NOAA Technical Memorandum ERL GLERL-67

Southern Lake Michigan Nutrients, Temperature Chlorophyll, Plankton, and Water Movement During 1983 and 1984

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Ann Arbor, Michigan
October 1987

UNITED STATES
DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

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SOUTHERN LAKE MICHIGAN NUTRIENTS, TEMPERATURE, CHLOROPHYLL, PLANKTON, AND WATER MOVEMENT DURING 1983 AND 1984[1]

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ABSTRACT. Several biological, chemical, and physical properties were determined in Lake Michigan for the region of the 100-m depth contour in the southeastern basin of Lake Michigan off Grand Haven, Michigan, in 1983 and 1984. The measurements are presented in tabular and graphical form, and a brief description is given of collection and preparation methods. The nutrient fluxes recorded for 1983 and 1984 are typical for oligo-mesotrophic, phosphorus-limited, temperate lakes, and the water movements recorded indicate that advection in Lake Michigan, on a lake-wide scale, is small.

1. INTRODUCTION

In 1983 and 1984 nutrient, chlorophyll, plankton, temperature, and water movement dynamics were determined both vertically and seasonally in the vicinity of a station on the 100-m depth contour approximately 26 km west of Grand Haven in southern Lake Michigan. These measurements were made in conjunction with an extensive ecosystem study conducted in 1983 and 1984 in southern Lake Michigan by the Great Lakes Environmental Research Laboratories, National Oceanic and Atmospheric Administration. This report presents chemical, physical, and biological parameters measured during the study in tabular and graphical form along with a brief description of the methods used in collection and preparation. These properties are useful when evaluating the seasonal dynamics of phytoplankton and zooplankton species composition and vertical structure, primary production, phytoplankton and particulate organic carbon sedimentation, zooplankton grazing, bacteria production and dynamics as described elsewhere (Scavia and Fahnenstiel, 1987; Fahnenstiel and Scavia, 1987a,b,c; Scavia et al., 1986; Laird et al., 1986; Gardner et al., 1986; Scavia and Laird, 1987; Laird et al., 1987; Fahnenstiel et al., 1984).

2. METHODS

2.1 Water Movement and Sampling Locations

Lakewater samples were collected aboard the R/V Shenehon between May and August of 1983 and 1984 from various depths in 5-L opaque Niskin bottles. Exact sampling locations were determined following a Lagrangian scheme in which parcels of water were tracked with a satellite-monitored drogue system deployed in the vicinity of a station on the 100-m depth contour, 26 km west

[1]GLERL Contribution No. 554

of Grand Haven, Michigan (43°1 X 86°37). These windowshade drogues (Scavia and Fahnenstiel, 1987) were 1 m wide and of variable length, set to the depth of the mixing layer (typically 10 m). In 1984, to minimize the effects of wave action on the drogue system, the top of the drogue was attached to a slender (~15-cm-diameter) spar buoy that was tethered to the drifter buoy. In this way, the spar buoy/drogue system was subjected to less wave-induced surge. The drifter buoy was tracked via the Argos satellite system (Pickett et al., 1983), and drifter location and hull temperature were captured, at best, every 4 hours, but usually every 8-12 hours. Net water movement velocities were determined from the distance between the beginning and end of drifter deployment divided by time of deployment. The drogue was released four times in 1983 (once each month) and seven times in 1984. Water velocity movement was also measured by current meters deployed in the surface water during 1984 (G.S. Miller, GLERL/NOAA, unpublished data).

2.2 Temperature

Temperature was measured with an electronic bathythermograph on board the R/V Shenehon; a thermistor mounted in the hull of a drifter buoy (Mini-TOD, Polar Research Laboratory, Inc.); thermistor chains (Saylor and Miller, 1983) moored in this region; and NOAA data buoy NDBC 45007 located 50 km from our site in 152 m of water.

2.3 Phosphorus

Determination of total phosphorus was based on the AutoAnalyzer method (Technicon Instruments Corp., 1976) after a wet oxidation digestion (Menzel and Corwin, 1965). Dissolved phosphorus was determined as above but on water passing a 0.2-μm-pore-size, 47-mm-diameter Nuclepore filter presoaked in distilled deionized water. Soluble reactive phosphorus was determined with automated procedure No. 155-71W (Technicon Instruments Corp., 1973; Malczyk and Eadie, 1980) on water passing the 0.22-μm filter. Particulate phosphorus was determined as the difference between total and total dissolved phosphorus.

2.4 Silica

Determination of particulate (biogenic) silica was done on materials collected on 47-mm, 0.4-μm Nuclepore filters following the wet alkaline extraction procedure of Krausse et al. (1983). Soluble reactive silica was determined with the automated procedure No. 105-71w/tentative (Technicon Instruments Corp., 1972a) on water passing a 0.2-μm Nuclepore filter. Total silica was determined by adding particulate and soluble reactive silica.

2.5 Chlorophyll

Chlorophyll <u>a</u> was determined on material collected on 47-mm glass fiber filters (Whatman GF/F). The filters were ground and extracted in 90% acetone prior to fluorometric assay (Strickland and Parsons, 1972).

2.6 Nitrate

Nitrate was measured by copper-cadmium reduction following automated procedure No. 158-71w (Technicon Instrument Corp., 1972b; Malczyk and Eadie, 1980).

2.7 Ammonium

Ammonium was determined by microfluorometric methods based on Ophthaladahyde derivation (Gardner, 1978; Gardner and Miller, 1981).

2.8 Short-Term Variability

To explore short-term (daily) variability, we sampled twice, 4 days apart at drogue locations, on each monthly cruise in 1983.

