THE UNIVERSITY OF MICHIGAN
Biological Station

Limnological Investigation of Florence Lake, South Manitou Island, Michigan

Technical Report No. 5

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and
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Douglas Lake

The University of Michigan Biological Station was established in 1909 at Douglas Lake near Pellston, Michigan, as a teaching and research facility. It occupies a 10,000-acre tract of semi-wilderness in northern lower Michigan, surrounded by a remarkable variety of upland and lowland deciduous and coniferous forests, meadows, marshes, bogs, dunes, lakes and streams. The three upper Great Lakes - Michigan, Huron and Superior - are nearby. As the largest and one of the most distinguished inland biological stations in the world, it serves as an intellectual meeting place for biologists and students from the United States and around the world.

The Biological Station is well-equipped for investigations of the diverse natural environments around it. In addition to the modern, winterized Lakeside Laboratory, which was funded by the National Science Foundation, the Station has 140 buildings, including laboratories, classrooms, and living quarters for up to 300 people. Special facilities include a library, study collections of plants and animals, a large fleet of boats, and a full array of modern laboratory and field equipment. The Station offers tranquility and harmony with nature - it is a place where plants and animals can be studied as they live.

Dr. David M. Gates, Director of the Station since 1971, and Mark W. Paddock, Assistant to the Director, have promoted new and exciting fields of research, including problem-oriented research to help cope with emerging environmental problems.

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This publication is one of a series of reports that are issued periodically to disseminate information on research generated at the Biological Station. For further information concerning other publications in this series or information on the Biological Station in general, address inquiries to: The University of Michigan Biological Station, Pellston, Michigan 49769 (Phone 616-539-8406).

LIMNOLOGICAL INVESTIGATION OF FLORENCE LAKE, SOUTH MANITOU ISLAND, MICHIGAN

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INTRODUCTION

Sleeping Bear Dunes National Lakeshore was established in 1970. When land acquisitions are completed, the new parkland will consist of portions of the coastal mainland in northwestern lower Michigan and North and South Manitou Islands in Lake Michigan. Since this is one of the more recently acquired natural areas in the National Park Service system, background environmental information was needed to provide a sound foundation for future management decisions. Terrestrial features and cultural history of this region had been documented (e.g., Hatt, 1948; Rogers, 1966; Vent, 1973) but information on inland aquatic resources was lacking.

The University of Michigan Biological Station, at the request of the National Park Service, conducted investigations to provide a baseline of environmental data on the Lakeshore's inland water bodies. A previous report (Stockwell and Gannon, 1975) contains results of water quality studies on the lower Platte River system and its associated lakes within the mainland boundaries of the National Lakeshore. This report provides a limnological survey of Florence Lake, the only inland lake on South Manitou Island. This data can be used for comparison with subsequent monitoring studies to detect changes in environmental quality and determine the extent to which the lake and its watershed can support recreational activity without sacrificing quality.

DESCRIPTION OF STUDY AREA

South Manitou Island is located in Lake Michigan, 9.7 km northwest of Glen Arbor, Michigan and 25.8 km southwest of Leland, Michigan (fig. 1). Surface area of the island is 2,158 ha and the shoreline length is 20.8 km. Florence Lake is an oblong-shaped water body located in the southeastern portion of the island. It has no surface inlets or outlets. Recent high water levels have flooded vegetation on its north and south shores. Vegetation and shoreline characteristics indicate that periodic fluctuations in water levels are probably commonplace.

South Manitou Island and surrounding areas were formed by giant glaciers which retreated from the Great Lakes region about 10,000 years ago. These glaciers and post-glacial great lakes (precursors to Lake Michigan) formed and filled Michigan's

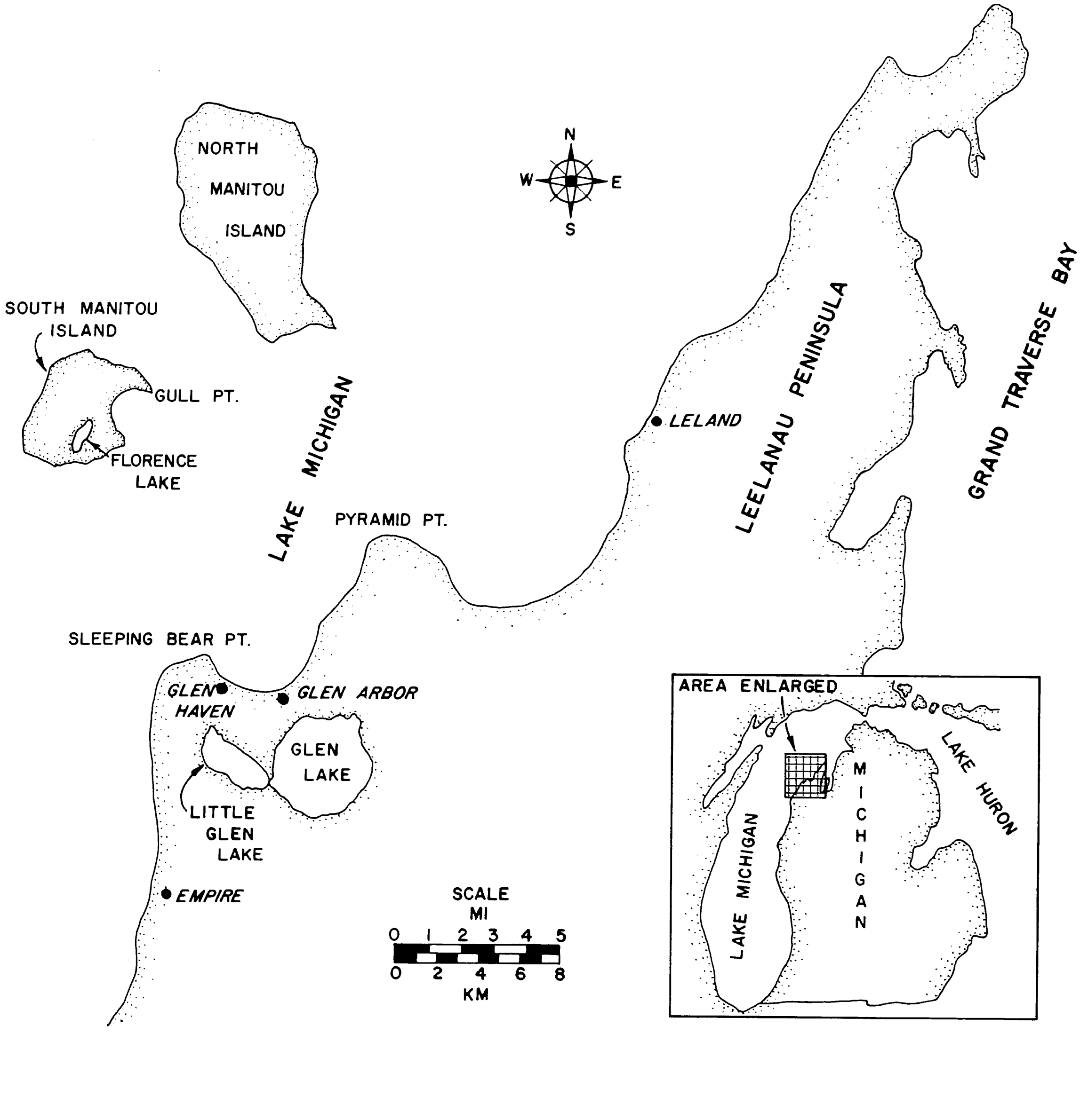

Fig. 1. Location of South Manitou Island and Florence Lake (45°N., 86°W.).

inland lakes, including Florence Lake. About 3,500 years ago, the Florence Lake basin and vicinity were submerged under Lake Nipissing, a great lake that was about 8 m above the present level of Lake Michigan. Waters receded to their present level as a result of postglacial uplift and changes in drainage. A series of sand ridges was formed by waves and currents as the water level waned and succeeded in cutting off the Florence Lake depression from the great lake (Rogers, 1966). Since the Florence Lake basin lies below the present level of Lake Michigan, fluctuations in Lake Michigan water levels likely affect the island's water table and the level of Florence Lake.

South Manitou Island is primarily a glacial moraine and probably overlies limestone bedrock. Soils range from pure sand in the unique belt of perched sand dunes on the island's west side to sandy loams with minor proportions of gravel and clay on the morainal uplands and lowland plains. Predominant soils near Florence Lake are gravelly, loamy sands overlying sand and gravel (Rogers, 1966).

South Manitou Island has varied habitats, ranging from sandy beaches and grassy dunes to shrub- and forest-covered dunes and hardwood forests mixed with some conifers. In general, the maple-beech association occurs on the better, loamy soils of the moraines and the pine-oak-aspen association is found on the poorer, sandy soils of the lowland embayments and near Florence Lake. On the Lake's eastern shore, abandoned farmland is being reclaimed by saplings and shrubs. Abandoned apple orchards and farmlands are found within the Lake's watershed as well as elsewhere on the island.

