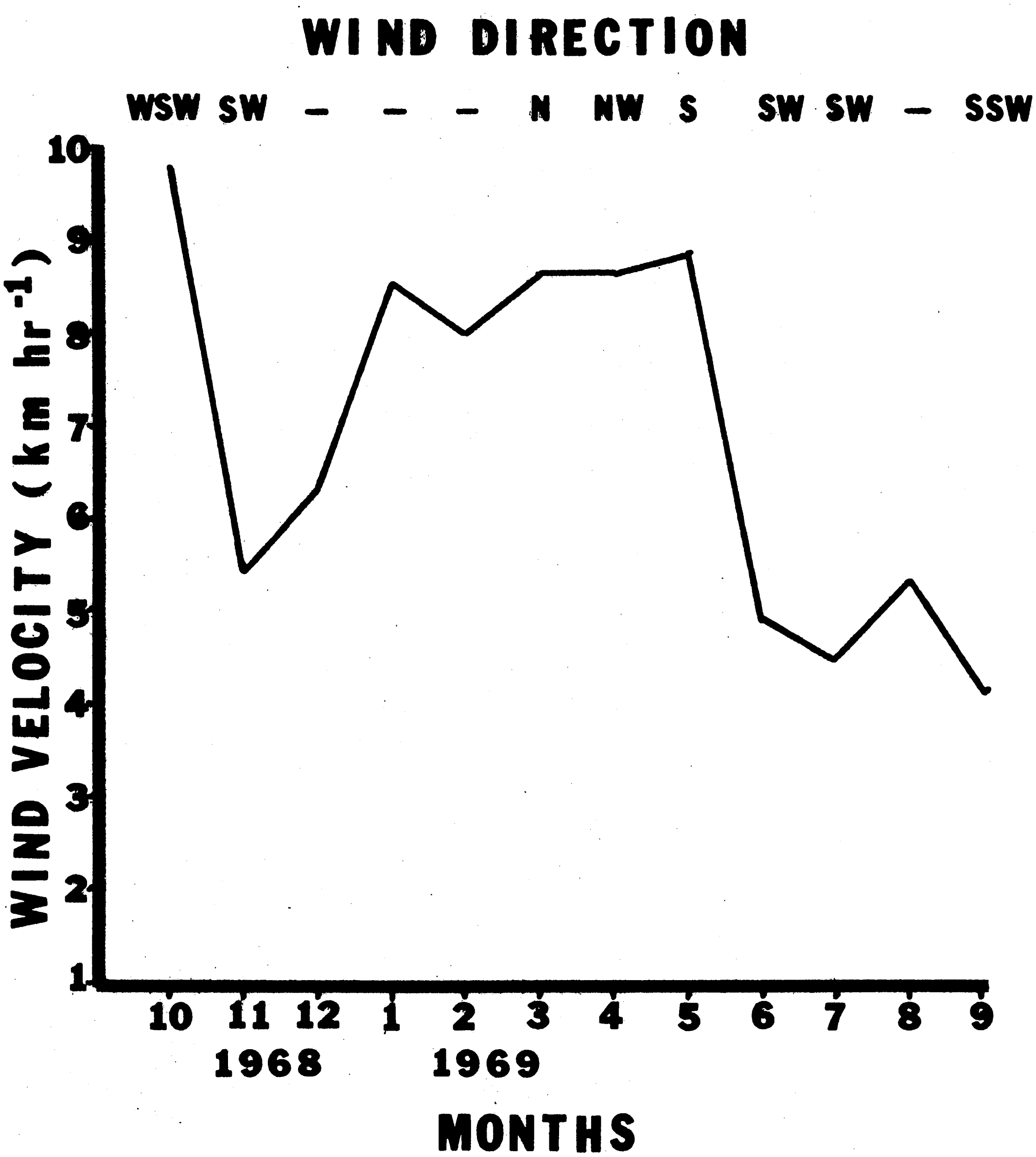
A greater phytoplankton density at transect 7, as inferred from comparisons between Ch a concentrations at transect 7 to 2 and 4, suggests that the turbidity observed at 7 was in fact due to plankton not just suspended inorganic solids. Greater mixing was indicated at transect 7 as this transect had the least sediment depth, the highest turbidity, orthograde DO, and homothermal temperature condition.

Wind Velocity

Wind velocity ranged from 2.38 to 13.21 km hr^{-1} (Appendix, Table 9). Monthly mean wind velocity ranged from 4.13 to 9.78 km hr^{-1} (Table

1). Wind velocity was consistently higher from early winter to early spring and lowest during mid-summer to early fall (Figure 11). Highest wind velocity was observed during mid-fall. Prevailing winds during the winter and early spring were from the N or NW, while prevailing winds during the remainder of the year were from the S, SW, or W.