2.9 Bacteria

Samples for bacterial counts were preserved with glutaraldehyde (2% final concentration) in autoclaved 25-mL vials; abundance was determined by the acridine orange direct count method (Hobbie et al., 1977).

2.10 Phytoplankton

Phytoplankton samples were preserved with acid Lugol's solution, then filtered or settled onto slides (Fahnenstiel and Scavia, 1987a). Conversion of phytoplankton taxon counts to carbon concentration was based on measurements of shapes and sizes and on carbon contents of Strathman (1966).

2.11 Zooplankton

Zooplankton were collected with vertical hauls of a O.&m-aperture, 153-μm-mesh plankton net. Animals were preserved in sugar-formalin (Haney and Hall, 1973) after narcotizing with club soda. Zooplankton dry weight was determined by converting abundance estimates with taxon-specific dry weights either from published values for Lake Michigan (Hawkins and Evans, 1979) or from original weight measurements on the 1983 and 1984 samples.

3. RESULTS

3.1 Water Movement

The most persistent features of our drogue tracks were inertial-period circles (17-h period, 2.8-km average diameter) and longer-term direction reversals (Figs. 1a,b), like the "meandering flow" described for similar drogues in offshore autumn

Lake Michigan water (Pickett et al., 1983). The net direction of drogue movement in our experiments varied throughout the summer, as well as during each deployment (Table 1). Drogue net speeds for each deployment ranged between 0.2 and 5.3 km day“ (Table 1) between May and September 1983 and 1984 (mean ± S.E. = 2.4 • 1.5 km day^{-1}). Our measurements of water-mass movements indicate that in offshore waters during summer, advective transport is minimal on a lake-wide scale.

3.2 Temperature

The lake warmed earlier in 1983 than in 1984 (Fig. 2a). It appears that although lake warming was approximately 20 days sooner in 1983, maximum surface temperature (-23” C) and thermocline depths were similar. The thermocline deepened to about 18-20 m by August of both years (Figs. 2b,c).

3.3 Phosphorus

In both years, total phosphorus (TP) concentrations were uniform vertically until the onset of stratification. In 1983, TP was already relatively high by May, and remained constant until stratification (Fig. 3a); in 1984, the vertically uniform TP concentrations increased until the lake stratified. The difference between the two years may reflect the differences in heating characteristics (Fig. 2a).

Table 1.--Drifter and current meter movement for 1983 and 1984

	Drifter 1983	Drifter 1984	Current meter 1984
May			
Net speed (km day^{-1})	2.3	-	-
Spread rate (km^2 day^{-1})	6.3	-	-
Time (days)	4		
Direction (°)	297		
June			
Net speed (km day^{-1})	1.8	0.2	1.1±0.6
Spread rate (km^2 day^{-1})	7.1	4	-
Time (days)	4	14	16
Direction (°)	127	38	-
July			
Net speed (km day^{-1})	1.7	0.8, 1.6*	1.3±0.9
Spread rate (km^2 day^{-1})	11.1	6.8, 7.5	-
Time (days)	4	3, 2	5
Direction (°)	82	90, 7	-
August			
Net speed (km day^{-1})	2.6	5.3, 3.8	3.7±1.5, 2.3±2.2
Spread rate (km^2 day^{-1})	8.9	12.2, 36.3	
Time (days)	4	1, 5	5, 5
Direction (°)	215	60, 237	-
September			
Net speed (km day-‘)	3.8	-	-
Spread rate (km^2 day^{-1})	35.7	-	-
Time (days)	6	-	-
Direction (°)	86		

* Drifter movement estimated twice during particular month.

During the period of stratification, TP remained high below the thermocline and decreased within the epilimnion. Epilimnetic concentrations after stratification were somewhat higher in 1984 compared with 1983 (Fig. 3c).

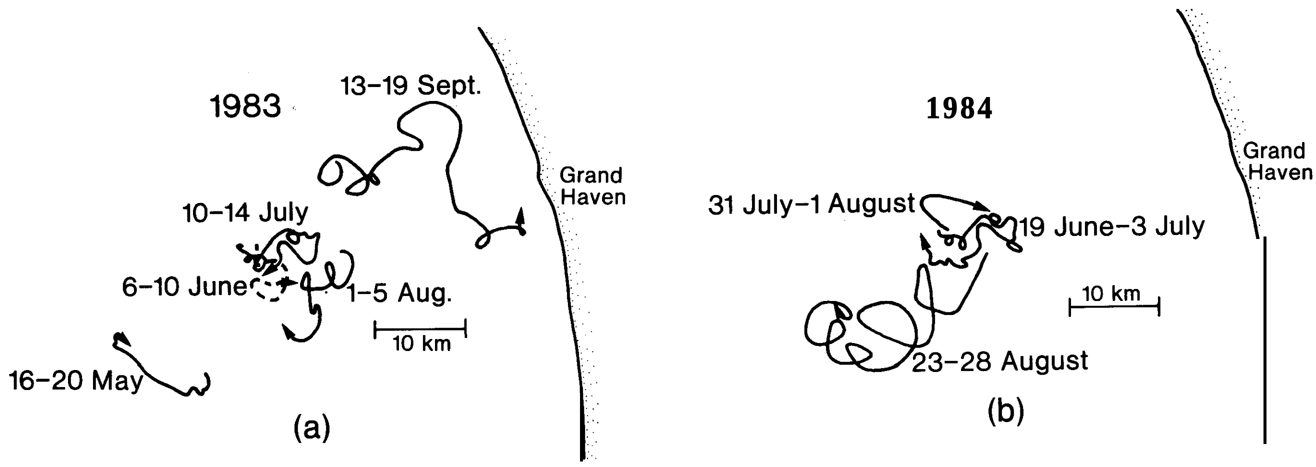


Figure 1.--a) 1983 and b) 1984 drogue tracks recorded in the vicinity of 26 km west of Grand Haven, Michigan.

