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Limnological Investigations
of Eagle Lake, Michigan

presented by

Robert John Ceru

has been accepted towards fulfillment
of the requirements for

Masters degree in Fisheries and Wildlife

E. W. Roelofs
Major professor

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LIMNOLOGICAL OBSERVATIONS
OF EAGLE LAKE, MICHIGAN

By

Robert John Ceru

A THESIS

Submitted to
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in partial fulfillment of the requirements
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ABSTRACT

LIMNOLOGICAL OBSERVATIONS OF EAGLE LAKE, MICHIGAN

By

Robert John Ceru

Limnological and biological parameters of Eagle Lake, Michigan were investigated between May-October, 1975, and March-November, 1976 in order to document present lake conditions. Results indicate mesotrophic conditions with thermal stratification and hypolimnetic oxygen depletion during the summer. Mean values were 4.5 meters for Secchi disk, 0.056 mg/liter for total phosphorus, and 0.45 mg/liter for total Kjeldahl nitrogen. Thirty-six phytoplankton genera were identified and their abundance and succession discussed. Mean summer Chlorophyll *a* concentration was 3.53 μg/liter during 1976. The rate of growth for bluegills compared favorably with the tentative state average.

ACKNOWLEDGEMENTS

The advice, guidance and support received from E. W. Roelofs, my major professor, during my graduate studies and in writing this thesis is gratefully acknowledged and appreciated.

Sincere appreciation is expressed to N. R. Kevern for his many thoughtful suggestions and assistance in initiating the research and for his critical review of the thesis.

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Special thanks is given to Mr. William Stout, President of the Eagle Lake Association for collecting Chlorophyll *a* and bacteria samples, and generously providing gas and the use of his house anytime during the study. His patience, support and encouragement stimulated enthusiasm throughout the study.

I thank my fellow students, particularly Robin Bentz, for helping collect these data.

Special gratitude is expressed to my brothers and sisters in the Work of Christ Community for their inspiration, understanding and encouragement. Particular thanks goes to Miss Dee Wilkie for typing the thesis and Mr. Richard Schaefer for doing all of the graphics.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Most previous water quality control work has been concentrated in problem areas, with resulting lack of good background water quality determinations in many areas (Michigan DNR, 1970). Once background measurements are determined, they provide a useful basis from which future water quality trends can be evaluated.

The purpose of this study was to obtain such background information on physical, chemical and biological parameters in Eagle Lake. This study will provide the residents of the lake with some technical data that will be a useful indication of the present water quality and provide a basis for future development and management of the lake.

DESCRIPTION OF STUDY AREA

Eagle Lake is located near Bloomingdale in the drainage basin of the Kalamazoo River (T1S., 1N. R14W., Sections 3, 34, and 35, Van Buren and Allegan Counties). It is a medium size (surface area of 91 hectares), relatively deep lake (mean and maximum depths of 6.7 and 19.0 meters respectively), with a small inlet on the southeastern shore. It has a watershed of 193 hectares (Marsh and Borton, 1974), which consists of deep to moderately deep, well to somewhat

poorly drained, nearly level to gently sloping, very coarse textured soils. Most of the northeast and south shoreline is bordered by wooded areas while the north end consists of a swamp dominated by cattails. The remainder of the shoreline is gently sloping and bordered by year-round homes.

Eight permanent sampling stations were established in order to standardize the sampling program (Figure 1). Stations 2, 3, 5 and 6 were all open water stations with no aquatic macrophyte colonization and a depth ranging from 16 to 19 meters. Stations 1, 4 and 8 were situated in near-shore areas ranging in depth from 1 to 1.5 meters. Mud bottoms of these latter stations were flat with abundant macrophyte growth. Station 7 had a depth of 9 meters with a sloping bottom and sparse macrophyte growth.

METHODS

A hydrographic map of Eagle Lake was obtained from the Michigan United Conservation Clubs. Areas were measured using a compensating polar planimeter and map measurer. The methods used in calculating the various morphometric parameters are those given by Welch (1948) and Cole (1975).

Samples for chemical analysis were obtained from spring until fall in 1975 and 1976 (Appendix Tables A1 and A2). Samples from stations 1, 4 and 8 were taken just below the surface. Samples from stations 2, 5 and 6 were

Figure 1. Locations of sampling stations for Eagle Lake, Michigan.

taken at the surface, epilimnion-thermocline interface and bottom. Water samples for Chlorophyll *a* determinations were collected bimonthly from station 2 between May and September, 1976.

Secchi disk visibility was measured approximately every two weeks between May and October in 1975 and March and November in 1976.

Phytoplankton samples were collected every two weeks between July and October, 1975 at stations 2, 3, 6 and 7 at the surface and 10 feet. Data for coliform bacteria were obtained from records of the Allegan County Health Department for the summers of 1974 and 1975.

Samples for water chemistry were collected with a 1-liter Kemmerer bottle. Dissolved oxygen, pH, alkalinity, hardness, and chloride analyses were performed in the field. Dissolved oxygen was titriometrically analyzed by the azide modification of the Winkler iodometric method (APHA, 1971). A Beckman portable pH meter was used to determine water pH. Alkalinity (phenolphthalein and methyl orange) was analyzed by the acid titration method (APHA, 1971). Hardness was measured by the EDTA titration method (Kevern, 1973). Mercuric nitrate titration was used to determine chloride concentrations (APHA, 1971). Nitrogen and phosphorus samples were taken to the Water Quality Laboratory of the Institute of Water Research at Michigan State University for analysis. Total phosphorus and total

Kjeldahl nitrogen were determined on a Technicon Auto-analyzer with the block digester technique.

Phytoplankton samples were obtained with a 1-liter Kemmerer bottle. When brought to the surface, 0.5 liter was transferred to a plastic bottle and a 1% solution of Lugol's killing and preserving liquid was added. Samples were brought to the laboratory and allowed to settle. Each smaple was reduced to 50 ml and centrifuged at 1400 RPM for 30 minutes. The concentrated phytoplankton was then transferred to a slide for identification and counting. Keys of Prescott (1951, 1970) and Smith (1950) were used in identifying algae to the generic level.

Samples for Chlorophyll *a* were obtained weekly from May through September, 1976 at station 2. Secchi disk visibility was measured prior to sampling for Chlorophyll *a*. A water sample was taken at twice the depth of the Secchi disk measurement and preserved immediately with 3-4 drops of a supersaturated solution of magnesium carbonate. Each sample was mailed to the Department of Natural Resources Laboratory in Lansing, Michigan where it was analyzed according to Standard Methods (APHA, 1971).

Aquatic insects were collected with a standard Eckman dredge (15.2 cm X 15.2 cm) on June 25, 1975 at 2, 4 and 8-meter depths along a transect from shore to station 2. Duplicate samples were collected and washed in a 30-mesh screen. The residue containing organisms was placed in a

1-liter bottle and preserved in an 80% alcohol solution and taken to the laboratory. Organisms were removed by careful picking and identified to the family level with the aid of Pennak (1953).

Aquatic plants were collected in late August, 1975. Plants were sampled by hand along many transects from shore to deep water. Plants were brought to the laboratory and identified with the aid of Fasset (1957).

Surface samples for coliform bacteria were collected randomly along the shoreline and analyzed according to standard methods (APHA, 1971).

Bluegill sunfish (Lepomis Macrochirus) were collected during the summers of 1975 and 1976 with 2 experimental gill nets, 6 by 200 feet with four sections of different mesh sizes (ranging from 1 to 4 inches, stretched measure); 2 cast nets of single mesh size (0.5 and 1.0 inches) and 10 feet in diameter; and angling.

The scale method as described by Lagler (1956) and Regier (1962) was employed in determining age and growth characteristics. Length measurements (standard and total) were made to the nearest millimeter. Weights were measured to the nearest gram for fish heavier than 30 grams and to the nearest 0.1 gram for fish under 30 grams.

Scale samples were collected by removing approximately 10-15 scales from the left side of the fish just below the lateral line and at the midpoint of the spiny dorsal fin.

Scales were dried in envelopes and plastic impressions were made with a roller press similar to the one described by Smith (1954). Scale impressions were enlarged and examined on a Bausch and Lomb microprojector.

From magnified impressions, measurements were made of the distance of each annulus and the anterior edge of the scale from the focus. The measurements were recorded on scale cards along the anterior radius. Calculated data for the lengths at the time of each annulus formation were obtained on a nomograph as described by Hile (1941).

PHYSICAL PARAMETERS

Morphometry

A hydrographic map of Eagle Lake is shown in Figure 2. The lake has a surface area of 91 hectares and a maximum depth of 19.0 meters (Table 1). Shore development is 1.7.

Table 1. Morphometric measurements for Eagle Lake, Michigan

Item	Value
Maximum Depth	19.0 meters
Mean Depth	6.7 meters
Area	909,361 square meters
Total Shore Length	5,596 meters
Shore Development	1.7
Volume	6,119,183 cubic meters
Volume Development	1.1

Areas and volumes of water at various levels are presented in Table 2. Although the lake has four deep basins,

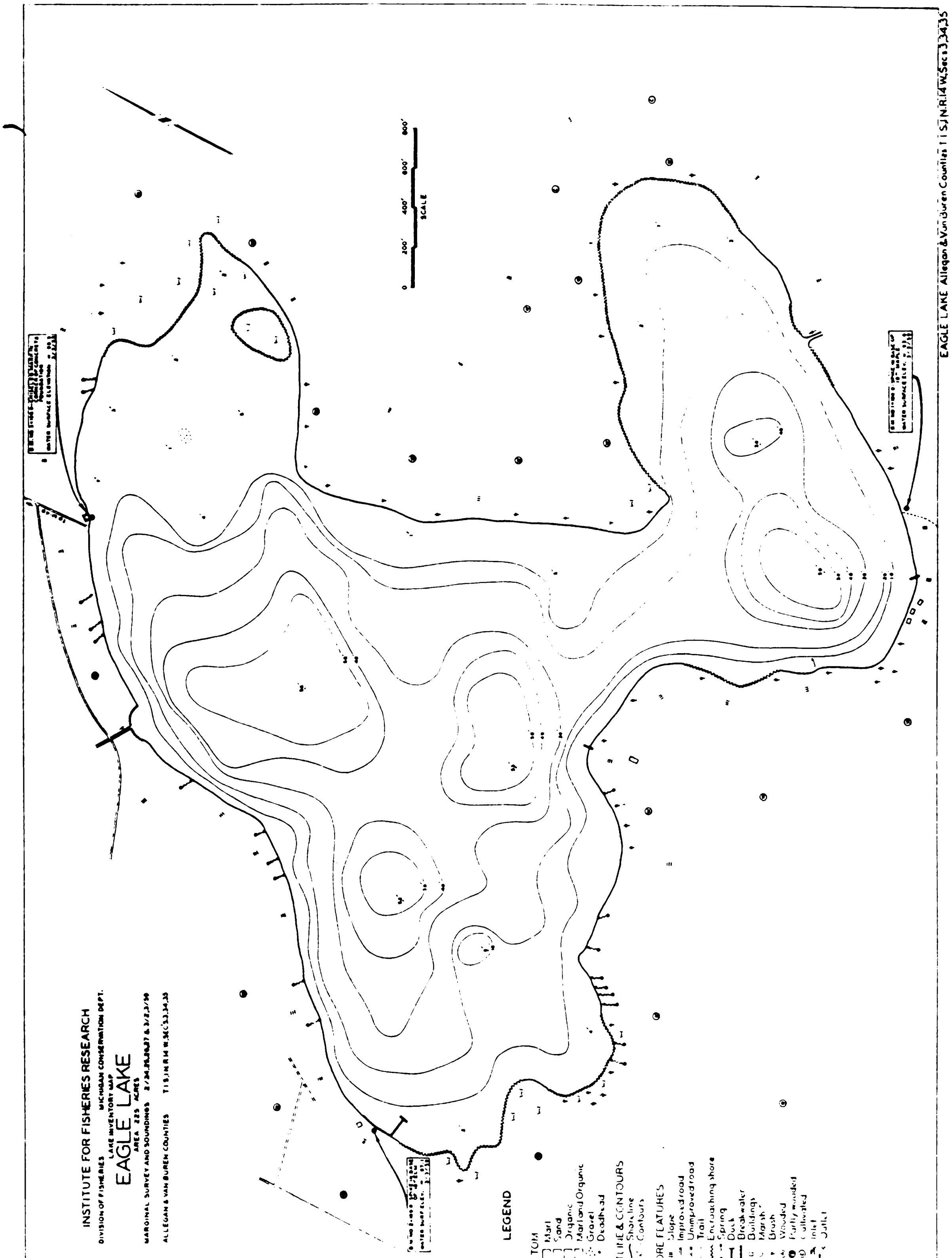


Figure 2. Hydrographic map of Eagle Lake, Michigan

extensive shallow areas in the north and southeast sections result in almost 70 percent of the lake's volume to be in the 0 to 6.1-meter stratum. A percent volume hypsograph (Figure 3) indicates that 50 percent of the lake's volume is contained above and below 4.1 meters.

Table 2. Areas and Volumes of Water at Various Levels for Eagle Lake, Michigan

Depth (meters)	Areas (square meters)	Areas (% of surface)	Stratum (meters)	Volume (cubic meters)	Volume (% of total)
0.0	909,361	100.0	0.0-3.1	2,337,118	38.2
3.1	621,115	68.3	3.1-6.1	1,672,567	27.3
6.1	471,071	51.8	6.1-9.1	1,147,308	18.8
9.1	283,695	31.2	9.1-12.2	645,099	10.5
12.2	141,073	15.5	12.2-15.2	317,091	5.2
15.2	67,180	7.4			

Volume development is 1.1, indicating a slightly U-shaped basin (Shannon and Brezonik, 1972). Most lakes that have been included in extensive morphometric studies have depressions that are U-shaped in cross section (Koshinsky, 1970; Hayes, 1957; Gorham, 1958; Neumann, 1959; Hutchinson, 1957).