Figure 11. Monthly mean wind velocity and wind direction, Lake Carl Blackwell, October 1968 through September 1969. Wind velocity based on a 4-day average, 3 days prior to sampling and including the sampling date. Data obtained from the O.S.U. weather station west of Stillwater.


WIND DIRECTION
WSW SW – – – N NW S SW SW – SSW
WIND VELOCITY (km hr-1)
10
9
8
7
6
5
4
3
2
1
10 11 12 1 2 3 4 5 6 7 8 9
1968 1969
MONTHS

CHAPTER V

SUMMARY AND CONCLUSIONS

The relationship between wind velocity and sediment depth in Lake Carl Blackwell was non-significat ($P > .05$). The correlation between sediment depth and wind velocity ($r = -0.56$) closely approached the .05 level of significance at transect 7 which had the smallest average water depth. A wind-induced sediment cycling relationship was not established by this analysis. Moreover, turbidity was not correlated with sediment depth. There was a highly significant ($P < .01$) correlation between turbidity and wind speed suggesting that perhaps some light, unconsolidated portion of the sediment may have been resuspended although sediment depth remained relatively unaffected. Phytoplankton biomass was positively related to wind velocity, suggesting that some of the turbidity-wind relationship was the result of phytoplankton blooms rather than suspended inorganic solids.

Primary productivity in Lake Carl Blackwell was not significantly limited by turbidity when examined by the correlation between turbidity to Pg, Pn and Ch a. Subjective interpretation of the graphical presentation of the relationship between primary productivity and turbidity indicated an inverse relationship between Pn and Pg/Rt and turbidity during short intervals during the fall of 1968 and the summer of 1969. Community metabolism suggests that autotrophic conditions apparently existed at transects 2 and 4 and that heterotrophic conditions existed at transect 7.

Longitudinal variation of sediment depth, dissolved oxygen at the surface, temperature, Pn Pg/Rt, and Ch a among transects was non-significant ($P > .05$). Longitudinal variation of trubidity, dissolved oxygen at the bottom, Pg, and Rt between transects 2 and 7 was significant ($P < .01$) and ($P < .05$). Also significant ($P < .01$) was longitudinal variation of turbidity between transects 4 and 7.

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APPENDIXES

Table 9. Wind velocity and sediment depth data collected at Transects 2, 4, and 7 in Lake Carl Blackwell, October 1968 through September 1969. Wind velocity data also taken from weather station 3.2 km west of Stillwater.

Date: Month Day	Wind velocity ($Km\ hr^{-1}$) Transect 2	Transect 4	Transect 7	Weather station	Wind direction	Sediment depth in meters Transect means 2	4	7	Mean[1]
1968									
10- 4				8.80	WSW	0.2	0.4	0.7	0.43
10-18	24.13	24.13	24.13	10.78	WSW				
11-12				8.08		0.7	0.7	0.3	0.57
11-20	3.22	0	0	2.85	SW				
12-17				6.37		0.5	0.7	0.5	0.57
1969									
1-23				8.54	N	1.0	0.9	0.5	0.80
2- 7				6.40	N				
2-28				9.67	N	1.2	1.5	0.4	1.03
3- 7	28.16	28.16	28.16	4.89					
3-12	12.07	12.07	12.07	7.93	N				
3-26	16.09	12.87	19.31	13.21	S				
4- 2				11.28					
4- 9	18.50	18.50	18.50	10.31	NW	-	-	-	-
4-25	22.53	22.53	22.53	4.41	S	0.8	0.5	0.7	0.67
5- 2	19.31	25.74	22.53	8.85	S	-	-	-	-
6- 5	11.26	16.09	4.83	4.83	SW	0.8	0.7	0.7	0.73
6-12	18.50	14.48	16.09	7.67	NE	-	-	-	-
6-19	0	16.09	0	2.38	SW	-	-	-	-
7- 3	12.87	12.87	8.04	5.70	SW	-	-	-	-
7-17	0	0	0	4.25	-	-	-	-	-
7-18	4.83	4.83	3.22	4.07	SW	0.6	0.5	0.8	0.63
7-29	0	0	0	4.02	-	-	-	-	-
8-13	0	0	0	6.13	-	1.0	1.3	1.0	1.10
8-27	0	0	0	4.55	-	-	-	-	-
9- 4	8.04	9.65	4.83	2.59	SSW	-	-	-	-
9- 8	-	-	-	6.44	-	0.7	1.2	0.9	0.93
9-12	0	0	0	3.67	-	-	-	-	-
9-23	16.09	17.70	12.87	4.39	NNE	-	-	-	-
9-25	-	-	-	3.56	-	-	-	-	-

[1]mean of transect means

Table 10. Water quality data collected at Transects 2, 4, and 7 in Lake Carl Blackwell, October 1968 through September 1969.