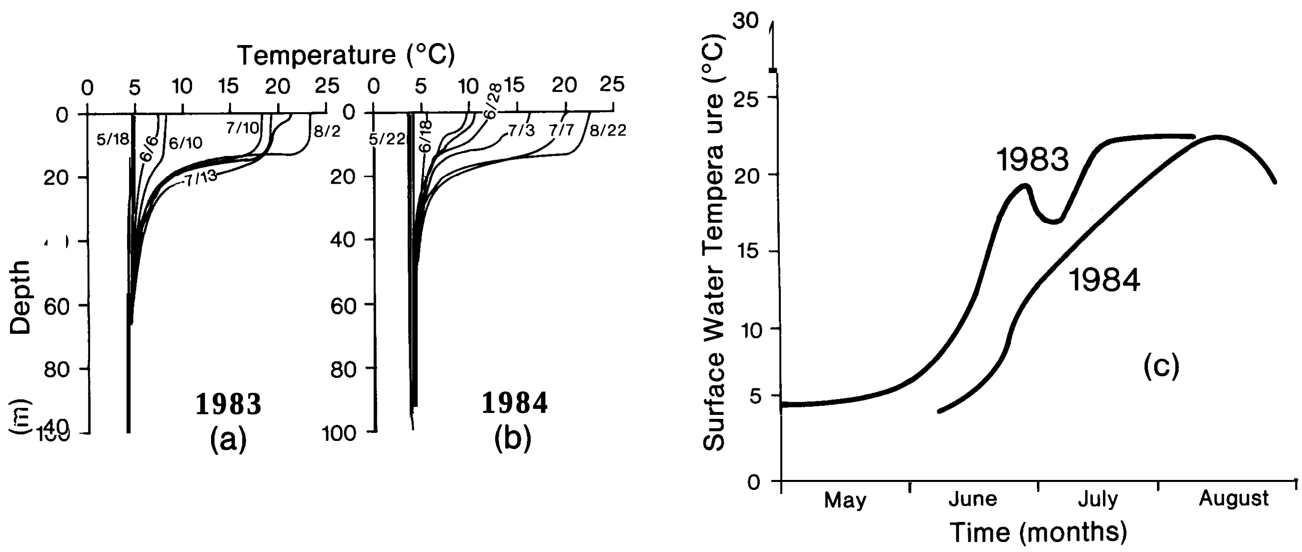


Figure 2.--a) Surface temperature for 1983 and 1984, b) plot of temperature versus depth in 1983 and c) plot of temperature versus depth in 1984.

3.4 Silica

Soluble silica concentrations were similar in both years (Figs. 4a,b). Concentrations in the surface waters decreased between 16 May and 10 July 1983 at a rate of 0.21 • 0.014 µmol day^{-1} (R^2 = 0.98, $p \leq 0.0001$) and between 22 May and 6 July 1984 at 0.25 • 0.013 µmol^{-1} day (R^2 = 0.96, $p < 0.001$). Concentrations in deeper water decreased prior to the onset of stratification and then remained fairly constant through the remainder of the season. Overall, throughout the water column, soluble silica concentration decreased to lower values in 1984 compared with 1983. Particulate silica concentrations were measured only in 1984. Epilimnetic concentration was highest on 22 May (8.0 µmol) and decreased steadily at a rate of 0.100 • 0.016 µmol day-' (R^2 = 0.95, $p < 0.03$) to 0.36 µmol on 21 August. Biogenic silica concentrations in the region below the thermocline (20-30 m) first increased and then decreased as summer progressed (Figs. 5a,b).

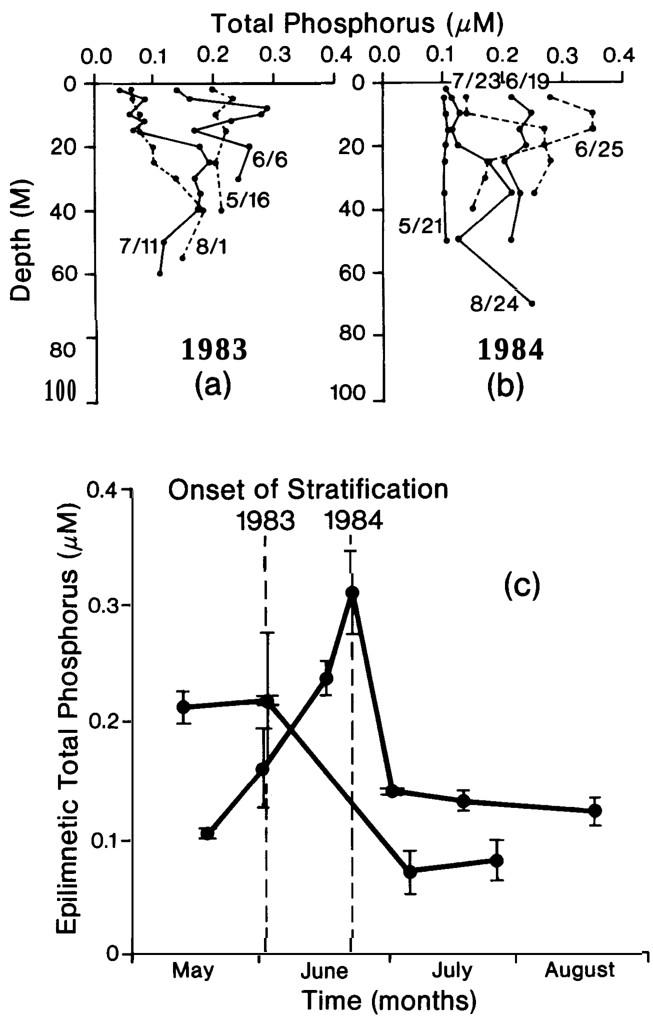


Figure 3.--a) Plot of total phosphorus concentration versus depth in 1983 and b) 1984 c) plot of epilimnetic total phosphorus versus time in 1983 and 1984. Dotted lines indicate time of stratification.