Human settlement on the island appears to be a comparatively recent occurrence. Although an Ottawa village was located on the mainland at Glen Arbor, the island was apparently not inhabited by native people. A lighthouse was constructed on South Manitou Island in 1839 and steamships stopped at the island to refuel their boilers with cordwood. Year-round residents then began to settle on the island. Early settlers were loggers, homestead farmers, and members of the Coast Guard. The last logging operation occurred in 1908. As timber resources were depleted, the island became mainly a homestead and resort area. The last year-round resident left the island in 1973 and only summer residents and visitors use it now (Vent, 1973).

Development near Florence Lake consists of a few abandoned farmhouses, orchards and farmland. Trail roads are at the north and south ends and along the west shore. Shoreline development includes three rental cottages on the east shore and one cottage and outbuilding on the southwest shore. A boat house, flooded by recent high water, is located at the south end. Fishermen are often observed along the shore.

METHODS

MORPHOMETRY

Florence Lake was mapped by the field team in September, 1975. A transit was set up at several points on the shoreline and opposite shore sites were marked. A motor boat, equipped with a timing device and a Seafarer Depth-Below Transducer, was then used to run the point-to-point transects at a constant speed. Depth readings were recorded and were used to construct a depth-contoured map of the lake. Major aquatic vegetation zones were also identified during the survey and were drawn on the map. Morphometric features of the lake were calculated according to the methods described by Welch (1948). The watershed boundary was determined from analysis of a U.S. Geological Survey quadrangle map (North Manitou Quadrangle, 1957). Since only 20-foot contour intervals were available, our determination of the watershed boundary is only approximate.

PHYSICOCHEMISTRY

Water samples were obtained at four stations in Florence Lake in September, 1974, and again in March, May, and September, 1975. Surface samples were taken at three shallow-water stations and a series of samples was collected from various depths at the deep, central station (fig. 2). We had previously taken a series of samples at this central station in May, 1974 in conjunction with an earlier study (Stockwell and Gannon, 1975).

Water temperature was recorded at 1-m intervals at the central station with a Whitney resistance thermometer. Light penetration readings were recorded at all stations with a submarine photometer. Secchi disc transparency measurements were also taken at all stations.

A 3-liter capacity Kemmerer water bottle was used to collect the water samples. Samples from each station were then placed in 300-ml B.O.D. bottles, pre-washed 8-oz. polyethylene bottles, and ground-glass stoppered bottles for later chemical analyses. All bottles were kept covered, protected from light, and iced to keep samples cool during transit.

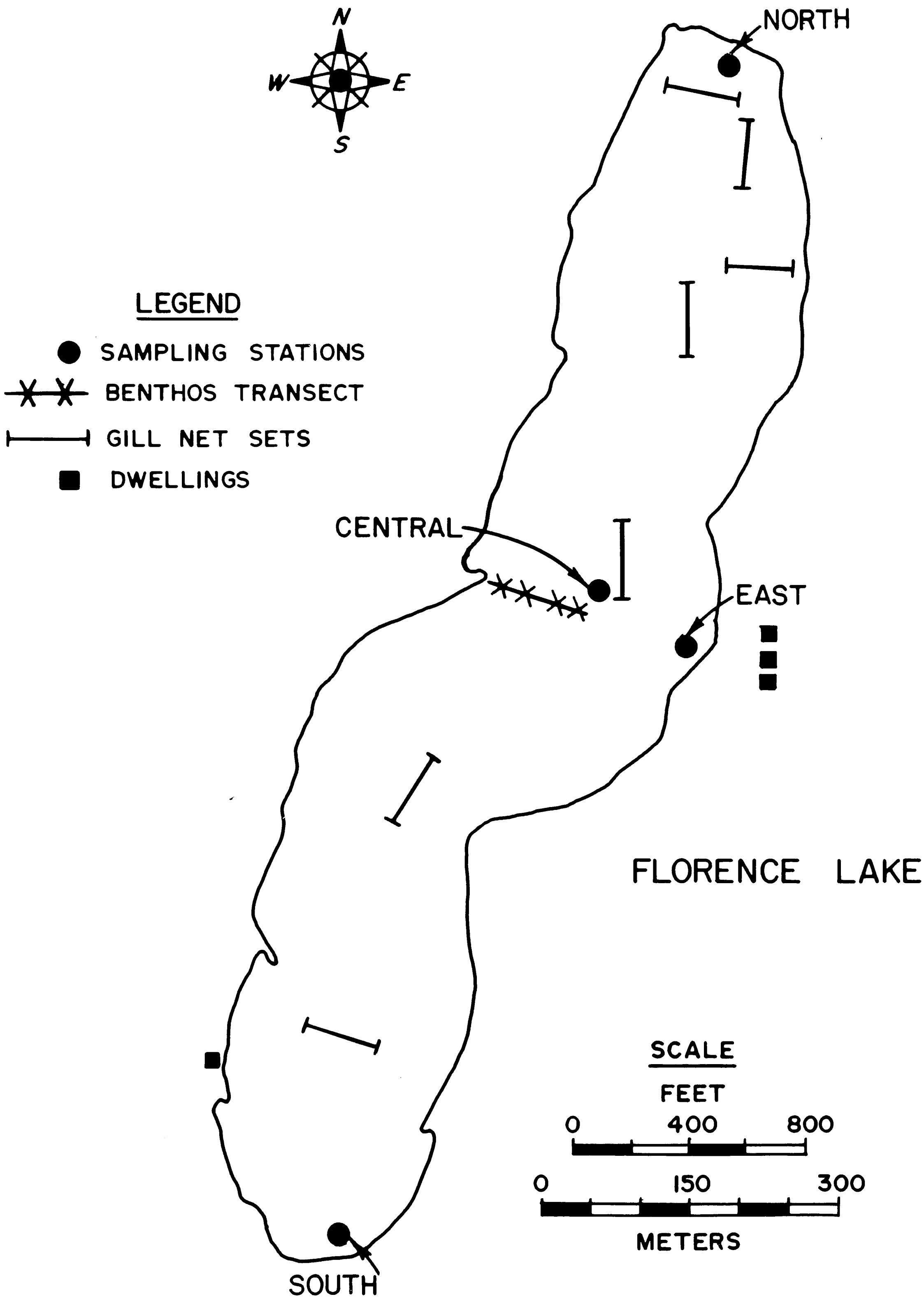

Fig. 2. Location of sampling stations in Florence Lake.

Water chemistry analyses for dissolved oxygen, alkalinity, and pH were completed in the field. Dissolved oxygen was determined titriometrically by the azide modification of the Iodometric Method (APHA, 1971). Total alkalinity was determined titriometrically with mixed bromocresol green-methyl red indicator solution (APHA, 1971). Field-testing of pH was accomplished with a portable Beckman Model N pH meter. Water samples collected for chlorophyll *a* tests were extracted with 90% acetone in the field, sealed with parafilm, covered with foil and placed in an ice chest for later fluorometric determination on a Turner Model III fluorometer (Strickland and Parsons, 1968). Samples for remaining chemical characteristics (anions and cations) were filtered and frozen until analyses could be performed in the water chemistry laboratory at The University of Michigan Biological Station.

Samples taken in May, 1974 were quick-thawed in a water bath to room temperature and chemical analyses were completed by the following methods. Chloride was measured potentiometrically with a Beckman Model H-5 expanded scale pH meter, fitted with a Beckman chloride electrode and salt bridge (APHA, 1971). Total phosphorus and soluble-reactive phosphorus were determined colorimetrically on a Beckman DB-GT spectrophotometer by the hybrid method of Gales et al. (1966) for digestion, and the method of Schmid and Ambühl (1965) for neutralization and color development. Magnesium, sodium, calcium, and potassium were determined by atomic absorption spectrophotometry on a Perkin-Elmer Model 305 atomic absorption spectrophotometer (EPA, 1974). Nitrate-nitrogen was determined colorimetrically on the Beckman DB-GT spectrophotometer (Müller and Widemann, 1955). Ammonia-nitrogen was also determined on the Beckman DB-GT spectrophotometer (Solórzano, 1969). Silica was determined colorimetrically on a Beckman DB-GT spectrophotometer by the Heteropoly Blue Method (APHA, 1971).

In the fall of 1974, our chemistry laboratory was automated. A Technicon Autoanalyzer II was used to analyze September, 1974 and all 1975 samples colorimetrically (Technicon, 1972-73). Following the quick-thaw procedure, chemical measurements were performed by the following methods. Ammonia-nitrogen and nitrate-nitrogen* analyses were performed immediately. Simultaneously, sample aliquots for soluble and total phosphorus were poured into test tubes and placed in a gravity drying oven for several days until the sample evaporated. Then the samples were digested with persulfate (Mentzel and

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*Nitrate-nitrogen analysis also includes nitrite-nitrogen.

Corwin, 1965), refrigerated overnight and analyzed the next day. Silica (reported as Si) and chloride analyses were performed on thawed samples that sat at room temperature for one day. Phosphorus, ammonia-nitrogen and silica measurements were determined by automated methods (Technicon Industrial Methods 155-7W, 154-71W, and 186-72W), similar to the manual methods previously used. Nitrate-nitrogen was analyzed by a copper-cadmium reduction method (Technicon Industrial Method 158-7W). Chloride was measured with a mercuric thiocyanate and ferric ammonium sulfate automated method (EPA, 1974).