Secchi Disk Transparency

Secchi disk data for 1975 and 1976 are shown in Figure 4. Average values were 5.2 meters and 3.8 meters in 1975 and 1976, respectively. In both years water clarity was

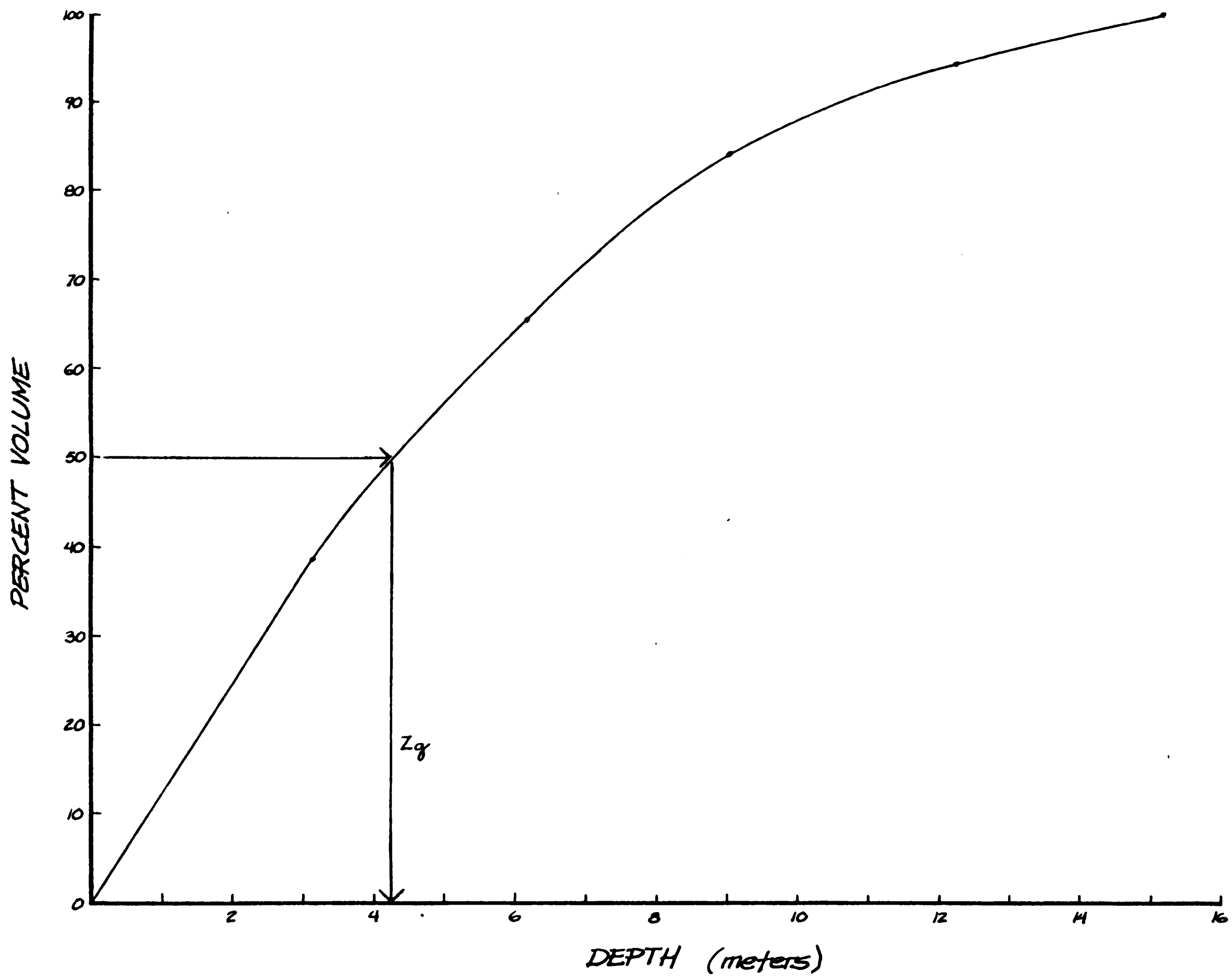


Figure 3. Percent volume hypsograph curve for Eagle Lake, Michigan. Center of gravity Zg, indicated at depth where 50% of volume lies above and below.

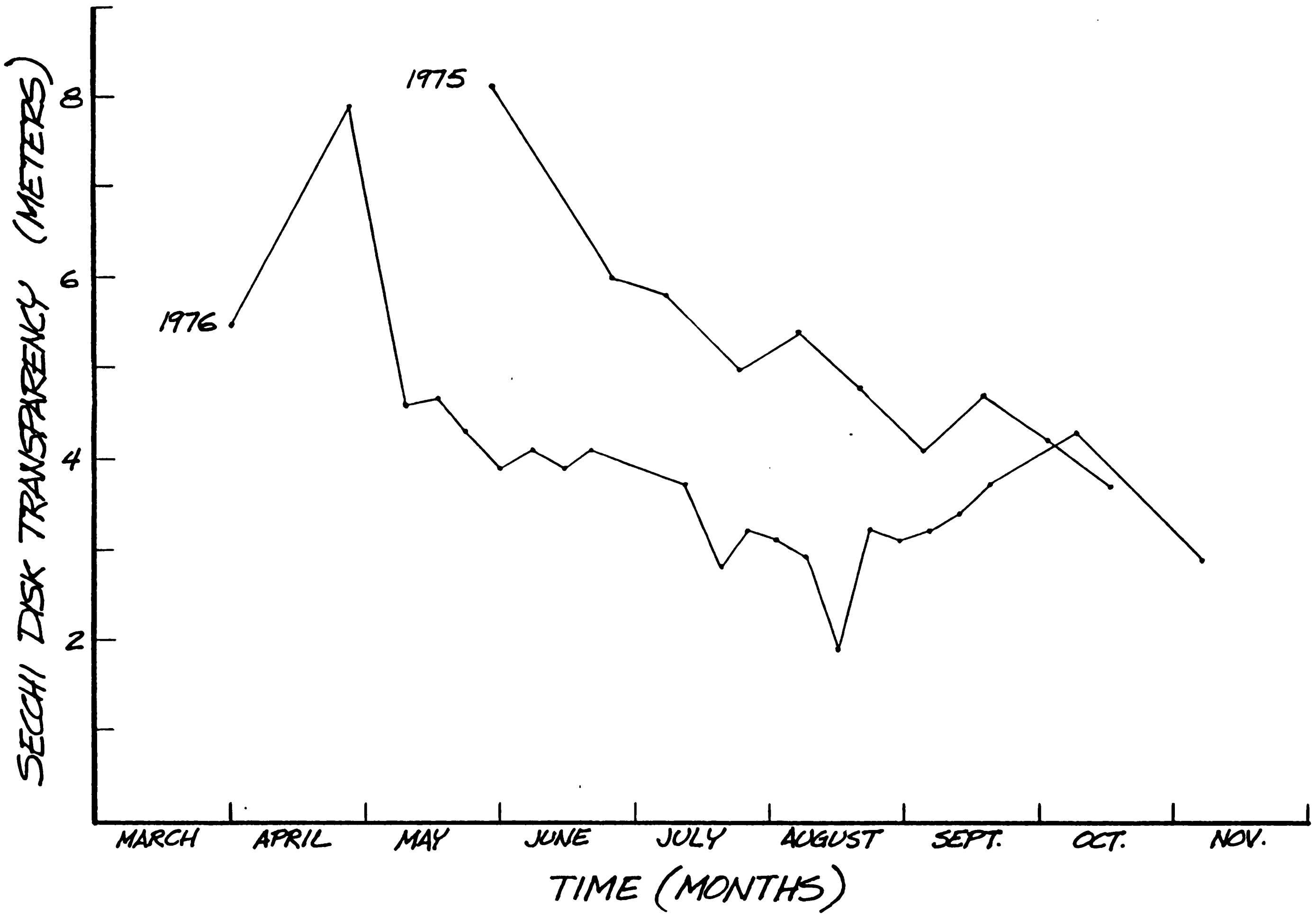


Figure 4. Secchi disk transparency for Eagle Lake, May-October, 1975; March-November, 1976.

highest in the spring and then decreased to the lowest readings in October and November. Although water transparency patterns were similar during both years, values ranged from 3.7 to 8.1 meters in 1975, and 2.9 to 7.7 meters in 1976. Mean monthly differences between the two years ranged from as high as 3.8 meters in May to as low as 0.3 meters in October.

In general, decreasing values for water transparency corresponded with increasing values for Chlorophyll *a* during 1976 and are thus related to phytoplankton production. Hrbacek et al. (1961) and Hutchinson (1957) found similar patterns. Wind velocity seemed to be much higher in 1976 than in 1975. This may be a partial explanation for the lower readings in 1976. Tressler and Domogalla (1931) state that the action of the waves produced by high winds in summer will stir up and distribute decomposition products and debris throughout the water mass.

Water Temperature

Maximum surface temperatures recorded were 25 C in late July, 1975 and 24.9 C in early August, 1976. Maximum hypolimnetic temperatures were 16.6 C in early September, 1975 and 17.7 C in June, 1976 (Appendix Tables A3, A4, A5).

Thermal stratification was already in progress (Figure 5) when this study was begun on May 28, 1975. The upper limit of the thermocline was at 3.7 meters and the lower limit at 6.0 meters. On September 3, 1975, the thermocline

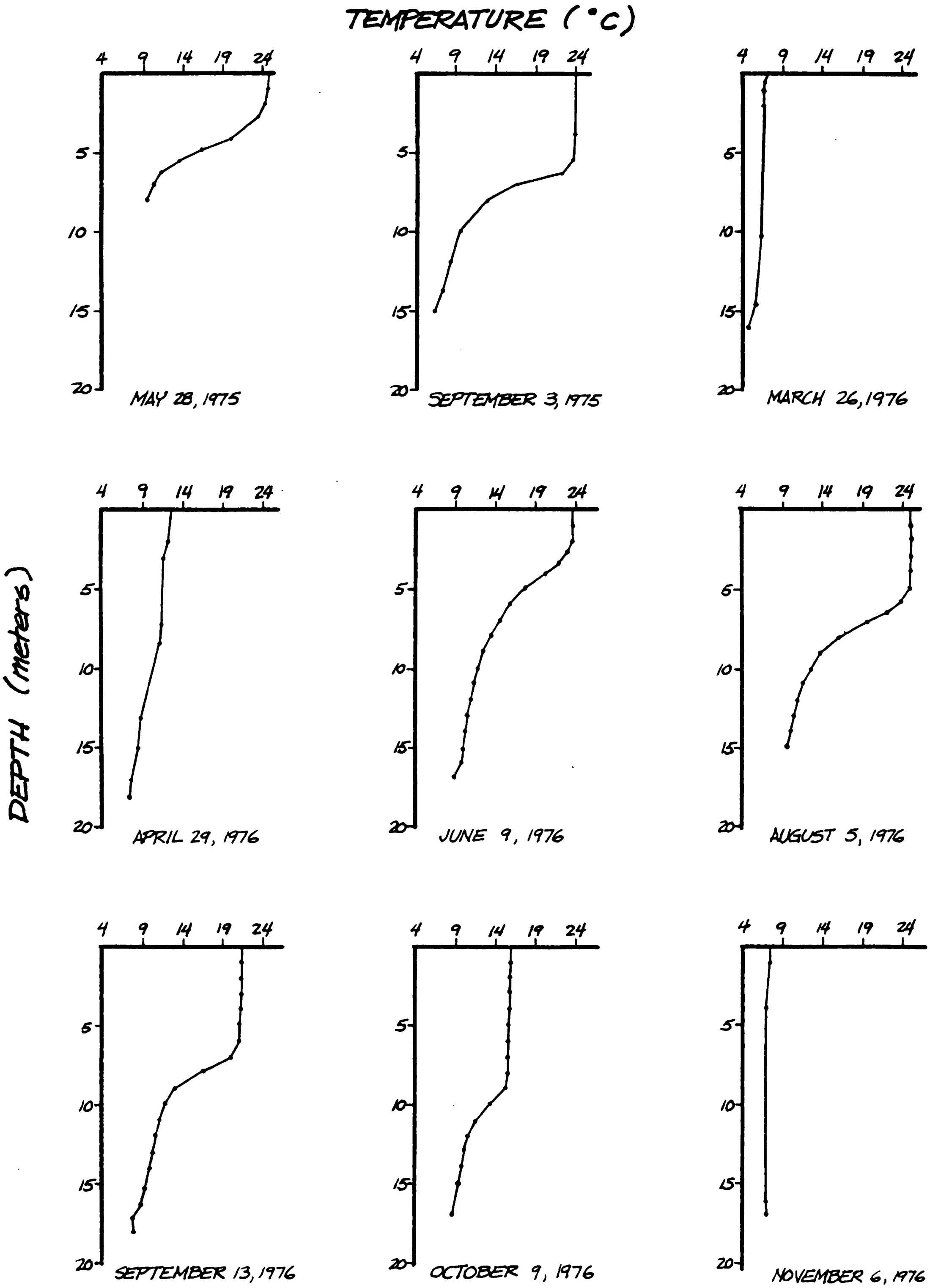


Figure 5. Temperature profiles for Eagle Lake, Michigan, 1975 and 1976.

occupied the stratum of water between 6.4 and 10.0 meters.