Date	Temperature (C) Sur.	Temperature (C) Bot.	D.O. (ppm) Sur.	D.O. (ppm) Bot.	Turbidity (ppm SiO_2)	Ch a (mg m^{-3})
			Transect 2			
1968						
10-18	18.4	18.4	3.72	4.06	31.0	4.59
11-20	7.8	7.8	4.39	5.46	25.0	5.45
1969						
1 -23	-	-	-	-	25.0	-
2 - 7	-	-	-	-	20.0	4.46
2 -28	6.8	6.5	-	-	22.7	-
3 - 7	6.5	6.0	-	-	21.0	-
3 -12	4.5	4.5	-	-	22.0	-
3 -26	7.8	7.7	11.81	11.06	44.0	4.12
4 - 2	11.2	10.8	-	-	44.0	-
4 - 9	17.8	-	-	-	41.2	-
4 -25	16.8	16.8	-	-	46.0	5.04
5 - 2	18.3	17.8	-	-	40.2	-
6 - 5	24.7	20.8	7.92	3.26	37.0	12.20
6 -12	24.5	22.4	-	-	32.7	-
6 -19	26.0	21.3	8.66	2.76	22.2	-
7 - 3	28.8	25.0	-	-	28.0	13.77
7 -17	31.3	26.0	8.18	1.79	-	-
7 -18	-	-	-	-	17.0	5.66
7 -29	28.7	26.0	5.89	1.03	38.2	8.43
8 -13	28.2	26.5	6.92	6.18	54.2	8.12
8 -27	27.5	27.0	5.93	4.08	45.2	4.98
9 - 4	27.0	26.8	7.34	7.64	42.6	7.54
9 -12	26.5	26.3	-	-	44.8	-
9 -23	23.3	22.9	-	-	40.8	-
9 -25	23.3	21.8	7.79	7.37	-	-
			Transect 4			
1968						
10-18	17.9	18.0	3.87	4.27	37.5	5.57
11-20	7.2	7.2	4.71	5.54	25.0	6.97
1969						
1 -23	-	-	-	-	25.0	-
2 - 7	-	-	-	-	22.0	4.18
2 -28	7.0	7.0	-	-	21.7	-

Table 10. (Continued)

Date	Temperature (C) Sur.	Bot.	D.O. (ppm) Sur.	Bot.	Turbidity (ppm SiO_2)	Ch a ($mg\ m^{-3}$)
1969						
3 - 7	6.0	6.0	-	-	21.7	-
3 -12	4.0	4.0	-	-	22.3	-
3 -26	7.8	7.0	11.75	10.42	47.7	5.35
4 - 2	11.8	10.5	-	-	44.5	-
4 - 9	17.8	-	-	-	43.5	-
4 -25	17.7	17.4	-	-	50.2	4.41
5 - 2	19.0	18.0	-	-	51.8	-
6 - 5	22.4	21.5	7.83	5.87	42.8	8.75
6 -12	24.8	23.7	-	-	33.5	-
6 -19	25.1	21.2	8.01	4.05	27.7	-
7 - 3	28.7	25.7	-	-	38.0	16.09
7 -17	31.9	27.2	7.96	1.64	-	-
7 -18	-	-	-	-	26.2	6.50
7 -29	28.4	27.0	6.29	2.47	45.2	8.46
8 -13	28.4	27.0	7.33	6.77	58.5	13.07
8 -27	27.6	26.8	6.21	5.03	51.0	6.54
9 - 4	27.1	26.0	7.47	6.45	45.2	10.98
9 -12	25.8	25.4	-	-	41.2	-
9 -23	23.0	22.8	-	-	41.2	-
9 -25	23.8	7.45	7.08	-	-	-
			Transect 7			
1968						
1 -18	17.6	17.6	3.77	4.06	42.0	7.02
11-20	6.3	6.3	5.20	6.04	30.0	7.36
1969						
1 -23	-	-	-	-	25.0	-
2 - 7	-	-	-	-	22.0	4.7
2 -28	9.0	9.0	-	-	33.0	-
3 - 7	6.0	5.5	-	-	26.0	-
3 -12	3.4	3.4	-	-	27.0	-
3 -26	7.8	7.8	11.62	11.69	109.7	4.32
4 - 2	12.5	12.3	-	-	59.3	-
4 - 9	17.8	-	-	-	58.3	-
4 -25	18.3	18.3	-	-	88.0	3.29
5 - 2	20.1	20.3	-	-	82.0	-
6 - 5	24.3	22.9	7.41	7.14	84.5	8.89
6 -12	25.2	25.2	-	-	56.7	-