BIOLOGY

Plankton Community

Phytoplankton samples were obtained only during September, 1975. A cylinder-cone plankton net with no. 20 (76 μm) nylon mesh, 0.25-m diameter, was towed horizontally near the surface at the north, south, and central stations. The samples were placed in 8-oz. jars, treated with Ütermohl's solution, and returned to the laboratory for identification. Subsamples were removed, wet mounts prepared, and all algae except diatoms were identified under a Bausch and Lomb compound microscope at 470 or 1000 X. Diatoms were cleaned and mounted according to the method described by Weber (1971) and then were identified under the compound microscope at 1000 X. Identifications were made according to Prescott (1951) and Weber (1971).

Zooplankton samples were obtained at all four stations on each survey date. The same plankton net was towed vertically from near bottom to the surface. To determine vertical distribution of zooplankton, a series of samples was collected at the central station in September, 1974, May, 1975, and September, 1975. Samples were taken at 1-m intervals from the surface to the bottom with a 30-liter capacity Schindler-Patalas plankton trap. All zooplankton samples were narcotized with 10% carbonated water (Gannon and Gannon, 1975) and preserved in 5% buffered formalin. Net tow samples were examined qualitatively for species composition and relative abundance. Total zooplankton abundance in the trap samples was determined quantitatively according to subsampling and enumeration procedures of Stemberger (1973) for rotifers and Gannon (1972) for micro-crustaceans. Major references used to identify zooplankters were Voigt (1957), Brooks (1959), Edmondson (1959), Wilson (1959), Yeatman (1959), and Ruttner-Kolisko (1974).

Benthic Community

An Ekman grab (15 x 15 cm) was used to collect bottom samples at the central station, at random inshore sites around the lake, and at five points along an east-west transect at depths of <1 m, 1 m, 2 m, 6 m, and 8 m. Samples were sieved with a no. 30 mesh screen and the benthic invertebrates were sorted and preserved in 5% buffered formalin for later identification in the laboratory.

The entire shoreline and all weed beds were qualitatively sampled with dip nets to obtain aquatic macroinvertebrates. Samples were sorted immediately and specimens were placed in vials and preserved in 5% buffered formalin for later laboratory identification.

Oligochaetes were identified with the keys of Hiltunen (1970). Chironomid midge larvae were identified according to Johannsen (1934, 1935, 1937*a*, 1937*b*); Roback (1957); Hamilton, Saether, and Oliver (1969); Mason (1973); and Saether* (personal communication). Ephemeroptera, Plecoptera, and Trichoptera were determined according to Hilsenhoff (1970). Ross (1944) was also used for trichopteran identifications. Other macro-invertebrates were determined according to Pennak (1953).

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A grapple hook was used to collect aquatic macrophytes, which were placed in plastic bags, tagged according to sampling sites, and returned to the laboratory for identification. Generic determinations were made according to Hotchkiss (1967).

Fish Community

Experimental gill nets were set in several deep-water locations to collect fish specimens, and inshore areas were sampled with a 100-foot seine. Small specimens were preserved whole in 5% buffered formalin for further study in the laboratory. Larger fish were measured and scale samples were collected for later analysis to determine age group. Fish were identified according to Eddy and Surber (1947). Disposition of fish specimens was completed in accordance with State of Michigan regulations.

RESULTS

MORPHOMETRY

Florence Lake is fairly small and relatively shallow (Table 1; fig. 3). It has a surface area of 33.2 ha and mean and maximum depths of 3.3 m and 7.9 m, respectively. The lake does not have any sizeable points or bays but has a number of small sand spits, formed by winds and currents, along the east and west shores. Its elongated shape and lack of shoreline

TABLE 1. MORPHOMETRIC FEATURES OF FLORENCE LAKE*

Feature	Metric	English
Maximum depth (Z_m)	7.9 m	26.0 feet
Mean depth ($\bar{Z}$)	3.3 m	10.9 feet
Maximum length (l)	1.4 km	0.9 miles
Maximum width (b_x)	0.3 km	0.2 miles
Shoreline length (L)	3.5 km	2.2 miles
Volume (V)	1,101.9 x 10^3 m^3	1,432.7 x 10^3 yd^3
Surface area (A_o)	33.2 ha	84.0 acres
Watershed area (A_d)	858.0 ha	2,112.0 acres
A_d/A_o	25.8	
Shoreline development factor	1.7	

*Definitions and notations follow Hutchinson (1957).

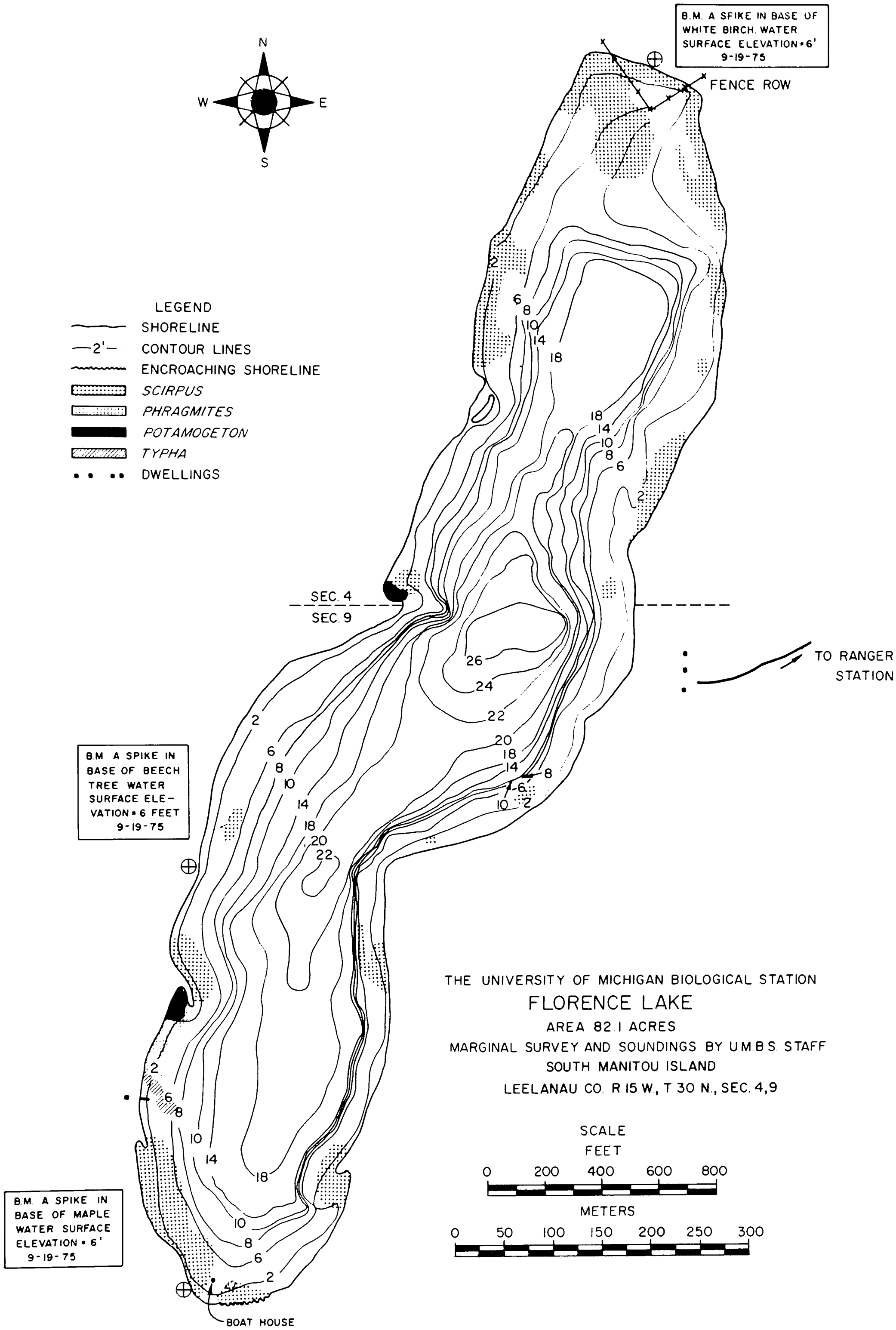

Fig. 3. Morphometric map of Florence Lake, South Manitou Island.

prominences result in a relatively low shoreline development factor (1.7). Florence Lake's watershed is 858 ha and encompasses nearly one-half (47.3%) of the entire island (fig. 4). The watershed is relatively large in comparison to the surface area of the lake.

PHYSICOCHEMISTRY

Surface waters had an average pH of 7.9 and total alkalinity of 57.4 mg/liter during the study period. Cations were moderately low and calcium was predominant. Nutrient concentrations, especially soluble-phosphorus, were low. Chlorophyll *a* levels were moderate (Table 2; Appendix A).