When the study resumed on March 26, 1976, the lake was not homothermous, having a 2.1 C temperature difference from surface to 16 meters. On June 8, 1976 the thermocline occurred between 5 and 8 meters. By October 9, 1976 its upper limit had reached 10 meters and its lower limit 12 meters. On November 6, 1976 the lake exhibited a homothermous condition.

Eagle Lake appears to be a dimictic lake with mixing periods during early March and November. Thermocline depth ranged from 2 to 5 meters on days when data were collected.

It is worthwhile to note that each sampling station exhibited different thermal conditions during thermal stratification near the bottom of the basin (Table 3). On March 26 and November 6, 1976, temperatures varied 0.1 to 0.5 C at a depth of 15 meters. However, between April 29 and October 9, 1976, bottom temperatures varied 1.4 to 3.8 C. Welch (1935), working on Douglas Lake, Michigan, also found that during thermal stratification the deep layers of different depressions developed different thermal properties.

Table 3. Bottom temperatures (^{o}C) for stations 2, 5 and 6 during 1976 in Eagle Lake, Michigan

Station	March 26	April 29	June 9	August 5	September 13	October 9	November 6
2	5.5	8.8	9.9	10.0	9.9	9.8	6.9
5	5.5	9.1	10.9	10.8	10.7	10.5	7.0
6	5.0	7.7	8.0	7.0	8.0	7.9	7.0

CHEMICAL PARAMETERS

Dissolved Oxygen

Dissolved oxygen content of Eagle Lake varied throughout the study period. Average surface values for May 28, 1975 and September 3, 1975 were 7.9 and 7.7 mg/liter respectively (Appendix Tables A6, A7). On May 28, 1975, a positive heterograde curve as described by Aberg and Rodhe (1942) was noted (Figure 6). Hypolimnetic oxygen depletion had already begun to appear. Bottom values for stations 2 and 5 averaged 4.6 mg/liter. By September 3, 1975, little or no oxygen remained in the hypolimnion.

Sampling resumed on March 26, 1976. Oxygen values showed little difference from surface to bottom. By June 9, a positive heterograde curve was recorded with an average metalimnion value of 11.4 mg/liter. This metalimmetic maximum decreased gradually until a typical clinograde curve existed from August to October. By November 6, fall turnover had occurred and uniform oxygen values were recorded.

Oxygen content in the hypolimnion decreased rapidly in 1976 after June 9. Average bottom oxygen values for stations 2 and 5 were 3.4 mg/liter, while station 6 had 0.6 mg/liter at the bottom. By September 13, there was no oxygen recorded from 14 meters to the bottom at all stations.

Early loss of dissolved oxygen may be due to plant and animal respiration, bacterial respiration in decomposition

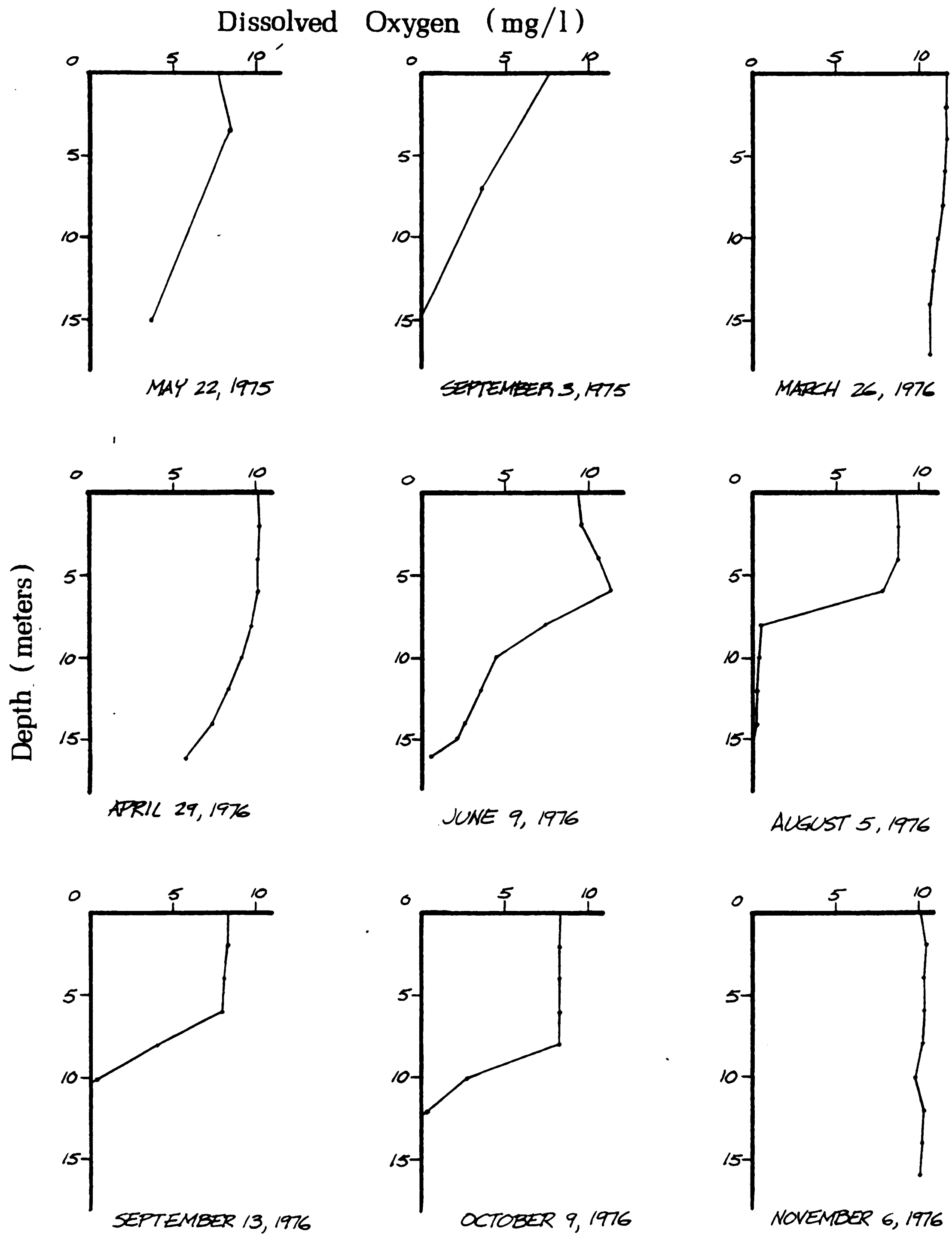


Figure 6. Dissolved oxygen profiles for Eagle Lake, Michigan.

of sedimenting organic matter (Wetzel, 1975), and chemical oxidation (Gjessing and Gjerdahl, 1970). A pattern of oxygen distribution in different basins existed that was similar to the one reported for temperature. During thermal stratification the deeper portions of station 6 showed much lower oxygen concentrations than the other two deep water stations. According to Wetzel (1975), uniform horizontal distribution of the oxygen profile in the hypolimnion is assisted by vertical turbulence, horizontal translocations, and density currents that move along the basin sediments.

Because station 6 is located in the deepest and steepest sloping basin in Eagle Lake, oxygen rich waters may not be circulating as well as in the other sections of the lake. Winds are normally out of the southwest and the hills to the southwest of station 6 may prevent the wind from completely circulating the water.

Alkalinity, Hardness, and pH

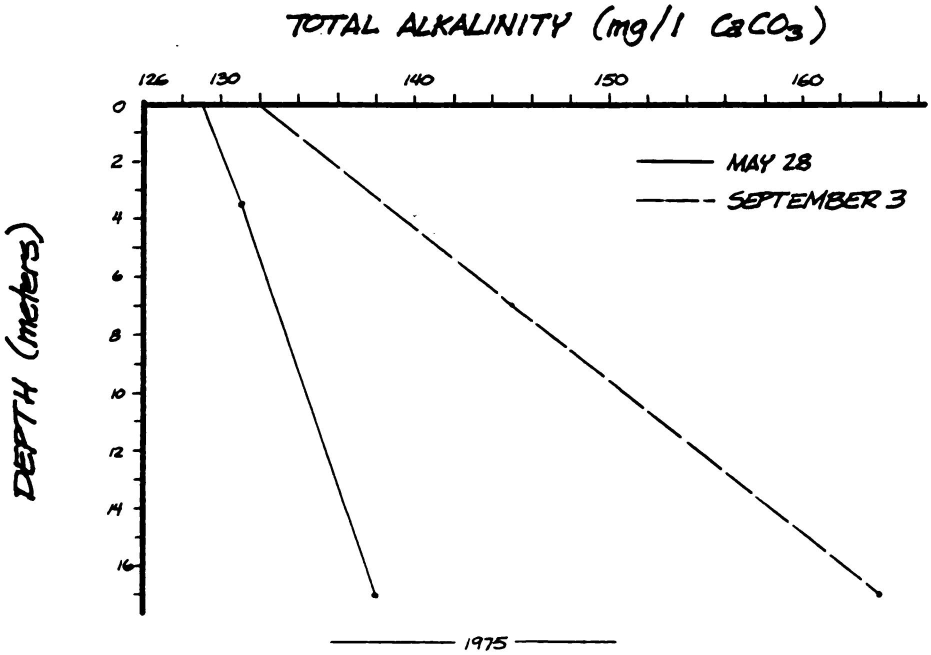
Eagle Lake waters were mostly alkaline, with pH values ranging from 7.0 to 8.4 in 1975 and from 6.6 to 8.4 in 1976 (Appendix Table A8). During stratification, pH decreased from surface to bottom. Greatest variation occurred in June and September, 1976, with differences of 1.2 and 1.3 pH units, respectively, from surface to bottom.

In the early spring during both years pH values increased in the metalimnion. Hutchinson (1957) and Cole

(1975) attribute this to the removal of CO_2 during photosynthesis by phytoplankton. Tucker (1957) reported that the five lakes he studied in Michigan all demonstrated decreasing pH values with depth during thermal stratification. Wetzel (1975) states that a combination of decompositional processes results in a decrease in pH of the hypolimnetic waters.

Mean alkalinity values (as $CaCO_3$) were 140 mg/liter in 1975 and 138 mg/liter in 1976 (Figure 7, Appendix Table A9). Average values increased from spring to late summer during 1975. During spring overturn, 1976, alkalinity values were almost uniform with depth. However, between June and September, 1976, alkalinity values in the epilimnion and metalimnion decreased while alkalinity values in the hypolimnion increased. Golterman (1975) attributes increasing alkalinity values in the hypolimnion to biogenic or abiogenic declarification of the epilmnion. During photosynthesis, algae utilize CO_2 which results in the precipitation of calcium carbonate (Wetzel, 1975). The sinking carbonate is redissolved in the hypolimnion by the carbonic acid formed from hydration of the CO_2 of decay (Cole, 1975).

Mean hardness values (as $CaCO_3$) were 151 mg/liter in 1975 and 149 mg/liter in 1976 (Figure 8, Appendix Table A10). Average hardness only varied 1 to 2 mg/liter between spring and late summer during both years. According to Kevern (1973), Eagle Lake may be classified as a moderate to hardwater lake.



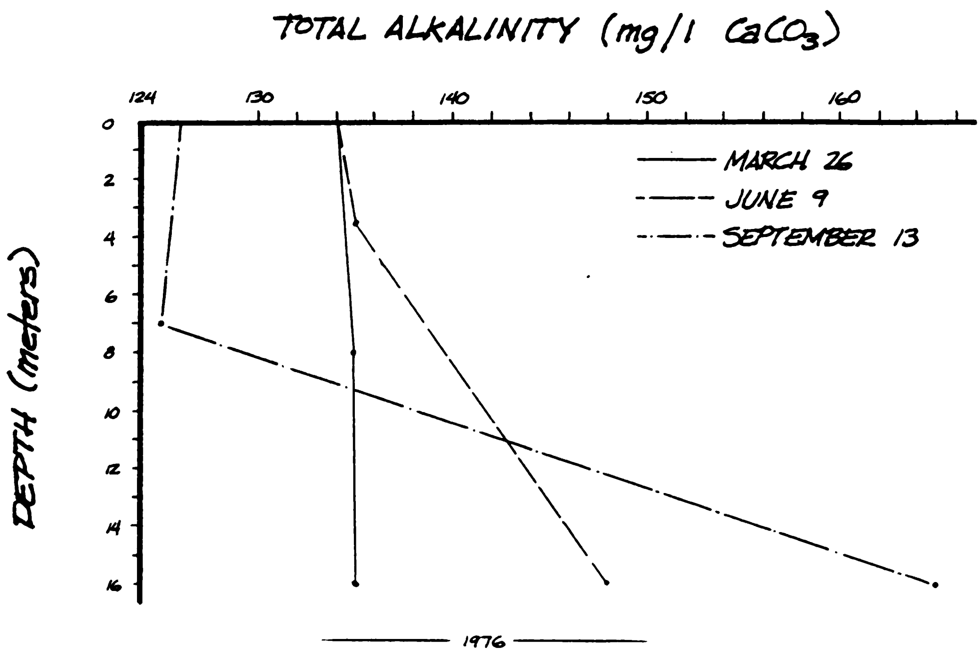


Figure 7. Depth distribution of total alkalinity in Eagle Lake, Michigan.