3.5 Chlorophyll

Chlorophyll a concentrations were uniform with depth until the onset of stratification in both years. During stratification epilimnetic concentrations steadily decreased; midsummer epilimnetic concentrations reached somewhat lower values in 1983 (0.5 $\mu g\,L^{-1}$) compared with 1984 (1.0 $\mu g\,L^{-1}$). In each year, chlorophyll concentrations remained high below the thermocline, creating the deep chlorophyll layer (DCL) whose dynamics and controls are detailed by Fahnenstiel and Scavia (1987b,c). Generally, after the lake stratified, the DCL deepened and broadened from a layer in the region 15 to 30 m to one in the region 15 to 50 m (Figs. 6a,b).

3.6 Nitrate

Nitrate (measured in 1983 only) concentrations varied both seasonally and vertically. Prior to the period of stratification, concentrations were uniform with depth. Concentrations (Fig. 7) decreased in the epilimnion between 6 June and 10 July. In July and August, nitrate concentrations remained low in the epilimnion, increased with depth through the region of the DCL, and increased slowly with time in the deeper hypolimnion.

3.7 Ammonium

Ammonium (measured in 1983 only) concentrations varied both seasonally and vertically. Prior to the period of stratification, concentrations were uniform with depth. Ammonium concentrations (Fig. 8) decreased in the epilimnion and DCL regions between 16 May and 6 June, increased in the epilimnion and decreased in the DCL between 6 June and 10 July, and then increased in the upper portion of the DCL between 10 July and 1 August.

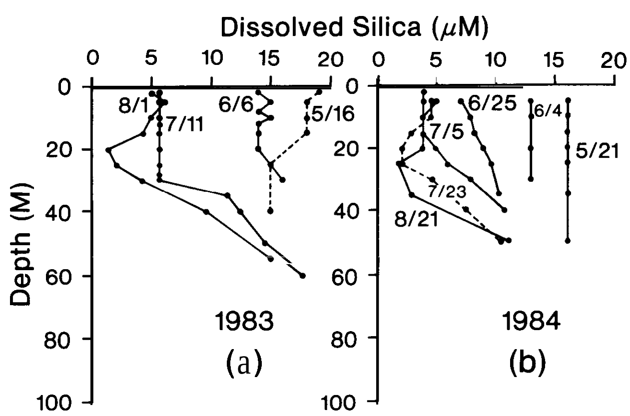


Figure 4 .--a) Plot of dissolved silica concentration versus depth in 1983 and b) plot of dissolved silica concentration versus depth in 1984.

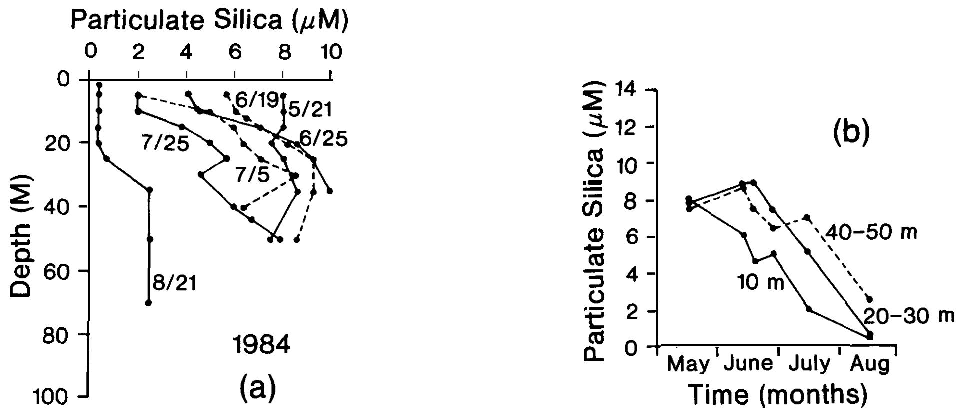


Figure 5.--a) Plot of particulate silica versus depth in 1984 and b) plot of particulate silica versus time at 10 m, 30-35 m, and 40-50 m depths.

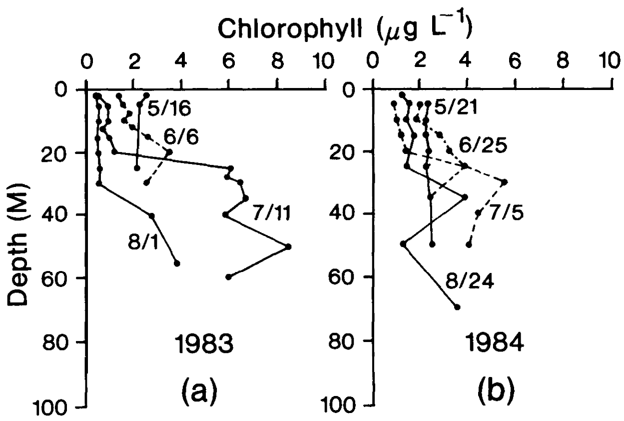


Figure 6.--a) Plot of chlorophyll concentration versus depth in 1983 and b) plot of chlorophyll concentration versus depth in 1984.

