LAKE LACAWAC

REPORT ON LIMNOLOGICAL CONDITIONS IN 1993

Robert E. Moeller
Craig E. Williamson

POCONO COMPARATIVE LAKES PROGRAM

Lehigh University

Department of Earth and Environmental Sciences
31 Williams Drive
Lehigh University
Bethlehem, Pennsylvania 18015

10 August 1994

Moeller, R. E. and C. E. Williamson. 1994. Lake Lacawac: Report on Limnological Conditions in 1993. Unpublished Report to the Lacawac Sanctuary. Department of Earth and Environmental Sciences, Lehigh University, 10 August 1994.

INTRODUCTION

Personnel from Lehigh University visited Lake Lacawac on 13 dates throughout 1993 as part of a routine monitoring program of three lakes. These lakes were selected to span a trophic gradient, Lake Lacawac occupying the intermediate ("mesotrophic") position in the gradient. Similar reports will be submitted to the owners of Lake Giles, an acidic, unproductive ("oligotrophic") lake, and Lake Waynewood, a nutrient-rich, productive ("eutrophic") lake. Because Lake Lacawac has been little disturbed throughout its recent history, and is currently preserved as part of The Lacawac Sanctuary, it serves as a valuable reference lake for the region.

The monitoring of these lakes in the Pocono region of northeastern Pennsylvania is a key component of Lehigh's Pocono Comparative Lakes Program (PCLP). This program aims to better understand the natural functioning of lakes, differences in lakes that arise through natural or man-made differences in their watersheds, and long-term trends that may be occurring in northeastern Pennsylvania. Through the cooperation of lake owners, scientists from Lehigh and other institutions are obtaining basic information that provides objective documentation of current lake conditions as well as a context for more intensive studies. Financial support from the Andrew W. Mellon Foundation has made these studies possible.

1993 was the sixth consecutive year of the monitoring program. The spring sampling in May completed the fourth full year of monthly sampling. With pending exhaustion of the Mellon grant, we initiated some changes beginning with the summer 1993 sampling (the sixth consecutive summer) to reduce sampling costs and to acquire additional data more closely tailored to continuing research efforts of the Lehigh investigators. These changes will be listed below, and in the **METHODS** section. They include reducing the non-summer sampling frequency (Lacawac was sampled only twice after the end of August). The present report summarizes conditions in Lake Lacawac over the full twelve-month period for 1993.

The format closely follows that of the previous four years. Physical/chemical data are presented as tables for each date, and are summarized in figures. The following parameters were measured: **TEMPERATURE, LIGHT PENETRATION, SECCHI DEPTH, DISSOLVED OXYGEN, ALKALINITY, pH,** and algal **CHLOROPHYLL-a. ZOOPLANKTON DATA** are presented as graphs that give the concentration (number of individuals per liter) averaged over the entire water column. This report also includes a test of the sampling effectiveness of the 202-μm and 48-μm mesh plankton nets for the major large zooplankton. The nets are compared side-by-side to collections with a Schindler trap **(APPENDIX III)**.

Samples of the algal **PHYTOPLANKTON** have been routinely collected but not usually analyzed. We did, however, prepare seasonal composite samples for three years (summer 1989 through spring 1992). These twelve samples have now been counted for us by algal specialists at PhycoTech (Baroda, MI). The results are tabulated in **APPENDIX II.**

Also included with the 1993 report is a table of chemical data from 1991-92 **(APPENDIX I)**. Giles was sampled at 5-6 depths on 6 dates (in April, July, September, and November 1991, plus February and April 1992). Values were obtained for **major cations (Ca, Mg, Na, K)** and for **chloride (Cl)** -- results for sulfate are not yet available. Nutrient analyses included (on most dates): **soluble reactive phosphorus (SRP), total dissolved plus particulate phosphorus (TP), ammonium (NH_4), nitrate (NO_3)**, and (on 3 dates only) **particulate carbon and nitrogen**. These analyses were supervised by Dr. Nina Caraco and Dr. Jonathan Cole at the Institute of Ecosystem Studies in Millbrook, NY. Dr. Robert Moeller also analyzed **total dissolved inorganic carbon (DIC)** and **pH** from each sample. Analyses from the second year of sampling (April 1992 through February 1993) have been suspended because of lack of funding, but the samples will be stored in case new support becomes available. Methods for the 1989 and 1991-92 analyses are summarized in **APPENDIX I.**

Changes effective in June 1993 included deleting the nighttime zooplankton sampling, adding a suite of chemical analyses of the regular water bottle collections from three depths, and changing the analytical procedure for chlorophyll analysis. The chemical analyses include **dissolved organic carbon (DOC)** as well as nutrients: **soluble reactive phosphorus (SRP), total dissolved phosphorus (TDP), total particulate phosphorus (TPP), ammonium** (NH_4) and **nitrate** (NO_3). Also, **total particulate matter** was measured as dry mass of seston per liter of water filtered. These analyses were performed at Lehigh under the supervision of Dr. Donald Morris.

A new research focus for investigators at Lehigh is the role of ultraviolet radiation in lakes. Lehigh has purchased instruments that measure ultraviolet radiation in addition to the visible wavelengths of solar radiation that we have monitored during the routine sampling. An example of the penetration of ultraviolet radiation is plotted in the **LIGHT** section of the report. In September 1993, Lehigh sponsored a workshop at the Lacawac Sanctuary to bring together investigators interested in comparing ideas, findings, and analytical methodologies regarding the role of potentially harmful levels of ultraviolet radiation in lakes. Part of the workshop involved an assessment of several different UV-measuring instruments, and was carried out on Lake Giles. Several of the scientific reports being prepared for publication as a result of the Lacawac workshop will contain information on Lake Lacawac, and will be cited in next year's report.

UV monitoring capability has been added to the meteorological station that Lehigh established at the Lacawac Sanctuary. With the assistance and cooperation of the Sanctuary, the meteorological station was set up on a raft in the middle of Lake Lacawac through the summer and autumn. Data from the station were routinely downloaded to an electronic database at Lehigh, where they will be accessible to researchers. Dr. Bruce Hargreaves has been directing this project.

The Lacawac Sanctuary continues to play a major role in this program as field laboratory and summer residence for the investigators. We especially appreciate the cheerful assistance of its Director, Sally Jones, and the long-term interest and encouragement of Arthur Watres and Clyde Goulden.

1993 METHODS AND RESULTS

Data included in this report are extracted from an electronic database maintained at Lehigh University by Dr. Craig Williamson. The field sampling, laboratory analyses, and computer data entry were supervised by Gina Brockway, in collaboration with Dr. Robert Moeller, Dr. Donald Morris, and Dr. Bruce Hargreaves. Gina Brockway and Timothy Vail carried out most of the field sampling and laboratory analyses. Gina and Tim determined alkalinity and pH, and along with Yin Zhong analyzed chlorophyll samples. Gina analyzed most of the nutrient samples. Macrozooplankton were counted by Paul Stutzman (Jan.--May), Natasha Vinogradova (June--Aug.), and Gina Brockway (Sept.--Nov.).

Microzooplankton were counted by Natasha Vinogradova (Jan.--July) and Gina Brockway (Aug.--Nov.). Gina managed all aspects of the computer database including data entry, data analysis, and printing of zooplankton graphs. Dr. Bruce Hargreaves has continued to oversee maintenance of the computerized database, which he and Scott Carpenter developed. Gina entered the physical/chemical data, which Robert Moeller checked and abstracted as tables and graphs.

Although efforts have been made to assure the accuracy of data included in the database, and compiled in this report, we cannot guarantee complete accuracy and do not claim specific levels of accuracy or precision. The data have been collected as part of a lake characterization program and may not be suitable for uses not envisioned by the investigators. A brief description of sampling and analytical techniques is included here. A more complete description was distributed in 1993:

Moeller, R.E., C.E. Williamson, J. A. Aufderheide and E. M. Novak. 1993. Sampling Protocols (1988-1993) of the Pocono Comparative Lakes Program. Unpublished Report, Lehigh University. (Available on loan through the Lehigh University Library System as part of the 1992 Annual Reports to lake owners.)

Information acquired through the Pocono Comparative Lakes Program is to be shared among scientists desiring to make broad comparative studies or considering research projects in these lakes. Inquiries to examine or use the data are invited. Of course, the primary right to publish extensive extracts from the database, or from this unpublished report to the lake owners, resides with the PCLP cooperating investigators and students who generated the data. As of August, 1994, most of the existing information is accessible through the software program Reflex™ (version 2, Borland International, copyright 1989) running on IBM PC-type microcomputers.

SAMPLING PROGRAM

On each sampling occasion, Lake Lacawac was visited during the day. The January through May sampling included a second visit after dark, following the 1989-1993 protocol. The night-time visit was required for optimal sampling of certain migrating zooplankton. Other parameters were measured, and samples were collected, during the day. Sampling was carried out at a fixed station (site "A") near the deepest part of the lake (about 13 meters or 40 feet). The thermal stratification existing on any date dictated the depths from which other samples were collected (**Figure 1**). The lake was sampled monthly until June (5 dates), then biweekly through August (6 dates) when surficial water temperature stayed above 20°C, then through during the autumn (2 dates--late September and mid-November).

TEMPERATURE AND PHYSICAL STRATIFICATION

Temperature was measured at 1-meter intervals with the thermister of a YSI™ oxygen meter, in degrees Celsius. Accuracy should be within 1 degree. (This is **Method #10.**)

Figure 2 shows the thermal stratification that develops during late spring and summer, then breaks down in the autumn. On day 21 (21 January) the lake was ice-covered, and displayed a weak "reverse stratification", which was also evident near the end of ice cover on day 82 (23 March). After ice-out (10 April at Lacawac), the water column briefly circulated from top to bottom during "spring turnover", as evident in the nearly

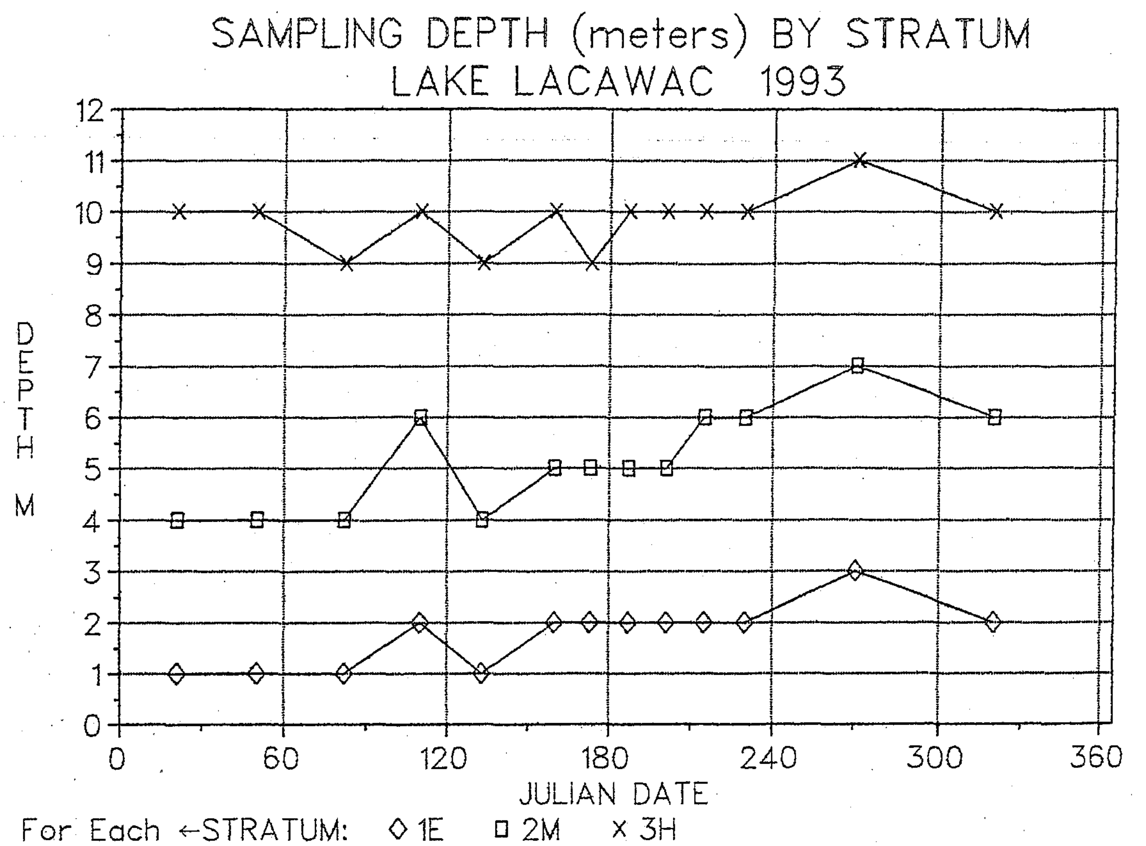


Figure 1. Depths of "EPI", "META", and "HYPO" samples from Lake Lacawac, 1993.

Sampling depths were selected by the field sampling crew based on the temperature profile on each date (see text for discussion).

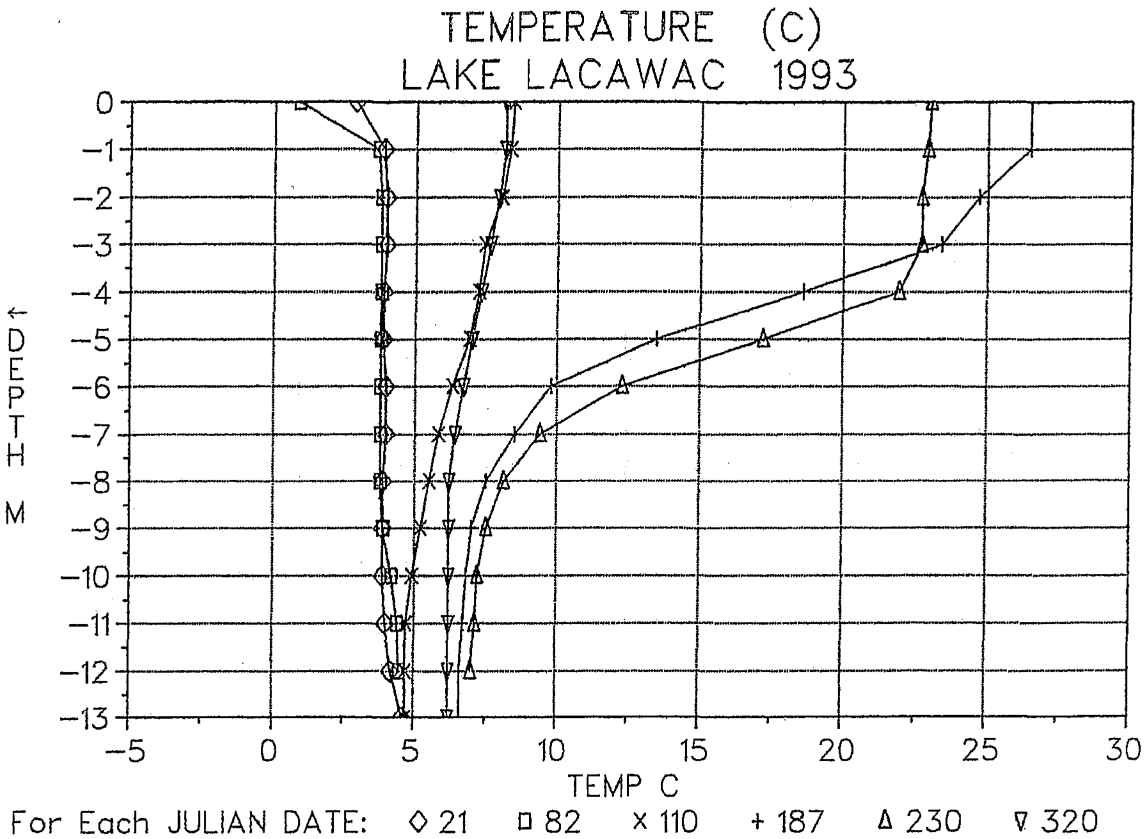


Figure 2. Temperature (degrees Celsius) in Lake Lacawac, 1993.

Values are plotted for six dates: **21 January** (day 21 --early ice cover), **23 March** (day 82 --late ice cover), **20 April** (day 110 --spring turnover), **6 July** (day 187 --midsummer stratification), **18 August** (day 230 --later stratification), **16 November** (day 320 --fall turnover).

isothermal 5-8°C water column on day 110 (20 April). Although the lake was weakly stratified on day 110, it apparently circulated again before day 133, since temperature at the bottom of the lake increased from 4.7 to 6.5°C. By day 187 (6 July) the surface water had warmed to 26°C. The water column was strongly stratified, consisting of three layers: an upper warm water layer, periodically circulating in contact with the atmosphere (the **EPILIMNION**, 0-3 meters, temperature 23-26.5°C); an intermediate layer of rapid temperature decrease with depth (the **METALIMNION**, 3-8 meters, temperature changing >1°C per meter); and a deep layer of cold water (the **HYPOLIMNION**, 8-13 meters, temperature 6.5-8°C). Lake heating during midsummer occurred mainly in the metalimnion; epilimnial temperature was highest early in July.

The usual course of thermal stratification is that of slow, gradual thickening of an epilimnion during the summer. By day 230 (18 August) the epilimnion extended to 4 meters. As the lake cooled during the autumn, the epilimnion thickened more rapidly until the lakewater was circulating from top to bottom. This period of full circulation, or "fall turnover", was in progress by day 320 (16 November), although the lake showed a slight ephemeral stratification on the warm, calm day it was sampled.

The 1992-93 winter ice cover began in late December, 1992 (13 cm of ice on December 31, 1992). Ice thickness increased through the winter, reaching 44 cm by 23 March. Ice did not go out until April 10 (Sally Jones, pers. comm.).

The temperature pattern in the lake is controlled by climate, and will differ only slightly from year to year. Two major variables are the durations of winter ice-cover (ca. 14-15 weeks in 1992-93) and the completeness of spring turnover. Spring turnover was complete in 1993, judging from the well oxygenated conditions encountered at 12-13 meter depths on day 110 (20 April).

Although December 1992 and early January 1993 were relatively warm, air temperatures during February and March were colder than normal **(Figure 11)**, accounting for the thickness of the ice. Summer was again warmer than usual, returning to a climatic trend that had been interrupted by a "normal" summer in 1992. **Figure 3** presents the detailed trends of water temperature at three fixed depths (2,6,10 meters) for comparison with other years.

Water samples for **pH**, **alkalinity**, **chlorophyll**, **algae**, and -- starting in June -- **dissolved organic carbon**, **sestonic particulate matter**, and **nutrients** were collected from mid-depths of the three layers when thermal stratification was well developed. During turnover periods, the lake was divided into three equal layers. Under ice-cover (e.g. 21 January), the topmost layer was 0-1m, and the remaining depths were divided at the Secchi depth (see **SECCHI DEPTH** below).

LIGHT PENETRATION

Light intensity at 1-meter intervals was calculated as a percentage of the light just below the lake surface (10 cm). Since 1988, four slightly different methods have been used to construct a 0-12 m profile of light penetration; method #12 (numbers correspond to codes from data tables) was used in 1993 through August, then method #13 was introduced.

Method 12. Two sensors, mounted 1-m apart on a common line, electronically computed the ratio of light intensities between the nominal depth and the depth above it. The percentage penetration profile was constructed from these ratios. The sensors are Licor™ submersible flat cosine-corrected sensors filtered to give a quantum response to photosynthetically available radiation ("PAR"). Units are microeinsteins per square meter per second ($\mu E/m^2.sec$).

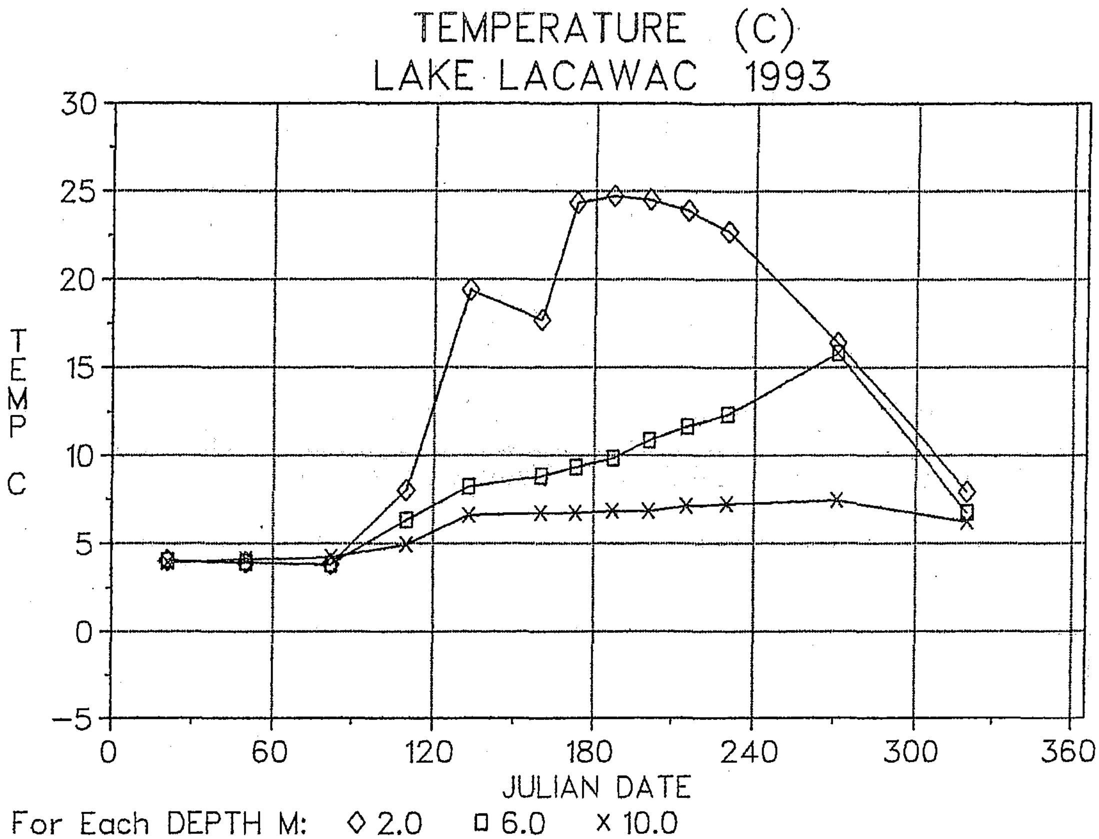


Figure 3. Temperature trends within Lake Lacawac, 1993.

Values (°C) are plotted for three fixed depths.

Method 13. A single sensor, separately measuring both UV wavelengths and PAR, is lowered 1-several times from a boom extending beyond the side of the boat. Water depth, temperature, and irradiance in 5 wavebands are logged automatically and continuously to a microcomputer disk for later data reduction. The instrument is a Biospherical Instruments PUV-500™ fitted with a high-resolution depth sensor. Like the Licor instrument, the sensor is calibrated to give a cosine response for measurement of downwelling radiation. It measures PAR (400-700 nm) as well as UV irradiance in ca. 10-nm bands around 380, 340, 320 and roughly 305 nm. Profiles with this instrument are more prone to noise from changing cloudiness than the dual-Licor unit used in Method 12, but we attempt to minimize problems by averaging or combining multiple profiles.

Light ("PAR") penetration is plotted on a logarithmic scale for six dates **(Figure 4)**. During the summer, depths above 4 m (i.e. all of the epilimnion) received at least 2-5% of the light penetrating the lake surface. The metalimnion received 0.1-5% of surface light, enough for low-to-moderate rates of algal growth. Too little light penetrated the hypolimnion to support autotrophic algal populations. Transparency was only slightly reduced during spring turnover (day 110), and the lake was quite clear during fall turnover (e.g. day 320). Under thick ice and snow cover on 23 March (day 82), however, light was strongly attenuated both through the ice/snow and in the water column.

We took advantage of having a scanning underwater radiometer with a submersible light collector at Lake Lacawac during the UV workshop to acquire a continuous plot of UV attenuation from 400 to 295 nm **(Figure 5)**. Attenuation increased fairly smoothly with decreasing wavelength.

Ultraviolet light is attenuated much more rapidly than PAR in Lake Lacawac, as data collected with our PUV-500 instrument shows **(Figure 5B)**. The 1% level for the mid-UV-B wavelengths (UV308) was at ca. 0.4 meters on 24 July 1993, compared to 10 meters in Lake Giles. This means that organisms in the warm summer epilimnion of Lake Lacawac (0-4 m) are only episodically exposed to potentially harmful levels of UV. Whether natural levels of ultraviolet radiation actually play important ecological roles in Lake Lacawac, or especially in much more UV-transparent lakes such as Giles, is the subject of on-going experimental investigations by Lehigh scientists.

SECCHI DEPTH

Secchi depth is the depth, in meters, at which a white-and-black quartered disk 20 cm in diameter just ceases to be visible to an observer lowering it from a boat. It is a measure of water transparency. We observed the Secchi disk with a small glass-bottomed viewing box to reduce glare from the lake surface.

The pattern of transparency **(Figure 6)** differed somewhat from that in 1992 but was at least broadly consistent with previous years. The amplitude, from lowest transparency under snow-covered ice to greatest transparency in mid-to-late summer, was greater than in previous years. The most consistent feature of the pattern in Lacawac is a summer minimum of transparency ($\leq$4 meters) in July or early August followed by weakly (1989, 1990) or strongly increased transparency by early fall (5-7 meters). A clear-water period in late spring or early summer is a common pattern in temperate lakes, but was only observed in 1992 in Lacawac.

OXYGEN CONTENT OF THE LAKEWATER

Dissolved oxygen was measured polarographically using a YSI™ submersible

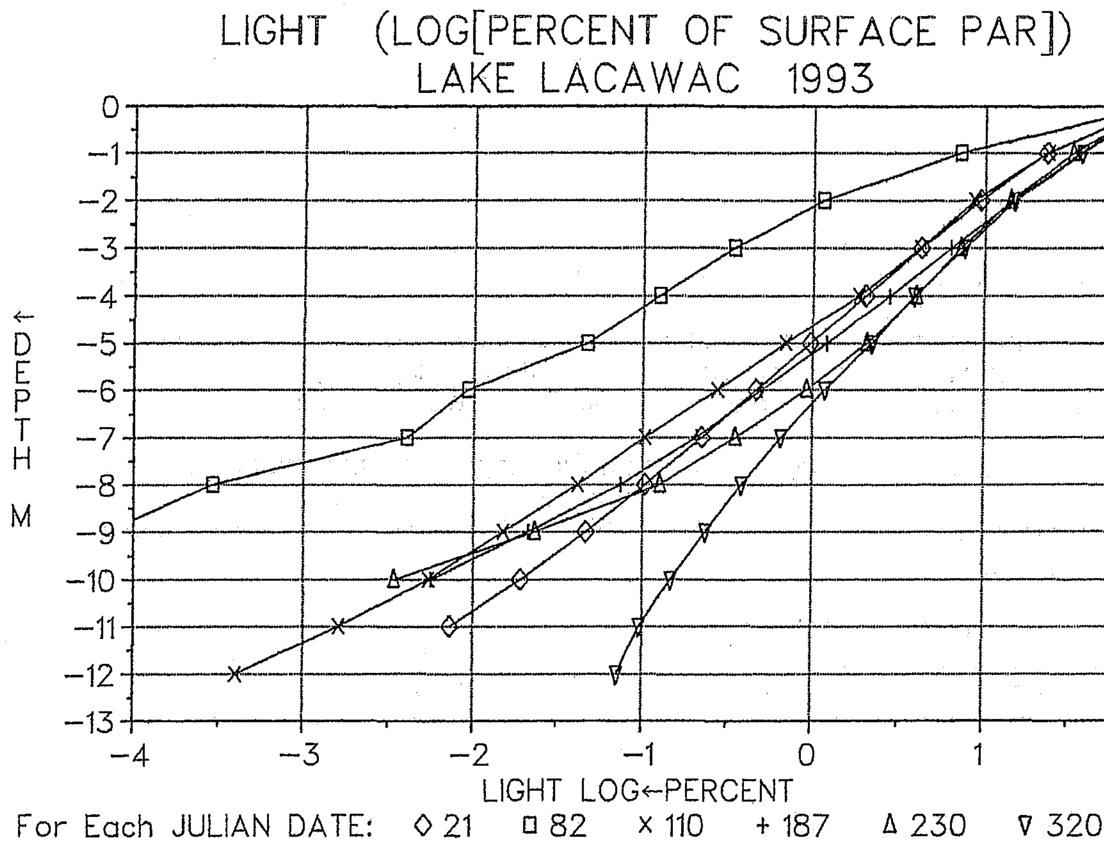


Figure 4. Light penetration in Lake Lacawac, 1993.