The temperature profile in May, 1974 indicated that the lake was still in the spring overturn period just prior to the onset of summer stratification (fig. 5). An algal bloom was apparently in progress. Secchi disc transparency was low (2.75 m) and chlorophyll *a* concentrations were moderate (mean of 8.9 μg/liter). However, light was still able to penetrate to the bottom in the deepest (7.9 m) portion of the lake. The light extinction coefficient (k) was -0.82. The compensation depth (i.e., the depth of 1% light transmittance) usually defines the limit of plant growth in lakes. Since the

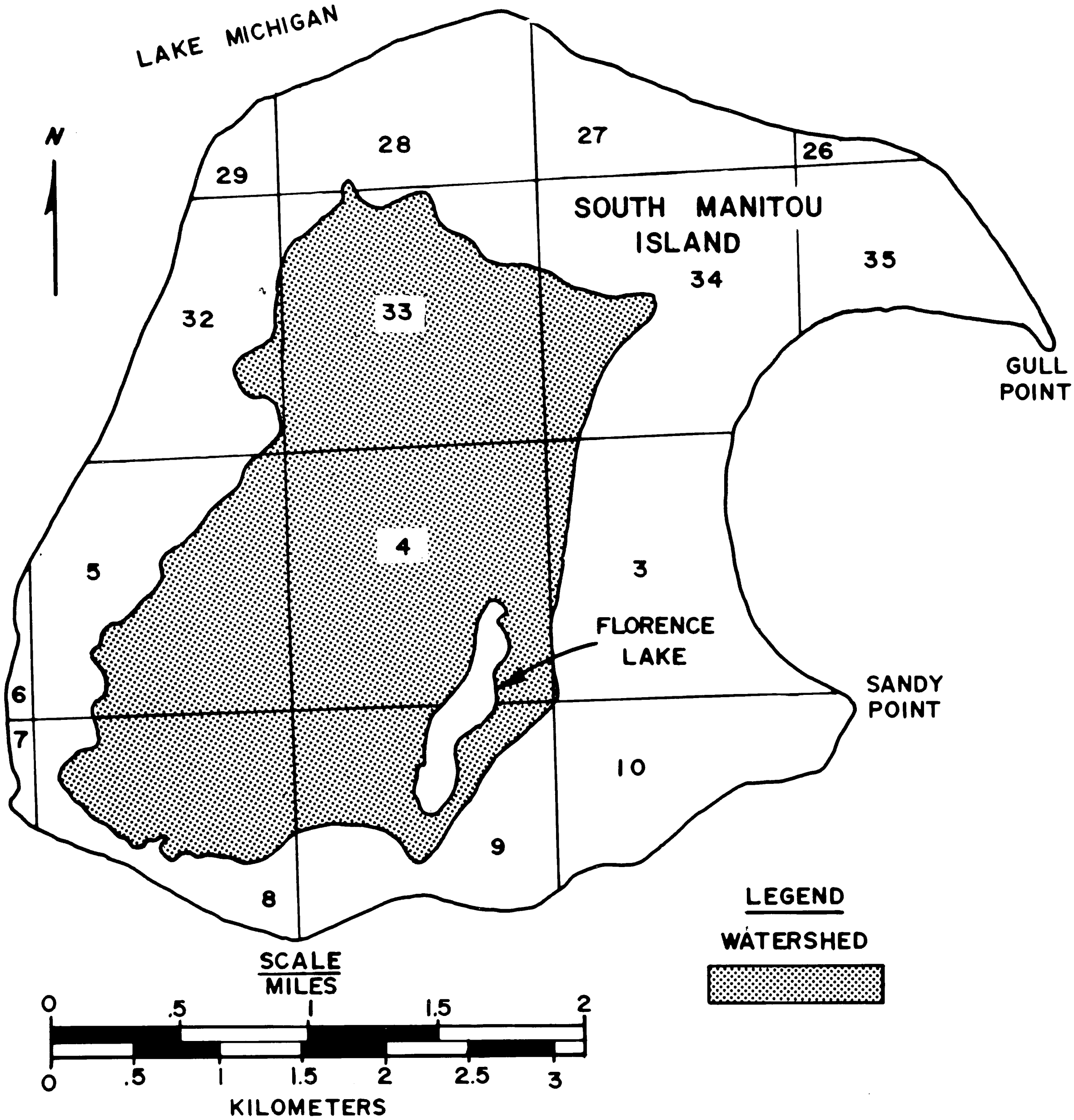

Fig. 4. Watershed (drainage basin) of Florence Lake. Numbers refer to township sections.

TABLE 2. SURFACE WATER CHEMISTRY AND CHLOROPHYLL *a* IN FLORENCE LAKE

Variable	Values* Ranges	Means
Dissolved oxygen (mg/L)	9.00-12.00	10.00
Dissolved oxygen (% sat.)	80.00-106.00	95.50
pH	7.30-8.20	7.90
Total alkalinity (mg/L as $CaCO_3$)	55.00-63.20	57.40
Specific conductance (μmhos/cm @ 25 C)	112.00-139.00	124.10
Chloride (mg/L)	0.15-5.20	1.83
Calcium (mg/L)	11.69-15.16	13.42
Magnesium (mg/L)	5.63-6.33	5.91
Potassium (mg/L)	0.92-1.46	1.22
Sodium (mg/L)	0.53-0.94	0.68
Ammonia-Nitrogen (μg/L)	11.00-337.00	142.80
(Nitrate + Nitrite)-Nitrogen (μg/L)	2.00-367.00	117.80
Soluble-Phosphorus (μg/L)	0.00-17.00	7.00
Total phosphorus (μg/L)	6.00-24.00	12.80
Silica (μg/L as Si)	21.00-336.00	117.60
Chlorophyll *a* (μg/L)	0.90-27.60	10.00

*Means and ranges for all stations and all sampling periods.

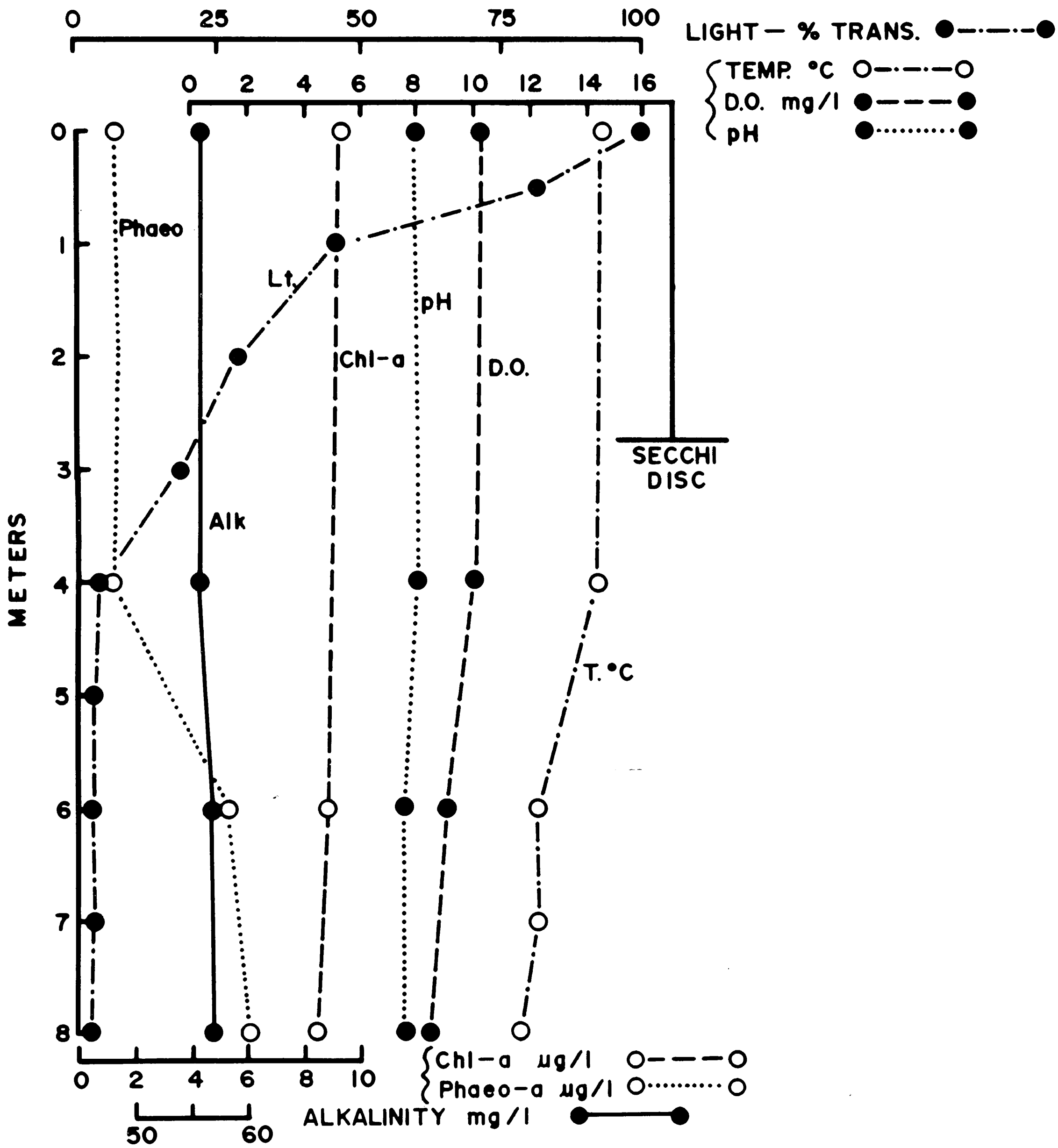

Fig. 5. Vertical distribution of selected chemical variables at the central station in Florence Lake on 25 May 1974.

compensation depth was 7 m in Florence Lake, photosynthesis could occur throughout most of the lake's volume.