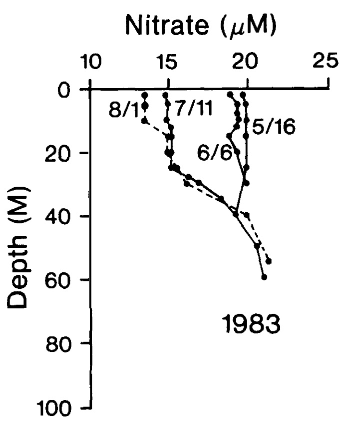


Figure 7.--Plot of nitrate concentration depth in 1983.

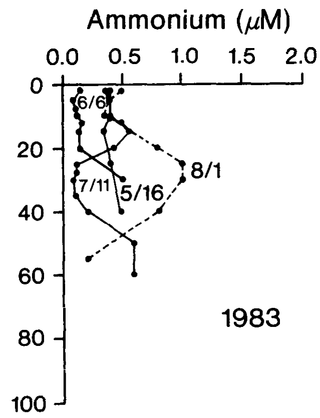


Figure 8.--Plot of ammonium concentration versus depth in 1984.

3.8 Short-Term Variability

In 1983 short-term variability was determined on the vertical profiles of most of the above parameters. Theoretically, changes in concentrations observed over this time frame should be due to biological and chemical alterations and not to water movements. During. the 4-day May cruise, temperatures remained uniform vertically and temporally, and no significant changes were detected in any other observed properties (Fig. 9a). In June, soluble silica concentrations decreased uniformly throughout the region sampled (O-30 m) and increased below the thermocline (Fig. 9b). Both of these changes were consistent with overall seasonal dynamics described above. In July there were no notable changes during the 4-day cruises (Fig. 9c). In August NH, increased in the 25-35 m region (Fig. 9d), which was consistent with overall seasonal dynamics described above (Fig. 9d).

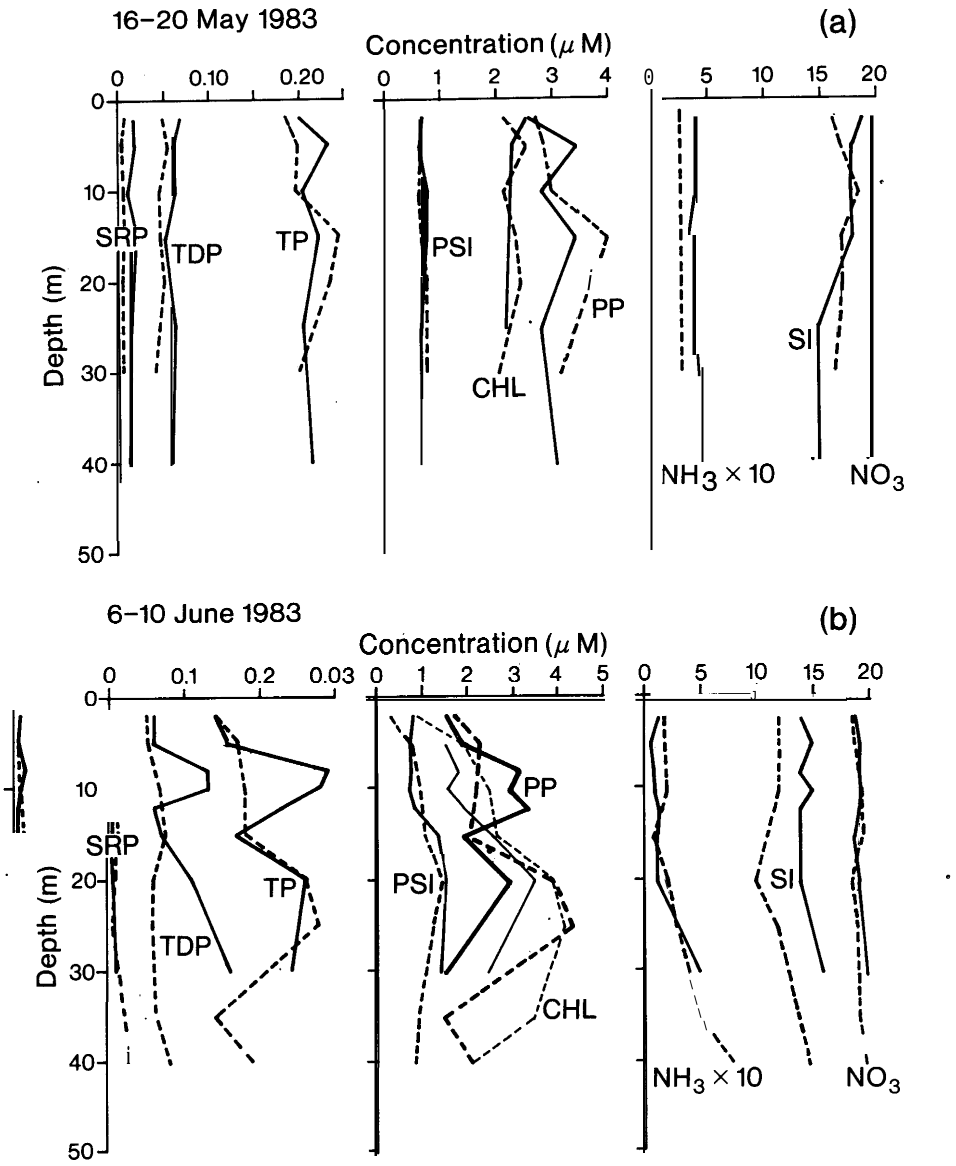
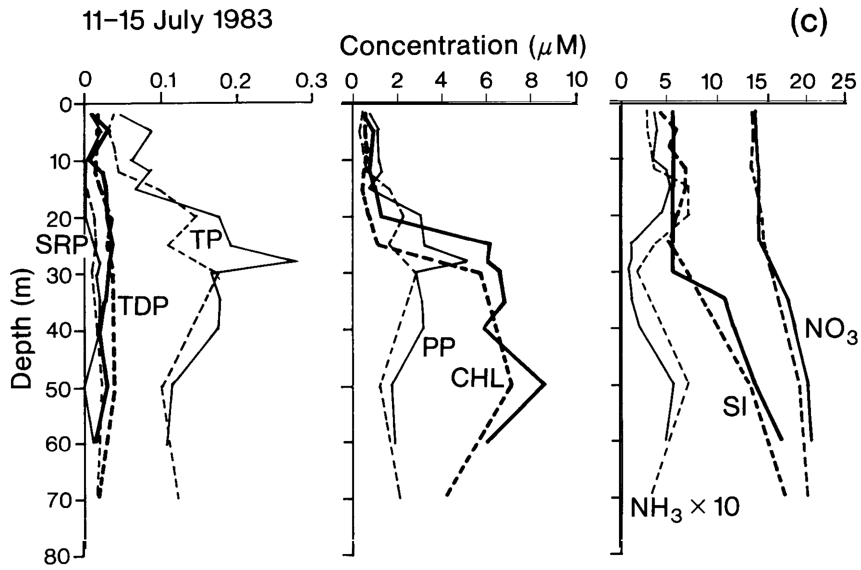