Values are percentages of the light at 0.1 m depth and are graphed on a logarithmic scale (i.e., 100% ="2", 10% ="1", 1% ="0", etc.) for six dates: **21 January** (day 21 --early ice cover), **23 March** (day 82 --late ice cover), **20 April** (day 110 --spring turnover), **6 July** (day 187 --midsummer stratification), **18 August** (day 230 --later stratification), **16 November** (day 320 --fall turnover).

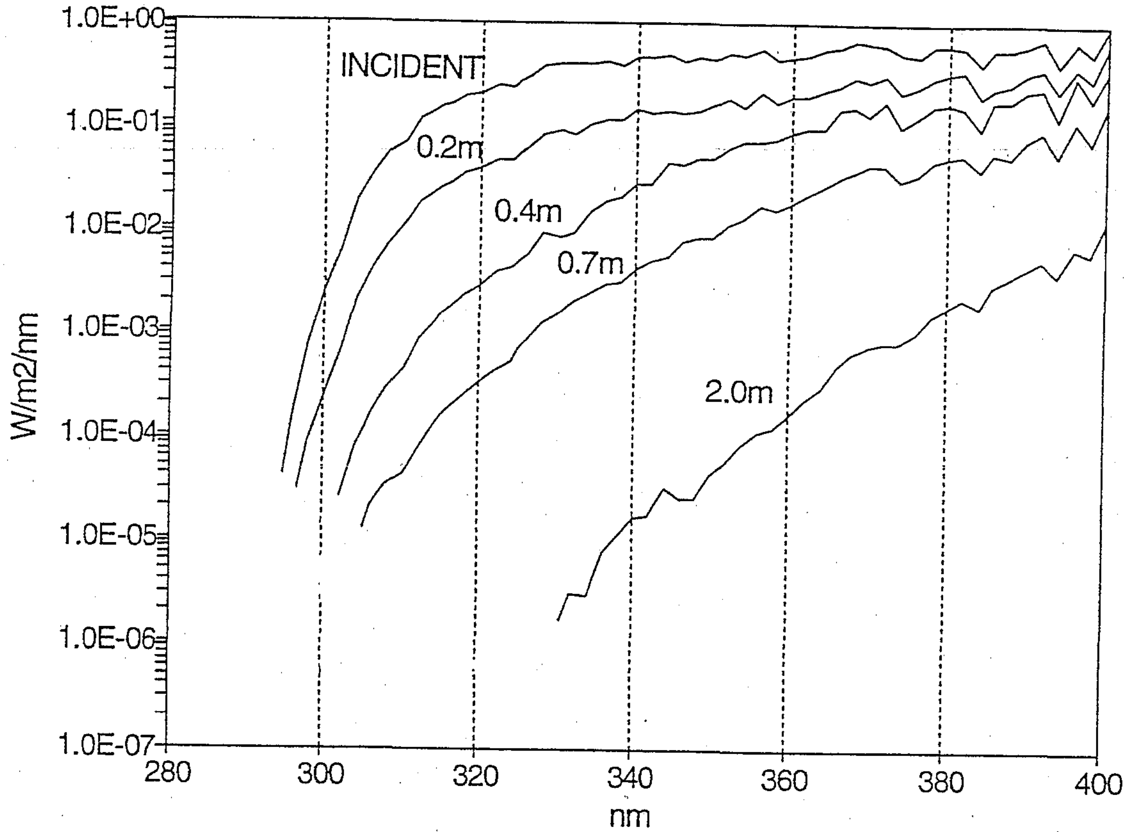


Figure 5. Attenuation of ultraviolet radiation in Lake Lacawac, 14 September, 1993.

The spectral distribution of ultraviolet light within the upper 2 m of Lacawac was measured with an Optronic Laboratories OL-752 spectroradiometer equipped with an integrating sphere collector and fiber optic submersible cable. Measurements were made between 2 and 3 pm EDST.

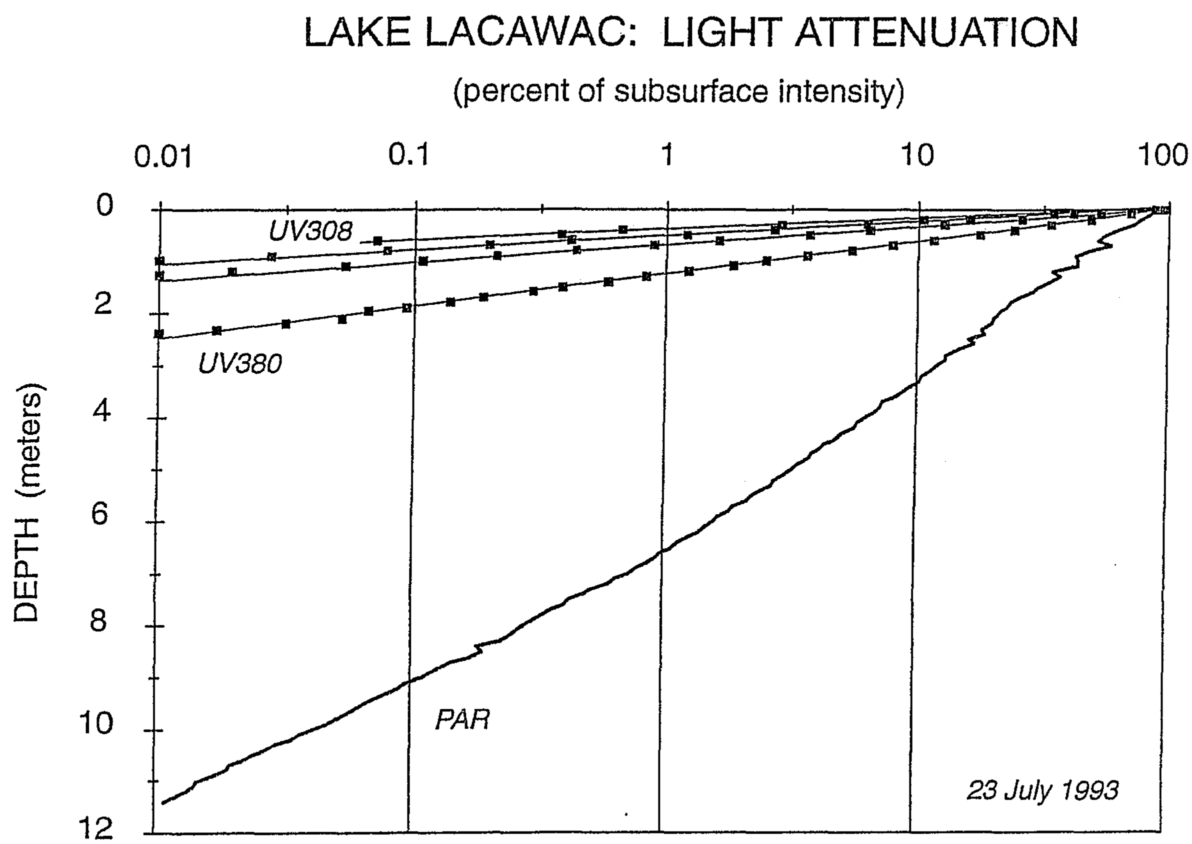


Figure 5B. Attenuation of PAR and UV irradiance in Lake Lacawac on 23 July 1993.

Data are from the PUV-500. All points within 0.1-m depth increments were averaged before plotting points (UV308, UV320, UV340, UV380 irradiance bands) or plotting a thick line connecting points (PAR, 400-700 nm)

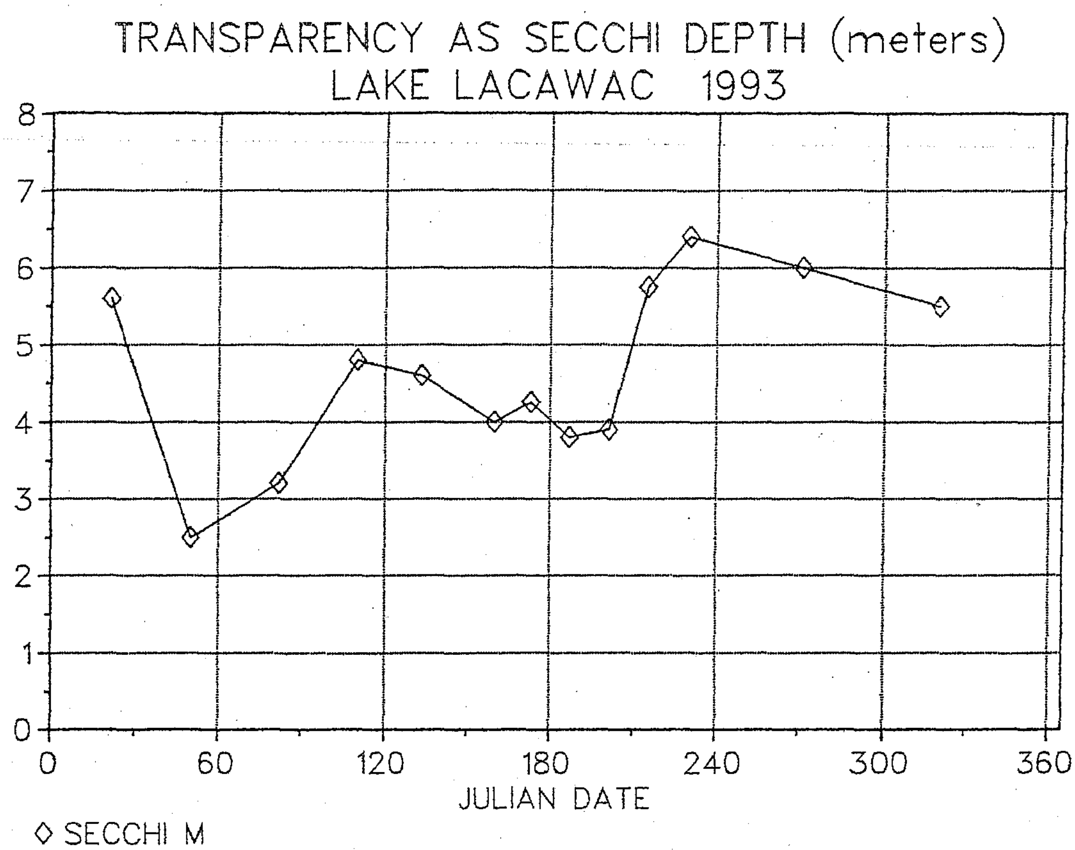


Figure 6. Transparency in Lake Lacawac, 1993.

Values plotted are the Secchi depths, in meters.

temperature-compensating oxygen meter. The meter was calibrated in air to 100% saturation immediately before use in the lake. The effect of Lake Lacawac's elevation above sea-level (1439 feet) was not taken into account when calibrating the meter, so compiled values are roughly 5% too high. Units are mg O_2 per liter. (This is **Method #10.**).

Often the meter did not give a true "zero" when dropped into definitely anoxic (oxygen-free) water. Values flagged with error code "4" in the data tables should be treated as true zeros.

Oxygen became moderately depleted below 9 meters during the relatively long winter ice/snow cover. Oxygen concentration was reset to atmospheric saturation during spring turnover, when the lake was still cold. During summer stratification, oxygen was again consumed within the deeper hypolimnion, and lost from the warming epilimnion via outgassing to the atmosphere. These processes created the metalimnetic oxygen maximum that was evident in early summer **(Figure 7)**. By day 230 (18 August), oxygen had been eliminated from the hypolimnion and was depleted in the lower metalimnion. These patterns have been very consistent from year to year.

ALKALINITY AND pH

Alkalinity is a measure of the acid neutralizing, or buffering capacity. Alkalinity was determined by potentiometric titration of a 100-ml sample using 0.1 or 0.01 N sulfuric acid as titrant and monitoring pH change with an Orion™ model SA250 pH meter and Ross™ epoxy-body combination electrode. Titration points between pH 4.4 and 3.7 were plotted, after Gran transformation, to give alkalinity in microequivalents per liter (μeq./L). (This is **Method #11.**) Alkalinity was analyzed monthly, on alternate sampling dates during summer.

Samples for alkalinity and pH were taken from duplicate water collections (acrylic plastic Van Dorn bottle) at three depths, designated "**E**" (epilimnion), "**M**" (metalimnion), and "**H**" (hypolimnion). Selection of these depths is described in the section **TEMPERATURE AND THERMAL STRATIFICATION.** Samples were stored in air-tight polypropylene bottles for up to 24 hr (refrigerated) before analysis, or, more usually, analyzed within a few hours of collection. Samples were warmed to room temperature before analysis. The pH meter and electrode described above were calibrated with commercial high ionic strength buffers. The pH was measured in 50-ml aliquots of sample, usually with gentle mixing. The following variant of the method was employed on all dates on 1993:

Method 12. As above, with 0.5 ml salt solution (Orion™ pHisa™ solution) added to increase ionic strength. Usually, this had little or no effect on the sample (pH change <0.1 unit). Also, a quality assurance protocol was followed, verifying electrode performance in distilled water and the stability of calibration.

Trends of pH are plotted for each layer in **Figure 8**. In the absence of intense biological activity, the pH of Lacawac would be about 6 with an alkalinity of about 30 μeq/L **(Figure 9)**, judging from values in late spring. These values portray a softwater, slightly acidic lake with little bicarbonate buffering capacity. Microbial metabolism generated substantial alkalinity in the anoxic hypolimnion **(Figure 9)**, but this was lost upon reoxidation of the water column during fall turnover and subsequent winter stratification. Levels and seasonal trends of both pH and alkalinity have been highly similar during the past 4.5 years of regular monitoring.

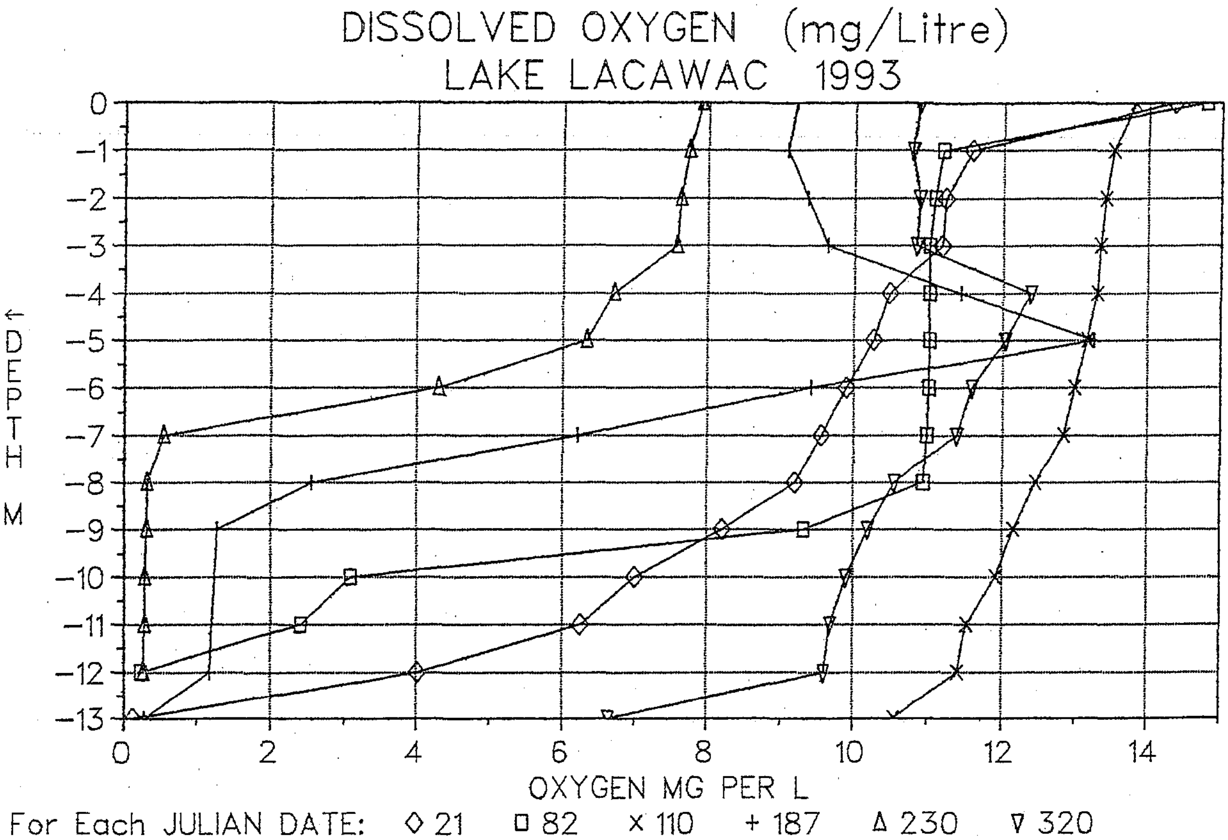


Figure 7. Dissolved oxygen in Lake Lacawac, 1993.

Values (mg oxygen per litre) are plotted for six dates: **21 January** (day 21 --early ice cover), **23 March** (day 82 --late ice cover), **20 April** (day 110 --spring turnover), **6 July** (day 187 --midsummer stratification), **18 August** (day 230 --later stratification), **16 November** (day 320 --fall turnover). Residual hypolimnetic concentrations <0.4 mg/L on day 230 and other dates are really "0.0".

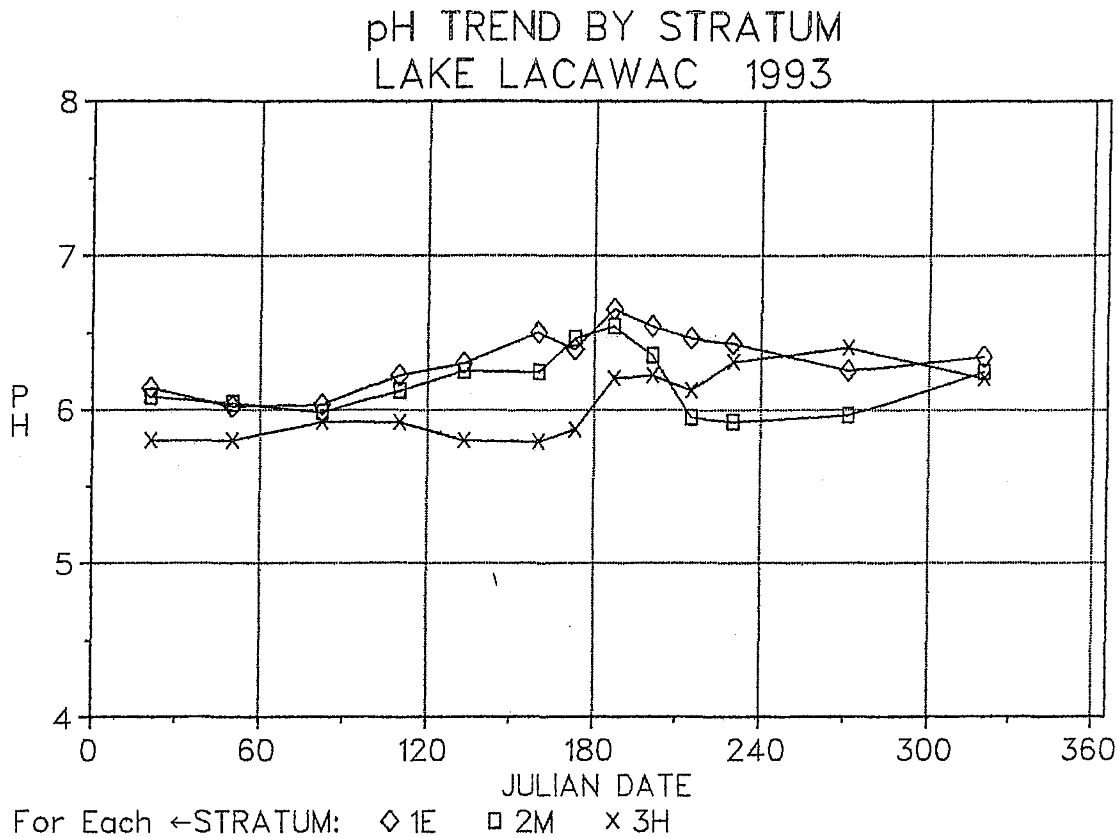


Figure 8. Trends of pH in Lake Lacawac, 1993.

Values are plotted for the mid-depths of the three layers, Epilimnion (1E), Metalimnion (2M), and Hypolimnion (3H). In autumn and winter, when these layers are not developed, samples are collected as described in **RESULTS AND METHODS**.

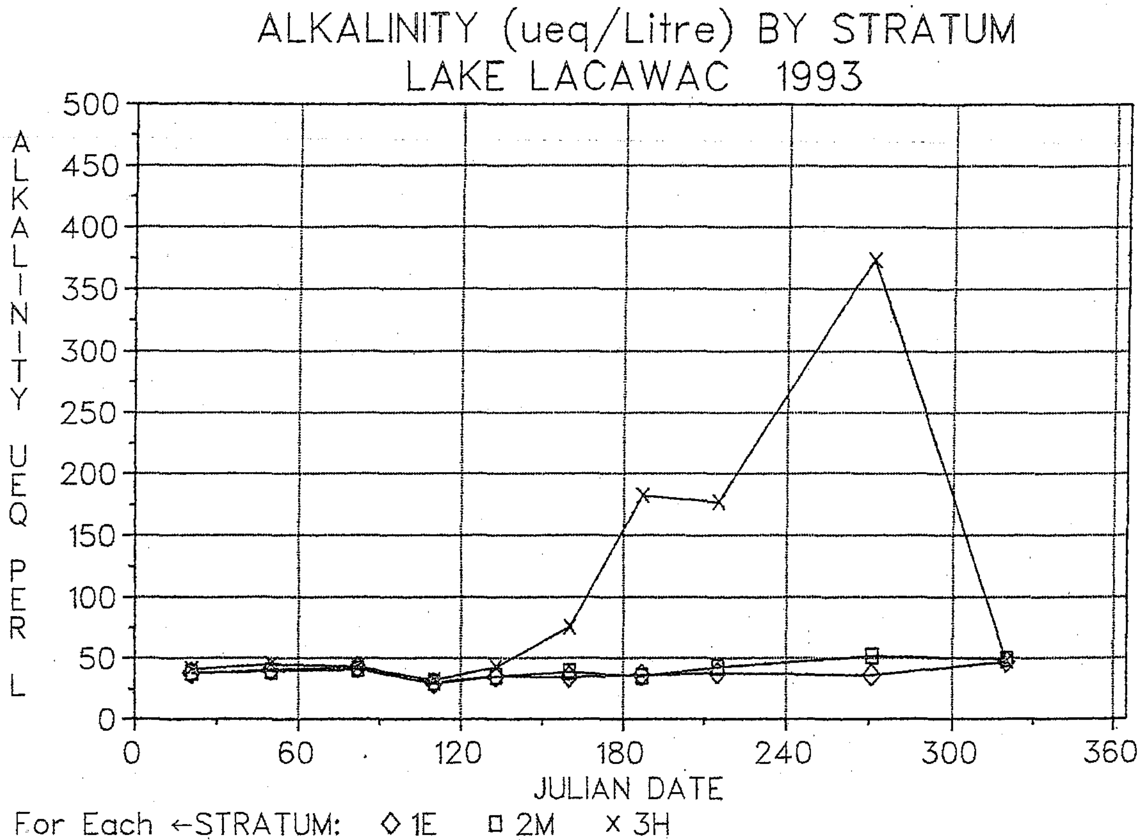


Figure 9. Trends of Alkalinity in Lake Lacawac, 1993.

Values are plotted for the mid-depths of the three layers, Epilimnion (**1E**), Metalimnion (**2M**), and Hypolimnion (**3H**). In autumn and winter, when these layers are not developed, samples are collected as described in **RESULTS AND METHODS**.

CHEMISTRY

Data from the 1991-92 chemical samplings are presented in **APPENDIX I**. Six depths were sampled on each of five dates distributed throughout the year. The 1989 data were included in the 1990 Annual Report. The sampling and analytical methods for both series are summarized in **APPENDIX I.**

Cation concentrations were similar in 1989 and 1991-92. Combining 1989 sulfate with 1991-92 chloride and other ion concentrations, calculating H^+ concentration from pH, and calculating bicarbonate (HCO_3^-) from pH and total dissolved inorganic carbon (DIC), gives a generalized ion balance for Lake Lacawac water. These averages were not weighted for volume differences at different depths. Depths with reduced oxygen ($\leq$ 3 mg/L) were excluded from the sampling date depth-integrated means, however. Additional parameters were extracted from the chemical database to more broadly characterize the lake **(Table 1)**.

Table 1. Chemical Characterization of Lake Lacawac.

		micromoles/L	microequivalents/L
Anions			
Sulfate	SO_4^{-2}	76. µM	143. µeq/L
Chloride	Cl^{-1}	23.5	23.5
Bicarbonate	HCO_3^{-1}	43.	43.
Nitrate	NO_3^{-1}	0.5	0.5
Cations			
Sodium	Na^{+1}	31.8 µM	31.8 µeq/L
Calcium	Ca^{+2}	74.	147.
Magnesium	Mg^{+2}	21.1	42.2
Potassium	K^{+1}	9.7	9.7
Hydrogen ion	H^+	0.01	0.01
Ammonium	NH_4^{+1}	3.9	3.9

Other Chemical Parameters		
pH[1]	6.03	
Alkalinity	30.	ueq/L
Conductivity (1989 data)	27.	umho/cm
Dissolved Inorganic Carbon (DIC)[2]	130.	uM
Dissolved Organic Carbon (DOC)	400.	uM
Total Phosphorus (totP)	0.46	uM

[1] IES *in situ* pH in 1989, PCLP lab pH in 1991-92
[2] includes mid-depths; epilimnetic DIC in summer is ca. 40 µM

The ion balance is very good (229 µeq/L for anions, 235 µeq/L for cations). Calcium is the dominant cation, sulfate is the dominant anion. At Lake Lacawac's pH of 6.0, bicarbonate provides a small buffering capacity (alkalinity 30 µeq/L). Bicarbonate makes up ca. one-third of the total dissolved inorganic carbon. Lacawac is, however, a very softwater lake, and dissolved organic carbon exceeds the DIC by 3 times (ca. 10 times in the epilimnion). Dissolved organic carbon is relatively high (400 µM).

Chemical analyses from 1993, which emphasized nutrients and dissolved organic carbon, are presented in **Table 2**. Dissolved organic carbon was consistently ca. 5 mg C/L (i.e. 400 µM, as cited above) from June through November. DOC was only slightly higher

Table 2. Lake Lacawac: Chemical Parameters in 1993.

Abbreviations: dissolved organic carbon (DOC), chlorophyll-a (Chl-a), pheophytin-a (Pheo-a), soluble reactive phosphorus (SRP), total dissolved phosphorus (TDP), total particulate phosphorus (TPP), ammonium (NH3), nitrate (NO3), particulate matter. Chlorophyll-a values are corrected for pheopigment.