Typical of the spring overturn period, each chemical variable had nearly the same value throughout the entire water column, indicating that wind-generated currents were completely mixing the lake (fig. 5; Table A-1). Dissolved oxygen was saturated in the upper 4 m of water, presumably because of photosynthetic activity by phytoplankton. Inorganic nutrients were generally low throughout the water column, another indication that the lake was experiencing a spring algal bloom.

Florence Lake was in an early phase of thermal stratification during the May, 1975 sampling period. The epilimnion extended from the surface to 2 m. The thermocline was broad, extending from 2 m to 6 m. The hypolimnion occurred from 6 m to the bottom, representing an extremely small fraction of the lake's volume. As in May, 1974, an algal bloom was in progress. Secchi disc transparency was low (2.5 m) and chlorophyll *a* levels were moderate (mean of 8.2 μg/liter). Light penetration was sufficient (k = -0.63) to allow photosynthetic activity to occur throughout the water column (fig. 6; Table A-2).

Surface chemical conditions were similar at all four stations in May, 1975 (fig. 6; Tables A-2 and A-3).

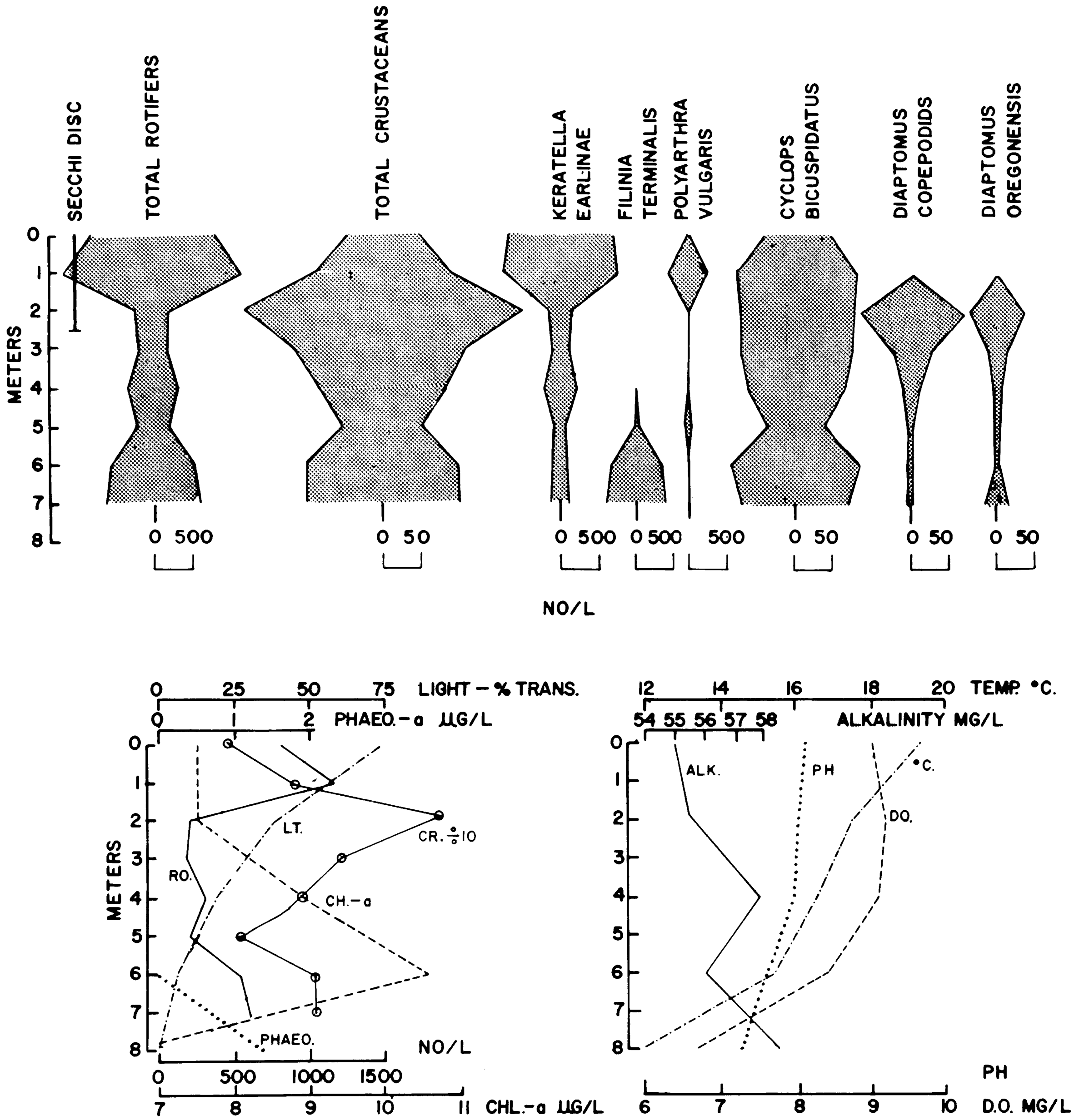

Fig. 6. Vertical distribution of selected chemical variables and zooplankters at the central station in Florence Lake on 22 May 1975.

Wind-generated currents apparently were keeping the epilimnetic waters of the lake well-mixed.

Slight stratification of most chemical variables was observed at the central station in May, 1975. Because of decomposition and respiration processes occurring in the hypolimnion, total alkalinity, calcium, ammonia-nitrogen, and total phosphorus were highest near bottom. Conversely, dissolved oxygen and pH were lowest near bottom. Soluble-phosphorus and silica levels remained low throughout the water column. Chlorophyll *a* was highest (10.6 μg/liter) near the bottom of the thermocline at 6 m (fig. 6; Table A-3).

Limnological conditions were similar in September, 1974 and 1975 except that a more pronounced algal bloom was in progress in 1974. Surface chemistry was similar at all stations in both years (Tables A-4 through A-7). Temperature profiles at the central station for September, 1974 and 1975 sampling periods indicated that the lake was undergoing fall overturn, based on similar temperatures throughout the water column (figs. 7 and 8). The largest algal bloom detected during the study occurred in September, 1974. The highest chlorophyll *a* (mean of 23.5 μg/liter) was recorded at this time. Light penetration was reduced by algal turbidity. The

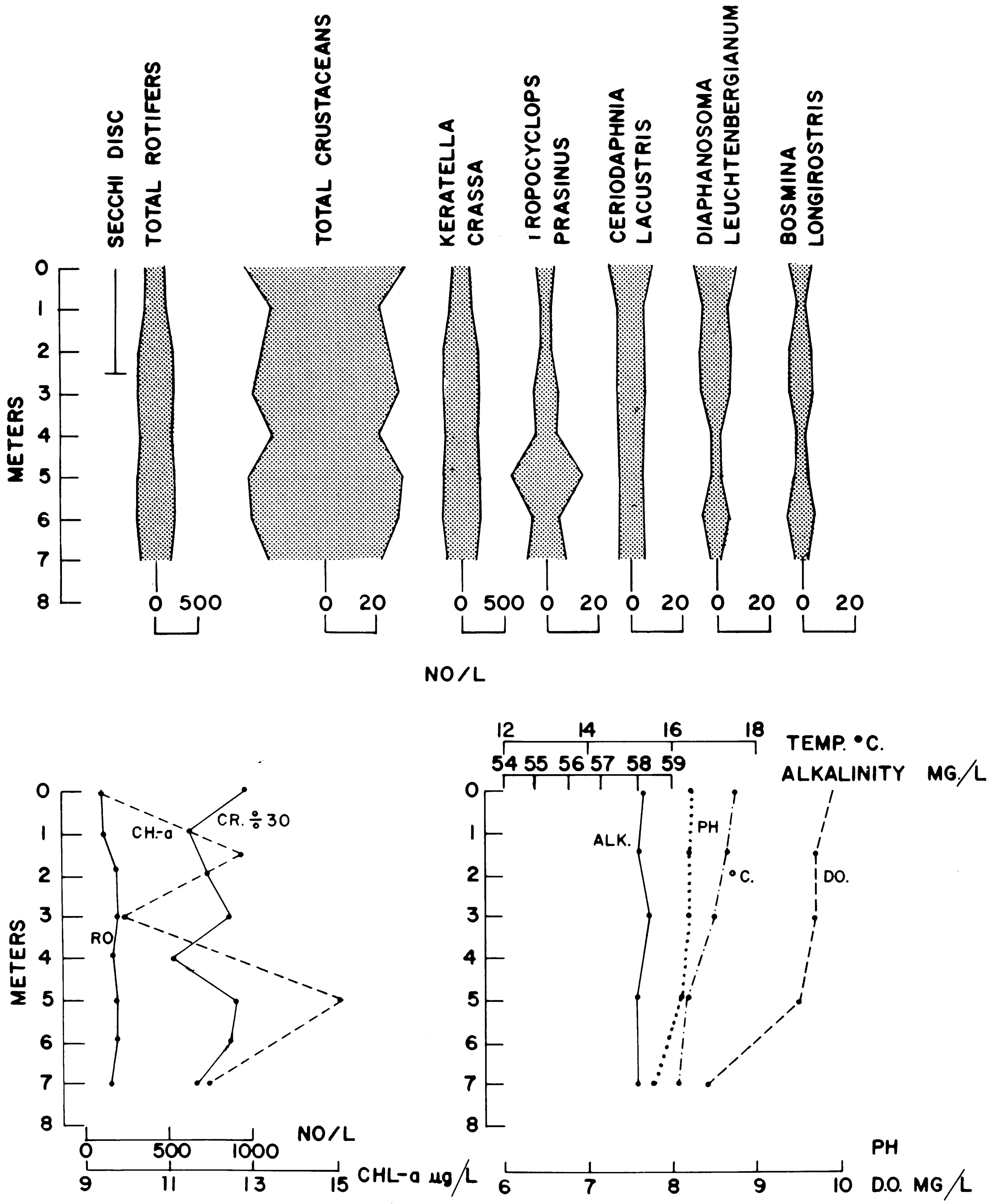

Fig. 7. Vertical distribution of selected chemical variables and zooplankters at the central station in Florence Lake on 27 September 1974.