Figure 9.--a,b) Depth profiles of nutrient and chlorophyll parameters at beginning and end of May and June 1983. Solid line represents the beginning and. dotted lines represents the end.



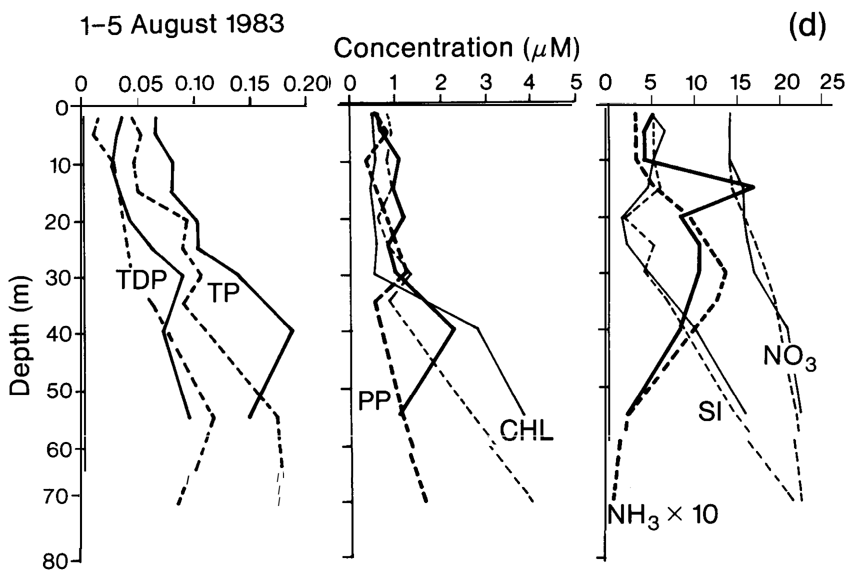


Figure 9.--c,d) Depth profiles of nutrient and chlorophyll parameters at the beginning and end of July and August 1983. Solid lines represent the beginning and dotted lines represent the end.

3.9 Bacteria

Bacteria abundances in surface waters, measured only in 1984, were in the range (0.67-1.02) X 10^6 cell mL^{-1} and were highest in June 1984 (Table 2).

3.10 Phytoplankton

Epilimnetic algal carbon concentrations were measured in both 1983 and 1984 and followed similar patterns. Diatoms dominated the phytoplankton assemblage in the spring, decreasing substantially by mid-July of both years (Table 2).

3.11 Zooplankton

Zooplankton dry weight was determined for several depth ranges and during day and night in 1984. In spring copepods dominated (Scavia and Fahnenstiel, 1987); in midsummer *Daphnia pulicaria* dominated, e.g. 70% by weight on 23 July, (Table 3).

Table 2. -- Seasonal bacteria and phytoplankton concentration for 1983 and 1984

	Bacteria concentration (cell mL^{-1})	Algal concentration (μg-C L^{-1})	
Day	bacteria X 10^6	Diatoms	Non-Diatoms
1983			
136	-	43.2	7.5
140		35.0	9.1
157		19.8	22.0
161		18.5	19.3
192		1.0	33.6
196	-	0.10	22.0
213	-	0.10	19.1
217		0.10	30.0
1984			
142	0.73	35.4	19.4
156	0.67	41.8	15.6
171	0.79	34.0	35.0
177	0.96		
187	1.02	17.8	36.5
205	0.74	6.9	17.2
237	0.68	3.2	13.0
319	0.80		

Table 3. -- Zooplankton concentration for 1984 (μg L^{-1})

Depth range / Day	157	171	177	179	185	187	206	212	215	229	235
0-40	8.00	8.62	42.2	61.6		35.5	35.6		99.8	89.7	65.8
0-40, night					50.0						
5-15			45.45								
0-10					38.0	44.9					1.7
0-10, night											
15-30						17.6					
15-30, night					12.8						
0-12							57.3				
25-40							26.3				
0-8								39.0			
21-30											229.6

4. DISCUSSION AND CONCLUSIONS

The seasonal progression of nutrient concentrations, observed during the 1983 and 1984 field experiments, is typical of oligo-mesotrophic, phosphorus-limited, temperate lakes. Soluble reactive phosphorus was at or below the limit of detection during most of the year and at most depths. Nitrate and soluble reactive silica concentrations were highest early in the year, and epilimnion values decreased dramatically after the onset of stratification. These temporal dynamics, as well as those of total phosphorus, are consistent between the two years when viewed relative to the timing of thermal stratification rather than to calendar date. Nitrate and soluble silica depletion was not confined. to the epilimnion, but rather extended through the metalimnion into the region of the deep. chlorophyll layer (DCL). Later in summer, when the DCL broadened and deepened, the zone of nutrient depletion extended only into the upper portion of the DCL. This is consistent with observations of active algal growth in the upper portions and severe light-limitation in the lower portions of the DCL (Fahnenstiel and Scavia, 1987b,c).