Date	Stratum	Depth (m)	DOC (mg C/L)	Chl-a (ug/L)	Pheo-a (ug/L)	SRP (ug P/L)	TDP (ug P/L)	TPP (ug P/L)	NH3 (ug N/L)	NO3 (ug N/L)	Part. Matter (mg/L)
09 Jun 93	E	2	5.09	1.8	5.9	1.9		5.6		44.0	1.48
	M	5	5.02	4.7	8.4	1.9		6.0		8.5	2.09
	H	10	4.47	0.9	4.4	9.8		20.2		107.	2.44
22 Jun 93	E	2	4.90	3.2	0.5	2.5	3.8	3.9	9.6	<0.1	0.55
	M	5	5.33	26.6	3.3	0.6	4.2	8.3	5.6	5.8	3.03
	H	9	4.36	3.0	-1.7	22.5	33.6	8.5	186.	4.0	0.54
06 Jul 93	E	2	5.29	3.6	0.9	0.7	4.2	4.3	5.2	8.6	
	M	5	5.01	3.6	1.0	0.7	4.3	3.5	5.1	25.2	0.55
	H	10	4.56	3.4	8.5	46.5	63.1	16.0	329.	12.4	1.04
20 Jul 93	E	2	4.91	2.0	2.3	0.4	3.3		3.5	<0.1	1.25
	M	5	5.03	3.7	5.3	0.6	3.4		4.5	1.4	1.61
	H	10	5.02	2.7	12.4	55.8	65.2		351.	<0.1	1.09
29 Jul 93	E		4.38							<0.1	
03 Aug 93	E	2	4.86	5.1	1.9	1.3	5.0		8.0		1.14
	M	6	4.72	2.1	2.1	1.6	5.8		5.7	3.2	1.20
	H	10	4.90	10.2	12.9	25.3	48.6		201.	4.4	2.26
18 Aug 93	E	2	4.57	4.2	1.7	0.4	4.4		7.8		0.70
	M	6	4.52	2.7	1.0	0.9	7.2		9.6		0.65
	H	10	5.60	12.6	15.5	61.0	78.8		354.		1.73
28 Sep 93	E	3	4.42	2.4	1.3	0.9	3.9		9.8		0.42
	M	7	4.49	0.8	3.4	1.3	4.4		16.8		0.64
	H	11	5.32	26.0	27.6	72.1	91.8		494.		3.80
16 Nov 93	E	2	4.83	2.0	0.3	1.4	9.7		54.3		0.66
	M	6	4.79	1.0	0.7	2.0	7.4		57.2		0.64
	H	10	4.94	0.9	0.6	1.7	8.1		67.0		0.62

in the anerobic hypolimnion in late summer (e.g. 5-5.5 mg/L). Phosphate was released into the anoxic hypolimnion, but was always at very low levels at "EPI" and "META" depths, where there was enough light for phytoplankton growth. Ammonium followed the same pattern as phosphate, accumulating in the hypolimnion but being reduced to low levels (3-10 μg N/L) in the better lighted depths during summer. Nitrate analyses are not complete, but suggest summer depletion from possibly higher surface water nitrate in June.

ALGAL CHLOROPHYLL-a

Chlorophyll-a is a measure of algal mass, since all algae contain this pigment. It is a widely used parameter for comparisons of lake trophic conditions. Chlorophyll samples came from the same Van Dorn collections used for pH and alkalinity. Samples were stored in 1-L polyethylene bottles for 2-12 hr (cool in darkness) before being filtered. Two analytical methods were used in 1993, both giving presumably comparable values for chlorophyll-a corrected for pheopigments (**CHLAC** in data tables and **Figure 11**), and chlorophyll-a including pheopigments (**CHLASUM** in data tables).

Method 12 (January-May). Subsamples were filtered and stored frozen (0.5 L onto Gelman™ A/E filters). Two samples were filtered from each depth: a whole-water sample (for total chlorophyll-a) and a sample fractionated with a 22-μm nitex net. Often the sum of fractions was less than the total. This sum was only treated as a replicate for total chlorophyll-a if it was greater than or equal to 85% of the whole sample. The percentage of chlorophyll passing the 22μm net (percent of the summed fractions) is presented in the data tables (**CHLAC P**). Intact filters were extracted overnight at 2-4°C, in darkness, in 12 ml of a 5:1 (vol/vol) mixture of 90% basic acetone and methanol. Extracts were centrifuged and read in a Sequoia-Turner™ model 112 fluorometer equipped with F4T5/B lamp, red-sensitive photomultiplier, 5-60 excitation filter and 2-64 emission filter. The meter was calibrated with dilutions of pure chlorophyll-a or chlorophyll-a,b extracts from higher plants; these were assayed first by standard spectrophotometric techniques. Each sample was reread after acidification (to 0.03 N) to allow correction for pheopigments. We verified that chlorophyll behaves virtually the same in the mixed solvent as in 90% acetone alone, and that the mixed solvent extraction gave results that were the same as or greater than those from parallel extraction in 90% acetone with grinding.

Method 13 (June-November). Samples were filtered onto glass fiber filters (Whatman GF/F). These were immediately placed in 10 ml of 90% ethanol, heated to boiling, extracted overnight in a freezer, and analyzed spectrophotometrically for chlorophyll-a and pheopigment [see citations in D.P. Morris and W.M. Lewis, Jr. 1992. Limnology and Oceanography 37(6):1179-1192]. No size-partitioning was performed.

In Lake Lacawac there was a distinct seasonal pattern of chlorophyll-a (**Figure 10**) that was consistent with previous years. Values were low (less than 6 μg/L) under the ice in January, but subsequently increased to 15-44 μg/L in the upper 2 meters under the snow-covered ice. The very high peak of 44 μg/L in the top meter in March likely represented motile algae that congregated in the higher light environment at the top of the ice and snow covered water column. Algae decreased to a minimum in late spring (1-5 μg/L), probably in response to grazing by the increasing zooplankton populations. Unlike earlier years, our data show increasing levels of chlorophyll-a, corrected for pheopigments, in the anoxic hypolimnion. The change in methodology accounts for the difference, since interfering pigments caused the fluorimetric technique used in 1989-1993 to assign all chlorophyll to the pheopigment phases. The nature of this "chlorophyll-a", however, is uncertain; part of it may be bacteriochlorophylls produced within the hypolimnion.

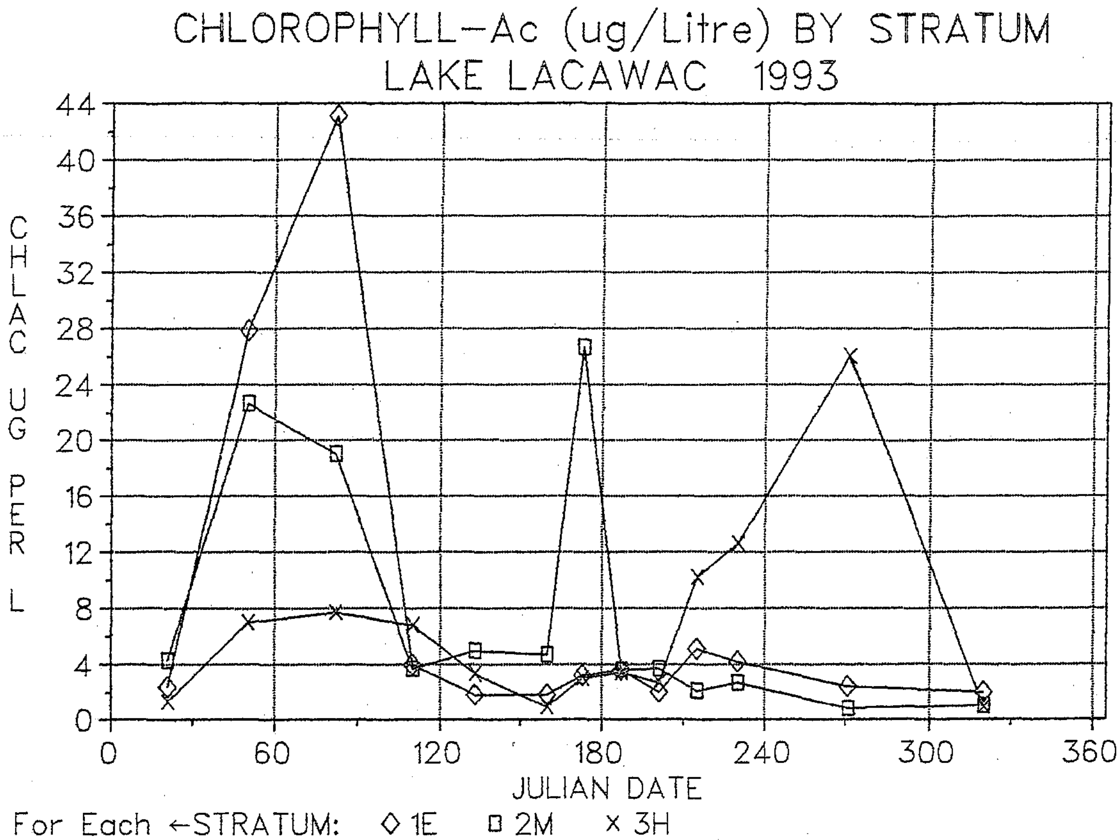


Figure 10. Trends of Chlorophyll-a in Lake Lacawac, 1993.

Values are plotted for the mid-depths of the three layers, Epilimnion (1E), Metalimnion (2M), and Hypolimnion (3H). In autumn and winter, when these layers are not developed, samples are collected as described in **RESULTS AND METHODS**. Chlorophyll-a values are corrected for pheopigments.

PHYTOPLANKTON

Phytoplankton subsamples were preserved from the EPI, META, and HYPO samples. These have not been routinely analyzed because of the effort required. To provide some idea of the algal communities prevalent at different seasons in the three study lakes, we prepared composite seasonal samples for three separate years (summer 1989 through spring 1992), which were submitted to a subcontractor (PhycoTech, Baroda, Michigan) for analysis. The original acid-Lugol's preserved samples are archived at Lehigh.

At PhycoTech, an appropriate volume was filtered onto a membrane filter, mounted on a microscope slide in resin (HPMA), and counted at 200x magnification. The count included a minimum of 300 cells/colonies. In most samples, an additional 100 cells of the smallest types were counted at 400x. For a few very large types the whole slide was scanned. Biovolumes were estimated from simple geometric shapes fitted to 1-several dimensions of the cells encountered.

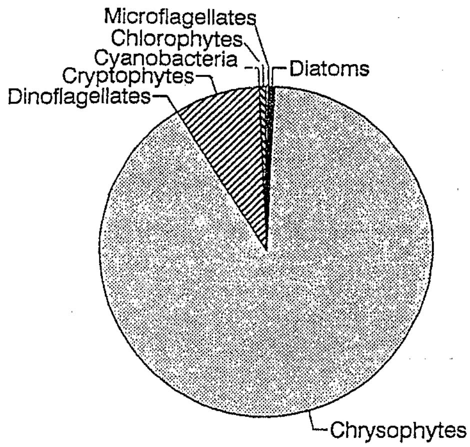
The analyses are presented as species biovolumes in **APPENDIX II.** Identifications at the genus or species level were directed by Ann St Amand at PhycoTech. These counts should include the several most abundant taxa, with a scattered inclusion of less common types. A summary of the seasonal representation of the main groups of algae is given as pie charts on the next page, along with the total algal biovolume for each season. Note that all depths (EPI, META, HYPO) contributed to each sample. "Winter" samples were collected beneath ice cover in January and February, "Spring" samples after ice-out in March through May, "Summer" samples during thermal stratification of June through September, and "Autumn" samples late in stratification (October) or during fall turnover in November or December.

In Lake Lacawac, phytoplankton tended to be more abundant in the winter and spring than in the summer or autumn. Flagellated chrysophytes such as *Synura* and *Mallomonas* strongly dominated the winter and spring community, with *Dinobryon* appearing in moderate abundance in spring, as in so many other lakes. Although *Synura* and *Mallomonas* declined during the summer, they remained abundant enough, in the metalimnion, to dominate the reduced summer phytoplankton. (However, note that the counted sample weights all three depths equally, significantly exaggerating the contribution of the deeper strata to the whole-lake community.) Diatoms and cyanobacteria were never an important part of the total biovolume. Cryptophytes were moderately abundant year-round, while green algae were important in summer and autumn and dinoflagellates were important in spring and autumn. The summer phytoplankton in Lacawac has been more diverse than in the two other lakes we study.

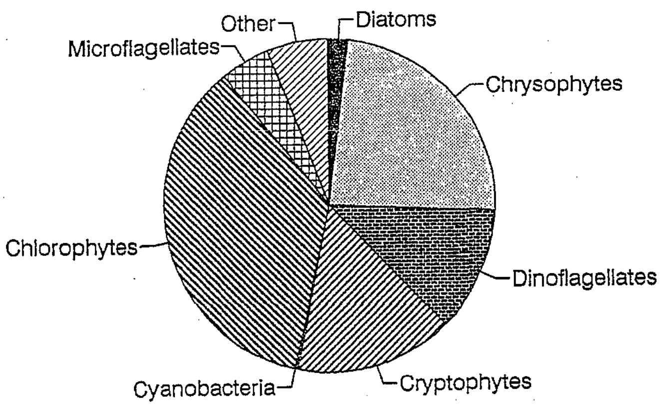
ZOOPLANKTON

Zooplankton receive a major emphasis in the PCLP program. These animals represent the key link between algal primary producers and fish populations. The intensity of grazing by herbivorous zooplankton strongly affects the kind of algae that dominate, and potentially can control (i.e. reduce) algal populations even in the face of abundant nutrient supply. Consequently the kinds and abundances of zooplankton have important implications for the water quality of a lake.

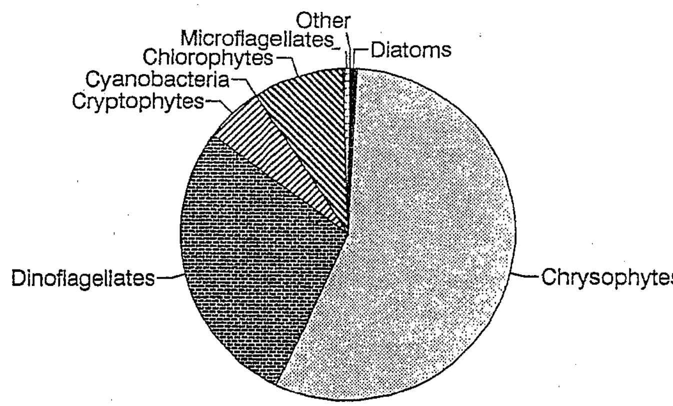
Zooplankton were sampled at day and night (January-May) or only during the day (June-November). The data presented here include nighttime samples when available, for consistency with previous years. Some species avoid the water column during the day, especially *Chaoborus*; for these taxa concentrations from summer and fall 1993 are not



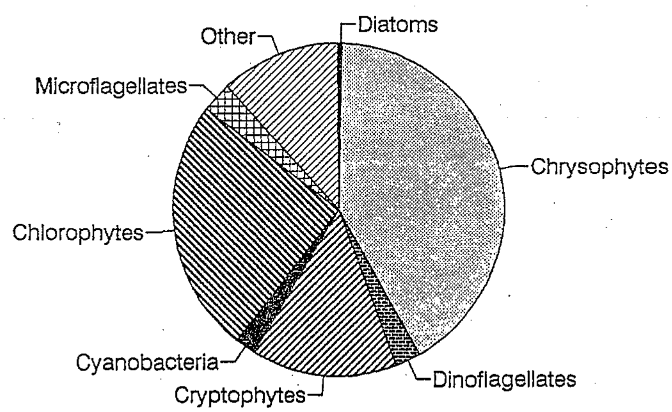
LACAWAC (WINTER 1170 x10^{3}um^3/mL)



LACAWAC (AUTUMN 472 x10^{3}um^3/mL)



LACAWAC (SPRING 1646 x10^{3}um^3/mL)



LACAWAC (SUMMER 265 x10^{3}um^3/mL)

comparable to earlier data. Hopefully for most species, including copepods, Cladocera, and certainly rotifers, the whole water-column means were little affected by sampling time. Zooplankton were collected with closing-style plankton nets that could be pulled through part of the water column open, collecting animals, then closed and pulled the rest of the way to the surface. In this way the water column was sampled as the three layers defined by temperature. In the present report, data are given as mean concentrations (numbers of individuals per liter) over the entire ca 12-m water column. Details of the depth-distributions, and daily patterns of vertical movement, are still being analyzed.

Two sizes of nets were used: a 30-cm diameter net with a mesh of 202 μm, for some macrozooplankton, and a 15-cm diameter Wisconsin-style net with a 48-μm mesh for microzooplankton as well as other macrozooplankton. These were mounted side-by-side in "bongo" configuration.

The effectiveness of these nets for sampling macrozooplankton was checked on 16 June 1993 in lakes Giles, Lacawac, and Waynewood. Each lake was visited after dark. At five stations the nets were hauled from 5 meter depth to the surface, and a parallel composite Schindler trap sample was collected from 0.5, 1.5, 2.5, 3.5, and 4.5 meters. Dr. Peter Schulze and Gaby Grad collected and preserved the samples. Gaby Grad later subsampled and counted the samples. The Schindler trap is a quick-closing transparent box (here 25-L in volume) that should minimize avoidance-responses of some zooplankton to the hydrodynamic effects of nets. The results for all three lakes are presented in **APPENDIX III**. Both nets performed well, the 48-μm net apparently somewhat better than the 202-μm net in lakes Giles and Lacawac. There may have been some underestimation of *Daphnia* even with the 48-μm net, but the pattern was not consistent across all three lakes. Basically, the 48-μm mesh Wisconsin net gave mean concentrations within 25% of those calculated from the Schindler trap series, with no compelling evidence of any serious systematic underrepresentation caused by net clogging or avoidance.

Microzooplankton includes mainly rotifers, but some copepods and small Cladocera also were counted from these samples. Our counting strategy was somewhat different in 1991-93 from that used in 1989 or 1990, with *Chaoborus* and some copepods (e.g. cyclopoid males and copepodids) being counted from the 48-μm sample that had been counted from 202-μm samples in 1989-90 samples. This change was made to increase collection efficiency of forms (e.g. small instar *Chaoborus*, copepodids, male copepods, etc.) that were going through the 202-μm mesh net. In addition, starting in June 1993 we only sampled during the day, potentially missing plankton that congregated within a meter of the lake bottom during daylight. Collections were duplicated for each depth range. Mean values are presented.

Seasonal trends in abundance are presented as a series of graphs for the most frequently encountered zooplankton, identified to genus and sometimes to species (**Figures 12-39**). **Table 3** lists the zooplankton identified to date. Updating some of the major features of Lake Lacawac's zooplankton community:

1) Rotifers in late spring peaked at 850/L, similar to peaks in earlier years. Rotifers typically exceed 500/L only in late spring. Winter levels were only ca. 100/L under thick ice and snow, compared to 300-600/L in winter 91-92 when ice was absent, or thin and snow-free most of the winter.

2) *Ascomorpha* did not have a spring maximum in 1993 or 1992, a change from 1990-91. *Asplanchna* had a short-lived May peak at 70/L, 10 times earlier sampled peaks. *Conochilus* is a fairly common summer rotifer with variable autumn populations that trace a 5-year trend (high in 1991, moderate in 1990 and 1992, very low in 1989 and 1993).

3) *Collotheca* (especially *C. mutabilis*) stands out as an uncommon species with an unusual multi-year population cycle. This rotifer is alternately abundant in late spring/summer and in autumn. In 1993 there was a modest summer population with no autumn population. In 1992 the rotifer was absent in summer but present in autumn.

4) *Gastropus* is an important spring rotifer with consistent spring population peaks succeeded by crashes to low summer levels -- caused perhaps by predation on this soft-bodied type. Autumn populations are quite variable (very low in 1993).

5) *Kellicottia longispina* is another major spring rotifer with reduced summer abundance and, as in several other common species, quite variable autumn populations.

6) *Keratella* spp were less abundant in winter and early spring than in previous years, possible a reflection of low light and poor food conditions.

7) *Ploesoma truncata* and *Synchaeta* spp are not usually abundant, but showed short-lived midsummer peaks of up to 30/L in 1993, greater than in previous years.

8) *Daphnia* overwinters at low level as non-reproducing adults, increases to a spring peak (ca. 5/L in 1993), followed by a variable decline early and/or late in the summer, and a second peak that may come early or late in the fall. In 1993, summer levels were relatively higher (1-5/L) than in most summers (0.5-2/L). Often *Daphnia* is more abundant than *Holopedium gibberum* during part or all of the summer, but in 1993 there was more *Daphnia* than *Holopedium* in samples from all dates. *Daphnia* and *Holopedium* populations seem to parallel each other seasonally, although *Holopedium* tends to be somewhate more important in late summer and autumn, with *Daphnia* more important in winter, spring and early summer. In analyzing detailed multi-year patterns, it will be important to assess whether these cladocerans are fluctuating out of phase, suggesting a competitive interaction as discussed by Alan Tessier, or whether the parallelism is the more pronounced trend.

9) *Leptodora* was present, but at exceptionally low concentration, in summer (<0.005/L). This may reflect the change to daytime sampling in early summer; *Chaoborus*, however, were not less abundant in the collections than in earlier years.

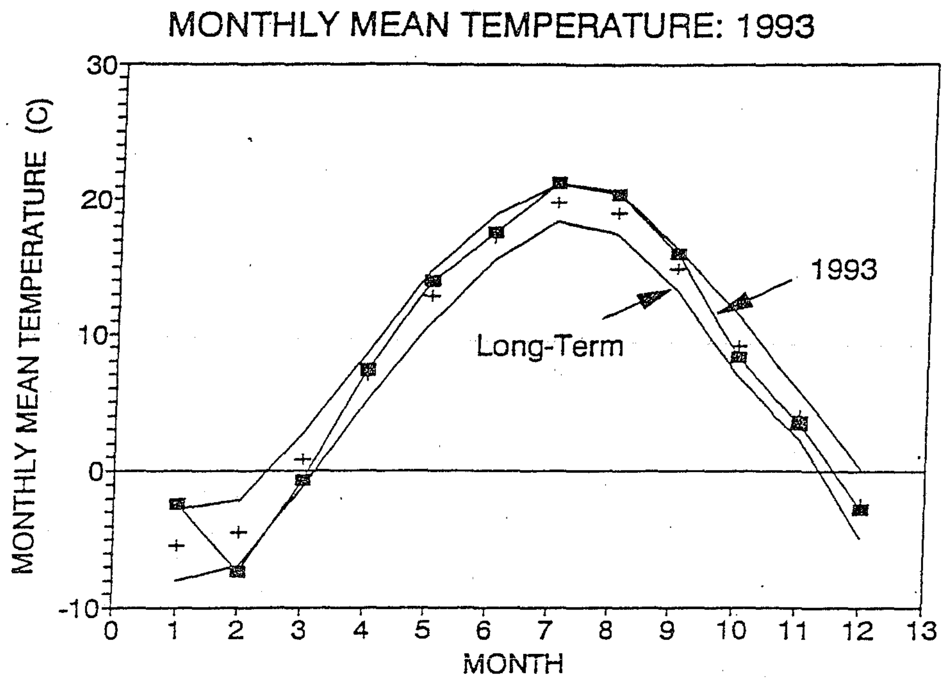
10) *Diaptomus minutus* adults were at about 3-6/L throughout the year, with a pronounced spring and early summer phase of reproduction. This species is remarkably consistent year-to-year.

11) We have discovered some confusion in our identification of cyclopoid copepodids. *Cyclops scutifer* is the most common species in spring, when intense reproduction occurs. The population disappears during the summer and autumn, with copepodids reappearing in early to late autumn and overwintering. In 1990-91 this emerging copepodid population was not recorded, apparently because they were counted as *Orthocyclops modestus*. We now feel that all copepodids should be lumped into an undifferentiated category, and only adults assigned to genus.

12) *Mesocyclops edax* was uncommon again in 1993, a major change from 1989-91. Unlike 1992, the poor development of *M. edax* did not correspond to greater populations of *Tropocyclops* or *Orthocyclops*.

CLIMATE IN 1993

Weather data were again obtained from NOAA for the cooperator's station at Hawley, PA (ca. 20 km N of Lake Lacawac). The monthly mean temperatures (monthly means of daily means) are plotted along with total monthly rainfall for 1993 versus the average of the previous 31 years **(Figure 11)**. The year included both relatively cold (February) and warm months (January, July, August). The summer was slightly warmer and drier than usual. The winter was cold enough for a long ice cover (late December to 10 April), and fairly snowy. A week after the major snowstorm of 14-15 March, we encountered melting snow on top of 44 cm of still-solid ice -- quite a contrast with the poor ice conditions of preceding winters.



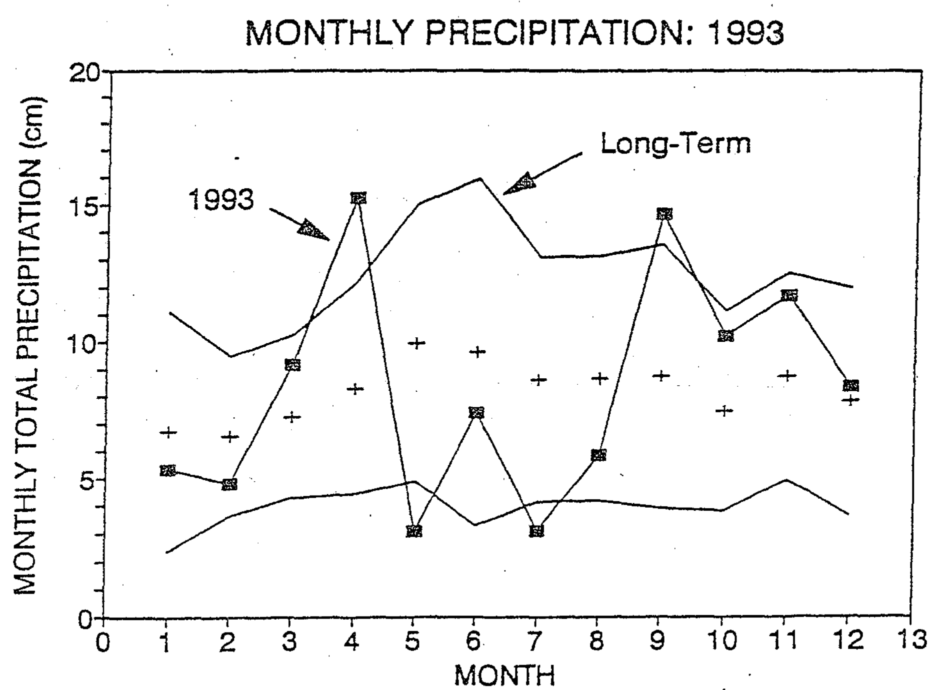


Figure 11. Monthly climate in 1993 compared to the 31-year averages.

(Top) Mean temperature (degrees Celsius). **(Bottom)** Monthly mean precipitation (cm rain or thawed snow). Data are from the NOAA cooperator's station at Hawley, PA. Long-term values (+) are enclosed in an envelope defined by one standard deviation of the monthly values. Data were not reported for July, so values from the Lacawac weather station were substituted. Lacawac values of temperature were adjusted down 0.7°C and precipitation was adjusted up by a factor of 1.32 to match average May, June, and August differences between the stations.

Table 3. Zooplankton species recorded from open-water samples in Lake Lacawac 1988-1993. Seasons of especially high or low abundance in 1993 are indicated.

	Taxon	Seasonal Abundance in 1993 High	Low
Diptera			
**	*Chaoborus punctipennis*	Su	
Cyclopoid Copepoda			
**	*Cyclops scutifer*		[F]
	Eucyclops agilis (rare)		
*	*Mesocyclops edax*		
*	*Microcyclops varicans* (rare)		
*	*Orthocyclops modestus*		
*	*Tropocyclops prasinus*		
Calanoid Copepoda			
	Diaptomus spp.		
**	*D. minutus*		
Cladocera			
	Bosmina sp.		
	Chydorus sp. (rare)		
**	*Daphnia* spp.		[early Sp]
	D. catawba		
*	*Diaphanosoma* sp.	early Su	[F,W,Sp]
**	*Holopedium gibberum*	late Su,F	[W, early Sp]
*	*Leptodora kindtii*		[W, early Sp]
Rotifera			
*	*Ascomorpha* spp.	Su	[late F,W,Sp]
*	*A. ovalis*	Su	[late F,W,Sp]
*	*Asplanchna* sp.	Sp	[F,W]
*	*Collotheca* spp.	late Sp, Su	[F,W]
*	*C. mutabilis*	Su	[F,W,Sp]
*	*Conochilus* spp.	late Sp, early Su	[W,Sp]
	Euchlanis parva (rare)		
	Gastropus spp.		
**	*G. hyptopus*	late Sp	[late F,W]
*	*G. stylifer*		
	Kellicottia sp.		
**	*K. longispina*	late Sp, early Su	[F,W]
**	*K. bostonensis*	late Sp	[F,W]
	Keratella spp.		

Continued next page

Table 3. Zooplankton in Lake Lacawac, 1993 (continued).

	Taxon	Seasonal Abundance in 1993 High	Low
**	*K. cochlearis*	late Sp	[F,W]
**	*K. crassa*	late Sp,Su	[W]
*	*K. hiemalis*	Sp	[Su,F,W]
*	*K. taurocephala*	Sp,Su	[F,W]
	Lecane spp. (rare)		
	L. flexilis		
	L. signifera		
	L. tenuiseta		
	Monommata spp. (rare)		
	Monostyla spp (rare)		
	M. closterocerca		
	M. copeis		
	M. lunaris		
	Notholca spp.		
	N. squamula		
	Notommata spp.		
	Ploesoma spp.		
*	*P. truncatum*	early Su	
**	*Polyarthra* spp.	late Sp, early F	[early Sp]
*	*Synchaeta* spp.	late Sp	[W,Su,F]
	Trichocerca spp.		
*	*T. cylindrica*	late Sp, early Su	[F,W,Sp]
*	*T. multicrinis*		
	T. porcellus		
*	*T. rousseletti*		
*	*T. similis*	early Su	[F,W,Sp]

Abbreviations for seasons of maximal or [minimal] abundance:
W (winter), Sp (spring), Su (summer), F (fall).