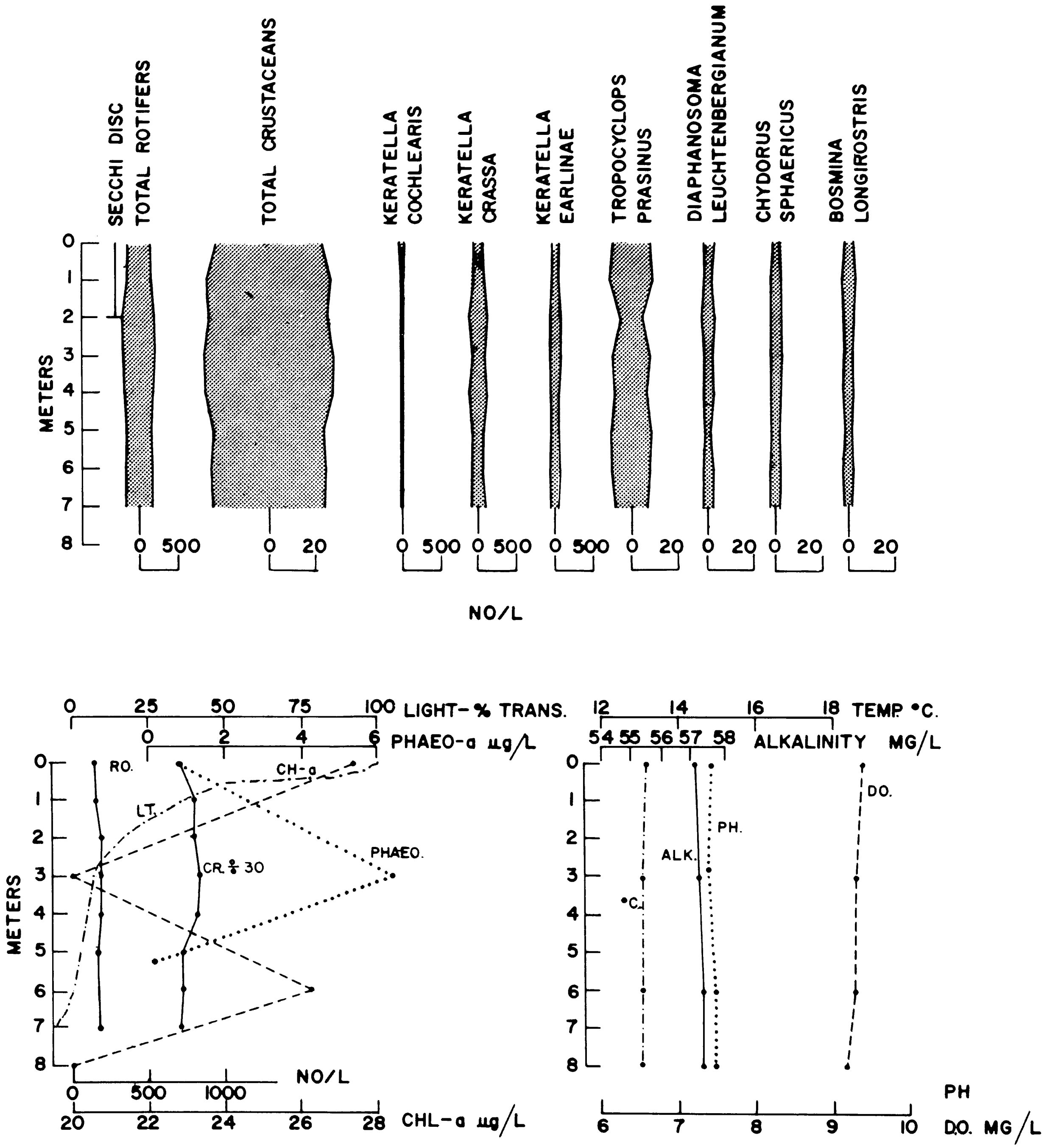

Fig. 8. Vertical distribution of selected chemical variables and zooplankters in Florence Lake on 18 September 1975.

extinction coefficient (k) was -1.06 and the Secchi disc was visible only to 2 m. The compensation depth for photosynthetic activity was 6 m (fig. 7; Table A-4).

The September, 1974 sampling period occurred shortly after the beginning of fall overturn. Nutrients regenerated in the hypolimnion by decomposition processes and by exchange reactions at the sediment-water interface during summer were distributed throughout the water column. Relatively high levels of total phosphorus (mean of 31 μg/liter) and silica (mean of 180 μg/liter) were undoubtedly at least partially responsible for the observed large algal bloom.

The September, 1975 sampling period apparently occurred later in the fall overturn period since chlorophyll *a* (mean of 9.4 μg/liter) and nutrients were generally lower and light transparency was greater (2.5 m) than in September, 1974. Chemistry conditions in September, 1975 were generally most similar to those observed during the spring overturn period of May, 1974 (figs. 5 and 8). Typical of the fall overturn period, dissolved oxygen conditions were near saturation and each chemical variable had nearly the same value throughout the water column in September, 1974 and September, 1975 (figs. 7 and 8; Tables A-4 and A-6).

In March, 1975, the ice thickness was 25-30 cm with no snow cover. Surface chemical conditions were similar at all stations although circulation in the lake was obviously limited by ice cover (Tables A-8 and A-9). Apparently, the lake is sufficiently small that near-surface chemical conditions are similar throughout the lake year-round.

Slight inverse thermal stratification was observed at the central station in March, 1975 (fig. 9). In comparison to ice-free seasons, algal biomass was low (mean of 1.3 μg/liter) and light penetration was high. The Secchi disc was visible to 5 m and the extinction coefficient (k) was -0.76. Light penetration was sufficient for photosynthesis to occur throughout the entire water column. However, stratification of chemical variables indicated that decomposition and respiration processes predominated in the bottom waters. Dissolved oxygen was nearly depleted (1% of saturation) and lowest pH (7.2) occurred near bottom. High values for nearly all cations and anions were recorded near bottom. Regeneration of inorganic constituents under low oxygen conditions was obviously occurring in the bottom waters (fig. 9; Table A-8).

Values for selected physicochemical variables from the central station in Florence Lake were compared with data from