Only small concentration changes in the quantities measured were observed during each of the 4-day experiments in 1983. This indicates that day-to-day nutrient variability is on a small scale.

Relatively low velocities of surface water movement were determined by both our drogue data and the 1984 current meter data, indicating that advective transport is minimal, on a lake-wide scale, in the surface waters of southern Lake Michigan.

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Appendix A: Nutrient and Chlorophyll Data From 1983

1983 Seasonal Total Phosphorus Concentrations (μmol)

Depth (m)\ Day	136	140	157	161	191	195	213	217
2	0.200	0.186	0.140	0.140	0.045	0.038	0.064	0.043
5	0.233	0.200	0.166	0.170	0.087	0.027	0.064	0.051
8			0.290			0.038		
10	0.204	0.196	0.280	0.180	0.061		0.079	0.045
12			0.230		0.086	0.043		
15	0.222	0.245	0.168	0.180	0.067	0.096	0.078	0.048
20		0.235	0.260	0.258	0.178	0.148	0.100	0.092
25	0.204			0.277	0.193	0.110	0.102	0.088
28					0.282			
30		0.200	0.240		0.169	0.177	0.138	0.105
35				0.140	0.179			0.088
40	0.213			0.190	0.750		0.185	
50					0.117	0.103		
55							0.147	0.172
60					0.110			
70								0.177

1983 Seasonal **Total Dissolved Phosphorus Concentrations (μmol)**

Depth (m) \ Day	136	140	157	161	191	195	213	217
2	0.068	0.049	0.060	0.050	0.005	0.013	0.034	0.014
5	0.061	0.055	0.060	0.053	0.030	0.015	0.030	0.009
8			0.130			0.013		
10	0.062	0.045	0.130	0.067	0.004	0.025		0.027
12			0.060	0.022		0.012		
15	0.051	0.045	0.070	0.076	0.028	0.019	0.032	
20		0.050	0.110	0.058	0.028	0.034	0.041	
25	0.063			0.057	0.036	0.030	0.061	
28					0.031			
30		0.041	0.160		0.031	0.036	0.088	0.043
35				0.062	0.025			0.061
40	0.058			0.080	0.019		0.070	
50					0.031	0.041		
55							0.093	0.115
60					0.015			
70						0.019		0.088

1983 Seasonal Dissolved . Silica Concentration (μmol)

Depth (m) \ Day	136	140	157	161	191	195	213	217
2	19.0	16.4	14.0	12.0	5.7	4.3	5.0	5.0
5	18.0	17.1	15.0	12.0	5.7	6.1	6.1	5.0
8							5.4	
10	18.0	18.5	14.0	12.0	5.7		5.0	5.0
12			15.0		5.7	7.1		
15	18.0	17.1	14.0	11.0	5.7	7.1	4.3	5.7
20		17.1	14.0	10.0	5.7	6.1	1.4	1.8
25	15.0		14.0	12.0	5.7	5.4	2.1	5.0
28					5.7			
30		16.4	16.0		5.7	7.1	4.3	3.9
35				14.0	11.4			6.4
40	15.0			15.0		12.5	9.6	
50					14.6	14.3		
55							15.0	13.9
60					17.9			
70						18.2		21.1

1983 Seasonal **Particulate . Silica Concentrations (μmol)** . . .

Depth (m) \ Day	136	140	157	161	191	195	213	217
2	0.680	0.670	0.860	0.370				
5	0.620	0.640	0.790	0.830				
8			0.820					
10	0.760	0.630	0.780	1.010				
12			0.900					
15	0.740	0.660	1.400	1.120				
20		0.740	1.590	1.490				
25	0.650			1.320				
28								
30		0.740	1.470					
35				0.980				
40	0.640							
50								
55								
60								
70								

1983 Seasonal Nitrate Concentrations (µmol)

Depth (m) \ Day	136	140	157	161	191	195	213	217
2	19.70	19.80	18.90	18.70	14.80	14.50	13.05	13.50
5	19.90	19.80	19.30	18.90	15.00	14.60	13.50	13.40
8			19.30			14.50		
10	19.90	19.80	19.40	19.50	14.90		13.50	13.40
12			19.30		15.20	14.30		
15	19.90	19.80	18.80	19.50	15.20	15.00	15.00	13.50
20		19.80	19.30	18.60	15.20	15.30	14.90	15.00
25	19.90			19.10	15.20	15.50	15.50	16.30
28					16.20			
30		19.80	19.90		16.90	16.50	16.10	17.40
35				19.30	18.30			18.40
40	19.30			19.90	19.20		19.90	
50					20.60	19.70		
55							21.30	20.80
60					21.00			
70						20.60		21.90