** Dominant species included in Figures.
* Other species included in Figures.

EXPLANATION OF DATA TABLES

The following 13 tables present the physical/chemical information acquired on each date in 1993. The headings, abbreviations, and analytical units are explained here.

DATE OF SAMPLE: Date of the daytime visit, as month/day/year.

JULIAN DATE: Day of the year, from 1-365.

TIME: Approximate mid-time of sampling, 24-hr clock in decimal format (e.g. 1:30 PM is "13.50").

SECCHI M: Secchi depth in meters (m).

WEATHER: Brief comments on weather, especially cloudiness.

PERSONNEL: Initials of sampling crew (see names below).

TMETHOD: Temperature method #10 (see **METHODS AND RESULTS**).

LMETHOD: Light methods #12, 13 (see **METHODS AND RESULTS**).

AMETHOD: Alkalinity method #11 (see **METHODS AND RESULTS**).

OMETHOD: Oxygen method #10 (see **METHODS AND RESULTS**).

PHMETHOD: pH method #12 (see **METHODS AND RESULTS**).

CAMETHOD: Chlorophyll-a methods #12, 13 (see **METHODS AND RESULTS**).

COMMENTS: Notes on unusual procedures, also ice thickness.

DATE OF: Date of sample (month/day/year).

JULIAN: Julian date.

STRA: Stratum or layer: **S** (air above surface), **E** (epilimnion), **M**(metalimnion), **H** (hypolimnion).

REP: Replicate (1 or 2); Replicates were usually analyzed for pH, alkalinity, chlorophyll--other data are merely repeated on rep 2 line for convenience in graphing.

DEPTH: Depth of sample (meters); **-1** for air above surface.

TEMP C: Temperature in degrees Celsius (°C).

OXYGEN: Dissolved oxygen (mg per liter--not corrected for elevation).

OFLAG: Error flag for oxygen; "4" means equals 0.0

LIGHT PC:	Light as percent of intensity at 0.1-m depth.
pH:	pH.
ALKAL:	Alkalinity as microequivalents per liter (μeq/L).
CHLAC:	Chlorophyll-a, corrected for pheopigments (μg/L).
CHLASUM:	Chlorophyll-a, including pheopigments (μg/L).
CHLAC P:	Percentage of CHLAC passing 22-μm net.

Names of Sampling Personnel:

EMB (EMN)	Gina Brockway (Novak)
LG	Lauren Graves
TM	Tom Murphy
BKS	Brian Sharer
PLS	Paul Stutzman
TLV	Tim Vail
YZ	Yin Zhong

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 1/21/93 JULIAN DATE: 21 TIME: 11.33

SECCHI M: 5.6 WEATHER: overcast, windy (S)

PERSONNEL: TLV EMN

TMETHOD: 10 LMETHOD: 12 AMETHOD: 11
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 12

COMMENTS: 20 cm ice

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
1/21/93	21	S	1	-1.0	2.1								
1/21/93	21		1	0.0	2.9	14.35		100.0000					
1/21/93	21	E	1	1.0	3.9	11.58		22.9253	6.15	38	2.55	2.67	
1/21/93	21	E	2	1.0	3.9	11.58		22.9253	6.12	38	2.16	2.37	29.10
1/21/93	21		1	2.0	4.0	11.22		9.4226					
1/21/93	21		1	3.0	4.0	11.18		4.2178					
1/21/93	21	M	1	4.0	3.9	10.48		2.0123	6.12	39	4.29	4.29	
1/21/93	21	M	2	4.0	3.9	10.48		2.0123	6.03	38	3.43	3.83	32.50
1/21/93	21		1	5.0	3.9	10.26		0.9717					
1/21/93	21		1	6.0	4.0	9.90		0.4620					
1/21/93	21		1	7.0	4.0	9.55		0.2221					
1/21/93	21		1	8.0	3.9	9.20		0.1038					
1/21/93	21		1	9.0	3.9	8.21		0.0463					
1/21/93	21	H	1	10.0	3.9	7.00		0.0191	5.77	42	1.39	2.94	
1/21/93	21	H	2	10.0	3.9	7.00		0.0191	5.83	39	1.14	1.93	48.30
1/21/93	21		1	11.0	4.0	6.25		0.0073					
1/21/93	21		1	12.0	4.2	4.02							
1/21/93	21		1	13.0	4.6	0.12	4						

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 2/19/93 JULIAN DATE: 50 TIME: 12.17

SECCHI M: 2.5 WEATHER: sunny

PERSONNEL: EMN, TLV, BKS

TMETHOD: 10 LMETHOD: 12 AMETHOD: 11
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 12

COMMENTS: 30cm ice, 6cm snow

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
2/19/93	50	S	1	-1.0									
2/19/93	50		1	0.0	1.2	13.96		100.0000					
2/19/93	50	E	1	1.0	3.8	11.59		2.2989	6.03	40	27.70	27.70	
2/19/93	50	E	2	1.0	3.8	11.59		2.2989	6.02	41	27.99	28.32	3.30
2/19/93	50		1	2.0	3.9	11.18		0.5709					
2/19/93	50		1	3.0	3.9	11.20		0.1558					
2/19/93	50	M	1	4.0	3.9	11.16		0.0500	6.06	40	24.40	24.40	
2/19/93	50	M	2	4.0	3.9	11.16		0.0500	6.03	39	20.91	21.31	4.00
2/19/93	50		1	5.0	3.9	11.17		0.0181					
2/19/93	50		1	6.0	3.9	11.13		0.0067					
2/19/93	50		1	7.0	3.9	11.12		0.0023					
2/19/93	50		1	8.0	3.9	11.13		0.0006					
2/19/93	50		1	9.0	3.9	11.00							
2/19/93	50	H	1	10.0	4.1	5.99			5.83	44	6.68	8.08	
2/19/93	50	H	2	10.0	4.1	5.99			5.76	46	7.17	7.74	5.30
2/19/93	50		1	11.0	4.2	4.19							
2/19/93	50		1	12.0	4.5	0.63							
2/19/93	50		1	13.0									

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 3/23/93 JULIAN DATE: 82 TIME: 13.00

SECCHI M: 3.2 WEATHER: overcast, 5-10mph breeze (SE)

PERSONNEL: TLV BKS

TMETHOD: 10 LMETHOD: 12 AMETHOD: 11
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 12

COMMENTS: 44cm snow covered ice

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
3/23/93	82	S	1	-1.0	5.8		4						
3/23/93	82		1	0.0	0.9	14.79		100.0000					
3/23/93	82	E	1	1.0	3.7	11.19		7.1839	6.05	44	43.78	43.78	
3/23/93	82	E	2	1.0	3.7	11.19		7.1839	6.01	42	42.44	43.03	3.20
3/23/93	82		1	2.0	3.8	11.08		1.1333					
3/23/93	82		1	3.0	3.8	11.01		0.3394					
3/23/93	82	M	1	4.0	3.8	11.01		0.1247	5.97	42	19.08	19.08	
3/23/93	82	M	2	4.0	3.8	11.01		0.1247	5.99	40	18.98	19.33	9.40
3/23/93	82		1	5.0	3.8	11.02		0.0468					
3/23/93	82		1	6.0	3.8	11.01		0.0093					
3/23/93	82		1	7.0	3.8	10.98		0.0040					
3/23/93	82		1	8.0	3.8	10.95		0.0003					
3/23/93	82	H	1	9.0	3.9	9.31		0.0001	5.91	45	7.68	7.93	
3/23/93	82	H	2	9.0	3.9	9.31		0.0001	5.92	41	4.16	4.79	8.70
3/23/93	82		1	10.0	4.2	3.08							
3/23/93	82		1	11.0	4.4	2.41							
3/23/93	82		1	12.0	4.5	0.23	4						
3/23/93	82		1	13.0									

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 4/20/93 JULIAN DATE: 110 TIME: 11.17

SECCHI M: 4.8 WEATHER: sunny, windy (S)

PERSONNEL: EMN TLV

TMETHOD: 10 LMETHOD: 12 AMETHOD: 11
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 12

COMMENTS: ice went out on 10 April (Sally Jones)

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
4/20/93	110	S	1	-1.0	17.5								
4/20/93	110		1	0.0	8.4	13.80		100.0000					
4/20/93	110		1	1.0	8.3	13.52		23.0734					
4/20/93	110	E	1	2.0	8.0	13.41		8.7234	6.24	29	3.94	4.42	
4/20/93	110	E	2	2.0	8.0	13.41		8.7234	6.21	30	3.17	3.57	24.90
4/20/93	110		1	3.0	7.4	13.34		4.1441					
4/20/93	110		1	4.0	7.2	13.29		1.8534					
4/20/93	110		1	5.0	6.9	13.16		0.6882					
4/20/93	110	M	1	6.0	6.3	12.99		0.2752	6.12	29	1.76	1.87	
4/20/93	110	M	2	6.0	6.3	12.99		0.2752	6.11	31	5.64	6.03	10.30
4/20/93	110		1	7.0	5.8	12.84		0.1031					
4/20/93	110		1	8.0	5.5	12.46		0.0415					
4/20/93	110		1	9.0	5.2	12.15		0.0151					
4/20/93	110	H	1	10.0	4.9	11.91		0.0054	5.93	33	4.49	5.19	
4/20/93	110	H	2	10.0	4.9	11.91		0.0054	5.91	32	9.03	9.32	6.60
4/20/93	110		1	11.0	4.7	11.52		0.0016					
4/20/93	110		1	12.0	4.7	11.40		0.0004					
4/20/93	110		1	13.0	4.7	10.56							

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 5/13/93 JULIAN DATE: 133 TIME: 12.50

SECCHI M: 4.6 WEATHER: mostly cloudy, windy (N)

PERSONNEL: EMB TLV

TMETHOD: 10 LMETHOD: 12 AMETHOD: 11
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 12

COMMENTS: secchi depth measured without box

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
5/13/93	133	S	1	-1.0	14.5								
5/13/93	133		1	0.0	19.3	9.21		100.0000					
5/13/93	133	E	1	1.0	19.4	8.58		31.1818	6.30	35	1.81	1.81	
5/13/93	133	E	2	1.0	19.4	8.58		31.1818	6.31	36	1.39	1.50	74.80
5/13/93	133		1	2.0	19.4	8.55		12.5128					
5/13/93	133		1	3.0	12.7	11.36		5.6850					
5/13/93	133	M	1	4.0	10.2	11.02		2.7611	6.26	35	4.97	5.19	
5/13/93	133	M	2	4.0	10.2	11.02		2.7611	6.24	36	2.52	2.94	73.80
5/13/93	133		1	5.0	9.3	11.26		1.2206					
5/13/93	133		1	6.0	8.2	10.06		0.5363					
5/13/93	133		1	7.0	7.6	9.39		0.2470					
5/13/93	133		1	8.0	7.3	8.67		0.1127					
5/13/93	133	H	1	9.0	6.8	6.78		0.0468	5.78	42	1.60	2.60	
5/13/93	133	H	2	9.0	6.8	6.78		0.0468	5.81	42	5.05	6.77	96.40
5/13/93	133		1	10.0	6.6	5.24		0.0155					
5/13/93	133		1	11.0	6.6	5.27		0.0049					
5/13/93	133		1	12.0	6.5	4.38		0.0017					
5/13/93	133		1	13.0	6.4	3.84		0.0003					

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 6/09/93 JULIAN DATE: 160 TIME: 16.58

SECCHI M: 4.0 WEATHER: sunny at 16 hr but partly cloudy at 13 hr for light

PERSONNEL: EMB TLV TM YZ

TMETHOD: 10 LMETHOD: 12 AMETHOD: 11
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 13

COMMENTS: light meter sensors gave ratio of 1.11 in air (should be 1.00)

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
6/09/93	160	S	1	-1.0	23.2								
6/09/93	160		1	0.0	20.8	9.15		100.0000					
6/09/93	160		1	1.0	20.2	9.13		21.9587					
6/09/93	160	E	1	2.0	17.7	9.62		7.7102	6.50	37	1.80	7.70	
6/09/93	160	E	2	2.0	17.7	9.62		7.7102	6.50	32			
6/09/93	160		1	3.0	17.3	9.67		3.1215					
6/09/93	160		1	4.0	15.4	9.87		1.4306					
6/09/93	160	M	1	5.0	11.4	10.29		0.6398	6.26	40	4.70	13.10	
6/09/93	160	M	2	5.0	11.4	10.29		0.6398	6.22	37			
6/09/93	160		1	6.0	8.8	8.39		0.3146					
6/09/93	160		1	7.0	7.7	6.53		0.1537					
6/09/93	160		1	8.0	7.2	4.69		0.0719					
6/09/93	160		1	9.0	6.9	3.48		0.0209					
6/09/93	160	H	1	10.0	6.7	2.23		0.0045	5.80	76	0.90	5.30	
6/09/93	160	H	2	10.0	6.7	2.23		0.0045	5.78	74			
6/09/93	160		1	11.0	6.6	1.48		0.0009					
6/09/93	160		1	12.0	6.6	0.88							
6/09/93	160		1	13.0	6.5	0.81							

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 6/22/93 JULIAN DATE: 173 TIME: 17.75

SECCHI M: 4.3 WEATHER: sunny, windy gusts to 25mph

PERSONNEL: TLV LG

TMETHOD: 10 LMETHOD: 12 AMETHOD:
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 13

COMMENTS:

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
6/22/93	173	S	1	-1.0	24.5		4						
6/22/93	173		1	0.0	24.4	8.39		100.0000					
6/22/93	173		1	1.0	24.4	8.38		30.2939					
6/22/93	173	E	1	2.0	24.3	8.34		13.2693	6.38		3.20	3.70	
6/22/93	173	E	2	2.0	24.3	8.34		13.2693	6.40				
6/22/93	173		1	3.0	21.1	9.57		6.0896					
6/22/93	173		1	4.0	15.9	11.30		1.9326					
6/22/93	173	M	1	5.0	12.3	11.75		0.7150	6.46		26.60	29.90	
6/22/93	173	M	2	5.0	12.3	11.75		0.7150	6.46				
6/22/93	173		1	6.0	9.3	8.42		0.3087					
6/22/93	173		1	7.0	8.1	5.54		0.1270					
6/22/93	173		1	8.0	7.4	3.08		0.0418					
6/22/93	173	H	1	9.0	7.0	1.30		0.0086	5.91		3.00	3.00	
6/22/93	173	H	2	9.0	7.0	1.30		0.0086	5.83				
6/22/93	173		1	10.0	6.7	0.20	4	0.0018					
6/22/93	173		1	11.0	6.6	0.17	4						
6/22/93	173		1	12.0	6.6	0.16	4						
6/22/93	173		1	13.0									

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 7/06/93 JULIAN DATE: 187 TIME: 17.33

SECCHI M: 3.8 WEATHER: sunny (hazy)

PERSONNEL: EMB TLV

TMETHOD: 10 LMETHOD: 12 AMETHOD: 11
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 12

COMMENTS: rep 2 CHLA by method 13

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
7/06/93	187	S	1	-1.0	27.2		4						
7/06/93	187		1	0.0	26.5	9.19		100.0000					
7/06/93	187		1	1.0	26.5	9.08		35.9195					
7/06/93	187	E	1	2.0	24.7	9.36		14.7151	6.66	38	3.78	3.78	83.30
7/06/93	187	E	2	2.0	24.7	9.36		14.7151	6.64	35	3.60	4.50	
7/06/93	187		1	3.0	23.4	9.63		6.3345					
7/06/93	187		1	4.0	18.6	11.43		2.7625					
7/06/93	187	M	1	5.0	13.5	13.26		1.2090	6.67	33	5.64	5.64	52.80
7/06/93	187	M	2	5.0	13.5	13.26		1.2090	6.41	37	3.60	4.60	
7/06/93	187		1	6.0	9.8	9.41		0.4969					
7/06/93	187		1	7.0	8.5	6.20		0.2084					
7/06/93	187		1	8.0	7.5	2.56		0.0744					
7/06/93	187		1	9.0	7.0	1.28		0.0212					
7/06/93	187	H	1	10.0	6.8	1.24		0.0056	6.19	183	0.00	10.89	0.00
7/06/93	187	H	2	10.0	6.8	1.24		0.0056	6.22	181	3.40	11.90	
7/06/93	187		1	11.0	6.7	1.21							
7/06/93	187		1	12.0	6.6	1.18							
7/06/93	187		1	13.0	6.6	0.28	4						

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 7/20/93 JULIAN DATE: 201 TIME: 17.17

SECCHI M: 3.9 WEATHER: mostly sunny, windy

PERSONNEL: EMB TLV

TMETHOD: 10 LMETHOD: 12 AMETHOD:
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 13

COMMENTS:

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
7/20/93	201	S	1	-1.0	28.9		4						
7/20/93	201		1	0.0	24.7	8.15		100.0000					
7/20/93	201		1	1.0	24.8	8.10		34.5781					
7/20/93	201	E	1	2.0	24.5	8.14		11.8337	6.56		2.00	4.30	
7/20/93	201	E	2	2.0	24.5	8.14		11.8337	6.52				
7/20/93	201		1	3.0	23.5	7.96		5.2454					
7/20/93	201		1	4.0	21.8	8.72		1.7982					
7/20/93	201	M	1	5.0	14.6	11.78		0.7527	6.36		3.70	9.00	
7/20/93	201	M	2	5.0	14.6	11.78		0.7527	6.34				
7/20/93	201		1	6.0	10.8	7.46		0.3654					
7/20/93	201		1	7.0	8.5	3.12		0.1496					
7/20/93	201		1	8.0	7.5	0.22	4	0.0478					
7/20/93	201		1	9.0	7.0	0.20	4	0.0148					
7/20/93	201	H	1	10.0	6.8	0.19	4	0.0037	6.23		2.70	15.10	
7/20/93	201	H	2	10.0	6.8	0.19	4	0.0037	6.20				
7/20/93	201		1	11.0	6.7	0.18	4	0.0009					
7/20/93	201		1	12.0	6.7	0.20	4						
7/20/93	201		1	13.0	6.7	0.18	4						

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 8/03/93 JULIAN DATE: 215 TIME: 10.25

SECCHI M: 5.8 WEATHER: sunny

PERSONNEL: EMB TLV

TMETHOD: 10 LMETHOD: 12 AMETHOD: 11
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 13

COMMENTS:

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
8/03/93	215	S	1	-1.0	24.3		4						
8/03/93	215		1	0.0	24.2	7.95		100.0000					
8/03/93	215		1	1.0	24.1	7.86		43.5350					
8/03/93	215	E	1	2.0	23.9	7.78		15.4874	6.50	36	5.10	7.00	
8/03/93	215	E	2	2.0	23.9	7.78		15.4874	6.43	39			
8/03/93	215		1	3.0	23.8	7.42		6.2855					
8/03/93	215		1	4.0	22.1	6.83		2.8753					
8/03/93	215		1	5.0	15.4	8.36		1.4625					
8/03/93	215	M	1	6.0	11.6	3.40		0.5962	5.94	42	2.10	4.20	
8/03/93	215	M	2	6.0	11.6	3.40		0.5962	5.96	43			
8/03/93	215		1	7.0	9.3	2.52		0.2459					
8/03/93	215		1	8.0	8.2	0.24	4	0.0911					
8/03/93	215		1	9.0	7.5	0.20	4	0.0266					
8/03/93	215	H	1	10.0	7.1	0.19	4	0.0055	6.11	175	10.20	23.10	
8/03/93	215	H	2	10.0	7.1	0.19	4	0.0055	6.12	178			
8/03/93	215		1	11.0	6.9	0.18	4	0.0012					
8/03/93	215		1	12.0	6.9	0.18	4						
8/03/93	215		1	13.0	6.9	0.16	4						

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 8/18/93 JULIAN DATE: 230 TIME: 12.67

SECCHI M: 6.4 WEATHER: mostly cloudy

PERSONNEL: EMB TLV

TMETHOD: 10 LMETHOD: 12 AMETHOD:
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 13

COMMENTS: a freshwater jellyfish collected at surface 8/28/93

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
8/18/93	230	S	1	-1.0	23.6		4						
8/18/93	230		1	0.0	23.0	7.91		100.0000					
8/18/93	230		1	1.0	22.9	7.74		32.6904					
8/18/93	230	E	1	2.0	22.7	7.62		14.3003	6.43		4.20	5.90	
8/18/93	230	E	2	2.0	22.7	7.62		14.3003	6.43				
8/18/93	230		1	3.0	22.7	7.57		7.2333					
8/18/93	230		1	4.0	21.9	6.71		3.9526					
8/18/93	230		1	5.0	17.2	6.33		2.0781					
8/18/93	230	M	1	6.0	12.3	4.30		0.9199	5.92		2.70	3.70	
8/18/93	230	M	2	6.0	12.3	4.30		0.9199	5.91				
8/18/93	230		1	7.0	9.4	0.54	4	0.3499					
8/18/93	230		1	8.0	8.1	0.32	4	0.1270					
8/18/93	230		1	9.0	7.5	0.31	4	0.0232					
8/18/93	230	H	1	10.0	7.2	0.28	4	0.0034	6.33		12.60	15.50	
8/18/93	230	H	2	10.0	7.2	0.28	4	0.0034	6.29				
8/18/93	230		1	11.0	7.1	0.28	4						
8/18/93	230		1	12.0	7.0	0.27	4						
8/18/93	230		1	13.0									

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 9/28/93 JULIAN DATE: 271 TIME: 17.08

SECCHI M: 6.0 WEATHER: windy, cloudy

PERSONNEL: EMB YZ

TMETHOD: 10 LMETHOD: 12 AMETHOD: 11
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 13

COMMENTS: too late to do light profile

DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
9/28/93	271	S	1	-1.0	14.5		4						
9/28/93	271		1	0.0	16.4	8.03							
9/28/93	271		1	1.0	16.4	8.05							
9/28/93	271		1	2.0	16.4	8.24							
9/28/93	271	E	1	3.0	16.4	8.39			6.23	38	2.40	3.70	
9/28/93	271	E	2	3.0	16.4	8.39			6.27	35			
9/28/93	271		1	4.0	16.4	8.56							
9/28/93	271		1	5.0	16.1	8.40							
9/28/93	271		1	6.0	15.8	7.85							
9/28/93	271	M	1	7.0	13.0	2.14			5.97	50	0.80	4.20	
9/28/93	271	M	2	7.0	13.0	2.14			5.94	54			
9/28/93	271		1	8.0	9.0	1.03							
9/28/93	271		1	9.0	7.7	0.95	4						
9/28/93	271		1	10.0	7.4	0.93	4						
9/28/93	271	H	1	11.0	7.3	0.88	4		6.41	376	26.00	53.60	
9/28/93	271	H	2	11.0	7.3	0.88	4		6.39	371			
9/28/93	271		1	12.0	7.2	0.76	4						
9/28/93	271		1	13.0	7.2	0.67	4						

LAKE LACAWAC: SUMMARY OF PHYSICAL/CHEMICAL DATA FOR 1993

DATE OF SAMPLE: 11/16/93 JULIAN DATE: 320 TIME: 15.00

SECCHI M: 5.5 WEATHER: Sunny

PERSONNEL: EMB PLS

TMETHOD: 10 LMETHOD: 13 AMETHOD: 11
OMETHOD: 10 PHMETHOD: 12 CAMETHOD: 13

COMMENTS: Light collected with PUV500

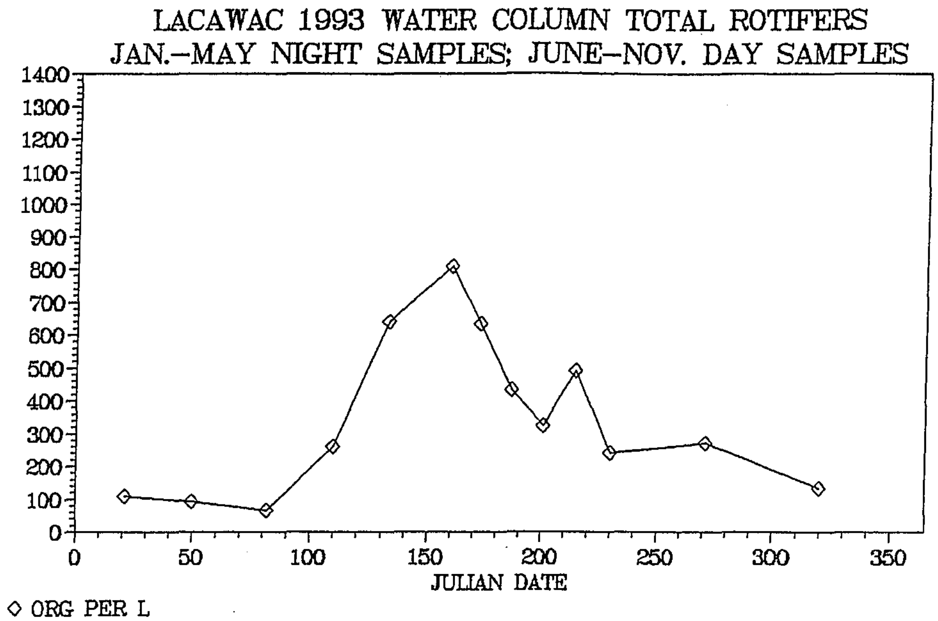
DATE OF	JULIAN	STRA	REP	DEPTH	TEMP C	OXYGEN	OFLAG	LIGHT PC	PH	ALKAL	CHLAC U	CHLASUM	CHLAC P
11/16/93	320	S	1	-1.0	9.1								
11/16/93	320		1	0.0	8.1	10.88		100.0000					
11/16/93	320		1	1.0	8.1	10.80		36.8000					
11/16/93	320	E	1	2.0	7.9	10.89		15.0100	6.34	45	2.00	2.30	
11/16/93	320	E	2	2.0	7.9	10.89		15.0100	6.33	50			
11/16/93	320		1	3.0	7.6	10.85		7.6600					
11/16/93	320		1	4.0	7.3	12.38		3.8300					
11/16/93	320		1	5.0	7.0	12.03		2.2100					
11/16/93	320	M	1	6.0	6.7	11.58		1.1800	6.23	49	1.00	1.70	
11/16/93	320	M	2	6.0	6.7	11.58		1.1800	6.24	49			
11/16/93	320		1	7.0	6.4	11.37		0.6470					
11/16/93	320		1	8.0	6.2	10.56		0.3830					
11/16/93	320		1	9.0	6.2	10.19		0.2360					
11/16/93	320	H	1	10.0	6.2	9.90		0.1480	6.19	49	0.90	1.50	
11/16/93	320	H	2	10.0	6.2	9.90		0.1480	6.22	47			
11/16/93	320		1	11.0	6.2	9.69		0.0960					
11/16/93	320		1	12.0	6.2	9.60		0.0710					
11/16/93	320		1	13.0	6.2	6.64							

ZOOPLANKTON GRAPHS

The following graphs present water-column mean concentrations of the common zooplankton at the main sampling station. Each data point is calculated by weighting concentrations in the three layers (EPI, META, HYPO) on each date by the relative thickness of the layer at the station, which is in the deepest part of the lake. Two replicate samples were taken in quick succession.

Data from January through May are from nighttime sampling (as in previous Annual Reports). Starting in June only daytime sampling was performed.

The electronic database contains the component concentrations within the three layers, separate counts for the two replicates, and similarly complete data from the comparable daytime sampling for the January--May dates.