Table 10. (Continued)

Date	Temperature (C)		D.O. (ppm)		Turbidity	Ch *a*
	Sur.	Bot.	Sur.	Bot.	(ppm SiO_2)	(mg m^{-3})
1969						
6 -19	25.8	22.4	7.61	6.35	40.3	-
7 - 3	29.2	28.9	-	-	65.2	17.57
7 -17	31.5	30.3	7.73	5.56	-	-
7 -18	-	-	-	-	44.2	10.07
7 -29	29.8	27.5	7.02	6.62	54.0	12.08
8 -13	28.2	27.7	7.12	7.33	67.3	15.65
8 -27	27.7	27.6	6.36	6.40	88.0	10.21
9 - 4	27.4	27.4	7.71	8.42	68.8	16.99
9 -12	25.6	25.4	-	-	61.8	-
9 -23	23.0	23.1	-	-	58.7	-
9 -25	24.2	22.6	7.76	7.27	-	-

Table 11. Primary productivity (g O_2 m^{-2} day^{-1}) Transects 2, 4, and 7 in Lake Carl Blackwell, October, 1968 through September, 1969.

Date	Pg	Rt	Pn	Pg/Rt
		Transect 2		
1968				
10-18	5.91	8.04	-2.13	0.74
11-21	1.24	2.16	-0.92	0.57
1969				
3-27	15.12	14.88	0.24	1.02
6- 6	3.84	3.84	0	1.00
6-20	13.38	13.34	0.04	1.00
7-18	2.11	2.06	0.05	1.02
7-30	6.80	1.94	4.86	3.51
8-14	6.94	6.96	-0.02	1.00
8-28	15.43	15.98	-0.55	0.97
9- 5	12.81	12.96	-0.15	0.99
9-25	14.21	12.00	2.21	1.18
		Transect 4		
1968				
10-18	2.31	3.53	-1.22	0.65
11-21	4.20	5.38	-1.18	0.78
1969				
3 -27	7.62	7.44	0.18	1.02
6 - 6	1.82	1.92	-0.10	0.95
6 -20	4.09	4.13	-0.04	0.99
7 -18	9.78	8.21	1.57	1.19
7 -30	9.16	9.36	-0.03	0.98
8 -14	9.57	9.60	-0.79	1.00
8 -28	3.77	4.56	-0.20	0.83
9 - 5	23.56	23.76	-0.20	0.99
9 -25	6.25	2.88	3.37	2.17

Table 11. (Continued)

Date	Pg	Rt	Pn	Pg/Rt
		Transect 7		
1968				
10-18	1.47	2.69	-1.22	0.52
11-21	0.85	1.01	-0.16	0.84
1969				
3 -27	7.54	7.44	0.10	1.01
6 - 6	0.28	0.38	-0.10	0.74
6 -20	0.34	0.48	-0.14	0.71
7 -18	4.29	4.20	0.09	1.02
7 -30	1.24	1.39	-0.15	0.89
8 -14	2.73	2.88	-0.15	0.95
8 -28	3.32	2.88	0.44	1.15
9 - 5	9.59	9.60	-0.01	1.00
9 -25	4.03	4.08	-0.05	0.99

Table 12. Temperature (C) data taken at Transect 2 in Lake Carl Blackwell.