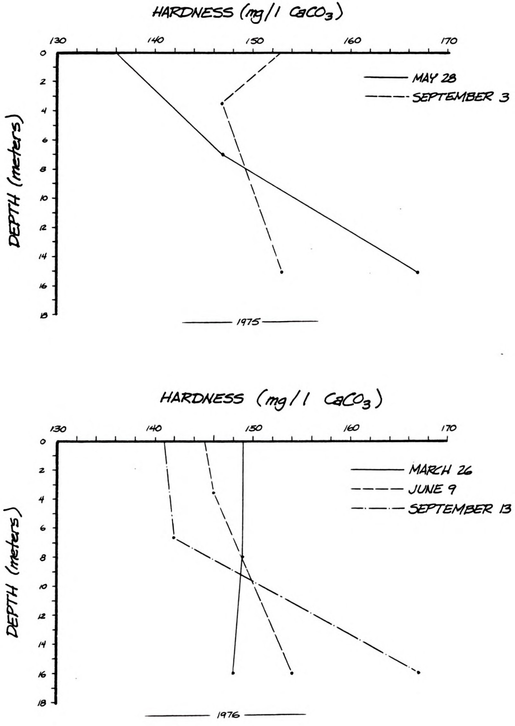


Figure 8. Depth distribution of hardness in Eagle Lake, Michigan.

Nitrogen

Nitrogen concentrations (all reported as N) in the surface water ranged from 0.11 to 1.79 mg/liter during the two years (Figures 9 and 10, Appendix Table All). Average nitrogen concentrations in surface waters varied during 1975 but showed little difference in 1976. Values ranged from 0.89 mg/liter on May 28, 1975 to 0.21 mg/liter on September 3, 1975. During spring overturn in 1976, nitrogen concentrations showed little difference with depth. With the exception of May 28, 1975, nitrogen values increased with depth during thermal stratification. It should be noted that nitrogen concentrations increased from 0.27 to 1.64 mg/liter in the bottom waters from March to September, 1976. Mean nitrogen concentration in surface waters was 0.45 mg/liter for both years. Mean nitrogen concentration in bottom waters was 0.89 mg/liter for both years.

According to a lake productivity table developed by Wetzel (1975), Eagle Lake is meso-eutrophic based on mean nitrogen concentration in surface waters. Sources of organic nitrogen may be from littoral macrophytes (Wetzel and Manny, 1972), decomposition of aquatic vascular vegetation (Nichols and Keeney, 1973) and allochthonous inputs (Manny, 1972).

Phosphorus

Total phosphorus concentrations (all reported as P) in the surface water ranged from 0.003 to 0.23 mg/liter during

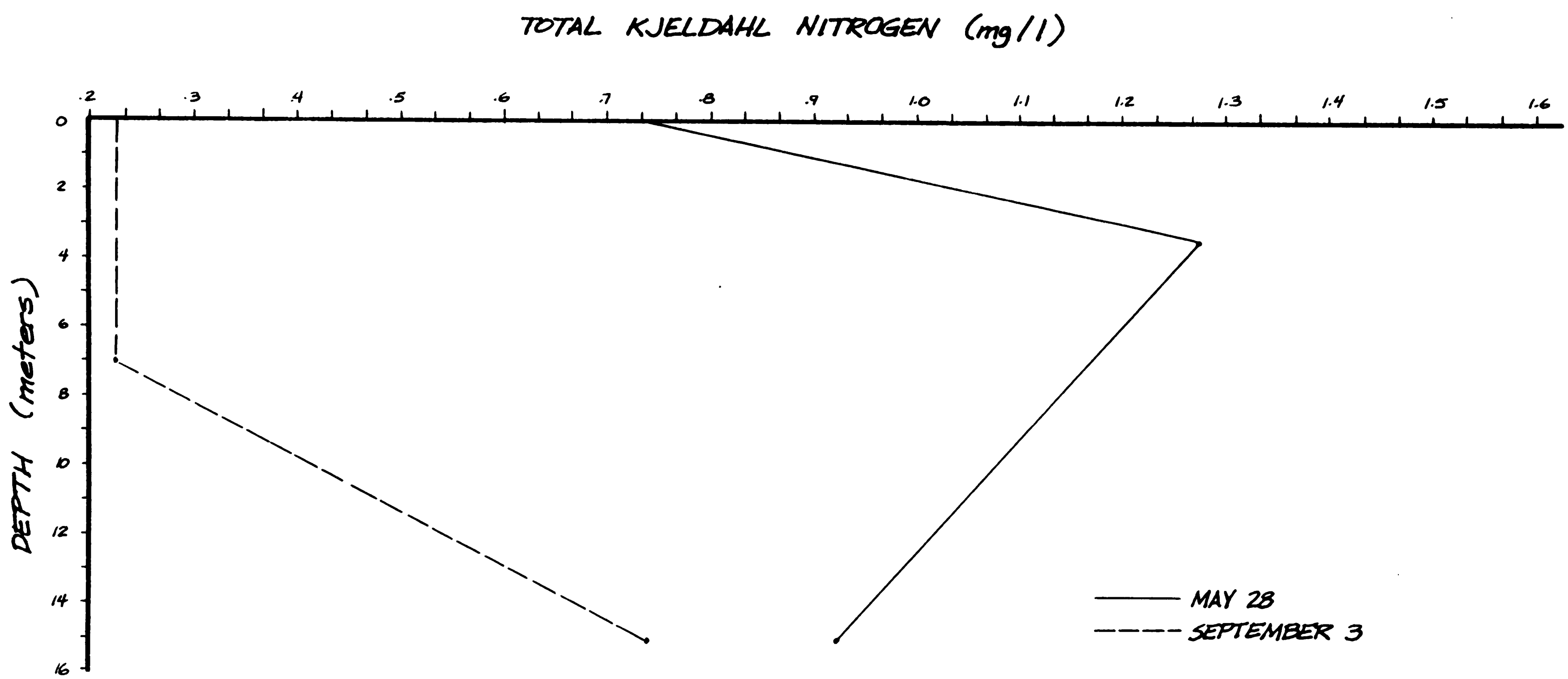


Figure 9. Depth distribution of total Kjeldahl nitrogen in Eagle Lake, Michigan during 1975.

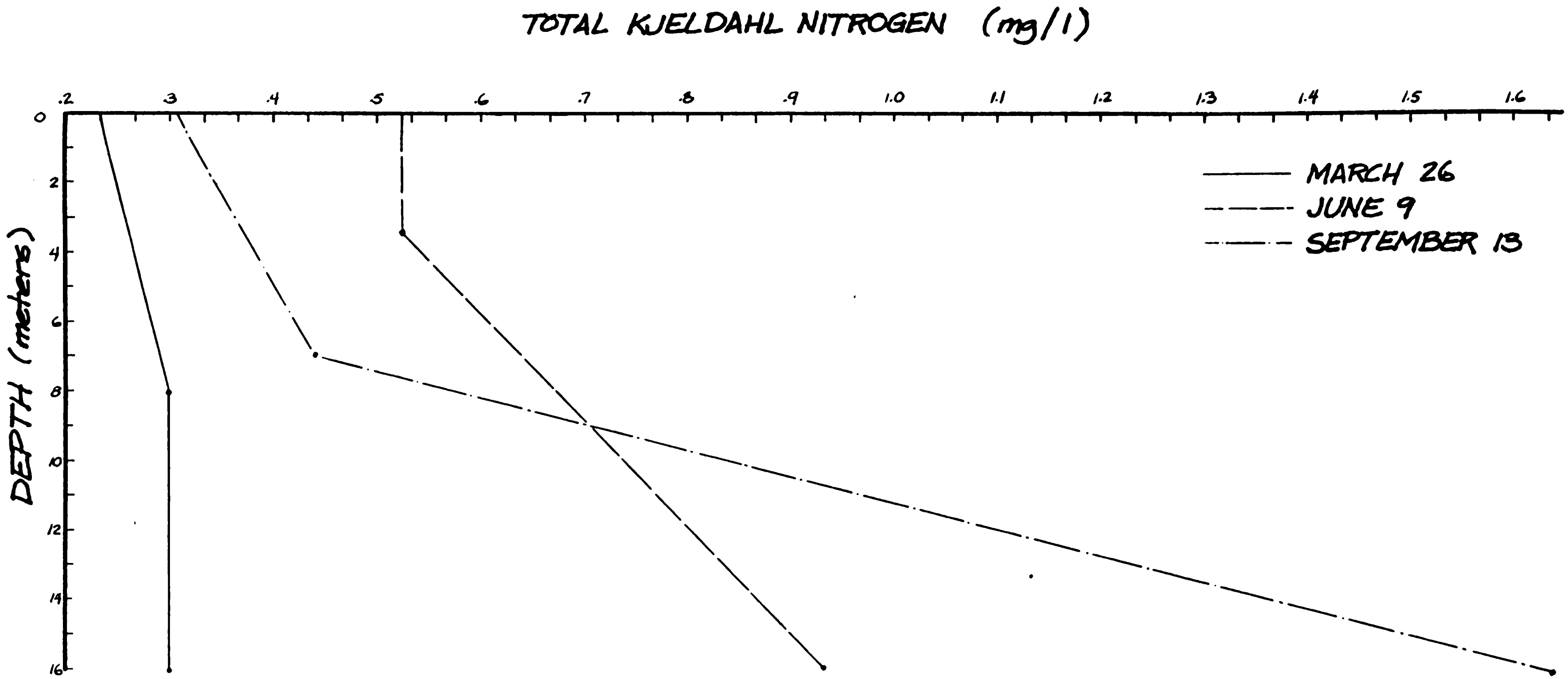


Figure 10. Depth distribution of total Kjeldahl nitrogen in Eagle Lake, Michigan during 1976.

both years (Figures 11 and 12, Appendix Table A12). Mean total phosphorus in the surface water during the study period was 0.056 mg/liter. During spring overturn in 1976, total phosphorus concentrations showed little difference with depth. During periods of thermal stratification, total phosphorus increased slightly in the metalimnion and markedly in the hypolimnion. Mean total phosphorus concentration in bottom waters was 0.18 mg/liter for both years. During 1975, mean total phosphorus concentrations for the entire lake decreased from May (0.15 mg/liter) to September (0.06 mg/liter), while in 1976, mean total phosphorus concentrations were low during spring turnover (0.08 mg/liter) and increased during the summer until September (0.118 mg/liter).

Total phosphorus concentration, considered a key factor in production and degree of eutrophication (Schindler et al., 1971; Jones, 1972; Kerekes, 1974), was high compared to data from other lake studies (Table 4). Mean surface water values from Eagle Lake exceed those found in northeastern Wisconsin lakes by a factor of almost 2.5. However, Eagle Lake values were far below those reported by Cowell et al. (1975) for Lake Thonotosassa, Florida, a lake receiving wastes from primary treated sewage and citrus processing plants. According to a lake productivity classification developed by Wetzel (1975), Eagle Lake is eutrophic based on total phosphorus concentrations. This conflicts somewhat with Secchi disk data presented earlier.

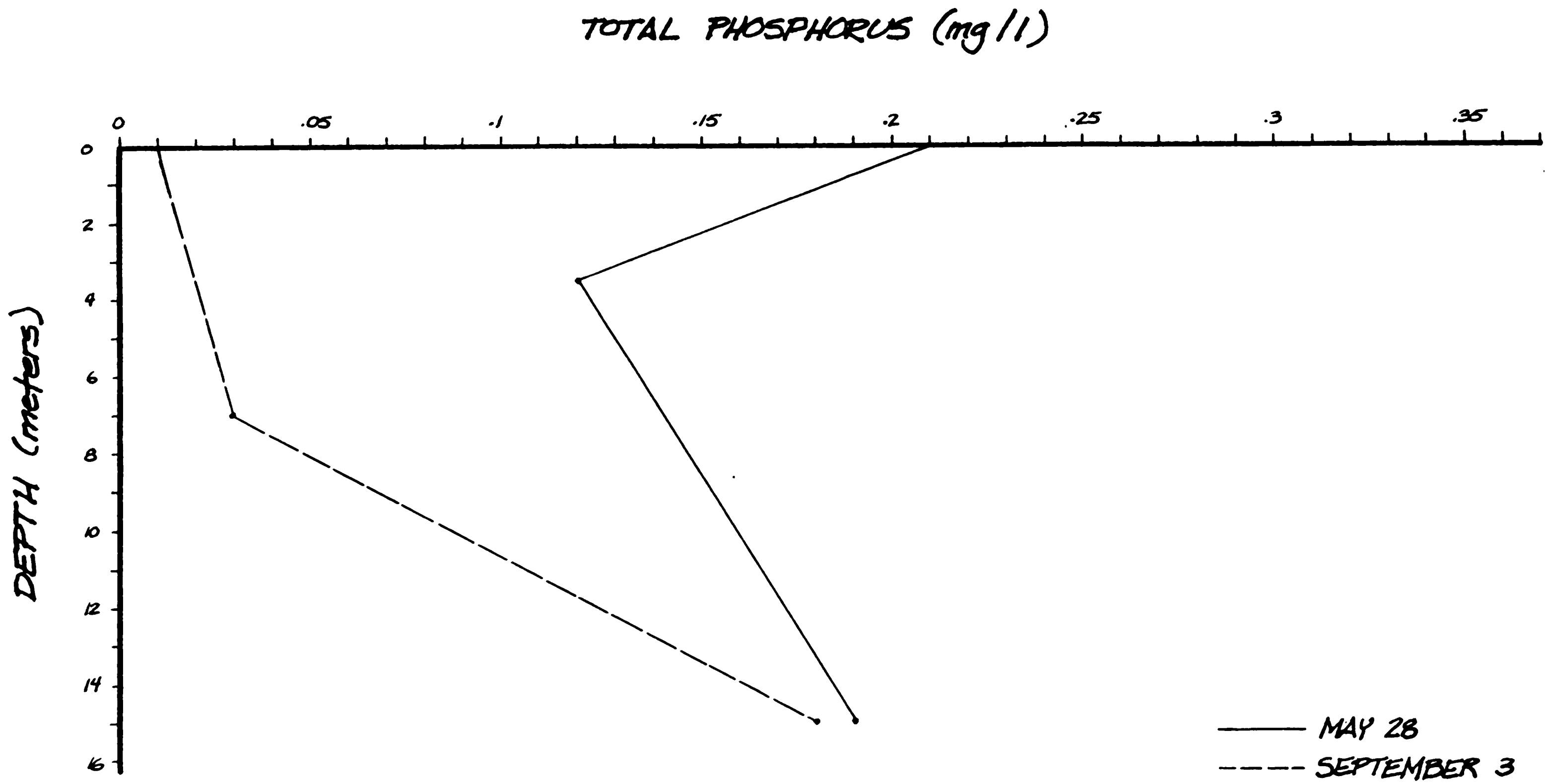


Figure 11. Depth distribution of total phosphorus in Eagle Lake, Michigan during 1975.