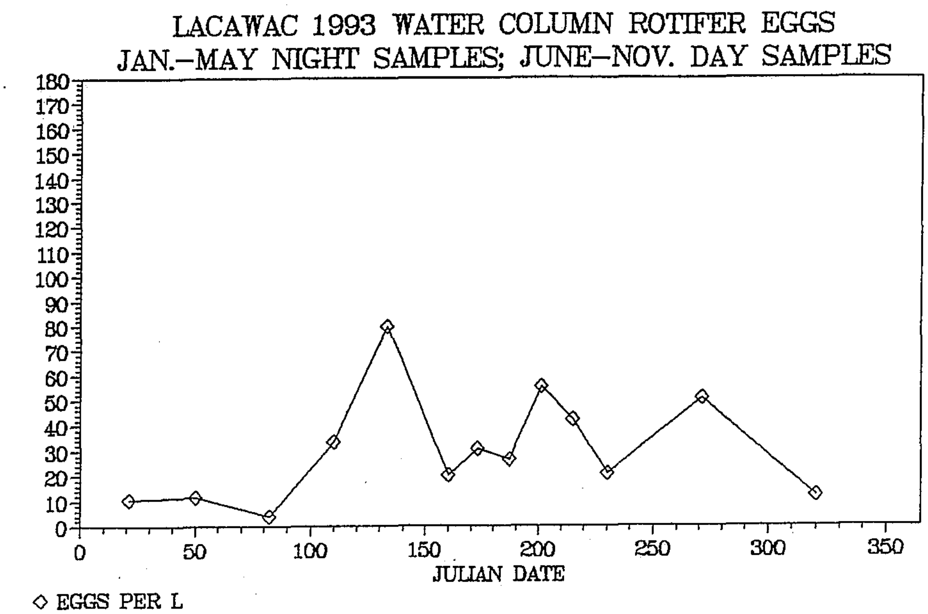
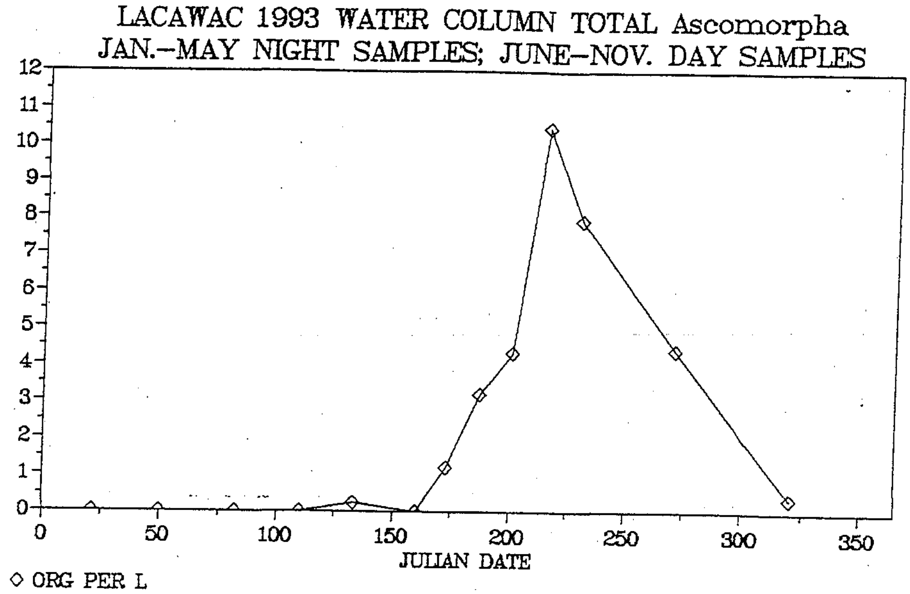


Figure 12. Rotifers in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean. **(Top)** Total individuals per litre. **(Bottom)** Rotifer eggs per litre.



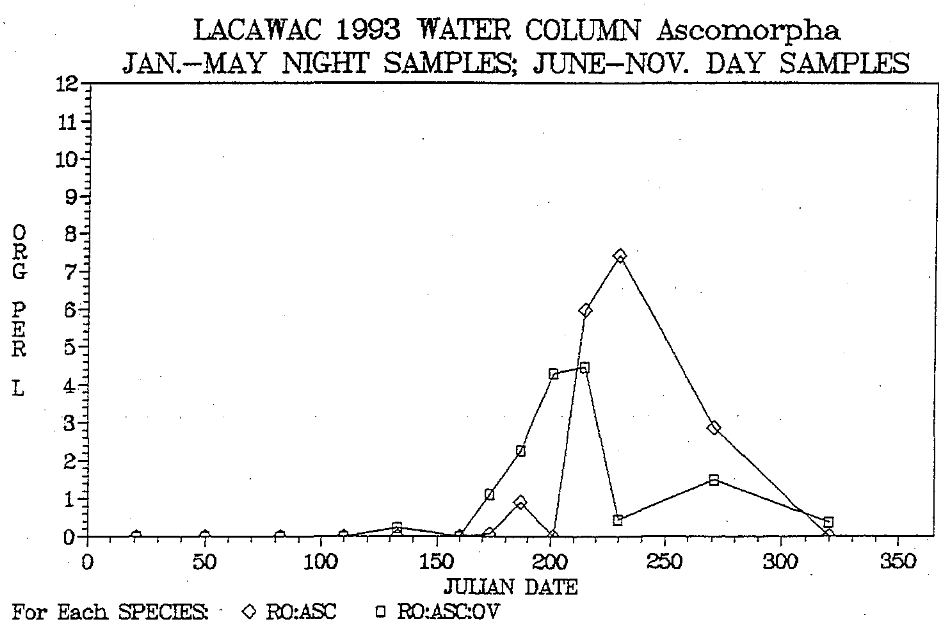


Figure 13. The rotifer *Ascomorpha* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean. **(Top)** Total individuals of all species per litre. **(Bottom)** *Ascomorpha* by species: **ASC** undifferentiated species, **OV** *A. ovalis*.

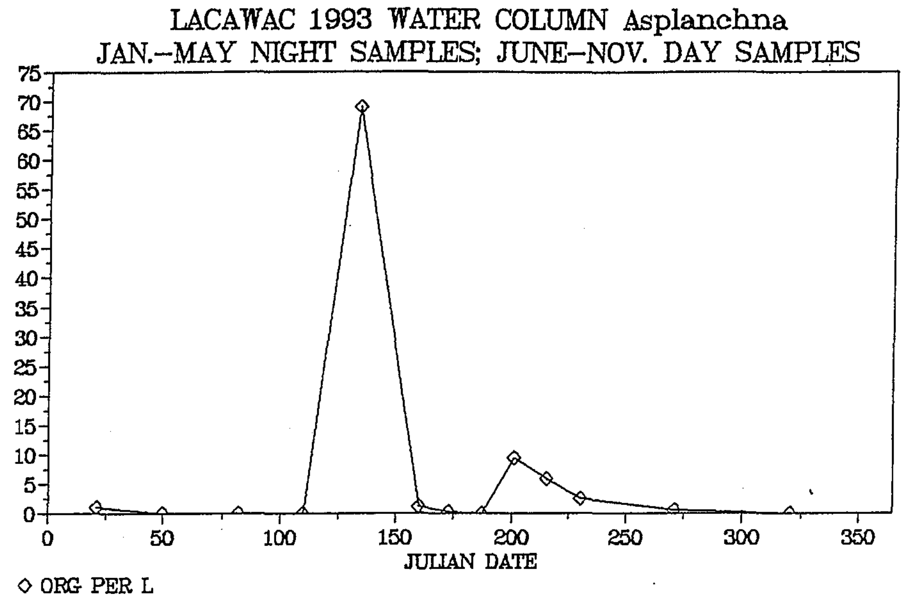
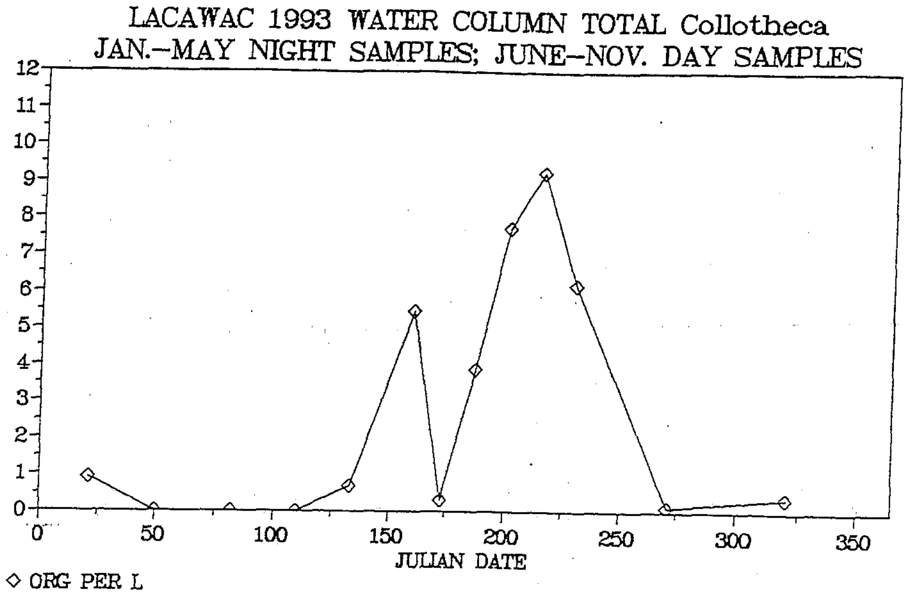


Figure 14. The rotifer *Asplanchna* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean.



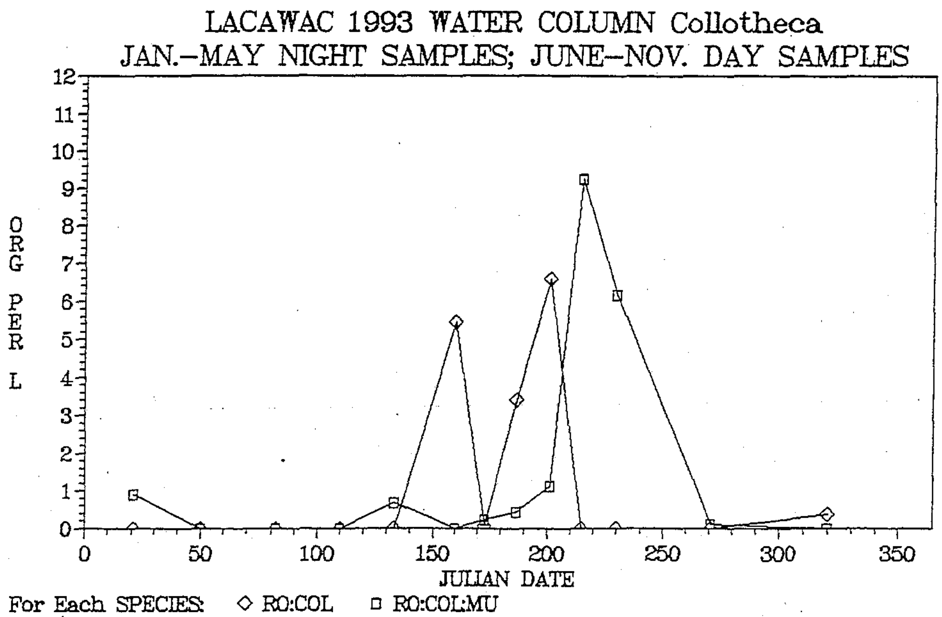
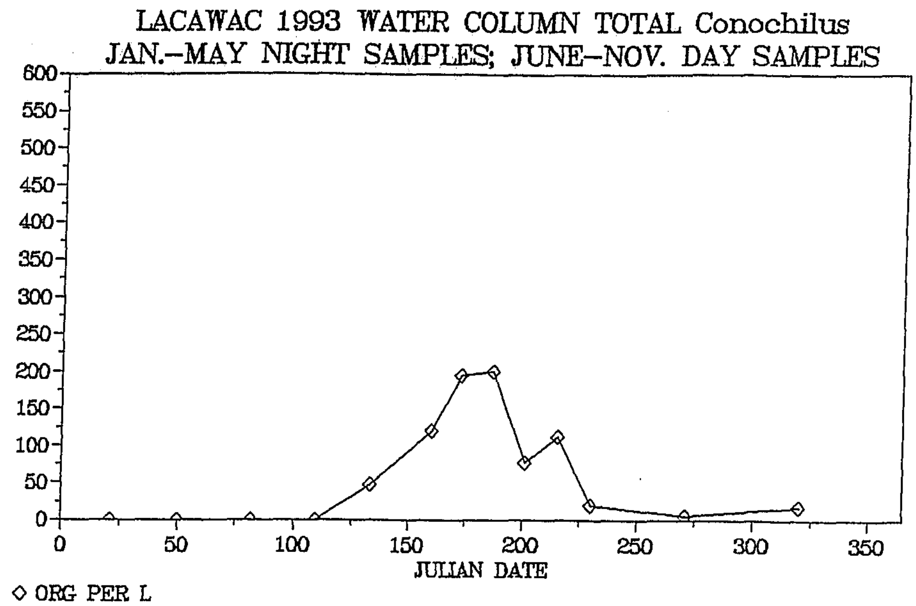


Figure 15. The rotifer *Collotheca* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean. **(Top)** Total individuals of all species per litre. **(Bottom)** *Collotheca* by species: **COL** undifferentiated species, **MU** *C. mutabilis*.



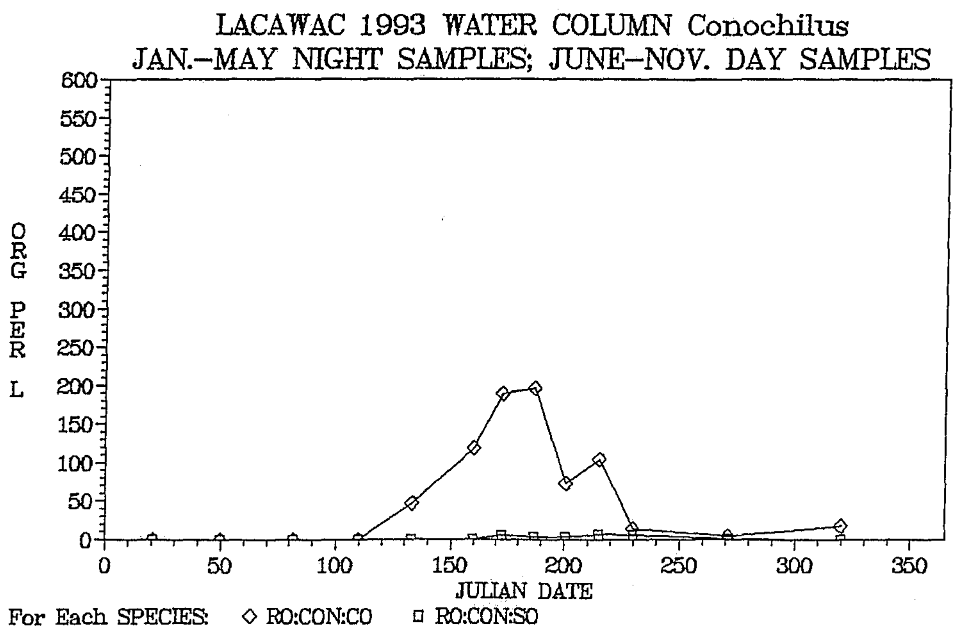
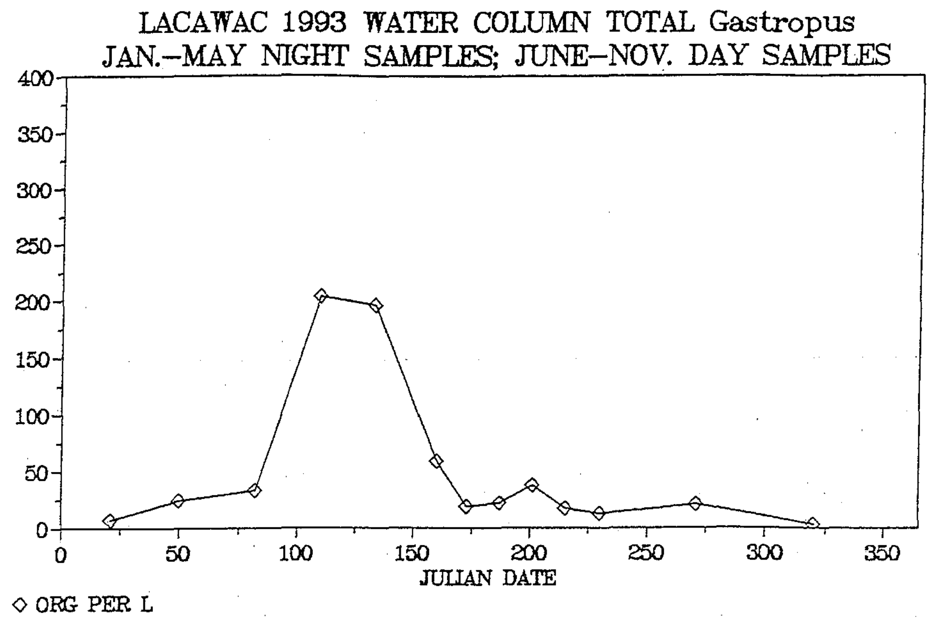


Figure 16. The rotifer *Conochilus* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean. **(Top)** Total individuals of all species per litre. **(Bottom)** *Conochilus* by species: **CO** colonial spp., **SO** solitary spp..



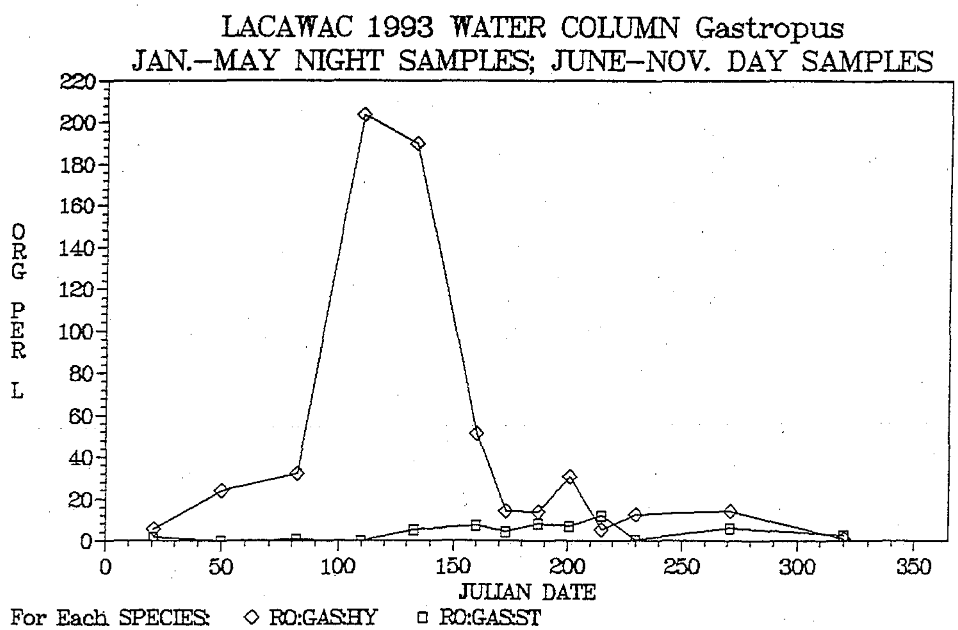
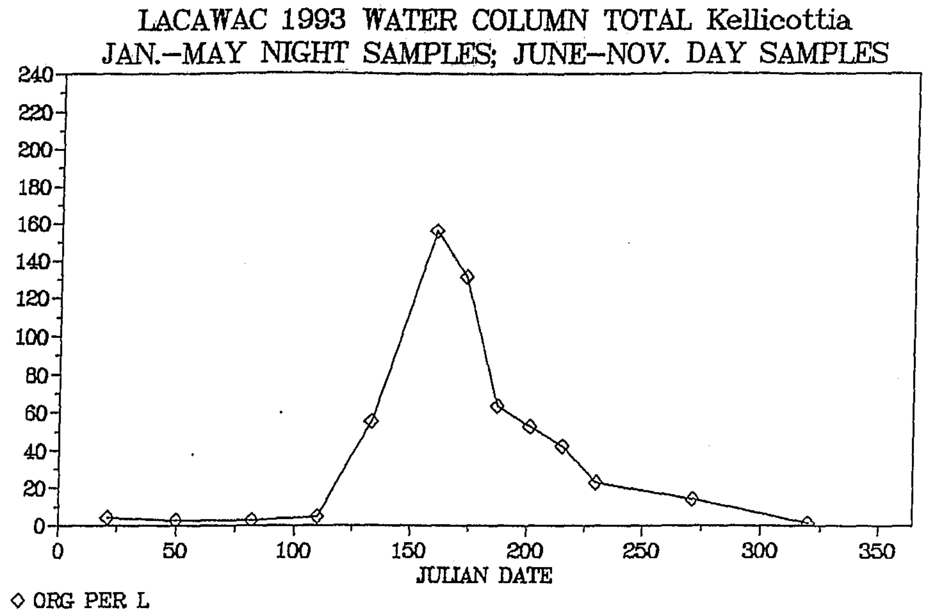


Figure 17. The rotifer *Gastropus* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean. **(Top)** Total individuals of all species per litre. **(Bottom)** *Gastropus* by species: **HY** *G. hyptopus*, **ST** *G. stylifer*.



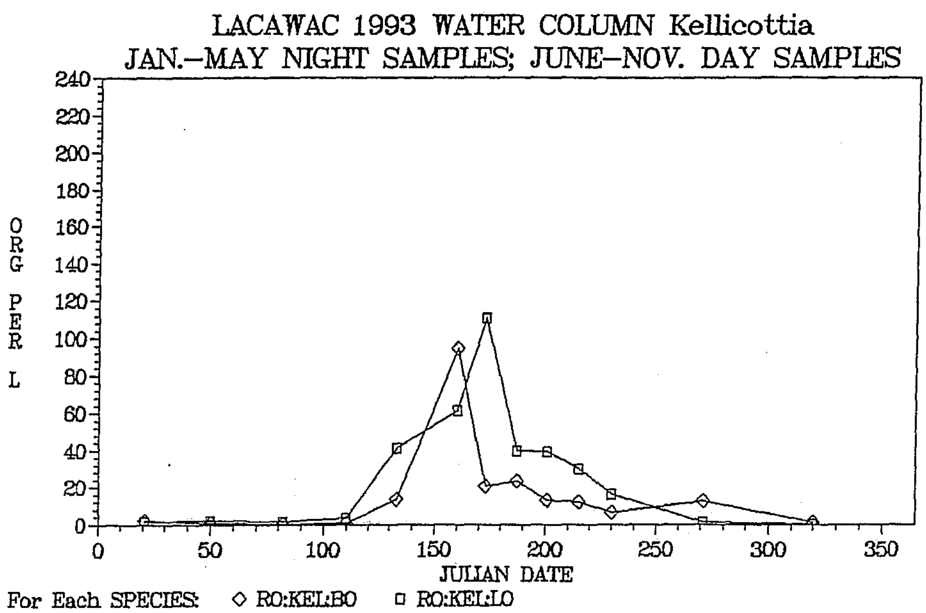
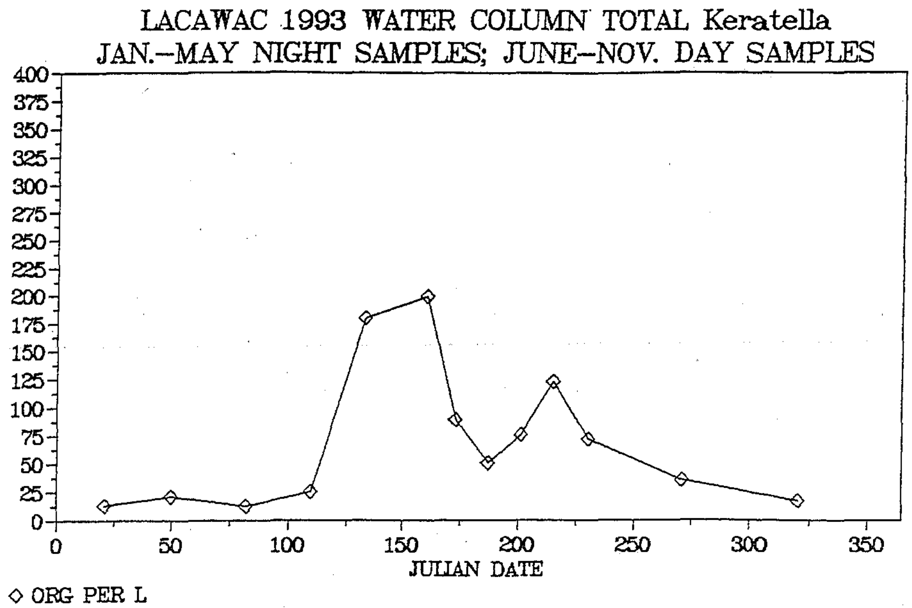


Figure 18. The rotifer *Kellicottia* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean. **(Top)** Total individuals per litre. **(Bottom)** *Kellicottia* by species: **BO** *K. bostoniensis* and **LO** *K. longispina*.



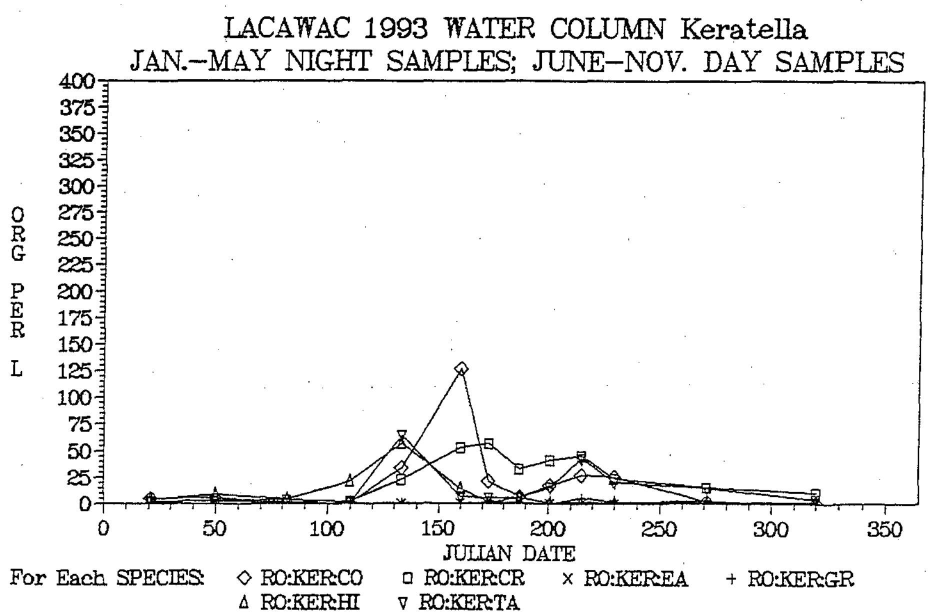


Figure 19. The rotifer *Keratella* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean. **(Top)** Total individuals per litre. **(Bottom)** *Keratella* by species: **CO** *K. cochlearis*, **CR** *K. crassa*, **EA** *K. earlinae*, **GR** *K. gracilenta*, **HI** *K. hiemalis*, and **TA** *K. taurocephala*.

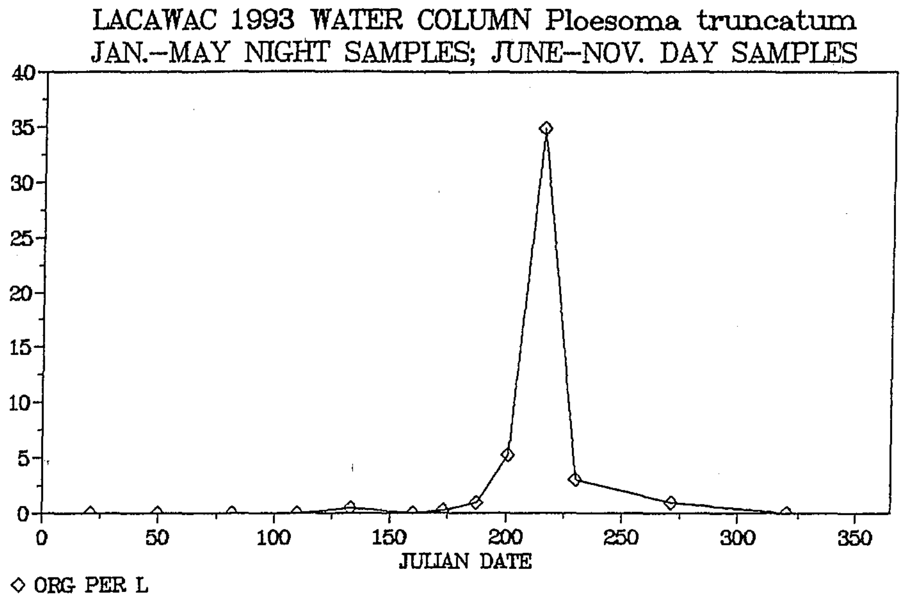


Figure 20. The rotifer *Ploesoma* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean.