Date	Surface	Water Depth (meters) 1	2	3	4	5	6	7	8	9	10	11
1968												
10-18	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4			
11-20	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8			
1969												
2 -28	6.8	6.8	6.8	6.5	6.5	6.5	6.5	6.5	6.5			
3 -12	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5			
3 -26	7.8	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.6	7.7	7.7	
3 -27	8.7	8.5	8.5	8.5	8.5	8.5	8.5	8.3	8.3	8.0		
4 - 2	11.2	11.2	11.1	11.1	11.1	10.9	10.9	10.8	10.8			
5 - 2	18.3	18.3	18.3	18.3	18.3	18.2	18.2	18.2	18.1	18.0	18.0	17.8
6 - 5	24.7	24.6	24.3	23.9	23.1	22.6	22.3	22.0	21.9	21.3	21.0	20.8
6 -19	26.0	25.9	26.0	25.6	22.8	22.5	22.3	22.2	22.0	21.8	21.5	21.3
7 - 3	28.8	28.8	28.8	28.8	28.8	28.7	28.7	27.2	26.5	25.8	25.3	25.0
7 -17	31.3	31.3	31.1	29.8	28.9	28.0	27.8	27.6	27.0	26.7	26.3	26.0
7 -29	28.7	28.7	28.6	28.2	28.2	28.0	28.0	27.7	27.5	26.7	26.3	26.0
8 -13	28.2	28.1	28.1	28.1	27.5	27.2	27.0	27.0	27.0	26.8	26.7	26.5
8 -27	27.5	27.6	27.6	27.6	27.5	27.5	27.2	27.1	27.1	27.2	27.1	27.0
9 - 4	27.0	27.0	27.0	27.0	27.0	26.9	26.9	26.9	26.8	26.8		
9 -12	26.5	26.7	26.7	26.7	26.6	26.5	26.5	26.4	26.3			
9 -23	23.3	23.2	23.2	23.2	23.2	23.2	23.1	23.0	22.9	22.9		
9 -25	23.3	23.4	23.2	22.5	22.1	22.1	22.0	22.0	21.8			

Table 13. Temperature (C) data taken at Transect 4 in Lake Carl Blackwell.

Date	Surface	Water depth (meters) 1	2	3	4	5	6	7	8	9	10
1968											
10-18	17.9	17.9	17.9	17.9	17.9	18.0	18.0				
11-20	7.2	7.2	7.2	7.2	7.2	7.2	7.2				
1969											
2 -28	7.0	7.0	7.0	7.0	7.0	7.0	7.0				
3 -12	4.0	4.0	4.0	4.0	4.0	4.0	4.0				
3 -26	7.8	7.7	7.7	7.7	7.7	7.7	7.5	7.3	7.0		
3 -27	8.5	8.3	8.3	8.3	8.3	8.3	8.0	8.0	8.0		
4 - 2	11.8	11.5	11.5	11.4	11.1	10.9	10.8	10.5			
5 - 2	19.0	18.8	18.8	18.8	18.8	18.7	18.7	18.7	18.0		
6 - 5	22.4	22.4	23.8	23.1	22.4	22.1	22.0	21.9	22.0	21.5	
6 -19	25.1	25.0	25.0	24.9	23.1	22.6	22.3	22.0	21.9	21.3	21.2
7 - 3	28.7	28.7	28.7	28.7	28.7	28.7	27.4	26.6	26.3	25.7	
7 -17	31.9	31.9	31.9	30.0	29.6	28.7	28.0	27.5	27.3	27.3	27.2
7 -29	28.4	28.6	28.5	28.4	28.0	28.0	27.9	27.7	27.7	27.0	
8 -13	28.4	28.4	28.4	28.1	27.2	27.0	27.0	27.0			
8 -27	27.6	27.5	27.6	27.6	27.2	27.1	26.0	26.9	26.8	26.8	
9 - 4	27.1	27.3	27.1	27.2	26.8	26.5	26.2	26.1	26.0	26.0	
9 -12	25.8	26.0	26.0	26.0	26.0	26.0	25.9	25.7	25.5	25.4	
9 -23	23.0	23.0	23.0	23.2	23.0	23.0	22.9	22.8			
9 -25	23.8	23.9	22.7	22.3	22.1	22.0	21.9	21.8	21.7	21.7	

Table 14. Temperature (C) data taken at Transect 7 in Lake Carl Blackwell.

Date	Surface	Water depth (meters) 1	2	3
1968				
10-18	17.6	17.6		
11-20	6.3	6.3		
1969				
2 -28	9.0	9.0		
3 -12	3.4	3.4		
3 -26	7.8	7.8		
3 -27	9.0	9.0		
4 - 2	12.5	12.3		
5 - 2	20.1	20.3	20.3	
6 - 5	24.3	24.2	22.9	
6 -19	25.8	25.0	23.0	22.4
7 - 3	29.2	29.2	29.2	28.9
7 -17	31.5	31.5	30.9	30.3
7 -20	29.8	29.8	29.3	27.5
8 -13	28.2	28.1	28.1	27.7
8 -27	27.7	27.7	27.6	
9 - 4	27.4	27.4	27.4	
9 -12	25.6	25.7	25.7	25.4
9 -23	23.0	23.1	23.1	23.1
9 -25	24.2	24.1	22.6	

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VITA

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