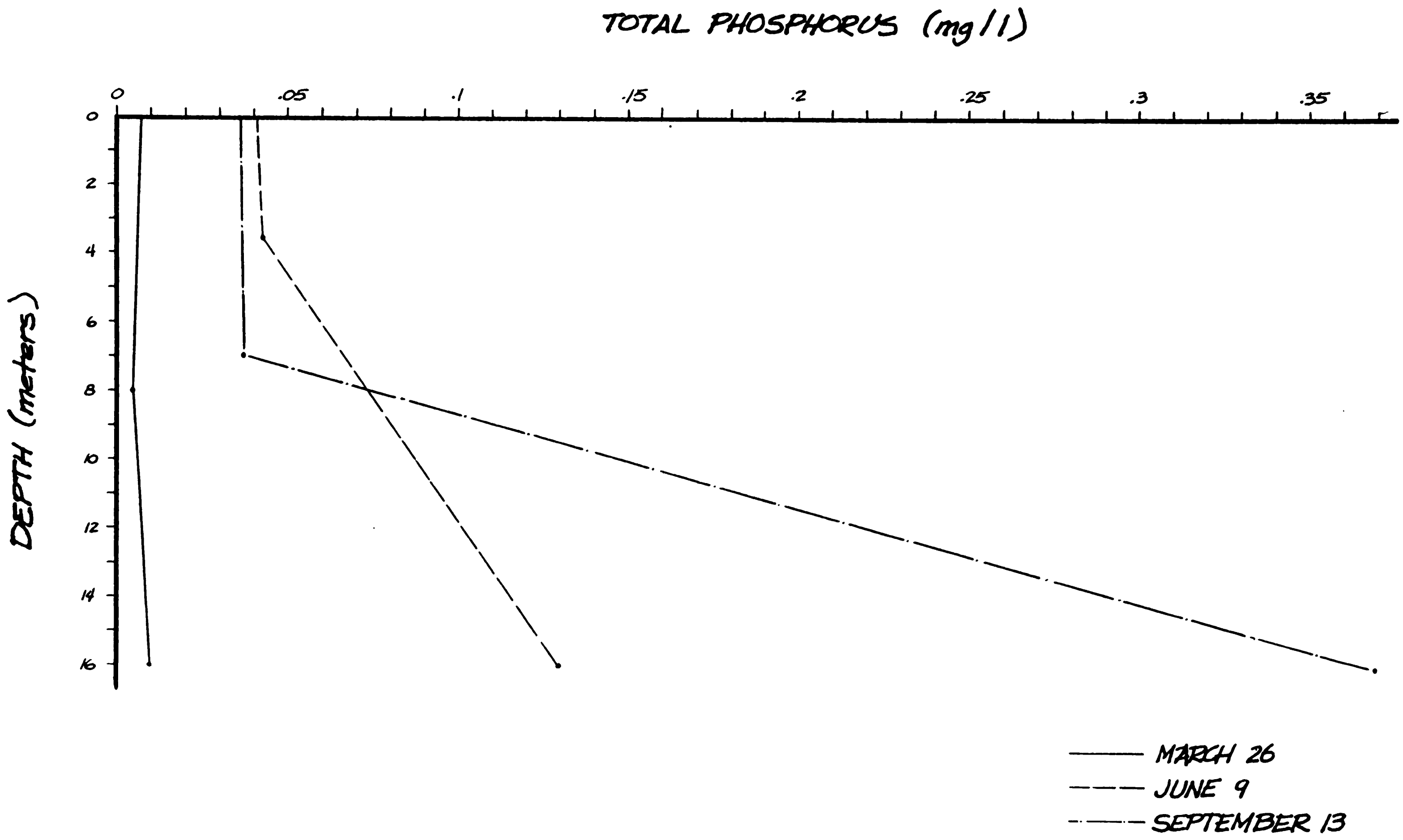


Figure 12. Depth distribution for total phosphorus in Eagle Lake, Michigan during 1976.

Table 4. Total phosphorus in surface waters of various lakes.

Region	Mean (mg/l)	Range (mg/l)
Northeastern Wisconsin Lakes (479) (Juday and Birge, 1931)	.023	.008 - .140
Spring Lake, Michigan (Bentz, 1977)	.031	.006 - .056
Minnesota Lakes (45) (Moyle, 1947)	.047	.005 - .200
Ontario Lakes (8) (Rigler, 1964)	-	.005 - .018
Michigan Lakes (5) (Tucker, 1957)	-	.007 - .014
Eagle Lake, Michigan	.056	.003 - .230

Increasing total phosphorus concentrations with depth during thermal stratification was also reported by Tucker (1957), Reid (1961), and Wetzel (1975). This may be attributed to horizontal water movements that carry phosphorus from the mud-water interface into the free water during near anaerobic conditions (Mortimer, 1971) and the continual sedimentation of sestonic phosphorus (Steiner, 1938 and Hutchinson, 1941).

Chlorides

Chlorides in Eagle Lake surface waters averaged 8.9 mg/liter in 1975 and 9.9 mg/liter in 1976. During both years values ranged from 8.1 to 10.0 mg/liter. Moyle (1949) reported that chlorides occur in Minnesota waters in concentrations usually between 0.0 and 10.0 mg/liter. According to Livingston (1963), average concentration of chloride in natural fresh waters is 8.3 mg/liter. Values above 50 mg/liter probably represent some contamination from human wastes (Kevern, 1973). It is safe to assume little contamination in Eagle Lake by domestic waste.

BIOLOGICAL PARAMETERS

Phytoplankton

A list of phytoplankton genera identified from Eagle Lake is given in Table 5. Throughout the summer, decreases in abundance of several green algae were accompanied by an increase in abundance of a number of blue-green algae. The only exception to this occurred on August 20, 1975. Algae in the Cryptophyta, Pyrrophyta, and Chrysophyceae decreased while Bacillariophyceae algae increased markedly. The algae which decreased at the same time as the populations of *Sphaerocystis* spp. and *Oocystis* spp. were *Schroederia* spp., *Cryptomonas* spp., and *Chroococcus* spp. Those algae which increased in number simultaneously with the above decreases included *Aphanizomenon* spp., *Anabaena* spp., *Lygnbya* spp., and *Asterionella* spp. The dominant genera in the Chlorophyta, Bacillariophyceae, and Cyanophyta were *Sphaerocystis* spp. and *Oocystis* spp., *Cyclotella* spp., and *Aphanizomenon* spp., respectively. Figures 13 and 14 show the dominants

Table 5. List of phytoplankton genera identified from Eagle Lake, Michigan between July and October, 1975. Genera are listed in order of decreasing relative abundance.

Cyanophyta	Chrysophyta: Bacillariophyceae
Aphanizomenon spp.	*Cyclotella* spp.
Aphanothece spp.	*Fragilaria* spp.
Anabaena spp.	*Synedra* spp.
Lyngbya spp.	*Cocconeis* spp.
Chroococcus spp.	*Asterionella* spp.
Aphanocapsa spp.	*Melosira* spp.
Microcystis spp.	*Cymbella* spp.
Merismopedia spp.	*Navicula* spp.
Coelosphaerium spp.	*Pinnularia* spp.
Gleotrichia spp.	*Rhopalodia* spp.
Chrysophyta: Chrysophyceae	Chlorophyta
Synura spp.	*Sphaerocystis* spp.
Dinobryon spp.	*Oocystis* spp.
Cryptophyta	*Cosmarium* spp.
Cryptomonas spp.	*Elakotothrix* spp.
Pyrrophyta	*Schroederia* spp.
Ceratium spp.	*Pediastrum* spp.
Euglenophyta	*Volvox* spp.
Trachelomonas spp.	*Gleocystis* spp.
	Staurastrum spp.
	Mougeotia spp.
	Closterium spp.

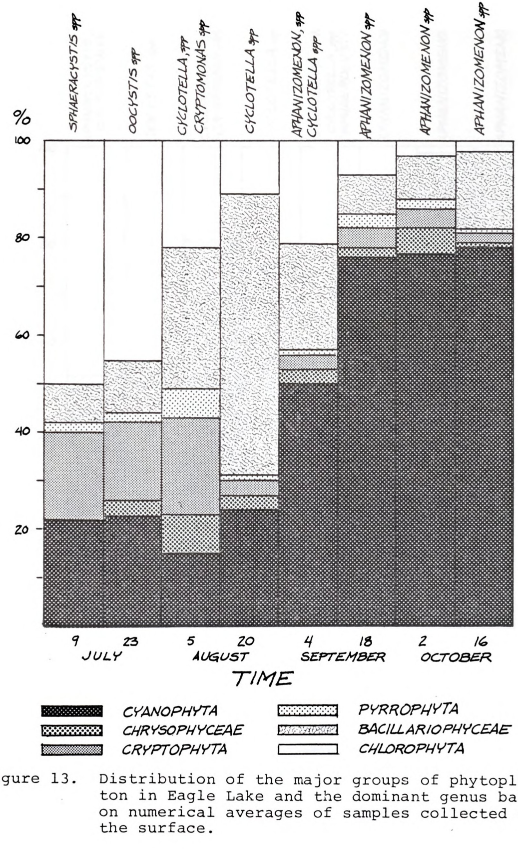


Figure 13. Distribution of the major groups of phytoplankton in Eagle Lake and the dominant genus based on numerical averages of samples collected at the surface.

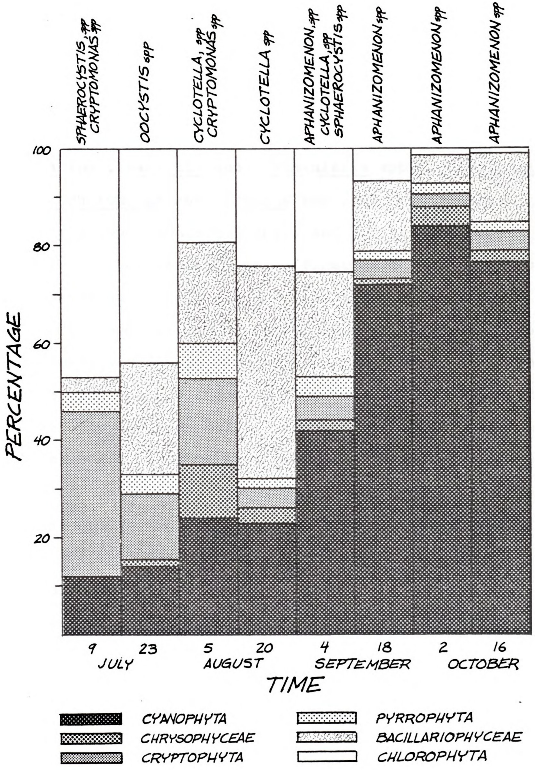


Figure 14. Distribution of the major groups of phytoplankton in Eagle Lake and the dominant genus based on numerical averages of samples collected at 10 feet below the surface.

and percent relative abundance for groups at the surface and ten feet. It should be noted that the following genera only occurred sporadically during the study period: *Merismopedia* spp., *Coelosphaerium* spp., *Gleotrichia* spp., *Cymbella* spp., *Navicula* spp., *Pinnularia* spp., *Rhopalodia* spp., *Trachelomonas* spp., *Volvox* spp., *Gleocystis* spp., *Staurastrum* spp., *Mougeotia* spp., and *Closterium* spp.

Only limited vertical stratification of phytoplankton was observed during the study period. During July and August, *Cryptomonus* spp. was more abundant at 10 feet than at the surface. During July, blue-green algae were concentrated at the surface. However, on August 5, the opposite was observed. A greater abundance of blue-green algae was noted at 10 feet than at the surface. Throughout the remainder of the study period, no real differences in abundance was observed for blue-green algae at either depth. Most of the phytoplankton was found more or less evenly dispersed at both water depths.

A review of phytoplankton records from other lake studies (Bozniak and Kennedy, 1968; Kratz, 1941; Riley, 1940; Birge and Juday, 1922; and Hutchinson, 1967) shows the sudden dominance of *Cyclotella* spp. in late August to be atypical.

Dinobryon spp. appeared in the lake throughout the study period, but with a low relative abundance. In many lakes *Dinobryon* spp. abundance has been correlated with a low phosphate concentration and oligotrophic conditions (Pearsall, 1932; Hutchinson, 1944; Rodhe, 1948; and Lund, 1965). In a recent study, Lehman (1976) reports that the population dynamics of *Dinobryon* spp. is substantially dependent on the physico-chemical environment.

Although the presence and dominance of *Aphanizomenon* spp. in the late summer may indicate eutrophy (Teiling, 1955), the presence of *Dinobryon* spp. and the minimum appearance of *Melosira* spp. and *Microcystis* spp. would indicate oligotrophic-mesotrophic conditions (Teiling, 1955 and Bozniak and Kennedy, 1968). A similar dominance of *Aphanizomenon* spp. during the summer was reported by Kratz (1941), and attributed to temperature.