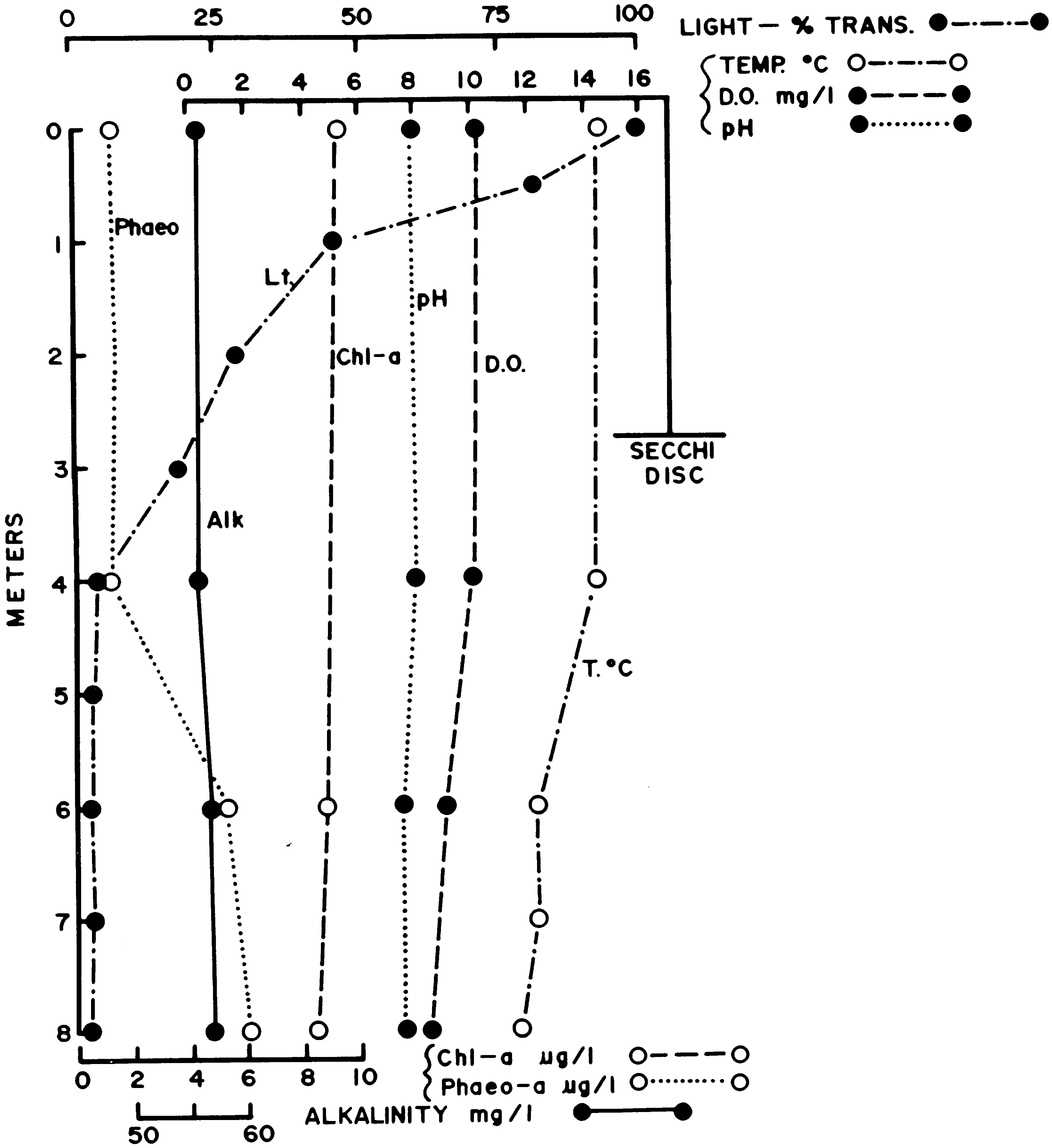

Fig. 9. Vertical distribution of selected chemical variables at the central station in Florence Lake on 21 March 1975.

a Lake Michigan station (Table 3). Total alkalinity was four times lower in Florence Lake than in Lake Michigan off South Manitou Island. Specific conductance was twice as low as that of Lake Michigan. Nutrients and chlorophyll *a* levels were higher in Florence Lake than in Lake Michigan, indicating that productivity is higher in the inland water body. In contrast, mineral content was substantially lower in Florence Lake than in Lake Michigan.

BIOLOGY

Plankton Community

Analysis of the plankton net tows from the central station revealed that the phytoplankton bloom in May, 1974 was primarily the blue-green alga, *Microcystis*. Other prevalent taxa were *Anabaena, Botryococcus, Ceratium, Dictyosphaerium,* and *Scenedesmus*. In contrast, *Botryococcus* was the most abundant alga in the plankton bloom of May, 1975. Both *Microcystis* and *Botryococcus* were prominent in the phytoplankton community in September, 1974. *Ceratium* and *Pediastrum* were also prevalent during this sampling period.

Detailed phytoplankton information was accrued only for the September, 1975 sampling period. A diverse assemblage of 132 phytoplankton taxa was observed in Florence Lake

TABLE 3. COMPARISON OF SELECTED CHEMICAL VARIABLES BETWEEN THE CENTRAL STATION IN FLORENCE LAKE AND A LAKE MICHIGAN STATION NEAR SOUTH MANITOU ISLAND (45° 07.2' N., 86° 04.4' W.) DURING SPRING

Variable	Florence Lake*	Lake Michigan†
Secchi (m)	2.6	8.0
pH	7.8	8.5
Total alkalinity (mg/L as $CaCO_3$)	56.5	223.2
Specific conductance (μmhos/cm)§	121.5	281.8
Chlorophyll *a* (μg/L)	8.6	1.1
Phaeophytin *a* (μg/L)	1.9	0.1
Chloride (μg/L)	1.9	7.9
Soluble-Phosphorus (μg/L)	4.6	3.2
Total phosphorus (μg/L)	10.2	5.0
(Nitrate + Nitrite)-Nitrogen (μg/L)	114.5	225.2
Ammonia-Nitrogen (μg/L)	121.2	5.1
Silica (μg/L as Si)	69.8	400.9

*Depth-averaged values for May, 1974 and May, 1975.

†Depth-averaged values for 22 April 1976, 2 June 1976, and 29 May 1977 (unpublished data, Great Lakes Research Division, The University of Michigan, Ann Arbor, Michigan).

§Specific conductance is corrected to 25 C.

(Appendix B). Approximately 100 were eulimnetic forms and the remaining taxa were tychoplankters that are more characteristic of the periphyton community. The blue-green algae, *Gomphosphaeria aponina* and *Microcystis aeruginosa*, were predominant in limnetic waters. However, other algae were also relatively abundant, including other blue-greens such as *Aphanothece, Gloeothece* and *Merismopedia;* several species of the green alga, *Scenedesmus;* the chrysophyte, *Mallomonas;* and the brown alga, *Ceratium.*

The phytoplankton population in March, 1975 was extremely sparse. Examination of the plankton net tow from the central station revealed that *Botryococcus* and *Peridinium* were most abundant.

The zooplankton community in Florence Lake consisted of 36 taxa of rotifers and 30 taxa of micro-crustaceans (Appendix C). Twenty-five rotifer species and 16 micro-crustacean species are limnetic. The remaining taxa are characteristic of littoral and benthic habitats and appear adventitiously in the limnetic zone. Predominant limnetic rotifers were *Keratella longispina* and *Polyarthra vulgaris*. The most prevalent micro-crustaceans were the copepods, *Diaptomus oregonensis, Epischura lacustris,* and *Cyclops bicuspidatus* *thomasi*, and the cladocerans, *Bosmina longirostris*, *Chydorus sphaericus*, *Ceriodaphnia lacustris*, *Daphnia retrocurva*, *Holopedium gibberum*, and *Diaphanosoma leuchtenbergianum*.

Differences in vertical distribution of zooplankton were evident during the thermally stratified conditions in May, 1975 (fig. 6). Rotifers exhibited two peaks in abundance, one in the epilimnion and the other in the hypolimnion. The peak in the upper waters primarily represented abundant populations of *Keratella earlinae* and *Polyarthra vulgaris*. The peak in the bottom waters resulted from an abundance of *Filinia terminalis*. Micro-crustaceans were more uniformly distributed than the rotifers. *Cyclops bicuspidatus thomasi* was the most abundant species throughout the water column. Immature and adult *Diaptomus oregonensis* were most prevalent in the epilimnion, especially at 2 m.

Zooplankton were less abundant during the September, 1974 and 1975 sampling periods than in May, 1975. Vertical distribution was nearly uniform in both September sampling periods since fall overturn and complete mixing of the water column was in progress. Predominant species were *Keratella crassa*, *K. earlinae*, *Tropocyclops prasinus mexicanus*, *Diaphanosoma leuchtenbergianum*, and *Bosmina longirostris* (figs. 7 and 8).

Benthic Community

The bottom sediments in Florence Lake range from firm sands near shore (0-1 m) to flocculent silts in the deepest (6-7.9 m) portion of the lake. A transition zone of sandy silts and silty sands occurs between the 2-m and 5-m contours.

The sands and sandy silts near shore provided suitable substrate for rooted aquatic plants. The following genera of aquatic macrophytes were observed: *Carex*, *Phragmites*, *Potomogeton*, *Polygonum*, *Scirpus*, and *Utricularia*. *Scirpus* (rushes) and *Potomogeton* (pond weeds) were most abundant. The macroscopic algae, *Chara* and *Nitella*, were also prevalent. Although light penetration was sufficient to support aquatic vegetation on most of the lake bottom, rooted plants were primarily confined to the firmer sediments from the lake edge to a depth of about 2 m (fig. 3).

A total of 110 macro-invertebrate taxa were recorded from Florence Lake (Appendix D). Most identifications were made only to genus. Approximately 50% of the taxa were collected in the aquatic vegetation. Members of many insect groups such as Coleoptera (beetles), Diptera (flies), Ephemeroptera (mayflies), Hemiptera (bugs), Odonata (dragon- and damselflies), and Trichoptera (caddis flies) were predominant among rooted plants. The remaining organisms (especially oligochaete worms, amphipods, molluscs, and dipterans of the families Ceratopogonidae and Chironomidae) were most prevalent in the bottom sediments.

Composition and abundance of benthic macro-invertebrates varied considerably along the inshore to offshore transect. Close to shore at a depth of <1 m, the wave-washed, firm sands provided a poor substrate for macro-invertebrates (13 taxa and 1,258 individuals/m^3). The small snail, *Amnicola,* the amphipod, *Hyalella,* and the chironomid midges were most prevalent. Apparently, the mosaic of micro-habitats offered by the bottom substrate (sand, organic detritus, and vegetation) at the 1-m depth supported the highest diversity (42 taxa) and abundance (16,899 individuals/m^3) of organisms (fig. 10). *Hyalella* and chironomid midge larvae, especially *Dicrotendipes, Polypedilum, Microtendipes,* and *Tanytarsus*, were predominant. The silty sands at the 2-m depth also provided a suitable substrate for benthic organisms, especially tubificid worms, chironomid midges and *Hyalella.* The flocculent silts in the deepest portion of the lake were an unsuitable substrate for all macro-invertebrates except the meroplanktonic phantom midge, *Chaoborus* (fig. 10).