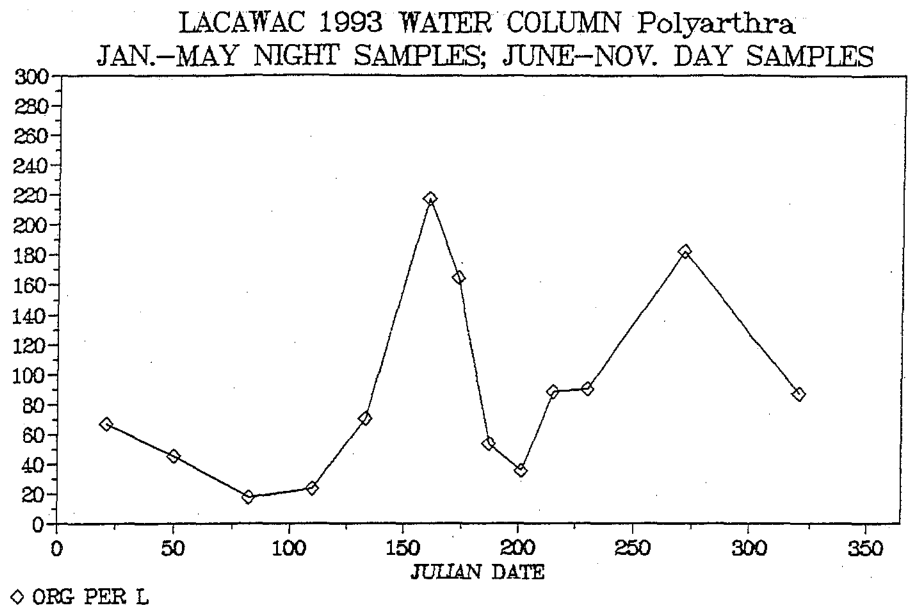


Figure 21. The rotifer *Polyarthra* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean.

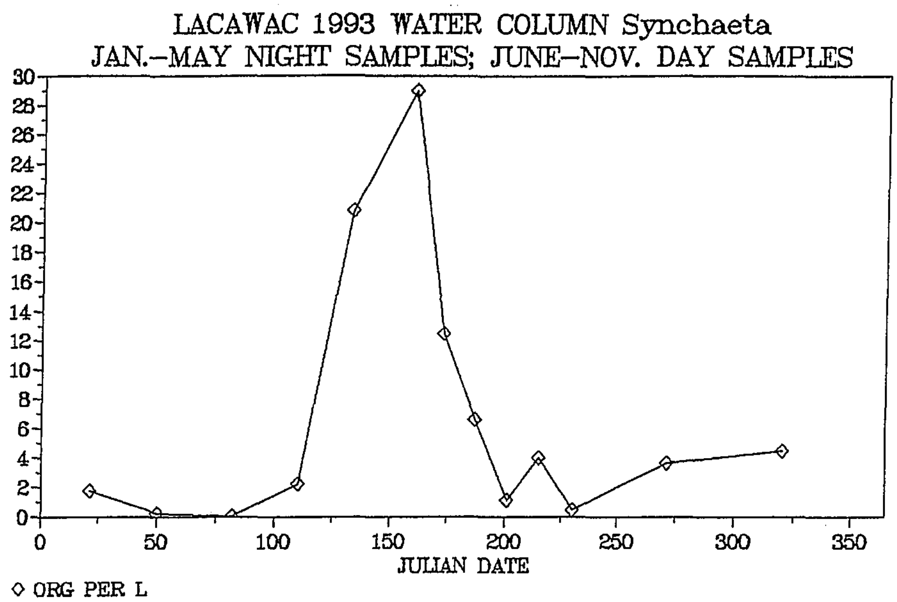


Figure 22. The rotifer *Synchaeta* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean.

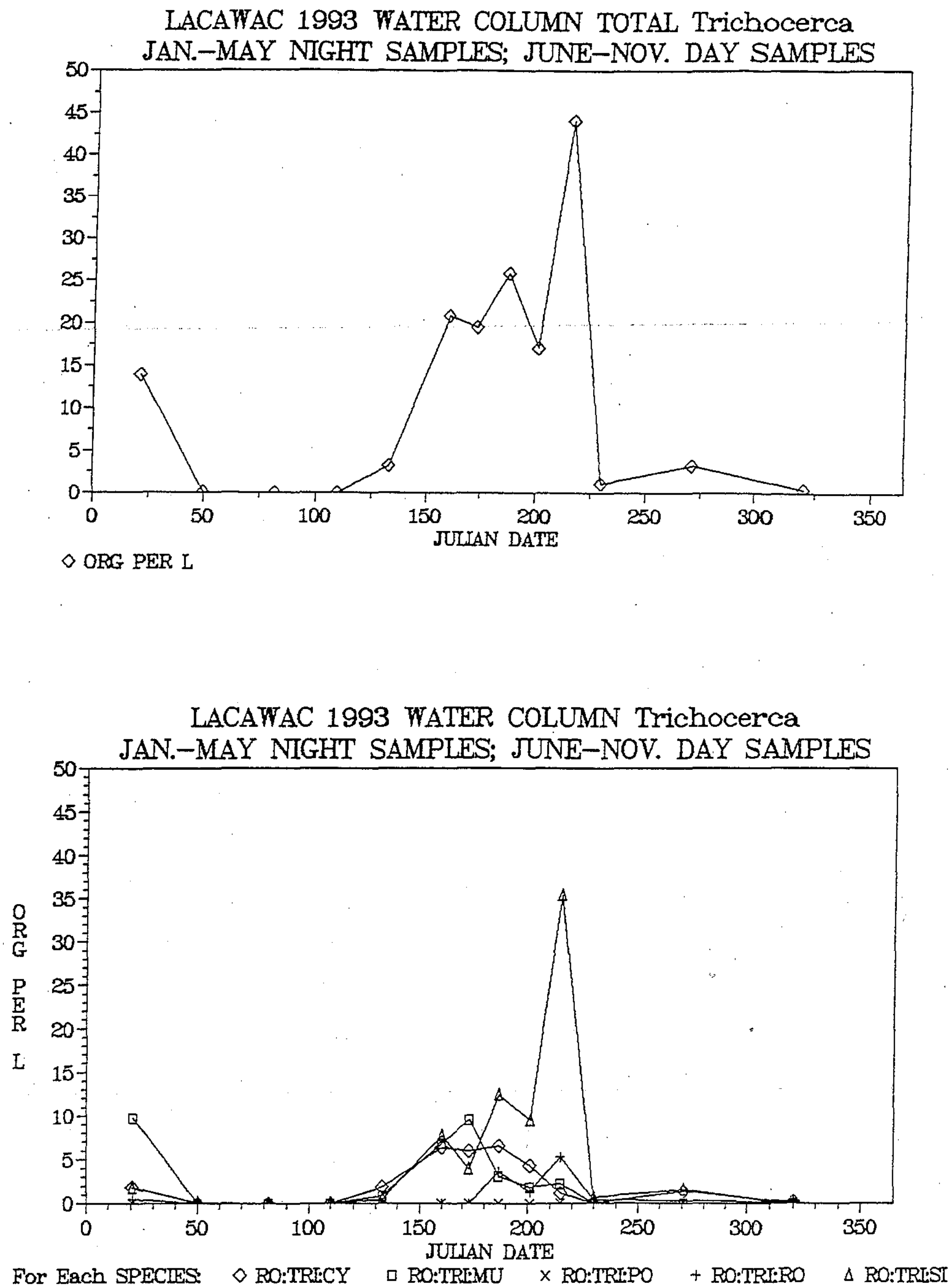


Figure 23. The rotifer *Trichocerca* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean. **(Top)** Total individuals per liter. **(Bottom)** *Trichocerca* by species: **CY** *T. cylindrica*, **MU** *T. multicrinus*, **PO** *T. porcellus*, **RO** *T. rousseleti* and **SI** *T. similis*.

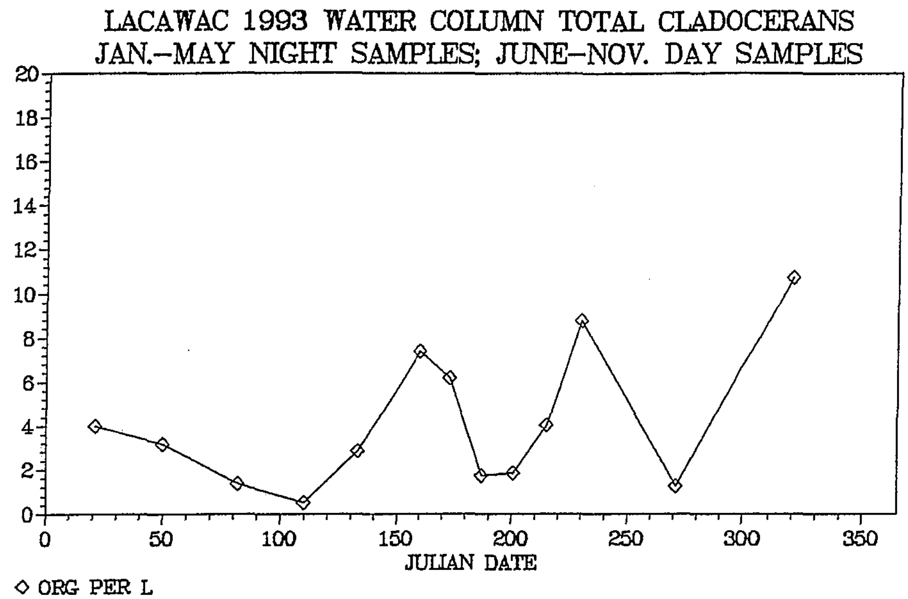
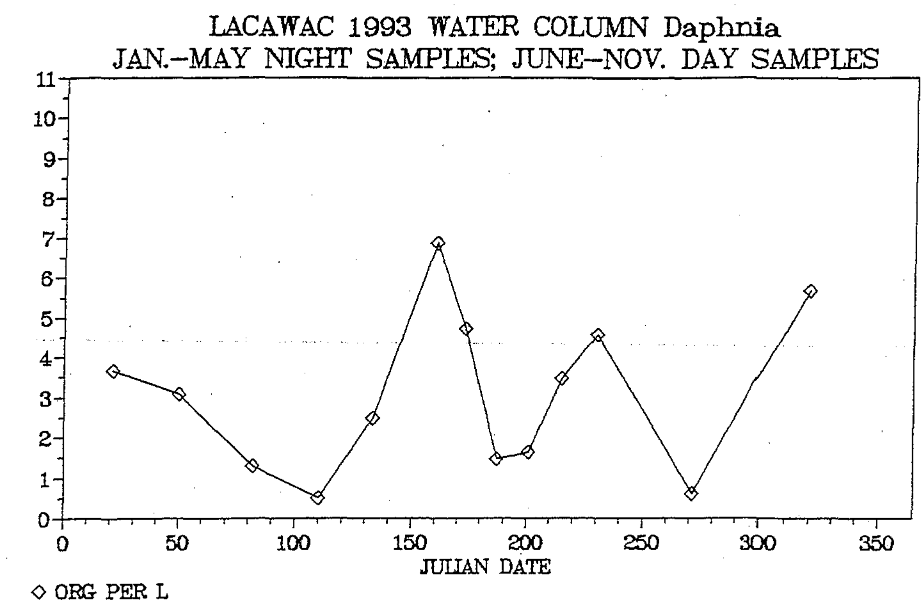


Figure 24. Cladocera in Lake Lacawac, 1993.

Net collections (202μm) from three depths have been combined to give a water column mean.



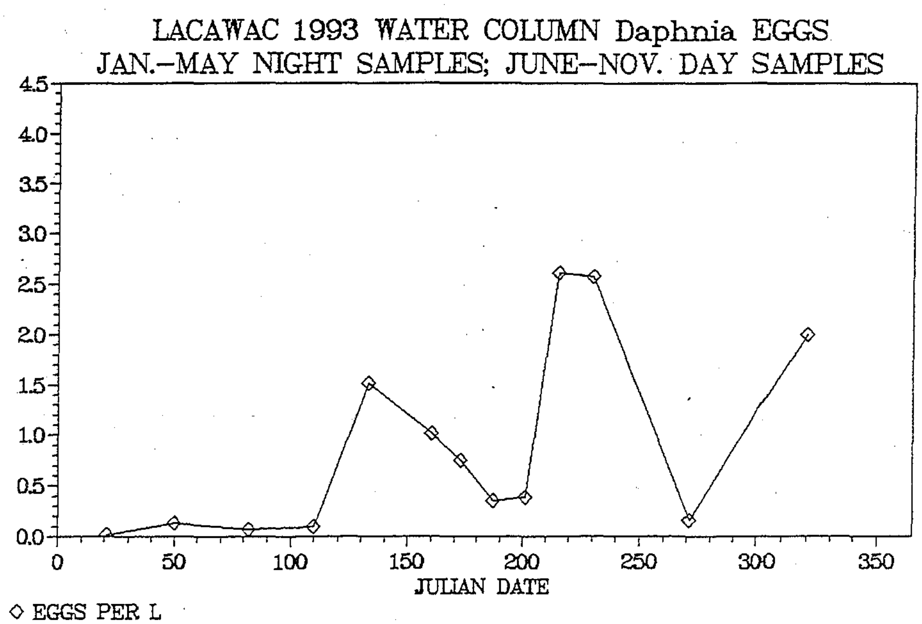


Figure 25. The cladoceran *Daphnia* in Lake Lacawac, 1993.

Net collections (202μm) from three depths have been combined to give a water column mean. **(Top)** Total individuals per litre. **(Bottom)** Total eggs per litre.

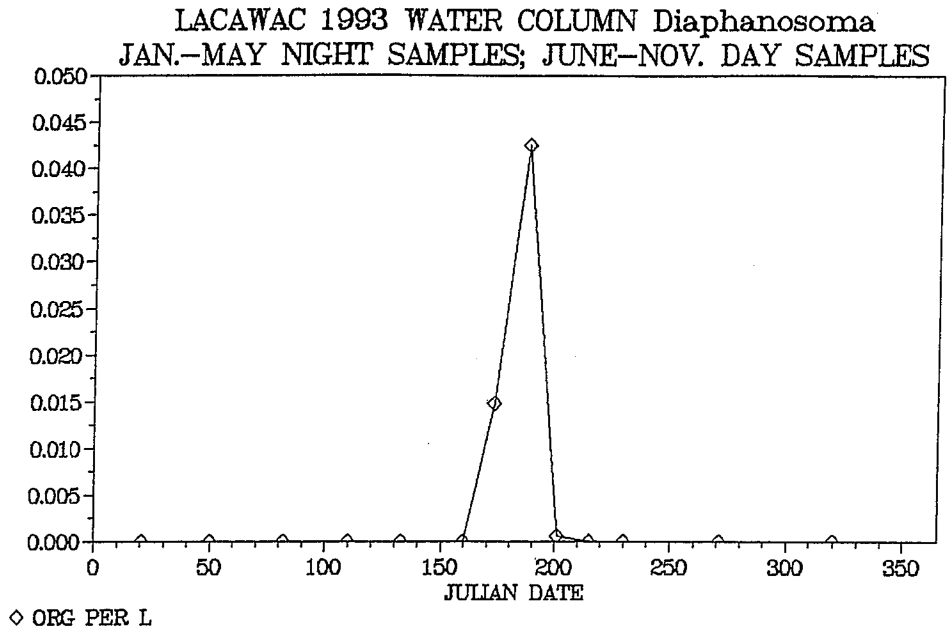
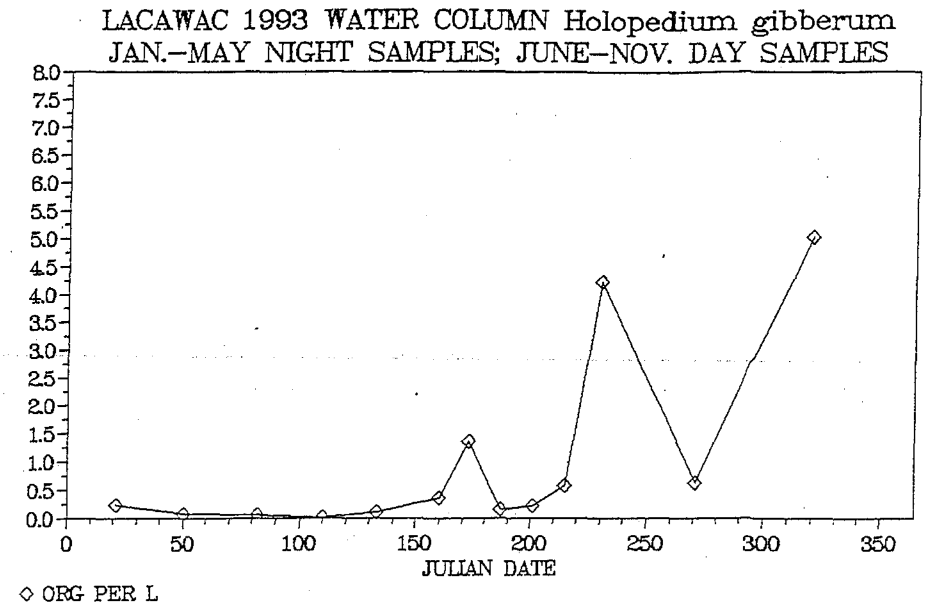


Figure 26. The cladoceran *Diaphanosoma* in Lake Lacawac, 1993.

Net collections (202μm) from three depths have been combined to give a water column mean.



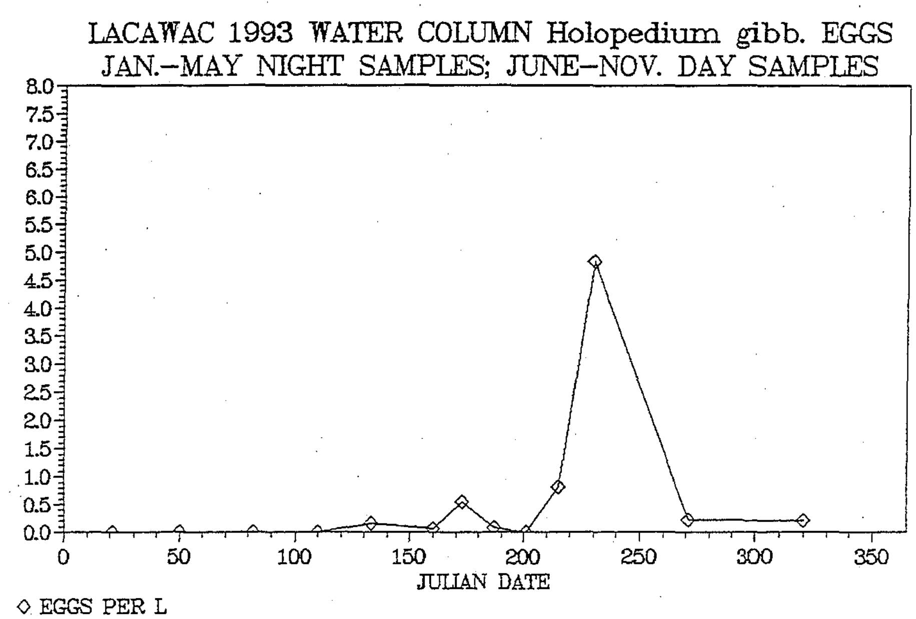


Figure 27. The cladoceran *Holopedium gibberum* in Lake Lacawac, 1993.

Net collections (202μm) from three depths have been combined to give a water column mean. **(Top)** Total individuals per litre. **(Bottom)** Total eggs per litre.

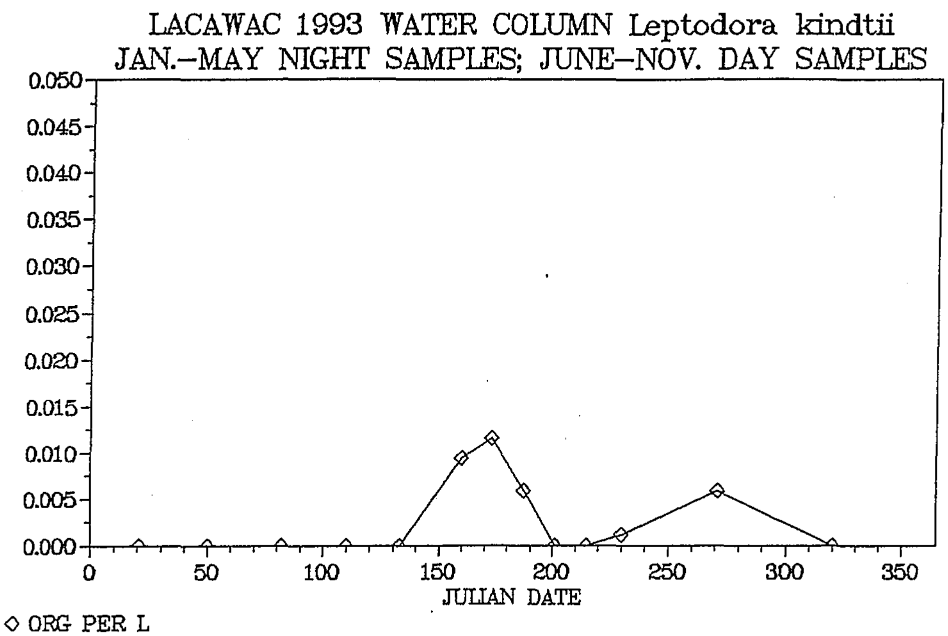


Figure 28. The cladoceran *Leptodora kindti* in Lake Lacawac, 1993.

Net collections (202μm) from three depths have been combined to give a water column mean.

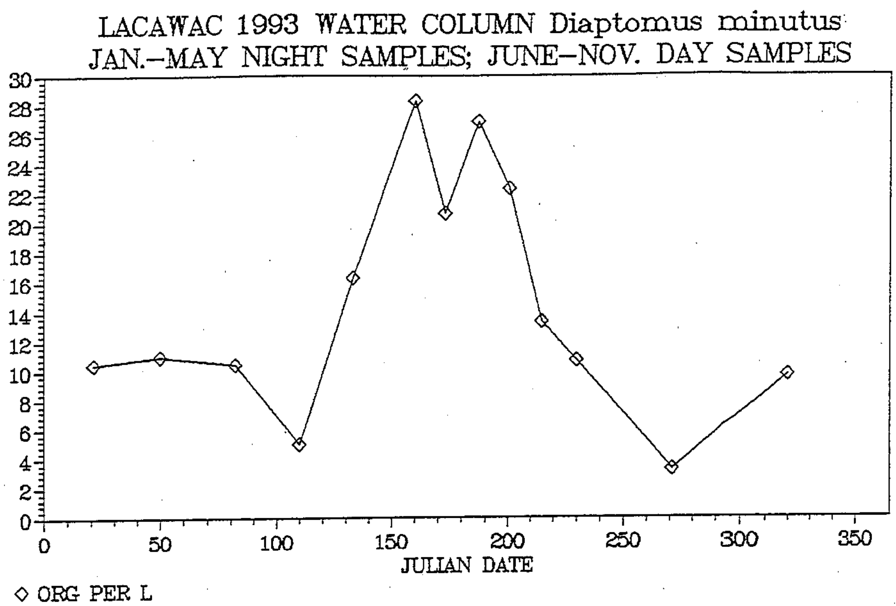
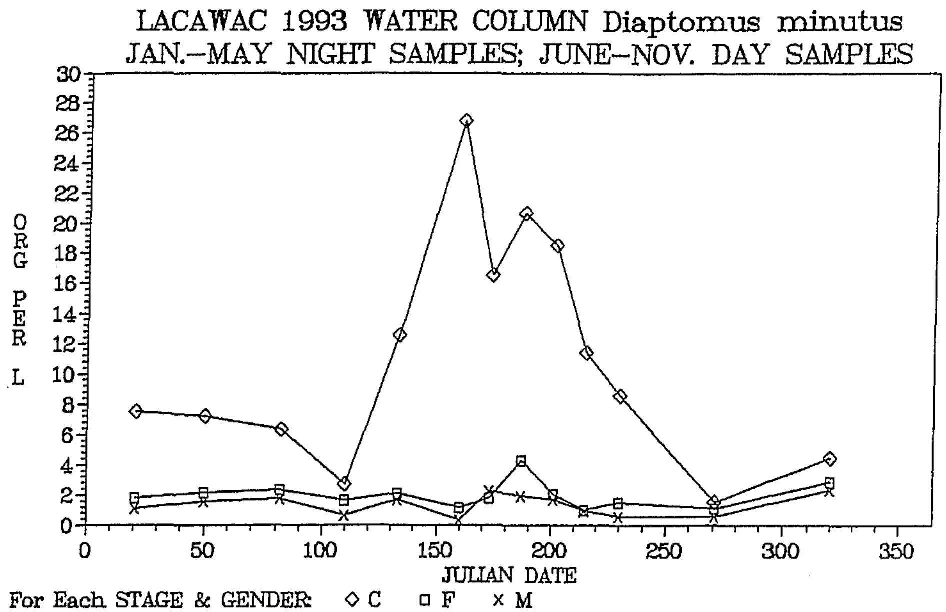


Figure 29. The calanoid copepod *Diaptomus minutus* in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean of individuals per litre, excluding nauplii. *D. minutus* was the only calanoid present.



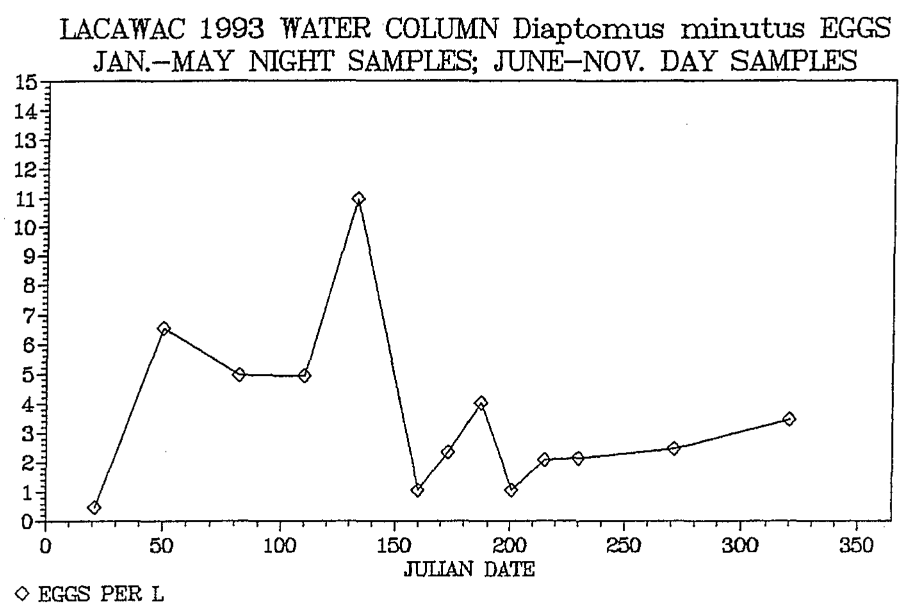


Figure 30. The calanoid copepod *Diaptomus minutus* in Lake Lacawac, 1993, by stage and gender.

Net collections (48μm) from three depths have been combined to give a water column mean. **(Top)** Adults (males and females separately) and copepodids. **(Bottom)** *D. minutus* eggs per litre.

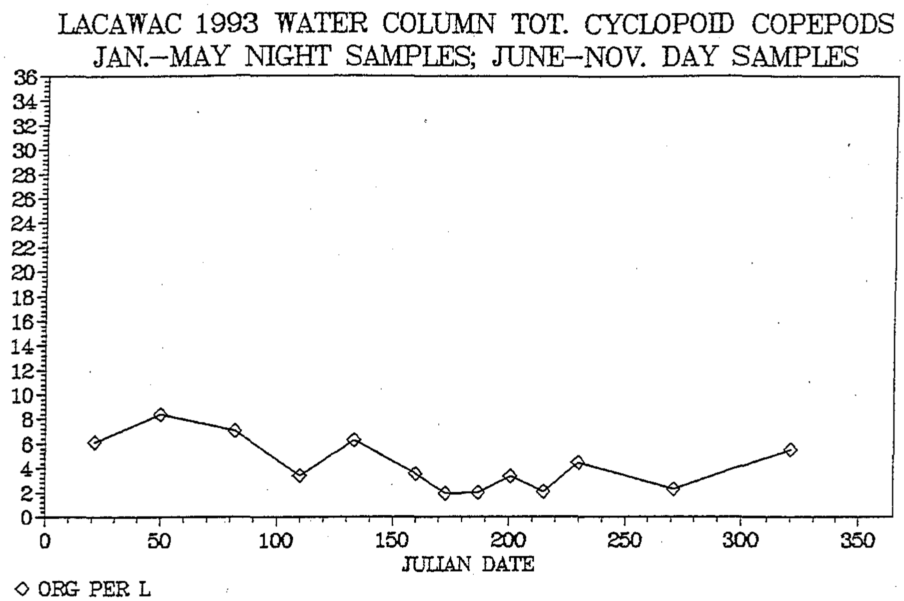


Figure 31. Total cyclopoid copepods in Lake Lacawac, 1993.