When Nygaard's (1949) compound index was applied to the lake, it indicated eutrophic conditions. However, in a phytoplankton study of twelve Adirondack lakes, Reynolds and Mercer (1974) showed that phytoplankton indexes were not always consistent with other parameters used to indicate trophic status.

Chlorophyll *a*

Values for Chlorophyll *a* ranged from 2.2 to 5.8 μg/liter during the summer of 1976. The mean chlorophyll *a* concentration was 3.5 μg/liter. Values tended to fluctuate throughout the summer with peak concentrations on May 30 and August 15 (Figure 15).

Eagle Lake would be classified as mesotrophic,

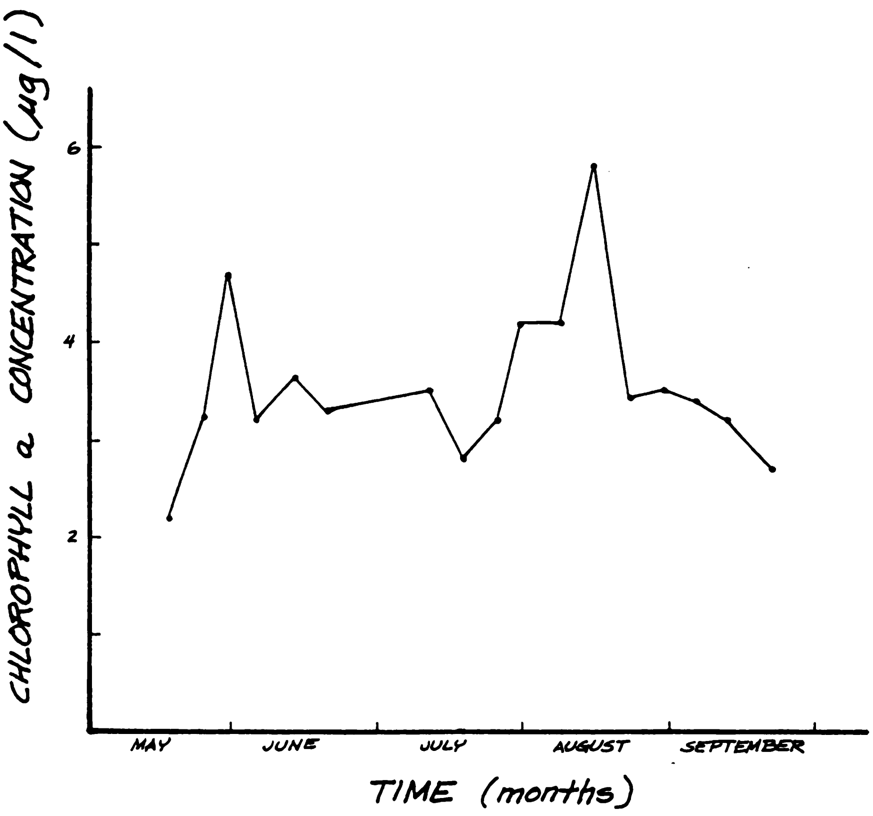


Figure 15. Chlorophyll *a* concentrations for Eagle Lake, Michigan during the summer, 1976.

utilizing only Chlorophyll *a* data (Wetzel, 1975; Michigan Self-Help Survey, 1977; Dobson, et al., 1974; and Sakamoto, 1966). Secchi disk data presented earlier support this conclusion.

Aquatic Insects

A list of aquatic insects collected and identified from Eagle Lake on June 25, 1975 is found in Table 6. At this time of the year aquatic insects in the order Diptera dominated in numbers of individuals.

Table 6. Relative abundance of aquatic insects collected from Eagle Lake, Michigan on June 25, 1975.

			Relative Abundance		
Order	Family	Genus	2 meters	4 meters	8 meters
Diptera					
	Chironomidae		D	D	D
	Chaoboridae		N	O	O
	Ceratopagonidae		O	N	O
Ephemeroptera					
	Ephemeridae	*Hexogenia*	N	O	N
Coleoptera					
	Dytiscidae		R	N	N

D = Dominant R = Rare
O = Occasional N = Not Present

Coliform Bacteria

Results from the summers of 1974 and 1975 for coliform data show that during both years total coliform counts ranged from 100-300 per 100 ml M.P.N. According to the Allegan County Health Department, coliform counts for Eagle Lake are normal for inland lakes and streams free of sewage pollution.

Aquatic Plants

The aquatic macrophyte growth was fairly abundant in most of the shallow areas in Eagle Lake. Table 7 gives the list of aquatic macrophytes collected from Eagle Lake in August, 1975.

Patches of the bulrush (*Scirpus validus*) and the spike rush (*Eleocharis* spp.) were scattered over the sandy shallow areas. Water lilies (*Nymphaea tuberosa* and *Nuphar* spp.) were abundant along the northern and southern shorelines. An abundant patch of cattails (*Typha* spp.) and Chara (*Chara* spp.) grew along the north shoreline. Many species of the pondweed (*Potamogeton* spp.) and wild cherry (*Vallisneria americana*) grew with Chara along the western shoreline.

Although aquatic macrophyte growth was fairly abundant, it does not appear to be at a nuisance level.

Fish

Fish collected from Eagle Lake are listed in Table 8. Age and growth determinations were made for bluegills only due to the large numbers of individuals collected.

Table 7. List of aquatic plants collected from Eagle Lake, Michigan in August, 1975.

Chara spp.
Eleocharis spp.
Typha spp.
Sparganium spp.
Elodea canadensis
Vallisneria americana
Potamogeton praelongus
Potamogeton Richardsonii
Potamogeton Robbinsii
Potamogeton amplifolius
Potamogeton natans
Potamogeton pictinatus
Potamogeton vaginatus
Brasenia Schreberi
Nymphaea tuberosa
Scirpus validus
Megalondonta beckii
Pontederia cordata
Peltandra virginica
Najas flexilis

Table 8. List of fish collected from Eagle Lake, Michigan during 1975 and 1976.

Scientific Name	Common Name
Lepisosteus oculatus (Winchell)	Spotted Gar
Esox lucius Linnaeus	Northern Pike
Micropterus salmoides (Lacepede)	Largemouth Bass
Pomoxis nigromaculatus (Lesueur)	Black Crappie
Chaenobryttus gulosus (Cuvier)	Warmouth
Lepomis cyanellus Rafinesque	Green Sunfish
Lepomis macrochirus Rafinesque	Bluegill
Lepomis gibbosus (Linnaeus)	Pumpkinseed
Perca flavescens (Mitchell)	Yellow Perch

The total length-scale radius relationship was determined from 209 bluegills in order to estimate the length of a fish at the time of previous annuli formation. This relationship is best described by the regression equation:

$$TL = 16.08 + 1.24\ (SR),$$

where TL is total length in millimeters and SR is scale radius X 27 in millimeters (Figure 16).

The mean calculated total length at ages one through six were found to be 49.5, 84.6, 122.2, 158.3, 181.2, and 186.0 millimeters (Table 9). Age group 4 (1972 year class) appears to have the best growth at each annulus. Age groups 1 and 2 (1975 and 1974 year class) show evidence of being

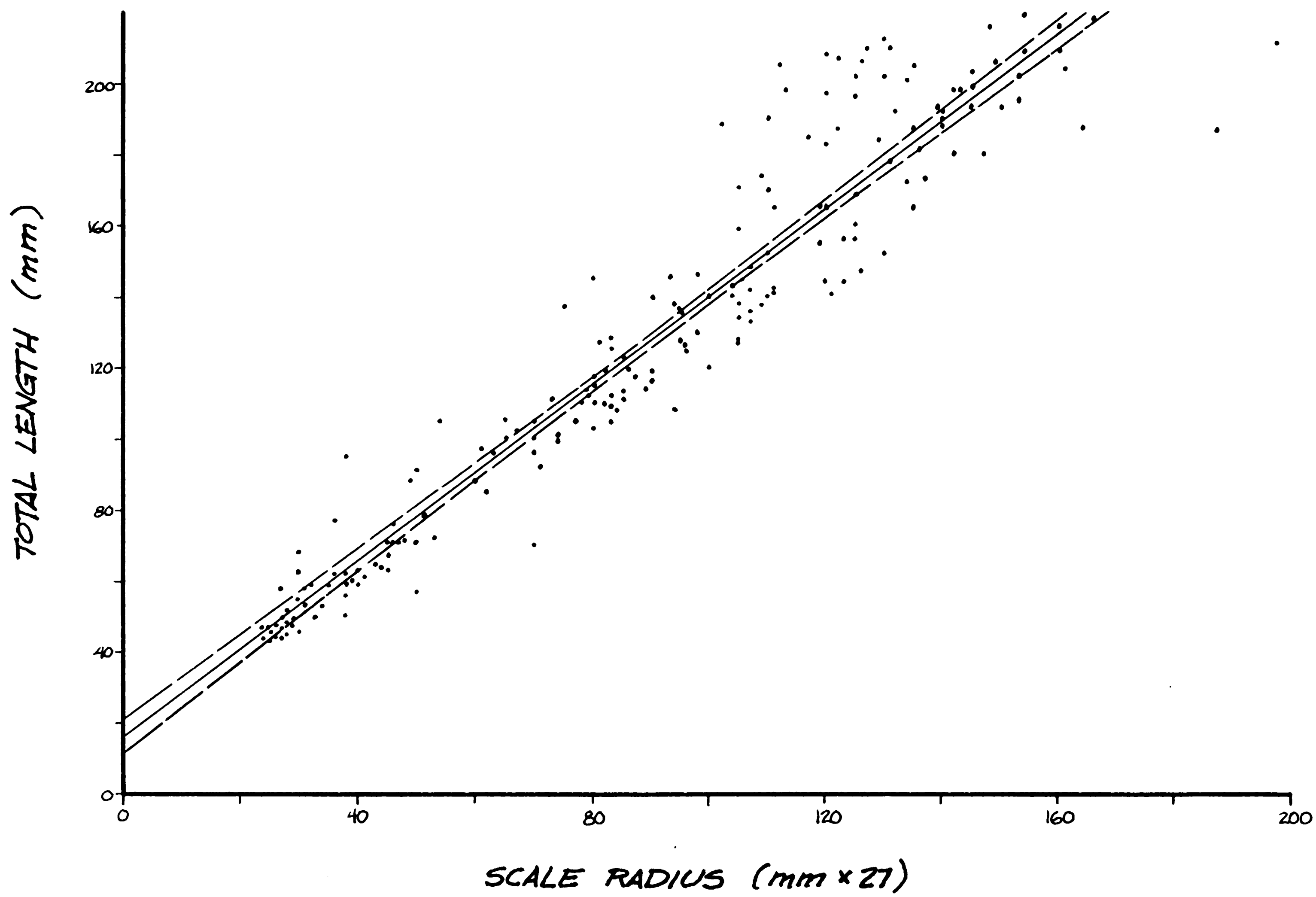


Figure 16. Total length-scale radius relationship for 209 bluegills from Eagle Lake, Michigan.

Table 9. Year class, ages, number, mean total length at capture, mean calculated total length, mean total length at each annulus and mean growth increment for bluegills from Eagle Lake, Michigan.

Class	Age	Number in Sample	Mean total length at capture (mm)	Mean Calculated Length (mm) at ages					
				1	2	3	4	5	6
1976	0	23	50.4						
1975	1	54	72.1	44.7					
1974	2	43	118.1	47.9	82.8				
1973	3	34	149.1	50.2	83.3	118.9			
1972	4	35	189.7	56.7	88.5	126.3	160.7		
1971	5	17	205.2	52.3	83.7	120.9	154.4	182.0	
1970	6	1	202.0	51.0	78.0	115.0	142.0	168.0	186.0
Mean (weighted) total Length at each annulus (mm)				49.5	84.6	122.2	158.3	181.2	186.0
Mean Growth Increment				49.5	35.1	37.6	36.1	22.9	4.8

slower in growth at each annulus.

A comparison of growth in length for Eagle Lake bluegills and the State average for Michigan is shown in Figure 17. The growth rate of bluegills (mean length at capture) compares favorably with the tentative average growth rate for the State. However, growth in length, utilizing mean calculated length for Eagle Lake bluegills, compares less favorably with the tentative State average during the first few years of growth. Bennet (1970) and Grice (1959) report that a large source of available food per individual fish is a primary controlling factor in the production of fish above average size. It is also possible that the low concentrations of dissolved oxygen during thermal stratification may slow growth rates during the early years (Stewart, et al., 1967).

Table 10 shows that the growth rate for Eagle Lake bluegills is about average or higher than growth rates for bluegills from other areas. Although growth rates are not extremely high, it is safe to say that Eagle Lake bluegills are not stunted.