1983 Seasonal Ammonium . Concentrations . (μmol)

Depth (m) \ Day	136	140	157	161	191	195	213	217
2	0.40	0.26	0.14	0.20	0.36	0.28	0.50	0.30
5	0.40	0.26	0.08	0.21	0.39.	0.28	0.40	0.30
8			0.11			0.32		
10	0.40	0.26	0.12	0.23	0.35		0.40	0.30
12			0.16		0.49	0.37		
15	0.34	0.26	0.13	0.11	0.56	0.75		0.50
20		0.26	0.14	0.23	0.43	0.73	0.80	0.90
25	0.40			0.31	0.11	0.37	1.00	1.10
28					0.11			
30		0.26	0.50		0.08	0.17	1.00	1.30
35			0.52	0.11				1.20
40	0.48			0.81	0.21		0.80	
50					0.59	0.75		
55							0.20	0.20
60					0.49			
70						0.33		0.10

1983 Seasonal Soluble **Reactive Phosphorus Concentrations (μmol)**

Depth **(m)** \ **Day**	136	140	157	161	191	195	213	217
2	0.017	0.006	0.009	0.009	0.020	0.016		
5	0.018	0.005	0.007	0.005	0.019	0.016		
8			0.016			0.010		
10	0.010	0.005	0.010	0.007	0.000			
12			0.006		0.000	0.000		
15	0.020	0.006	0.006	0.013	0.000	0.000		
20		0.004	0.008	0.010	0.000	0.013		
25	0.014			0.007	0.010	0.016		
28					0.019			
30		0.005	0.012		0.013	0.010		
35					0.019			
40	0.011			0.031	0.019			
50					0.000	0.023		
55								
60					0.010	0.016		
70								

1983 Seasonal Chlorophyll Concentrations ($\mu g\ l^{-1}$)

Depth (m) \ Day	136	140	157	161	191	195	213	217
2	2.55	2.13	1.42	0.93	0.43	0.54	0.50	0.84
5	2.27	2.53	1.58	1.94	0.93	0.54	0.53	0.93
8			1.85			0.59		
10		2.13	1.63	2.54			0.55	0.81
12			1.97		0.71	0.60		
15		2.32	2.62	2.70		0.48	0.45	0.93
20		2.42	3.55	3.91	1.25	0.74	0.53	0.61
25	2.16			4.21	6.09	1.13	0.59	0.84
28					5.98			
30		2.03	2.54		6.52	5.62	0.52	1.34
35				3.56	6.73			0.87
40				2.12	5.84			
50					8.49	7.08	2.80	2.71
55							3.86	
60					5.98	4.14		4.16
70								

Appendix B: Nutrient and Chlorophyll Data From 1984

1984 Seasonal Total Phosphorus Concentrations (µmol)

Depth (m) \ Day	142	156	171	177	187	205	237
2							0.106
5	0.103	0.126	0.216	0.280	0.139	0.132	0.116
8							
10	0.106	0.187	0.248	0.350	0.142	0.216	0.129
12							
15	0.110		0.229	0.345	0.268	0.135	0.116
20	0.106	0.190	0.239	0.265	0.271	0.350	0.126
25	0.103		0.203	0.277	0.184	0.270	0.174
28							
30		0.135			0.174	0.310	
35	0.103		0.229	0.252			0.216
40					0.148	0.200	
50	0.106		0.213			0.190	0.126
55							
60							
70							

1984 Seasonal Total Dissolved Phosphorus Concentrations (μmol)

Depth (m) \ Day	142	156	171	177	187	205	237
2							0.135
5	0.019	0.029		0.139	0.045	0.090	0.138
8							
10	0.029	0.042		0.097	0.039	0.090	0.077
12							
15	0.042			0.181	0.039	0.120	0.065
20	0.023	0.029		0.045	0.048	0.080	0.074
25	0.026			0.106	0.052	0.130	0.097
28							
30		0.052			0.061	0.070	
35	0.022			0.087			0.071
40					0.032	0.080	
50	0.045					0.100	0.087
55							
60							
70							0.065

1984 Seasonal **Dissolved. Silica.. Concentrations. (µmol)**

Depth (m) \ Day 142		156	171	177	187	205	237
2							3.9
5	16.0	13.0		7.1	5.0	4.6	3.9
8							
10	16.0	13.0		7.9	3.9	4.6	3.9
12							
15	16.0			8.2	3.9	2.9	3.9
20	16.0	13.0		8.9	5.0	2.1	3.9
25	16.0			9.6	6.0	2.1	1.8
28							
30		13.0			7.9	4.6	
35	16.0			10.3			2.9
40					10.7	7.5	
50	16.0					10.4	1.11
55							
60							
70							2.10

1984 **Seasonal Particulate Silica Concentrations (μmol)**

Depth (m) \ Day	142	156	171	177	187	205	237
2							
5	8.0		9.0	3.9			
8							
10	8.0		9.0	4.6			
12							
15	8.0		9.0	7.1			
20	7.5		9.0	8.6			
25	8.0		9.0	9.3			
28							
30							
35	8.6		10.0	10.0			
40							
50	7.5		11.0				
55							
60							
70							

1984 Seasonal **Chlorophyll Concentrations (μg L^{-1})**

Depth (m) \ Day	142	156	171	177	187	205	237
2							1.25
5	2.37	2.19	2.26	2.02	0.94	4.43	1.57
8							
10	2.27	2.60	2.88	1.87	1.16,	1.43	1.45
12							
15	2.28	2.28	3.13	2.84	2.27	5.53	1.77
20	2.38	2.53	2.96	3.25	2.62	4.05	1.56
25	2.27	2.27	3.17	2.93	3.21	3.97	1.45
28							
30		2.91			3.21	1.23	
35	2.44	2.44	2.68	2.39			3.93
40					2.30	0.90	
50	2.49	2.49	1.66			1.06	1.23
55							
60							
70							3.59