Net collections from three depths have been combined to give a water column mean as individuals per litre. Adult females were counted from the 202μm net samples, other stages from 48μm net samples (nauplii are not included).

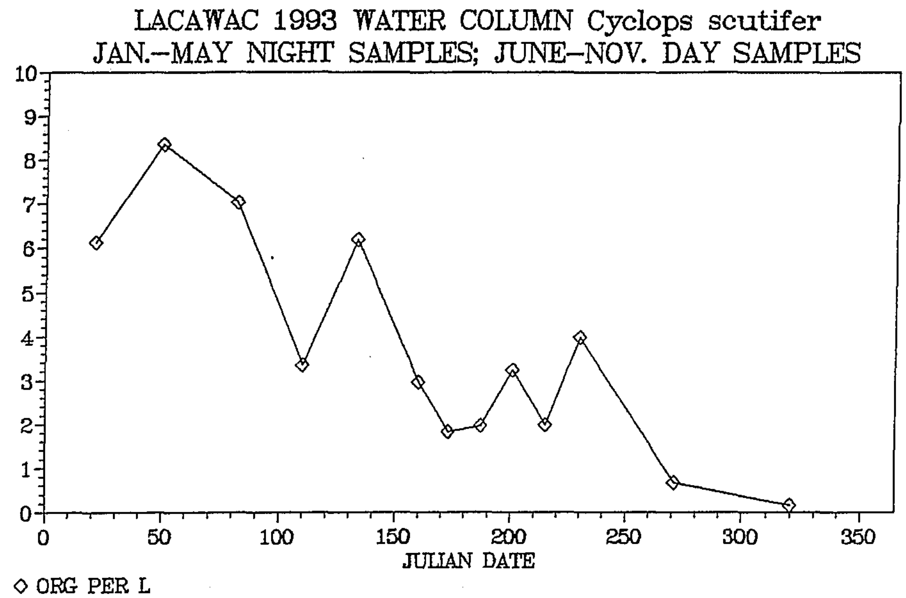
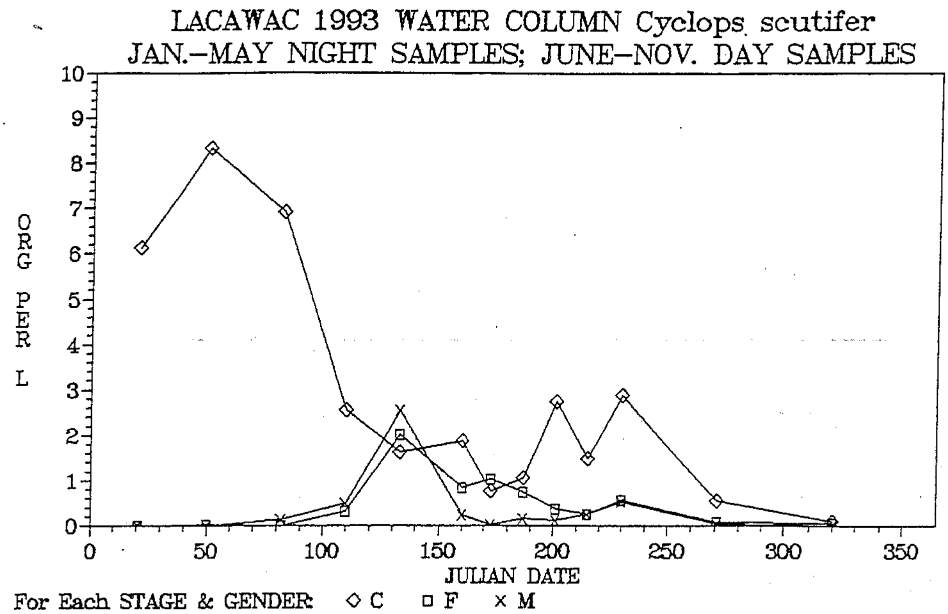


Figure 32. The cyclopoid copepod *Cyclops scutifer* in Lake Lacawac, 1993.

Net collections from three depths have been combined to give a water column mean. Adult females were counted from 202μm net samples, males and copepodids from 48μm net samples (nauplii are not included).



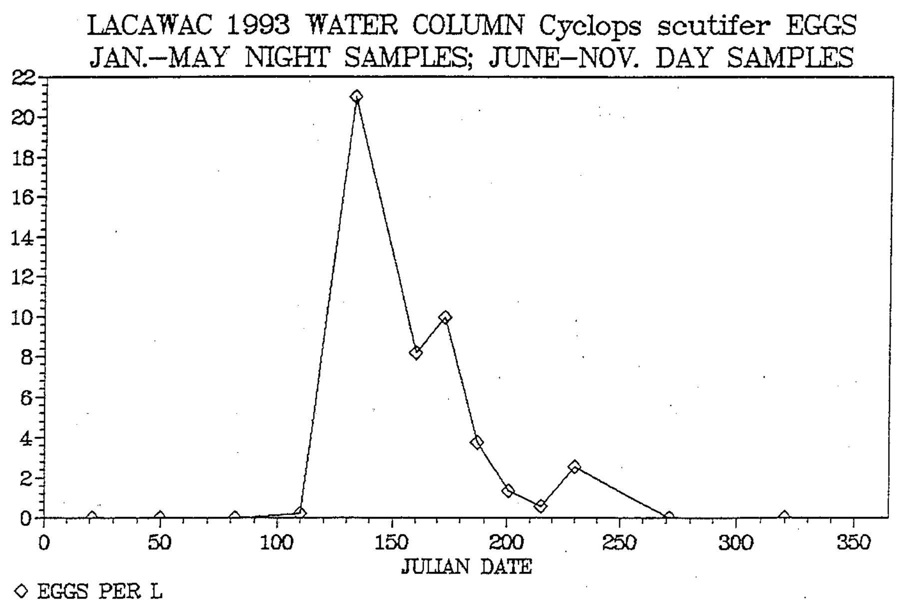
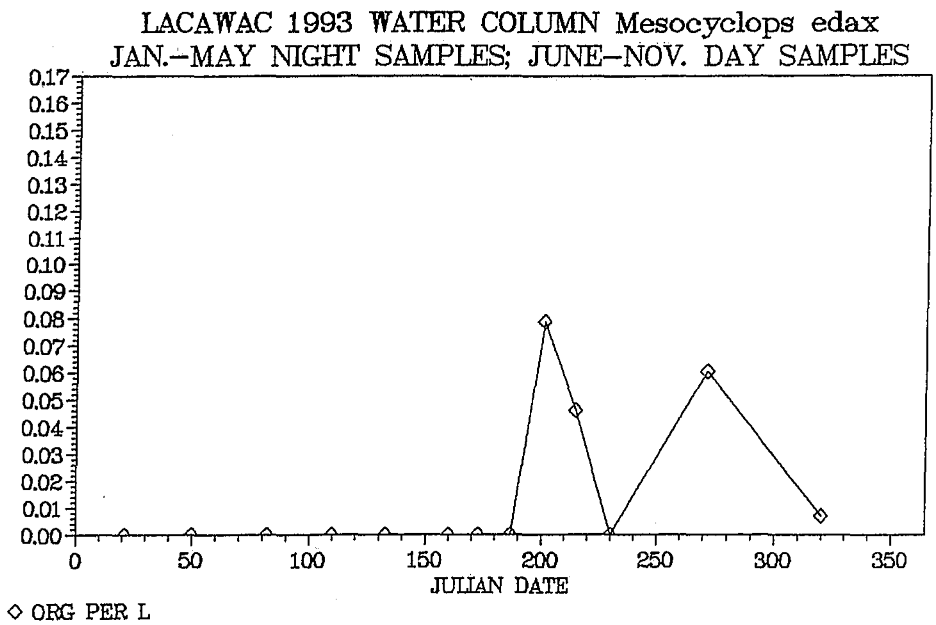


Figure 33. The cyclopoid copepod *Cyclops scutifer* in Lake Lacawac, 1993, by stage and gender.

Net collections from three depths have been combined to give a water column mean. **(Top)** Adults (males and females separately) and copepodids. **(Bottom)** *C. scutifer* eggs per litre. Adult females were counted from the 202μm net samples, males and copepodids from 48μm net samples (nauplii were not included).



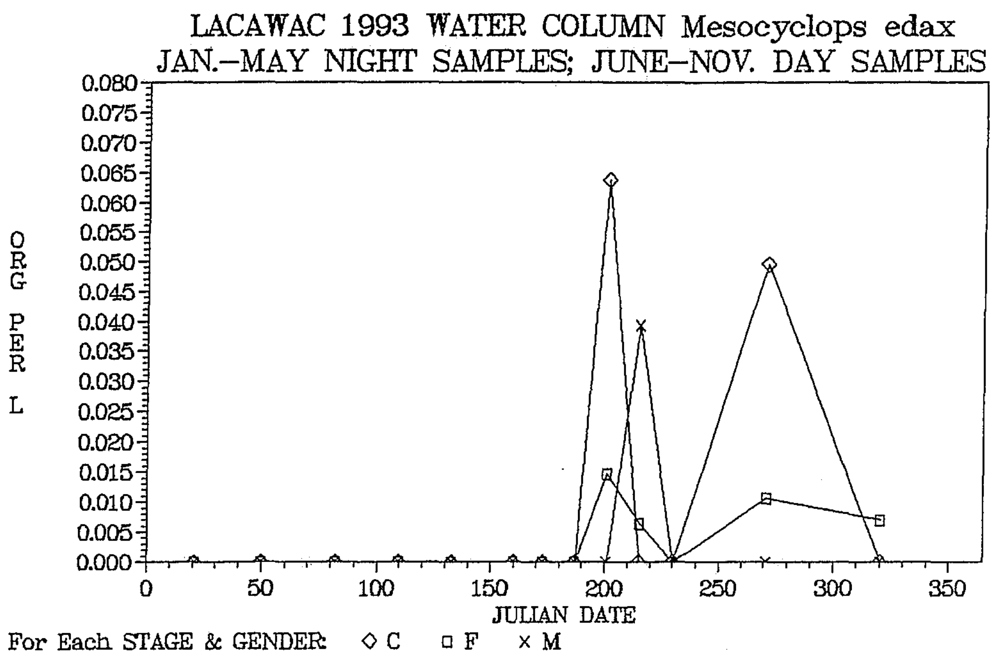


Figure 34. The cyclopoid copepod *Mesocyclops edax* in Lake Lacawac, 1993.

Net collections from three depths have been combined to give a water column mean. **(Top)** Total individuals per litre (nauplii excluded). **(Bottom)** Adults (males and females separately) and copepodids. Adult females were counted from the 202μm net samples, males and copepodids from 48μm net samples.

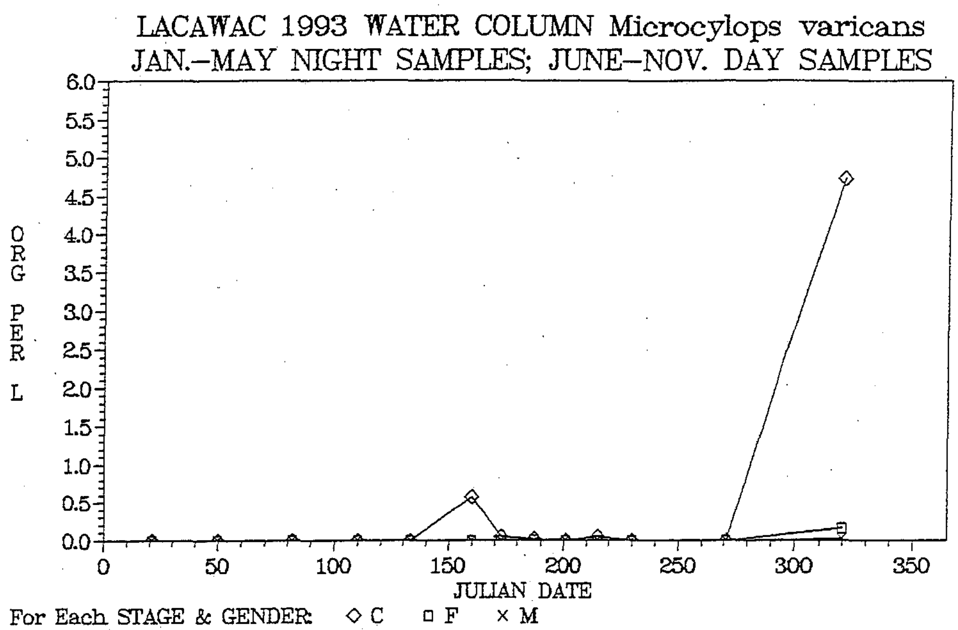
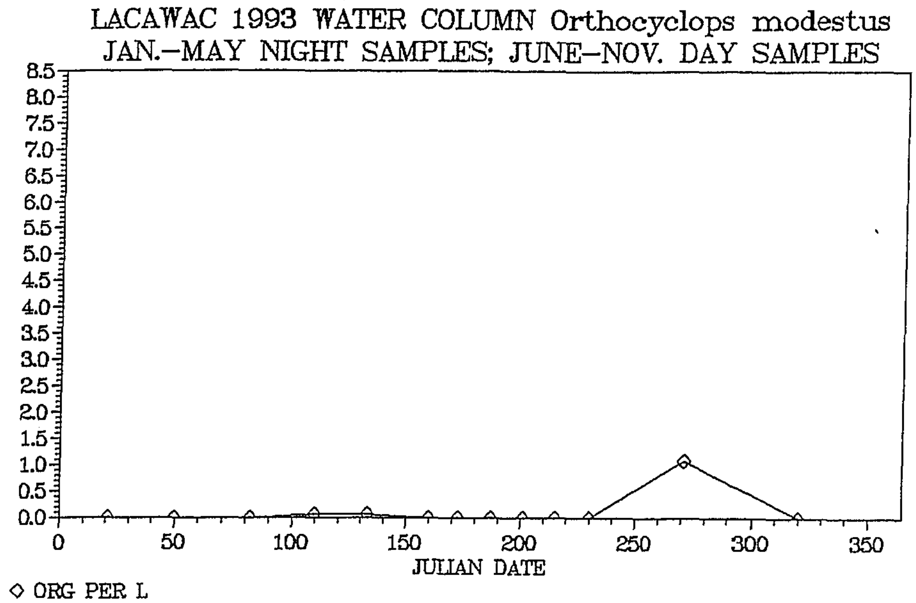


Figure 35. The cyclopoid copepod *Microcyclops varicans* in Lake Lacawac, 1993.

Net collections from three depths have been combined to give a water column mean of adults (males and females separately) and copepodids per litre. Adult females were counted from the 202μm net samples, males and copepodids from 48μm net samples.



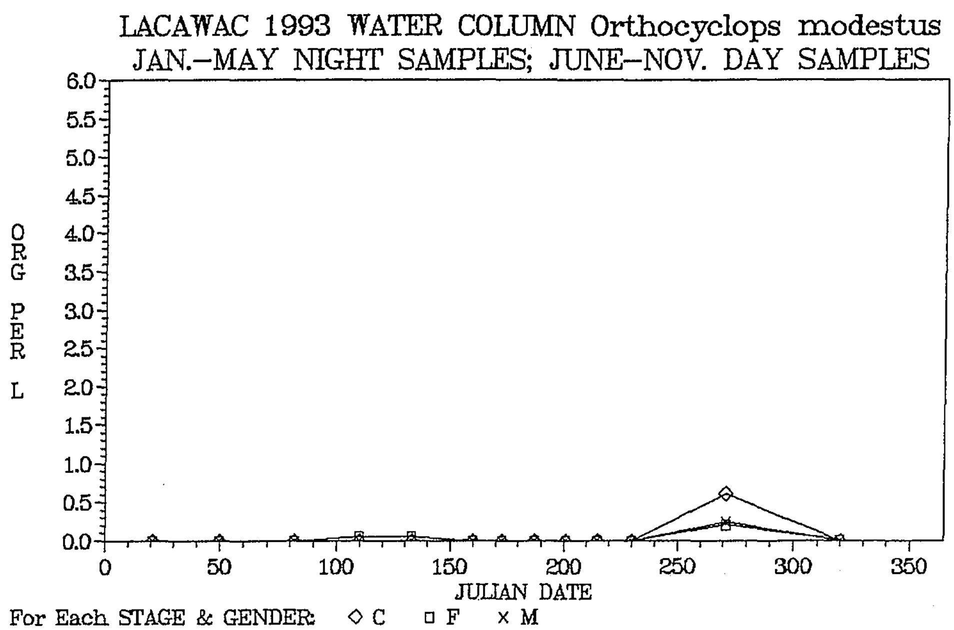
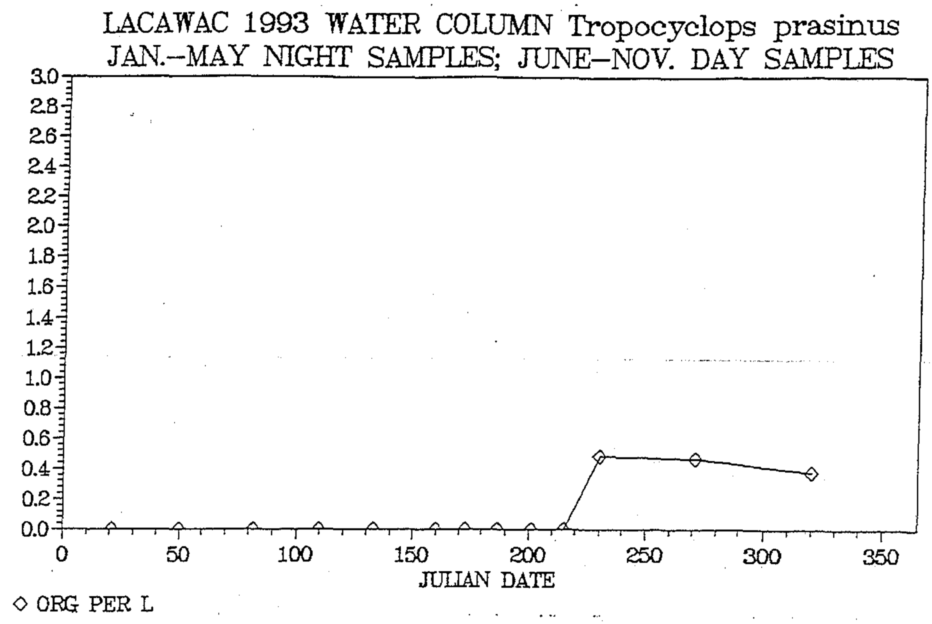


Figure 36. The cyclopoid copepod *Orthocyclops modestus* in Lake Lacawac, 1993.

Net collections from three depths have been combined to give a water column mean. **(Top)** Total individuals per litre (nauplii excluded). **(Bottom)** Adults (males and females separately) and copepodids. Adult females were counted from the 202μm net samples, males and copepodids from 48μm net samples.



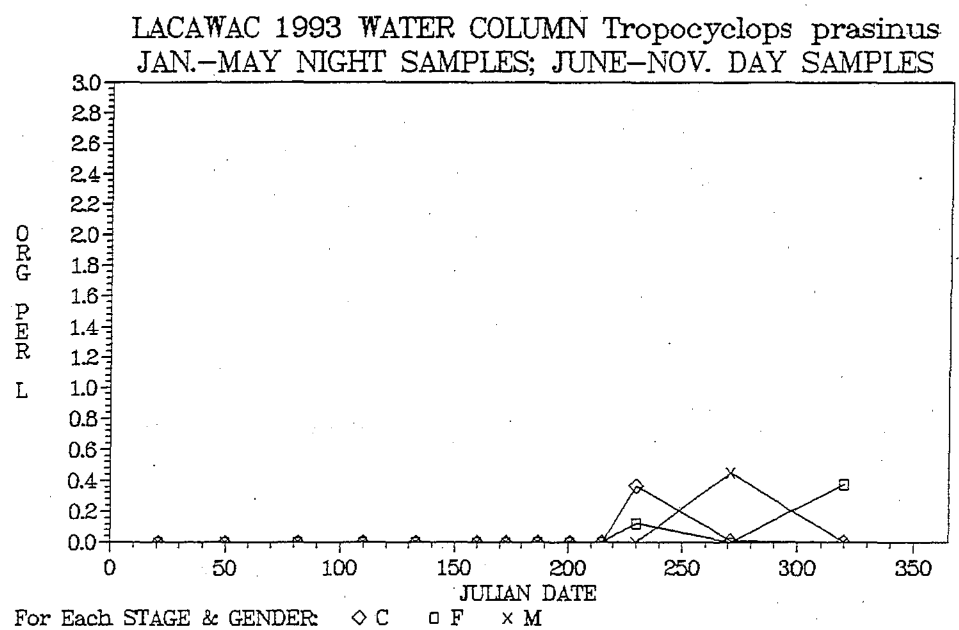


Figure 37. The cyclopoid copepod *Tropocyclops prasinus* in Lake Lacawac, 1993.

Net collections from three depths have been combined to give a water column mean. **(Top)** Total individuals per litre (nauplii excluded). **(Bottom)** Adults (males and females separately) and copepodids, all counted from 48μm net samples.

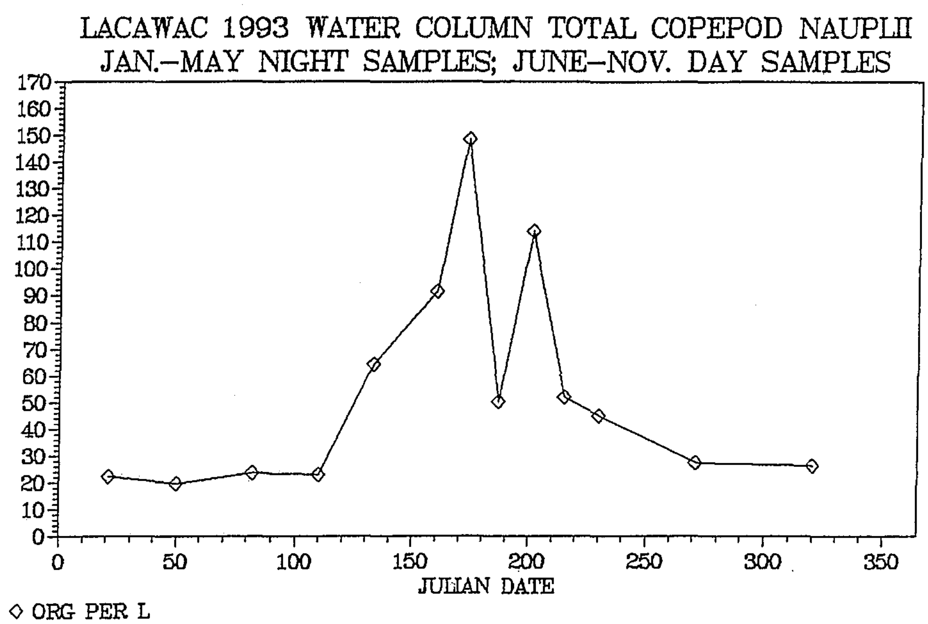


Figure 38. Total copepod nauplii in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean. Nauplii of calanoid and cyclopoid species were not differentiated.

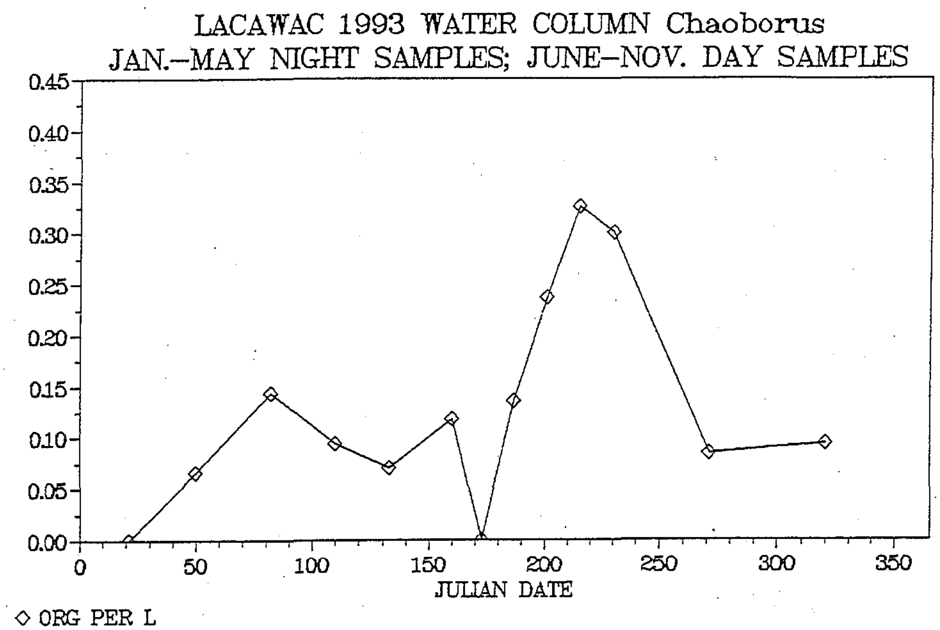


Figure 39. The dipteran *Chaoborus* spp. in Lake Lacawac, 1993.

Net collections (48μm) from three depths have been combined to give a water column mean. The change from night to day sampling in June has probably caused some underestimation of population size following the change.

APPENDIX I: CHEMISTRY 1991-92

Chemical sampling in 1991-92 used field and analytical procedures similar to those employed in the 1989 sampling by Dr. Jonathan Cole and Dr. Nina Caraco of the Institute of Ecosystem Studies. A brief resume of the methods is presented here, highlighting differences between the two years. The 1989 results are summarized in the 1990 Annual Report (R.E. Moeller and C.E. Williamson, unpublished report, 1991). The 1991-92 results, from 6 dates, are presented in **Table L.AI.**

FIELD SAMPLING

Samples were collected during the day at the routine sampling station. Water was collected with a battery-operated peristaltic pump through 6-mm inside diameter clear tygon tubing. On the same day, profiles for temperature and dissolved oxygen were obtained *in situ* with a YSI meter (the usual PCLP methods #10 for temperature and dissolved oxygen). Six depths were sampled, including the regular "EPI", "META", and "HYPO" depths, plus 0.5 m and two other meta- or hypolimnetic depths.

Several discrete samples were collected at each depth: (1) a 250-ml polypropylene bottle of unfiltered sample for Ca, Mg, K, Na, Cl, and total phosphorus; (2) a second 250-ml polypropylene bottle of unfiltered sample for pH; (3) a 125-ml polypropylene bottle of filtered water for nutrients (47-mm Whatman GF/F glass fiber filter in a filter holder inserted into collection line just before pump); (4) a 60-ml glass BOD bottle of unfiltered water for total dissolved inorganic carbon; and (5) 35-ml of unfiltered sample into a 50-ml polypropylene centrifuge tube containing 5 ml of zinc acetate solution for sulfate (also sulfide in 1989). The zinc acetate solution was prepared as follows: add 5 volumes of solution I (26 g/L of zinc acetate) to 1 volume of solution II (sodium hydroxide 60 g/L), mix well and pipet suspension from a continuously mixed beaker. Finally, several liters of water were collected from 0.5 m or the "EPI" depth with Van Dorn bottle for particulate total organic carbon and nitrogen.

Soon after collection (in boat or back in laboratory), samples were acidified as follows:

DIC -- add 1.5 ml of 5N H_2SO_4 and place plastic cap over the stopper
Cation sample -- add 2 ml of 1N H_2SO_4
Nutrient sample -- add 1 ml of 1N H_2SO_4

ANALYTICAL METHODS

Analyses of pH were performed in the laboratory at room temperature within 4-8 hr of sampling (routine PCLP method #12, using Ross electrode and adding pHisa solution). Alkalinities are reported for the separate PCLP sampling (same day, different time using Van Dorn sampler, then Gran titration -- Method #11). Total dissolved inorganic carbon was determined by equilibrating 25 ml of acidified solution with 25 ml of N_2 in a 50-ml polypropylene syringe, then injecting 0.5 ml into a gas chromatograph (Shimadzu GC 8A, TCD detector, column of Poropak-Q, He carrier) calibrated with sodium carbonate solutions acidified in the BOD bottles (modified from M.P. Stainton.