The standard length-weight relationship was determined by constructing a scatter diagram utilizing the standard length in millimeters and weight in grams for 184 bluegills (Figure 18). The mathematical relationship between length and weight may be expressed in logarithmic form as

$$\text{Log } W = \log a + n \log L$$

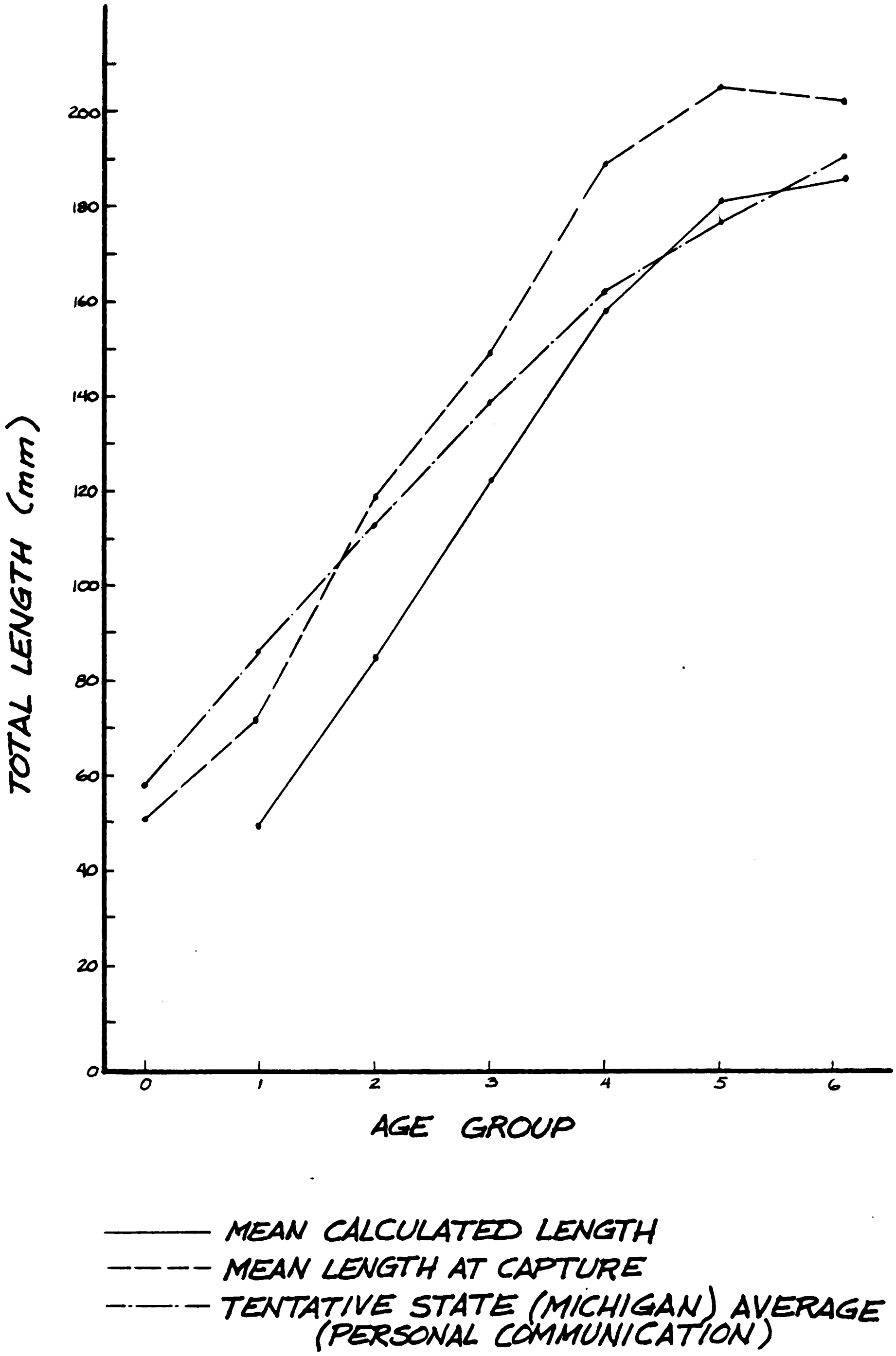


Figure 17. Growth in length of bluegills collected from Eagle Lake, Michigan.

Table 10. A comparison of average total lengths of bluegills at each annulus between Eagle Lake, Michigan and other lakes.

Lake and Location	Year of Life 1	2	3	4	5	6	7
1. Deep Lake, Michigan	45.7	63.5	106.7	162.6	205.7	226.1	251.5
2. Spring Lake, Michigan	38	79	112	137	157	173	
3. Third Sister Lake, Michigan	37.0	54.0	76.0	105.0	136.0	153.0	
4. Missouri State Average	35.6	86.4	132.1	165.1	187.9	203.2	210.8
5. Minnesota State Average	49	86	124	155	180	198	211
6. Indiana State Average	40	60	128	174	198	217	246
7. Illinois State Average	81	117	145	168	188	213	
8. Eagle Lake, Michigan	49.5	84.6	122.2	158.3	181.3	186.0	

1. Carbine and Applegate (1948)
2. Bentz (1977)
3. Brown and Ball (1942)
4. Purkett (1958)
5. Kuehn (1949)
6. Ricker (1942)
7. Lopinot (1958, 1967)

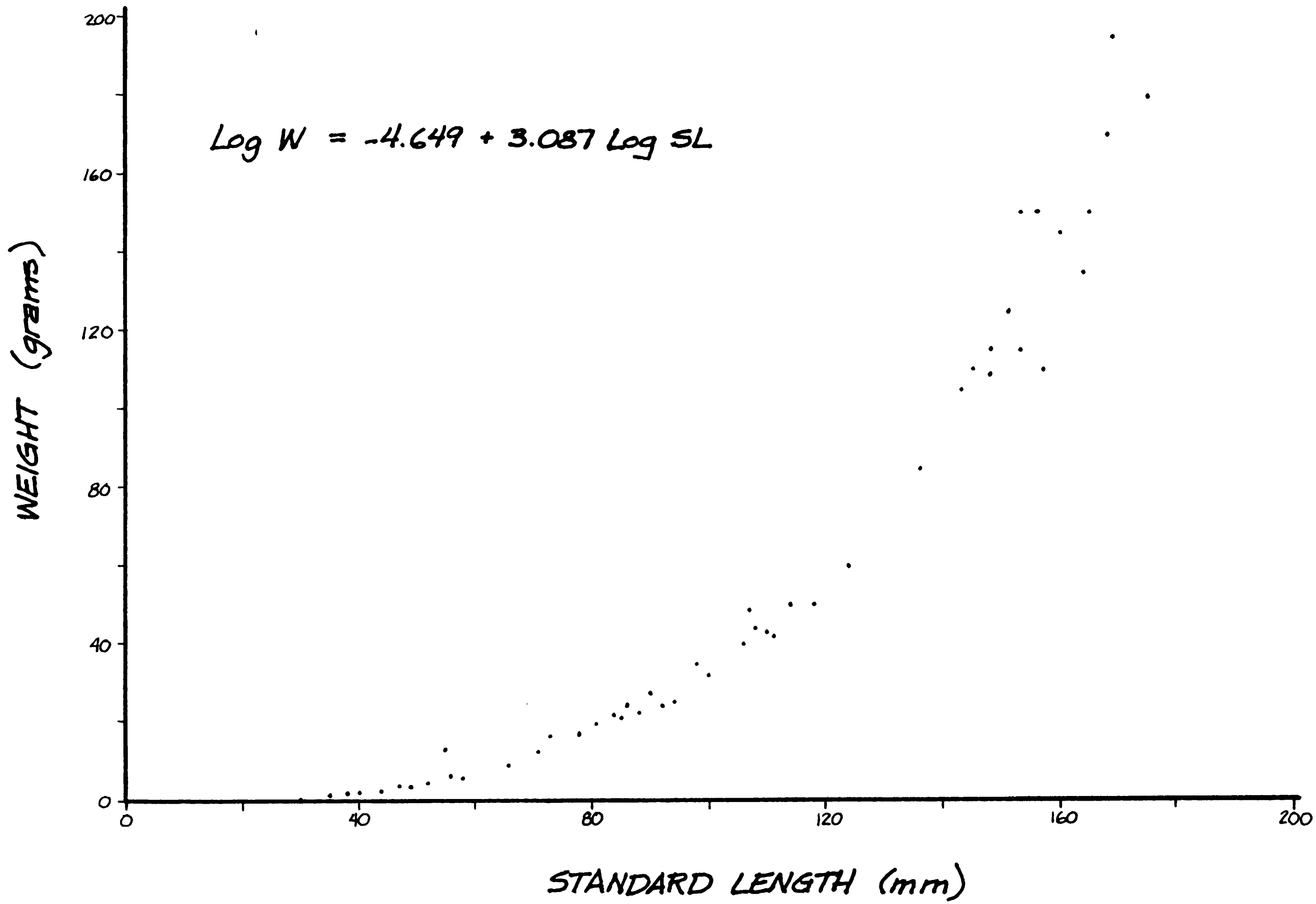


Figure 18. Length-weight relationship of 184 bluegills from Eagle Lake, Michigan.

where

$$W = \text{weight in grams}$$
$$n = \text{slope of the line}$$
$$\text{Log } a = \text{y-intercept}$$
$$L = \text{standard length}$$

The length-weight relationship was found to be best described by the equation Log W = -4.649 + 3.087 Log SL.

The coefficient of condition, K, a measurement of relative plumpness, was calculated from 184 bluegills. K is calculated from the equation

$$K_{SL} = \frac{W \text{ X } 10^5}{L^3}$$

where

$$L = \text{standard length in millimeters}$$
$$W = \text{weight in grams}$$

The condition value for each age group of bluegills from Eagle Lake is shown in Figure 19. Mean condition value was 3.32. The condition value increased with age until after the 4th year where it decreased slightly. According to Minnesota standards, average condition value for bluegills ranges from 3.3 - 4.0 (Carlander, 1944). Beckman (1944), after studying over 500 lakes located in all parts of Michigan, reports mean condition values ranging from 3.26 - 3.96 for bluegills of similar size to those found in Eagle Lake.

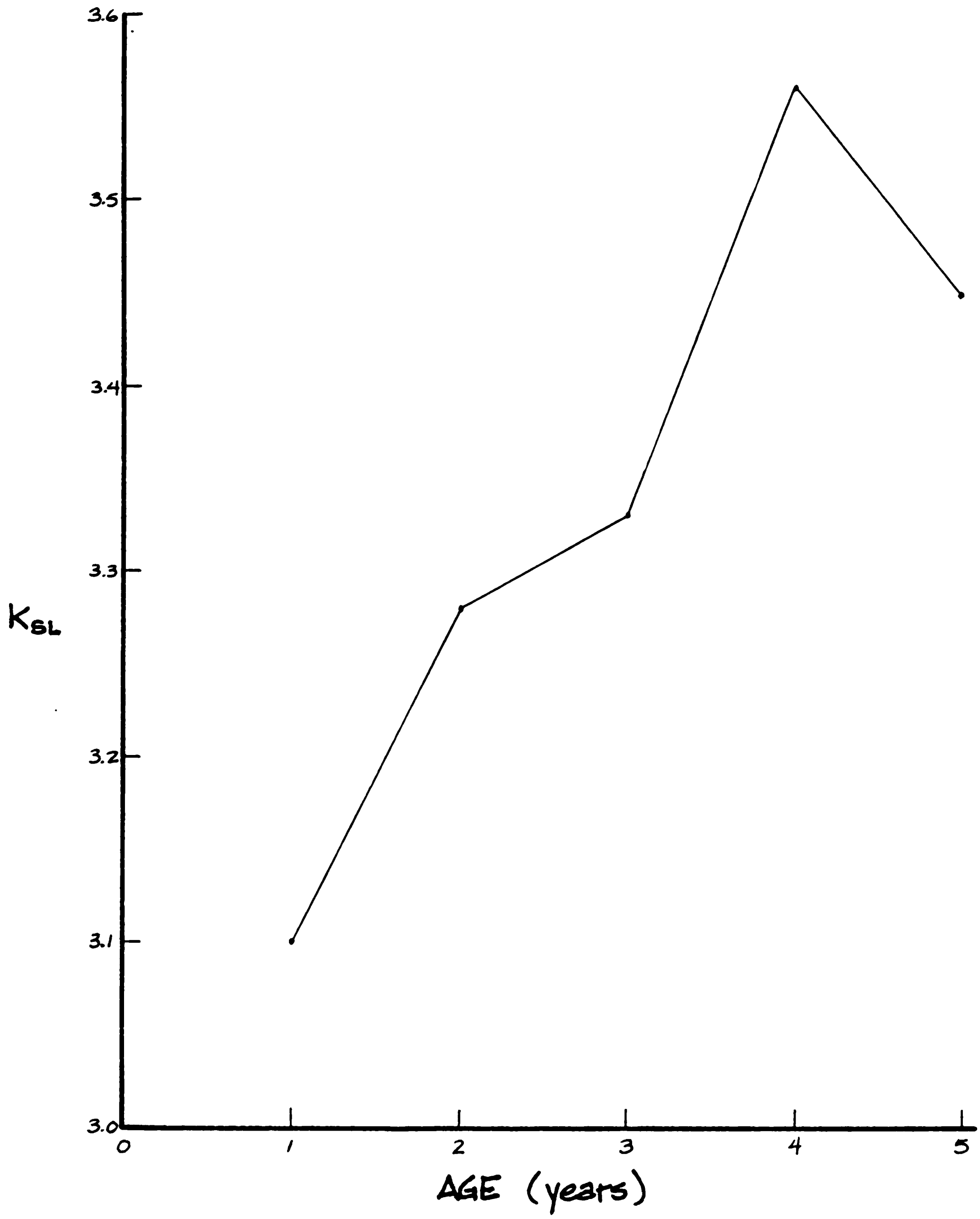


Figure 19. Condition coefficients for bluegill collected from Eagle Lake, Michigan during 1975 and 1976.

SUMMARY

1. Limnological and biological parameters of Eagle Lake, Michigan were studied between May - October, 1975, and March - November, 1976 in order to document present lake conditions.
2. Physical-chemical measurements indicated that the lake registered between oligotrophy and eutrophy on the tropic spectrum. Thermal stratification and hypolimnetic oxygen depletion occurred at all deep water stations during the summer of both years. Secchi disk transparency was fairly high in 1975 and moderate during 1976. Mean total phosphorus and total Kjeldahl nitrogen concentrations for the two years were 0.056 mg/liter and 0.45 mg/liter, respectively. Chloride data indicated little contamination from domestic waste.
3. Thirty-six phytoplankton genera were identified from samples during 1975. Green algae dominated during July but then declined steadily in abundance. Diatoms began increasing in late June and dominated during late August. Blue-green algae remained fairly low in abundance during July and August. However, during September and October blue-greens dominated the phytoplankton population. Chlorophyll *a* values ranged from 2.2 to 5.8 μg/liter during the summer of 1976.
4. Five families of aquatic insects were collected on

June 25, 1975. Dipterans were the most numerous at the 2, 4 and 8-meter depths.

5. Total coliform bacteria counts from 1974 and 1975 were in the normal range for inland lakes free of sewage pollution.
6. Fourteen genera and sixteen species of aquatic macrophytes and macroalgae were identified. Aquatic macrophyte growth did not appear to be at a nuisance level.
7. Age and growth determinations were made for 209 bluegills collected between 1975 and 1976. The rate of growth for bluegills compared favorably with the tentative State average and with bluegills in other lakes of the Midwest for which data are available. Coefficient of condition values were average for the species.

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APPENDIX

Table A1. Sampling schedule by date (month/day) for various parameters in Eagle Lake, Michigan during 1975.

Date	Secchi Disk	Temperature	Dissolved Oxygen	pH	Total Alkalinity	Hardness	Total Kjeldahl Nitrogen	Total Phosphorus	Chlorides
5/28	X	X	X	X	X	X	X	X	X
6/25	X								
7/7	X								
7/23	X								
7/28	X								X
8/6	X								
8/20	X								
9/3	X	X	X	X	X	X	X	X	
9/4	X								
9/18	X								
10/2	X								
10/16	X								

Table A2. Sampling schedule by date (month/day) for various parameters in Eagle Lake, Michigan during 1976.

Date	Secchi Disk	Temperature	Dissolved Oxygen	pH	Total Alkalinity	Hardness	Total Kjeldahl Nitrogen	Total Phosphorus	Chlorides
3/26	X	X	X	X	X	X	X	X	
4/29	X	X	X						
5/9	X								
5/16	X								
5/23	X								
5/31	X								
6/7	X								
6/9	X	X	X	X	X	X	X	X	
6/14	X								
6/20	X								
7/11	X								
7/19	X								
7/25	X								
8/1	X								
8/5	X	X	X						
8/8	X								
8/22	X								
8/29	X								
9/5	X								
9/12	X								
9/13	X	X	X	X	X	X	X	X	X
9/19	X								
10/9	X	X	X						
11/6	X	X	X						

Table A3. Summary of water temperature values (^{o}C) for Eagle Lake recorded during 1976 at Station 2.

Depth (m)	DATE 1976 March 26	April 29	June 9	Aug. 5	Sept. 13	Oct. 9	Nov. 6
0	6.9	12.8	24.2	24.7	21.2	15.6	7.1
1	6.5	12.1	24.1	24.8	21.2	15.5	7.1
2	6.4	11.7	23.3	24.8	21.2	15.5	7.1
3	6.4	11.5	22.0	24.8	21.1	15.5	7.0
4	6.3	11.3	20.0	24.8	21.1	15.5	7.0
5	6.3	11.2	18.0	24.8	21.1	15.5	7.0
6	6.2	11.1	15.2	24.0	21.1	15.5	7.0
7	6.2	11.0	14.0	19.0	20.1	15.5	7.0
8	6.1	11.0	13.0	16.0	17.0	15.5	7.0
9	6.1	10.9	12.3	13.9	13.5	15.3	7.0
10	6.0	10.7	12.0	12.5	12.4	13.8	7.0
11	6.0	10.1	11.8	12.0	11.8	12.0	6.9
12	5.8	9.2	11.3	11.6	11.6	11.1	6.9
13	5.5	9.0	11.0	11.0	10.8	10.7	6.9
14	5.5	8.8	10.3	10.5	10.0	10.1	6.9
15	5.5		9.9	10.0	9.9	9.8	
16			9.5			9.8	

Table A4. Summary of water temperature values (^{o}C) for Eagle Lake recorded during 1976 at Station 5.

Depth (m)	DATE 1976 March 26	April 29	June 9	Aug. 5	Sept. 13	Oct. 9	Nov. 6
0	7.0	13.5	23.8	25.0	21.3	15.9	7.0
1	6.5	13.0	23.7	25.0	21.2	15.8	7.0
2	6.3	12.8	23.2	25.0	21.2	15.8	7.0
3	6.2	12.0	22.0	24.9	21.2	15.8	7.0
4	6.1	11.9	20.0	24.9	21.2	15.8	7.0
5	6.1	11.8	17.7	24.9	21.0	15.8	7.0
6	6.0	11.6	15.1	23.0	21.0	15.8	7.0
7	6.0	11.5	14.2	20.0	20.2	15.8	7.0
8	6.0	11.3	13.2	16.2	17.0	15.7	7.0
9	6.0	11.2	12.5	14.0	13.2	15.4	7.0
10	5.9	11.0	12.0	12.6	12.2	13.8	7.0
11	5.8	10.8	11.9	11.9	11.8	12.2	7.0
12	5.8	10.0	11.5	11.5	11.4	11.7	7.0
13	5.7	9.7	11.2	11.2	10.9	11.2	7.0
14	5.6	9.1	11.0	11.0	10.8	11.0	7.0
15	5.5	9.0	10.9	10.8	10.7	10.5	7.0
16		8.9	10.8		10.1	10.2	7.0

Table A5. Summary of water temperature values (^{o}C) for Eagle Lake recorded during 1976 at Station 6.

Depth (m)	DATE 1976						
	March 26	April 29	June 9	Aug. 5	Sept. 13	Oct. 9	Nov. 6
0	7.1	12.7	23.0	25.0	21.5	15.8	7.2
1	7.0	12.5	23.0	25.0	21.4	15.8	7.2
2	6.8	12.1	23.0	25.0	21.3	15.8	7.2
3	6.5	12.0	21.8	25.0	21.2	15.8	7.1
4	6.4	11.9	20.3	24.9	21.2	15.7	7.1
5	6.3	11.9	17.5	24.8	21.0	15.7	7.1
6	6.2	11.4	15.9	22.5	20.9	15.6	7.1
7	6.1	11.2	14.2	18.8	20.0	15.6	7.1
8	6.1	11.0	13.0	15.0	15.5	15.5	7.1
9	6.0	9.9	11.7	12.8	12.4	14.9	7.1
10	6.0	9.0	11.0	11.2	10.9	11.8	7.0
11	5.9	8.6	10.4	10.3	10.0	10.2	7.0
12	5.4	8.4	9.8	9.5	9.3	9.5	7.0
13	5.2	8.0	8.8	8.3	8.6	8.8	7.0
14	5.1	7.7	8.3	8.0	8.2	8.2	7.0
15	5.0	7.4	8.0	7.0	8.0	7.9	7.0
16	4.9	7.3	7.9		7.9	7.9	7.0
17	4.9	7.2	7.7		7.9	7.9	7.0
18		7.1			7.9	7.9	

Table A6. Summary of dissolved oxygen concentrations (mg/l) for Eagle Lake during 1975 and 1976.

		DATE								
	Depth	1975		1976						
Station	(m)	May 28	Sept. 3	March 26	April 29	June 9	Aug. 5	Sept. 13	Oct. 9	Nov. 6
2	0	7.8	8.3	11.4	10.3	9.6	8.7	8.3	8.3	-
	2			11.4	10.2	9.6	8.7	8.3	8.2	-
	4	8.5		11.4	10.1	10.7	8.6	8.3	8.2	-
	6		4.1	11.2	10.1	11.4	8.3	8.3	8.3	-
	8			11.1	9.9	7.9	0.6	4.9	8.1	-
	10			10.9	9.6	5.3	0.4	0.3	5.3	-
	12			10.6	8.7	4.4	0.2	0.0	0.3	-
	14	4.8	0.1	10.4	7.7	3.9	0.2	0.0	0.0	-
	15			10.3						-
	16					0.5	0.2	0.0	0.0	-
5	0	8.2	8.1	12.0	10.0		8.7	8.5	8.2	10.1
	2			12.0	10.0		8.7	8.5	8.3	
	4			11.8	10.1		8.7	8.0	8.3	10.2
	6		4.4	11.6	9.9		8.6	8.2	8.1	
	8			11.4	9.6		0.4	3.0	8.2	10.3
	10			10.8	9.4		0.3	0.5	1.5	
	12	4.4		10.4	9.1		0.2	0.0	0.4	10.2
	14		0.1	10.0	8.1			0.0	0.0	
	15			9.6						
	16				6.1			0.0	0.0	

Table A7. Summary of dissolved oxygen concentrations (mg/l) for Eagle Lake during 1975 and 1976.

		DATE								
	Depth	1975		1976						
Station	(m)	May 28	Sept. 3	March 26	April 29	June 9	Aug. 5	Sept. 13	Oct. 9	Nov. 6
6	0	7.7	7.0	12.0	10.3	9.8	-	8.5	8.6	10.3
	2			12.1	10.4	9.7	9.1	8.4	8.5	10.5
	4	8.5		12.2	10.3	10.6	8.5	8.1	8.5	10.5
	6		3.0	12.1	10.3	11.6	6.3	7.7	8.4	10.4
	8			12.0	9.7	6.2	0.5	4.1	8.1	10.3
	10			11.8	8.2	2.5	0.4	0.4	1.0	9.9
	12			11.7	7.4	1.7	0.3	0.0	0.0	10.3
	14			11.6	6.4	0.6	0.1	0.0	0.0	10.2
	16			11.4	5.5	0.5	0.0	0.0	0.0	10.1
	17			11.4						10.1
	18	1.5	0.0		4.4		0.0	0.0	0.0	

Table A8. Summary of pH values for Eagle Lake recorded during 1975 and 1976.

		1975		1976		
Station	Depth	May 28	September 3	March 26	June 9	September 13
2	Surface	7.6	7.9	7.6	8.2	7.9
	Mid-Depth	7.6	7.3	7.7	8.3	7.9
	Bottom	6.9	7.0	7.7	7.1	6.6
5	Surface	8.2	8.4	7.7	8.3	7.9
	Mid-Depth	8.1	7.5	7.8	8.4	7.7
	Bottom	7.9	7.2	7.8	7.3	6.6
6	Surface	8.1	8.2	7.7	8.4	7.8
	Mid-Depth	8.4	7.5	7.8	8.4	7.5
	Bottom	7.1	7.2	7.6	7.2	6.6

Table A9. Summary of total alkalinity concentrations (mg/l $CaCO_3$) for Eagle Lake recorded during 1975 and 1976.

		1975		1976		
Station	Depth	May 28	September 3	March 26	June 9	September 13
2	Surface	122	-	135	134	126
	Mid-Depth	126	141	134	137	126
	Bottom	134	164	133	153	164
5	Surface	130	131	133	136	129
	Mid-Depth	130	140	135	134	125
	Bottom	140	164	135	143	171
6	Surface	135	132	134	133	124
	Mid-Depth	126	156	137	135	125
	Bottom	140	166	136	147	161

Table A10. Summary of hardness concentrations (mg/l $CaCO_3$) for Eagle Lake recorded during 1975 and 1976.

		DATE				
		1975		1976		
Station	Depth	May 28	September 3	March 26	June 9	September 13
2	Surface	154	140	151	146	140
	Mid-Depth	142	148	148	146	144
	Bottom	154	162	149	156	168
5	Surface	152	136	148	144	142
	Mid-Depth	152	144	148	145	144
	Bottom	156	156	147	152	170
6	Surface	152	132	148	146	140
	Mid-Depth	146	150	153	146	138
	Bottom	148	182	148	154	164

Table A11. Summary of total Kjeldahl nitrogen concentrations (mg/l) for Eagle Lake recorded during 1975 and 1976.

		DATE				
		1975		1976		
Station	Depth	May 28	September 3	March 26	June 9	September 13
2	Surface	0.78	0.23	0.27	0.49	0.28
	Mid-Depth	0.50	0.23	0.27	0.52	0.53
	Bottom	1.73	0.62	0.20	1.25	1.59
5	Surface	0.79	0.21	0.17	0.52	0.30
	Mid-Depth	1.35	0.23	0.25	0.51	0.39
	Bottom	0.52	0.57	0.20	0.63	1.79
6	Surface	0.66	0.23	0.26	0.54	0.35
	Mid-Depth	1.98	0.20	0.38	0.53	0.41
	Bottom	0.54	1.02	0.40	0.91	1.54
1	Surface	1.23	0.23	0.20	0.62	0.32
4	Surface	1.43	0.11	0.20	0.52	0.32
8	Surface	0.46	0.23	0.19	0.50	0.32

Table A12. Summary of total phosphorus concentrations (mg/l) for Eagle Lake recorded during 1975 and 1976.

		DATE				
		1975		1976		
Station	Depth	May 28	September 3	March 26	June 9	September 13
2	Surface	0.21	0.01	0.008	0.039	0.027
	Mid-Depth	0.09	0.01	0.003	0.037	0.039
	Bottom	0.14	0.27	0.011	0.190	0.370
5	Surface	0.20	0.01	0.004	0.037	0.030
	Mid-Depth	0.15	0.06	0.004	0.043	0.037
	Bottom	0.14	0.06	0.009	0.035	0.390
6	Surface	0.23	0.01	0.005	0.047	0.052
	Mid-Depth	0.13	0.01	0.010	0.059	0.034
	Bottom	0.29	0.22	0.011	0.160	0.350
1	Surface	0.08	0.01	0.018	0.056	0.030
4	Mid-Depth	0.09	0.06	0.006	0.048	0.024
8	Bottom	0.07	0.01	0.009	0.007	0.027

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