1973. J. Fish. Res. Bd Canada 30:1441-1445). Blanks were subtracted from standards but not samples. DIC was analyzed within a few days of collection. Particulate C,N samples were prepared by filtering 1-1.5 liters (Lake Lacawac) onto precombusted 47 mm Whatman GF/F glass fiber filters, which were stored frozen.

Water samples for other chemical samples were stored at room temperature for many months before analysis at the Institute of Ecosystem Studies. Calcium (Ca) and magnesium (Mg) were determined by ICP emission, potassium (K) and sodium (Na) by atomic absorption spectrophotometry. Auto-analyzer methods were used for chloride (Cl), nitrate (NO_3, using cadmium reduction), soluble reactive phosphorus (SRP, using molybdenum blue reaction), and ammonium (NH_4, using the phenol-hypochlorite method of Solorzano). Sulfate (SO_4) was determined by ion chromatography -- these analyses are not yet reported for the 1991-92 series. Sulfide (S_2-, 1989 only) was determined spectrophotometrically (N. Gilboa-Garber. 1971. Anal. Biochem. 43:129-133). In the 1989 series, total and total dissolved iron (tFe and tdFe) were measured spectrophotometrically using the α,α-bipyridyl method. Total phosphorus (tP) was measured by molybdenum blue reaction after persulfate digestion. Particulate carbon and nitrogen were determined using a Perkin-Elmer elemental analyzer.

The earlier June-October 1989 sampling series differed from that described above for 1991-92 as follows. In 1989, temperature and oxygen profiles were obtained simultaneously with the pump sampling, as was *in situ* conductivity (not measured in 1991-92). pH was measured immediately in the boat with a battery-powered meter. Methane as well as CO_2 was determined gas chromatographically from the acidified sample in the 60-ml BOD bottle. Chloride was not determined in 1989. The persulfate digest of the unfiltered sample (for total phosphorus) also was analyzed for total iron (tFe). The total phosphorus and iron procedures were repeated on the filtered nutrient sample to give values for total dissolved phosphorus (tdP) and total dissolved iron (tdFe). This was not done in 1991-92.

SUMMARY OF PARTICULATE C,N DATA

Particulate organic carbon (C) and nitrogen (N) were determined on several dates in 1989 and 1991-92. Analyses are not available for other dates, because not enough sample was filtered to give reliable values.

Lake	Date	Depth m	C µM	N µM	C/N molar
Lacawac	06/19/89	0.5	48.9	6.46	7.6
Lacawac	08/04/89	0.5	35.6	3.34	10.7
Lacawac	"	5.	35.5	3.02	11.8
Lacawac	"	12.	55.8	6.39	8.7
Lacawac	09/15/89	0.5	39.7	4.33	9.2
Lacawac	"	6.	59.4	5.93	10.0
Lacawac	"	12	63.3	7.76	8.2
Lacawac	10/04/89	0.5	14.0	1.70	8.2
Lacawac	9/21/91	0.5	31.9	3.91	8.2
Lacawac	11/23/91	0.5	59.7	5.33	11.2
Lacawac	02/22/92	1.	53.8	5.80	9.3

analyses of N. Caraco and J. Cole

Table L.A.1. CHEMICAL CHARACTERIZATION OF LAKE LACAWAC (1991-92).

Date	Depth	Temp	O2	pH	Alkalinity	DIC	Ca	Mg	K	Na	Cl	SO4	NH4	NO2	P SRP	P totP
	m	C	mg/L		uEq/L	uM	mg/L	mg/L	mg/L	mg/L	uM	uM	uM	uM	uM	uM
04/12/91	0.5	10.6	10.74	6.20	--	49	2.87	0.50	0.36	0.68	25	--	2.5	<0.5	<0.05	--
04/12/91	2	10.4	10.45	6.24	30.9	45	2.81	0.51	0.37	0.66	23	--	3.1	<0.5	0.07	--
04/12/91	5	8.4	10.64	6.23	30.8	52	2.88	0.50	0.37	0.66	22	--	2.9	<0.5	0.08	--
04/12/91	8	6.1	10.50	6.01	--	88	2.88	0.50	0.35	0.68	22	--	2.7	<0.5	0.05	--
04/12/91	10	6.1	10.12	5.89	28.4	116	2.84	0.49	0.37	0.68	23	--	3.1	<0.5	0.07	--
04/12/91	12	6.2	9.77	5.84	--	130	2.85	0.50	0.37	0.67	24	--	2.7	<0.5	<0.05	--
07/03/91	0.5	23.7	7.44	6.31	--	46	2.79	0.52	0.34	0.75	25	--	4.5	<0.5	0.11	--
07/03/91	2	23.8	7.32	6.28	25.9	44	2.89	0.50	0.37	0.69	25	--	3.9	<0.5	0.14	--
07/03/91	4	21.7	7.79	6.17	--	66	2.83	0.51	0.37	0.68	23	--	4.5	<0.5	0.13	--
07/03/91	6	11.9	6.74	5.88	27.9	158	2.82	0.50	0.38	0.72	24	--	3.7	<0.5	0.14	--
07/03/91	10	6.9	0.00	6.28	64.5	415	3.10	0.53	0.43	0.80	24	--	16.5	<0.5	0.31	--
07/03/91	11	6.7	0.00	6.41	--	470	3.35	0.53	0.43	0.74	24	--	23.3	<0.5	0.71	--
09/22/91	0.5	19.3	7.49	6.21	--	84	2.84	0.52	0.39	0.76	23	--	4.0	<0.5	0.09	--
09/22/91	3	18.7	7.37	6.12	--	78	2.88	0.52	0.38	0.78	23	--	4.3	<0.5	0.08	--
09/22/91	7	13.5	0.82	5.75	--	405	3.04	0.52	0.35	0.82	26	--	5.1	<0.5	0.15	--
09/22/91	8	9.9	0.20	5.89	--	482	3.14	0.52	0.40	0.79	23	--	5.0	<0.5	0.15	--
09/22/91	11	7.2	0.00	6.46	--	805	3.78	0.57	0.46	0.77	31	--	48.8	<0.5	4.37	--
09/22/91	12	7.1	0.00	6.49	--	817	3.78	0.54	0.49	0.80	34	--	56.5	<0.5	5.10	--
11/23/91	0.5	8.7	10.71	6.28	--	71	1.97	0.36	0.25	0.65	24	--	5.6	0.7	0.05	0.58
11/23/91	2	8.3	10.55	6.31	34.5	71	2.92	0.52	0.40	0.66	23	--	3.0	<0.5	0.05	0.37
11/23/91	6	5.7	10.19	6.28	36.7	82	2.90	0.52	0.42	0.65	23	--	4.3	<0.5	0.05	0.45
11/23/91	8	5.6	9.81	6.17	--	110	2.89	0.53	0.40	0.65	22	--	5.6	1.1	0.07	--
11/23/91	10	5.6	9.58	6.16	38.0	101	2.90	0.53	0.40	0.65	22	--	5.3	0.6	0.06	0.39
11/23/91	11	5.6	9.69	6.15	--	105	2.84	0.53	0.40	0.65	22	--	5.8	0.6	0.07	0.64
02/22/92	1	3.4	11.74	5.92	29.8	117	3.15	0.56	0.38	0.71	26	--	2.7	1.8	<0.05	0.90
02/22/92	4	3.5	11.71	5.93	30.5	117	3.22	0.56	0.42	0.70	24	--	2.7	1.9	0.05	0.65
02/22/92	7	3.5	11.68	5.96	--	118	3.21	0.56	0.40	0.68	25	--	3.7	1.8	0.05	0.39
02/22/92	9	3.5	11.71	5.93	30.0	120	3.26	0.56	0.38	0.70	25	--	3.3	1.9	0.05	0.42
02/22/92	11	3.5	11.71	5.92	--	117	3.10	0.55	0.40	0.70	25	--	3.3	1.9	<0.05	0.54
02/22/92	12	3.5	11.71	5.93	--	114	3.16	0.56	0.40	0.68	24	--	3.0	1.9	<0.05	0.75
04/10/92	0.5	6.2	12.18	6.20	--	58	3.05	0.54	0.37	0.67	22	--	2.6	<0.5	0.05	0.51
04/10/92	2	4.9	12.38	6.18	28.7	59	3.13	0.55	0.37	0.73	23	--	3.1	<0.5	0.05	0.41
04/10/92	5	4.6	12.27	6.20	27.1	61	3.13	0.55	0.36	0.67	23	--	4.3	<0.5	0.06	0.33
04/10/92	7	4.5	12.21	6.18	--	68	3.06	0.55	0.36	0.67	22	--	4.0	<0.5	0.05	0.34
04/10/92	11	4.1	11.67	6.10	27.6	78	3.01	0.54	0.36	0.67	23	--	3.9	<0.5	0.06	0.41

APPENDIX II: PHYTOPLANKTON (1989-1992)

The following 5 pages present phytoplankton data in the form of species biovolumes. The first table summarizes the seasonal data over all three years. The subsequent four tables present the counts for the 12 composite samples. The samples were analyzed by Ann St Amand (PhycoTech).

Table L.AII.1. Phytoplankton from Lake Lacawac, 1989-1992. Major species with their abundance as biovolume. Values are means of three years, where a single sample was counted from each year, representing a composite of all dates and sampling depths during the periods January--February (winter), March--May (spring), June--September (summer) and October--December (autumn).
[Corrected version of 1/27/95]

Alga	Biovolume of species ($10^3 \mu m^3$/mL)			
	winter	spring	summer	autumn
Diatoms				
Asterionella formosa	4.9	1.0	0.1	1.7
Cyclotella spp.		0.1	0.8	
Meridion sp.		5.2		
Navicula sp.				0.4
Nitzschia sp.			0.1	
Tabellaria fenestrata	1.9	5.2		6.7
Chrysophytes				
Chrysosphaerella longispina			0.2	
Diceras sp.	0.4	0.4		0.7
Dinobryon bavaricum				2.8
Dinobryon cylindricum				0.3
Dinobryon divergens	0.3	1.8		3.9
Dinobryon sertularia	5.6	13.	3.0	10.
Dinobryon cysts		0.5		
Dinobryon spp. (monads)	2.7	28.		24.
Kephyrion sp.				0.5
Mallomonas akrokomos			23.	
Mallomonas caudata			7.8	57.
Mallomonas spp.	150.	56.	33.	12.
Psephonema aenigmaticum			0.2	
Ochromonas sp.	0.4			0.4
Stichogloea olivaceae		0.7	3.0	
Synura uvella/sphagnicola	880.	810.	40.	
Uroglena sp.	22.	13.		
misc. Chrysophyta		4.1		0.1
Cryptophytes				
Cryptomonas sp.	0.4	0.4	1.9	2.1
Cryptomonas erosa	4.3	27.	12.	9.5
Cryptomonas ovata	90.	60.	20.	51.
Rhodomonas minuta	3.1	5.1	3.8	8.6
Chlorophytes				
Ankistrodesmus falcatus		1.0		0.2
Arthrodesmus incus			6.8	
Botryococcus braunii			0.6	
Cosmarium sp.			5.6	150.
Crucigenia rectangularis			3.2	0.4
Crucigenia tetrapedia			0.1	0.2
Crucigenia sp.			1.1	
Dictyosphaerium pulchellum		130.		
Dispora crucigenioides				0.7
Elakatothrix gelatinosa	0.1		0.1	

continued

Table L.AII.1. Phytoplankton from Lake Lacawac, 1989-1992. Major species with their abundance as biovolume. (continued)

Alga	Biovolume of species ($10^3 \mu m^3$/mL)			
	winter	spring	summer	autumn
Chlorophytes (continued)				
Kirchneriella lunaris			0.5	
Monomastix astigmata	0.2	0.8	0.8	0.2
Nephrocytium lunatum			0.1	
Oocystis borgei/lacustris			0.1	
Oocystis parva		9.0	7.4	3.6
Quadrigula chodatti			0.3	0.1
Quadrigula lacustris			0.3	
Schroederia judayi	0.8	0.1		0.4
Schroederia setigera		0.2	0.1	
Selenastrum minutum			0.1	
Sphaerocystis schroeteri			0.8	
Staurastrum paradoxum	5.5		0.5	
Tetraedron caudatum			0.1	
Tetrastrum staurogeniaeforme			2.2	
Ulothrix sp.				0.3
colonial Chlorophyte		0.5	21.	13.
filamentous Chlorophyte			0.1	
misc. Chlorococcales	0.1	1.0	14.	5.9
Dinoflagellates				
Glenodinium sp.			0.7	
Gymnodinium spp.		10.	0.6	23.
Peridinium inconspicuum			1.4	
Peridinium umbonatum			3.4	
Peridinium wisconsinense			0.4	
Peridinium sp.		450.		33.
dinoflagellate cyst		3.2		
Cyanobacteria				
Anabaena sp.			0.1	
Aphanizomenon flos-aquae			1.2	
Aphanothece sp.			0.2	
Coelosphaerium naegelianum	0.1		0.5	0.9
Merismopedia tenuissima			3.2	
Oscillatoria limnetica		0.1		0.7
Oscillatoria sp.			0.1	
coccoid Cyanobacteria	0.1			0.2
Other				
Euglena acus			0.5	
Euglena gracilis			7.6	24.
Gonyostomum sp.			20.	
Phacus sp.			0.1	
Trachelomonas sp.			2.7	
microflagellates (misc.)	2.7	12.	7.8	22.
unidentifiable cyst				3.5
Total Biovolume ($10^3 \mu m^3$/mL):	1170.	1646.	265.	472.

Table L.AII.2. Spring phytoplankton from Lake Lacawac--major species and their abundance as biovolume. A composite sample from each year of all dates and sampling depths during the period March through May was counted.

Alga	Type	Biovolume of species ($10^3 \mu m^3$/mL)			
		1990	1991	1992	mean
Diatoms					
Asterionella formosa	Dia		1.4	1.5	1.0
Cyclotella sp.	Dia	0.3			0.1
Meridion sp.	Dia		15.7		5.2
Tabellaria fenestrata	Dia			15.7	5.2
Chrysophytes					
Diceras sp.	Chr	1.3			0.4
Dinobryon divergens	Chr		5.4		1.8
Dinobryon sertularia	Chr	33.3	4.4		12.6
Dinobryon cyst	Chr		1.6		0.5
Dinobryon monads	Chr	84.4			28.1
Mallomonas sp.	Chr		30.5		10.2
Mallomonas sp. 3	Chr	26.5		110.8	45.8
Stichogloea olivaceae	Chr	0.8	1.3		0.7
Synura uvella/sphagnicola	Chr	17.6	23.5	2385.2	808.8
Uroglena sp.	Chr	5.5	32.2		12.6
misc. Chrysophyta	Chr			12.4	4.1
Cryptophytes					
Cryptomonas sp. 1	Cry		0.6	0.6	0.4
Cryptomonas erosa	Cry	4.1	43.4	34.6	27.4
Cryptomonas ovata	Cry	80.8	66.6	34.1	60.5
Rhodomonas minuta	Cry	1.8	13.6		5.1
Chlorophytes					
Ankistrodesmus falcatus	Chl	2.0	1.0		1.0
Dictyosphaerium pulchellum	Chl			392.1	130.7
Monomastix astigmata	Chl		0.3	2.0	0.8
Oocystis parva	Chl	26.9			9.0
Schroederia judayi	Chl			0.3	0.1
Schroederia setigera	Chl	0.6			0.2
colonial Chlorophyte	Chl	1.6			0.5
misc. Chlorococcales	Chl	3.1			1.0
Dinoflagellates					
Gymnodinium sp.	Din			29.4	9.8
Gymnodinium sp. 3	Din			1.1	0.4
Peridinium sp.	Din	312.2	128.8	899.2	446.7
dinoflagellate cyst	Din			9.5	3.2
Cyanobacteria					
Oscillatoria limnetica	Cya		0.3		0.1
Other					
microflagellates (misc.)	var	7.0	14.6	14.2	11.9
Total Counted Biovolume ($10^3 \mu m^3$/mL):		609.8	385.2	3942.7	1645.9

Table L.AII.3. Summer phytoplankton from Lake Lacawac--major species and their abundance as biovolume. A composite sample from each year of all dates and sampling depths during the period June through September was counted. *[Corrected version of 1/27/95]*

Alga	Type	Biovolume of species ($10^3 \mu m^3$/mL)			
		1989	1990	1991	mean
Diatoms					
Asterionella formosa	Dia			0.1	0.1
Cyclotella sp.	Dia	0.8	1.1	0.5	0.8
Nitzschia sp.	Dia		0.2		0.1
Chrysophytes					
Chrysosphaerella longispina	Chr			0.6	0.2
Dinobryon sertularia	Chr	0.9	6.4	1.9	3.0
Mallomonas akrokomos	Chr		70.3		23.4
Mallomonas caudata	Chr	23.5			7.8
Mallomonas spp.	Chr	99.7		0.6	33.4
Psephonema aenigmaticum	Chr	0.4	0.1		0.2
Stichogloea olivaceae	Chr		2.3	6.6	3.0
Synura uvella/sphagnicola	Chr		117.3	1.7	39.7
Cryptophytes					
Cryptomonas sp. 1	Cry		0.2	5.4	1.9
Cryptomonas erosa	Cry	6.7	1.8	28.6	12.4
Cryptomonas ovata	Cry	32.4	15.0	11.1	19.5
Rhodomonas minuta	Cry	3.8	3.7	4.0	3.8
Chlorophytes					
Arthrodesmus incus	Chl	20.1		0.3	6.8
Botryococcus braunii	Chl			1.8	0.6
Cosmarium sp.	Chl	16.3		0.4	5.6
Crucigenia rectangularis	Chl	4.3	1.7	3.6	3.2
Crucigenia tetrapedia	Chl			0.1	0.1
Crucigenia sp.	Chl	1.0	1.3	1.0	1.1
Elakatothrix gelatinosa	Chl			0.2	0.1
Kirchneriella lunaris	Chl	1.3		0.1	0.5
Monomastix astigmata	Chl		1.7	0.8	0.8
Nephrocytium lunatum	Chl			0.1	0.1
Oocystis borgei/lacustris	Chl			0.4	0.1
Oocystis parva	Chl	2.4	19.4	0.4	7.4
Quadrigula chodatti	Chl			0.9	0.3
Quadrigula lacustris	Chl		0.9		0.3
Schroederia setigera	Chl			0.2	0.1
Selenastrum minutum	Chl		0.1		0.1
Sphaerocystis schroeteri	Chl			2.3	0.8
Staurastrum paradoxum	Chl			1.6	0.5
Tetraedron caudatum	Chl			0.1	0.1
Tetrastrum staurogeniaeforme	Chl		6.5		2.2
colonial Chlorophyte	Chl	1.6	60.3	0.6	20.8
filamentous Chlorophyte	Chl			0.1	0.1
misc. Chlorococcales	Chl	0.2	36.5	4.3	13.7

continued

Table L.AII.3. **Summer phytoplankton from Lake Lacawac--major species and their abundance as biovolume.** (continued)

Alga	Type	Biovolume of species ($10^3 \mu m^3$/mL)			
		1989	1990	1991	mean
Dinoflagellates					
Glenodinium sp.	Din			2.0	0.7
Gymnodinium sp.	Din			1.7	0.6
Peridinium inconspicuum	Din			4.1	1.4
Peridinium umbonatum	Din	9.4		0.8	3.4
Peridinium wisconsinense	Din			1.3	0.4
Cyanobacteria					
Anabaena sp	Cya			0.1	0.1
Aphanizomenon flos-aquae	Cya	3.7			1.2
Aphanothece sp.	Cya			0.6	0.2
Coelosphaerium naegelianum	Cya	0.1	0.1	1.4	0.5
Merismopedia tenuissima	Cya	4.6	2.2	2.7	3.2
Oscillatoria sp.	Cya		0.2	0.1	0.1
Other					
Euglena gracilis	Eug		22.7		7.6
Euglena acus	Eug			1.6	0.5
Gonyostomum sp.	Rha	25.0	32.2	2.8	20.0
Phacus sp.	Eug			0.4	0.1
Trachelomonas sp.	Eug			8.1	2.7
microflagellates (misc.)	var	3.5	6.5	13.3	7.8
Total Counted Biovolume ($10^3 \mu m^3$/mL):		261.7	410.6	121.4	265.2

Table L.AII.4. Autumn phytoplankton from Lake Lacawac--major species and their abundance as biovolume. A composite sample from each year of all dates and sampling depths during the period October through December was counted.

Alga	Type	Biovolume of species ($10^3 \mu m^3$/mL)			
		1989	1990	1991	mean
Diatoms					
Asterionella formosa	Dia		5.2		1.7
Navicula sp. 1	Dia			1.1	0.4
Tabellaria fenestrata	Dia		20.2		6.7
Chrysophytes					
Diceras sp.	Chr		2.0		0.7
Dinobryon bavaricum	Chr	0.7	7.8		2.8
Dinobryon cylindricum	Chr	0.9			0.3
Dinobryon divergens	Chr		3.6	8.1	3.9
Dinobryon sertularia	Chr		7.0	24.5	10.5
Dinobryon monads	Chr		7.1	66.3	24.5
Kephyrion sp.	Chr	1.6			0.5
Mallomonas caudata	Chr	98.0	73.5		57.2
Mallomonas sp. 3	Chr	14.1		22.0	12.0
Ochromonas sp.	Chr		1.3		0.4
misc. Chrysophyta	Chr		0.2		0.1
Cryptophytes					
Cryptomonas sp. 1	Cry	0.8	1.1	4.5	2.1
Cryptomonas erosa	Cry	3.5	23.1	2.0	9.5
Cryptomonas ovata	Cry	26.3	65.0	61.5	50.9
Rhodomonas minuta	Cry	2.6	9.7	13.6	8.6
Chlorophytes					
Ankistrodesmus falcatus	Chl	0.2	0.4		0.2
Botryococcus braunii	Chl		440.		146.7
Crucigenia rectangularis	Chl	0.9	0.4		0.4
Crucigenia tetrapedia	Chl		0.7		0.2
Dispora crucigenioides	Chl		2.0		0.7
Monomastix astigmata	Chl		0.6		0.2
Oocystis parva	Chl		10.8		3.6
Quadrigula chodatti	Chl		0.4		0.1
Schroederia judayi	Chl	0.5	0.2	0.4	0.4
Ulothrix sp.	Chl			0.8	0.3
colonial Chlorophyte	Chl	0.8	2.1	37.1	13.3
misc. Chlorococcales	Chl	15.9	1.6	0.2	5.9
Dinoflagellates					
Gymnodinium sp.	Din		69.7		23.2
Peridinium sp.	Din			99.1	33.0
Cyanobacteria					
Coelosphaerium naegelianum	Cya	0.1	2.6		0.9
Oscillatoria limnetica	Cya		2.0		0.7
coccoid Cyanobacteria	Cya			0.6	0.2
Other					
Euglena gracilis	Eug	70.6			23.5
microflagellates (misc.)	var	7.5	13.6	45.2	22.1
unidentifiable cyst	var		10.6		3.5
Total Counted Biovolume ($10^3 \mu m^3$/mL):		245.0	784.5	387.0	472.2

Table L.AII.5. Winter phytoplankton from Lake Lacawac--major species and their abundance as biovolume. A composite sample from each year of all dates and sampling depths during the period January through February was counted. *[Corrected version of 1/27/95]*

Alga	Type	Biovolume of species ($10^3 \mu m^3$/mL)			
		1990	1991	1992	mean
Diatoms					
Asterionella formosa	Dia	3.9		10.7	4.9
Tabellaria fenestrata	Dia		5.8		1.9
Chrysophytes					
Diceras sp.	Chr	1.3			0.4
Dinobryon divergens	Chr		0.9		0.3
Dinobryon sertularia	Chr		16.7		5.6
Dinobryon monads	Chr		8.2		2.7
Mallomonas sp.	Chr		35.5		11.8
Mallomonas sp. 3	Chr	38.5		363.7	134.1
Ochromonas sp.	Chr			1.2	0.4
Synura uvella/sphagnicola	Chr	111.3		2513.6	875.0
Uroglena sp.	Chr		65.4		21.8
Cryptophytes					
Cryptomonas sp. 1	Cry		0.6	0.6	0.4
Cryptomonas erosa	Cry	5.3	6.1	1.4	4.3
Cryptomonas ovata	Cry	15.7	246.4	6.9	89.7
Rhodomonas minuta	Cry	7.4	1.9		3.1
Chlorophytes					
Elakatothrix gelatinosa	Chl			0.4	0.1
Monomastix astigmata	Chl	0.6			0.2
Schroederia judayi	Chl	2.0	0.3	0.2	0.8
Staurastrum paradoxum	Chl		16.5		5.5
misc. Chlorococcales	Chl			0.2	0.1
Cyanobacteria					
Coelosphaerium naegelianum	Cya		0.3		0.1
coccoid Cyanobacteria	Cya		0.1		0.1
Other					
microflagellates (misc.)	var	5.7	5.4	8.2	2.7
Total Counted Biovolume ($10^3 \mu m^3$/mL):		191.7	410.1	2907.1	1169.6

APPENDIX III: ZOOPLANKTON SAMPLING

Table. L.AIII. Zooplánkton collection with nets compared to Schindler trap.

Values are concentrations (avg #/L ±SD) from N=5 vertical hauls or trap series (1 each at five stations in each lake). The ratios (R_{48}, R_{202}) are net values divided by trap values. The lakes were sampled the evening of 16 June 1993. Details of methods are discussed in the text (see **ZOOPLANKTON**).

	Schindler Trap		202-μm Net			48-μm Net		
	avg	±SD	avg	±SD	R_{202}	avg	±SD	R_{48}
Lake Giles								
Daphnia (total)	22.38	±2.17	15.81	±2.18	*0.706*	18.53	±1.19	*0.828*
Daphnia (large)	19.07	1.71	14.59	2.13	*0.765*	16.03	1.36	*0.841*
Daphnia (small)	3.31	0.70	1.21	0.18	*0.366*	2.49	0.21	*0.753*
Holopedium gibberum								
Diaptomus (total)	23.23	3.38	19.97	2.04	*0.860*	23.79	3.13	*1.024*
D. minutus	23.07	3.40	19.85	2.09	*0.860*	23.60	3.12	*1.023*
D. oregonensis								
D. spatulocrenatus	0.16	0.08	0.12	0.09	*0.775*	0.18	0.11	*1.138*
Cyclopoid copepods								
Asplanchna								
Lake Lacawac								
Daphnia (total)	6.16	±0.90	4.17	±0.75	*0.677*	5.03	±0.80	*0.817*
Daphnia (large)	4.08	0.79	2.46	0.36	*0.602*	3.22	0.73	*0.789*
Daphnia (small)	2.08	0.18	1.71	0.42	*0.823*	1.81	0.10	*0.871*
Holopedium gibberum	1.33	0.53	1.32	0.40	*0.995*	1.11	0.60	*0.839*
Diaptomus (total)								
D. minutus	5.36	0.66	4.04	0.52	*0.754*	6.31	0.92	*1.178*
D. oregonensis								
D. spatulocrenatus								
Cyclopoid copepods	1.84	0.53	1.26	0.25	*0.686*	1.92	0.31	*1.045*
Asplanchna	0.52	0.20	1.03	0.18	*1.981*	0.68	0.29	*1.308*
Lake Waynewood								
Daphnia (total)	21.55	±2.52	21.70	±4.93	*1.007*	25.83	±4.82	*1.199*
Daphnia (large)	14.55	1.51	12.96	2.76	*0.891*	16.86	3.26	*1.159*
Daphnia (small)	7.00	1.16	8.74	2.35	*1.248*	8.97	1.68	*1.282*
Holopedium gibberum								
Diaptomus (total)								
D. minutus								
D. oregonensis	0.10	0.04	0.14	0.04	*1.469*	0.12	0.04	*1.245*
D. spatulocrenatus								
Cyclopoid copepods	0.05	0.02	0.05	0.02	*1.174*	0.05	0.02	*1.043*
Asplanchna	1.88	0.45	2.46	0.64	*1.309*	2.44	0.74	*1.298*