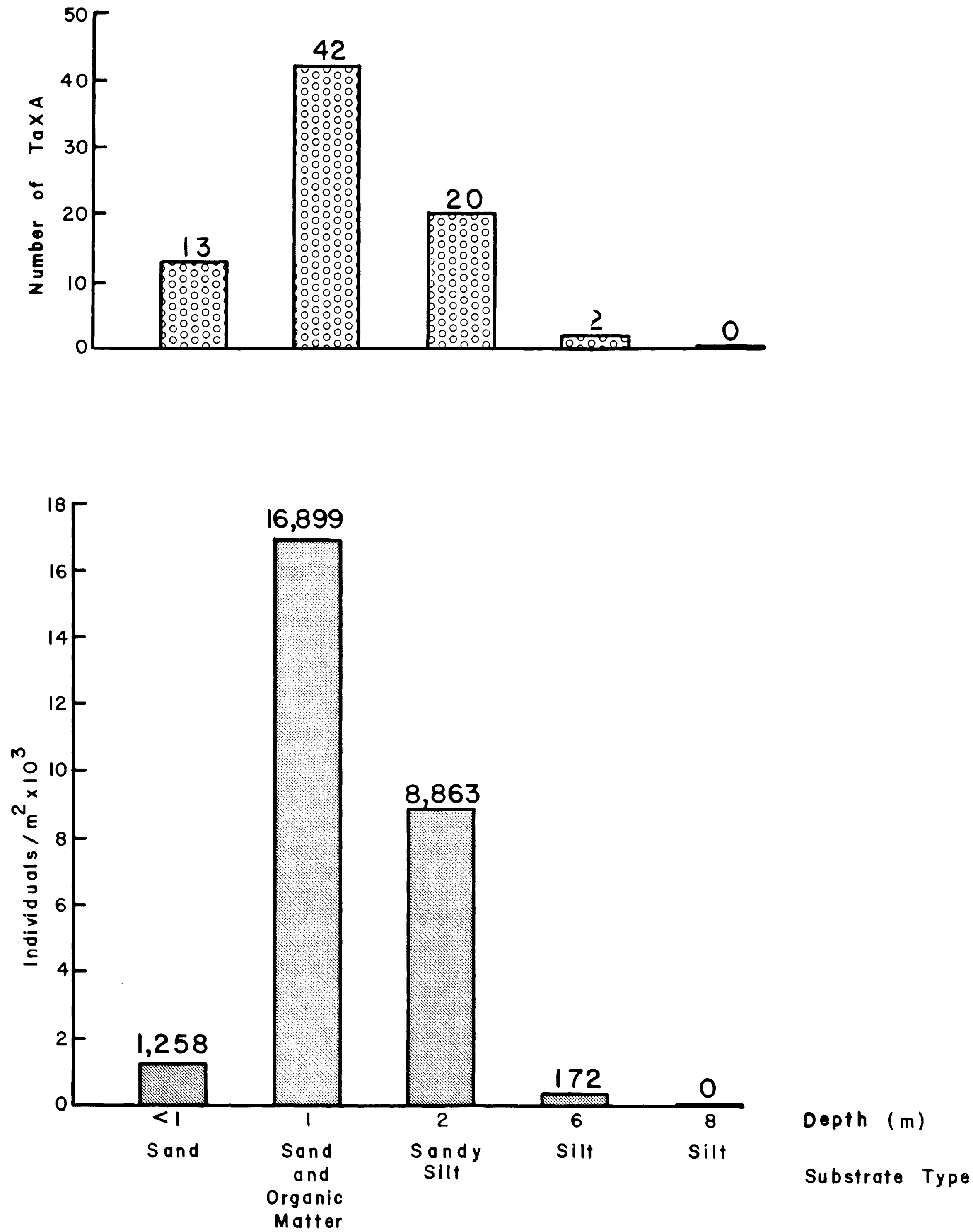

Fig. 10. Number of taxa (upper graph) and abundance (lower graph) of macro-invertebrates along the inshore-offshore transect in Florence Lake.

Fish Community

Four species of fish were observed in Florence Lake: *Perca flavescens* (yellow perch), *Esox lucius* (northern pike), *Micropterus dolomieui* (smallmouth bass), and *Etheostoma exile* (Iowa darter). More intensive collecting would have undoubtedly revealed more species, especially of forage fishes.

Condition of fish species in Florence Lake appeared to be excellent. Mean lengths of yellow perch and northern pike at successive ages were compared with averages for other Michigan Lakes (Table 4). Growth rates for both species in Florence Lake were greater than average.

Florence Lake fishes were infested with black spot and yellow grub parasites. Frequency of these parasites was especially high on yellow perch and northern pike. However, there was no indication that these parasites were adversely affecting Florence Lake fish populations.

DISCUSSION

LIMNOLOGICAL FEATURES

Florence Lake is moderately soft and slightly alkaline. It has no surface inlet, so groundwater seepage provides the major source of water. Since the lake lies so close to Lake Michigan and its basin extends below the level of the Great

TABLE 4. MEAN LENGTHS (IN INCHES) OF YELLOW PERCH AND NORTHERN PIKE IN FLORENCE LAKE AT SUCCESSIVE AGES COMPARED WITH AVERAGE GROWTH RATES IN MICHIGAN LAKES*

Age	YELLOW PERCH Florence Lake	YELLOW PERCH Other Michigan Lakes	NORTHERN PIKE Florence Lake	NORTHERN PIKE Other Michigan Lakes
0	2.6	3.1	12.2	10.2
I	6.8	4.6	16.9	15.6
II	8.4	6.1	21.1	19.4
III	10.0	7.0	23.8	22.2
IV	11.9	8.0	29.1	24.6

*Data for other Michigan lakes was taken from Laarman (1964).

Lake, sub-surface seepage of Lake Michigan water into Florence Lake would normally occur. However, Florence Lake contains substantially softer water than Lake Michigan. This suggests that some factor, such as a sub-surface clay layer, inhibits this seepage. The fact that specific conductance of Florence Lake was twice as low as that of Lake Michigan and three times lower than well water 0.8 km east of Florence Lake supports this assumption.

The lake experiences overturn during spring and fall, and thermally stratifies during the period from late May to mid-September. Ice cover begins around late December and remains until April or early May. Slight inverse thermal and chemical stratification occur in winter.

Nutrient values for Florence Lake vary with the seasonal cycles. During spring the concentration of inorganic nutrients was low since available nutrients were primarily incorporated as organic matter in the phytoplankton bloom. During summer stratification, the higher values for all plant nutrients in the hypolimnion reflected the regeneration of nutrients by decomposition processes. The overturn in September redistributed these accumulated nutrients throughout the water column. This resulted in the highest mean values for inorganic nutrients, and stimulated the fall plankton bloom. The lower accumulation of inorganic nutrients observed in winter was primarily because of slower metabolism in the cold water. By late winter, however, inorganic nutrients were sufficiently high to stimulate the spring phytoplankton bloom.

The flora and fauna of Florence Lake are typical of other small, northern Michigan inland lakes and most taxa observed are present in mainland lakes of similar morphometry. No rare or endangered species were detected. The diversity of phytoplankton, zooplankton, and benthos populations is indicative of excellent water quality. Although phytoplankton blooms were observed, they were never excessive. The balance of open water and littoral weed beds provides an optimum habitat for the fish community. The fact that growth rates of yellow perch and northern pike were better than average for Michigan inland lakes is another indication that the lake is in excellent ecological balance.

LAKE CLASSIFICATION

Lakes have been classified into three basic types: oligotrophic, eutrophic, and mesotrophic. Recent studies (National Academy of Science, 1972; Tierney et al., 1975) classify lakes with chlorophyll *a* values of 4-10 μg/liter as mesotrophic. Based on this scale, Florence Lake falls in the mesotrophic classification, since mean surface and depth-averaged chlorophyll *a* values were 10.0 μg/liter and 10.3 μg/liter, respectively. Eutrophic chlorophyll *a* values (depth-average of 23.5 μg/liter) were found only during the algal bloom of September, 1974. Carlson (1977) developed a trophic state index (TSI) based on chlorophyll *a*, Secchi disc transparency, and total phosphorus values. According to this index, Florence Lake is mesotrophic (fig. 11).

Composition of the phytoplankton community also indicates mesotrophy. Most of the blue-green, green, chrysophyte, and yellow-brown algae found in Florence Lake occur in eurytopic conditions. Although the eutrophic indicator, *Microcystis aeroginosa*, was prominent during algal blooms, other taxa which occur in the oligotrophic waters of Lake Michigan, such as *Botryococcus* and *Scenedesmus*, were also prevalent in Florence Lake during the algal blooms. The presence of both eutrophic and oligotrophic elements is indicative of mesotrophy.

Diatoms were not a major component of the plankton. Most species observed are characteristic of alkaline waters, although a few species of *Fragillaria, Gomphonema, Nitzschia* and *Synedra* are more indicative of eutrophy. *Asterionella formosa*, one of the more prevalent diatoms in the lake, is found in water bodies ranging from mesotrophic to eutrophic (Lowe, 1974).

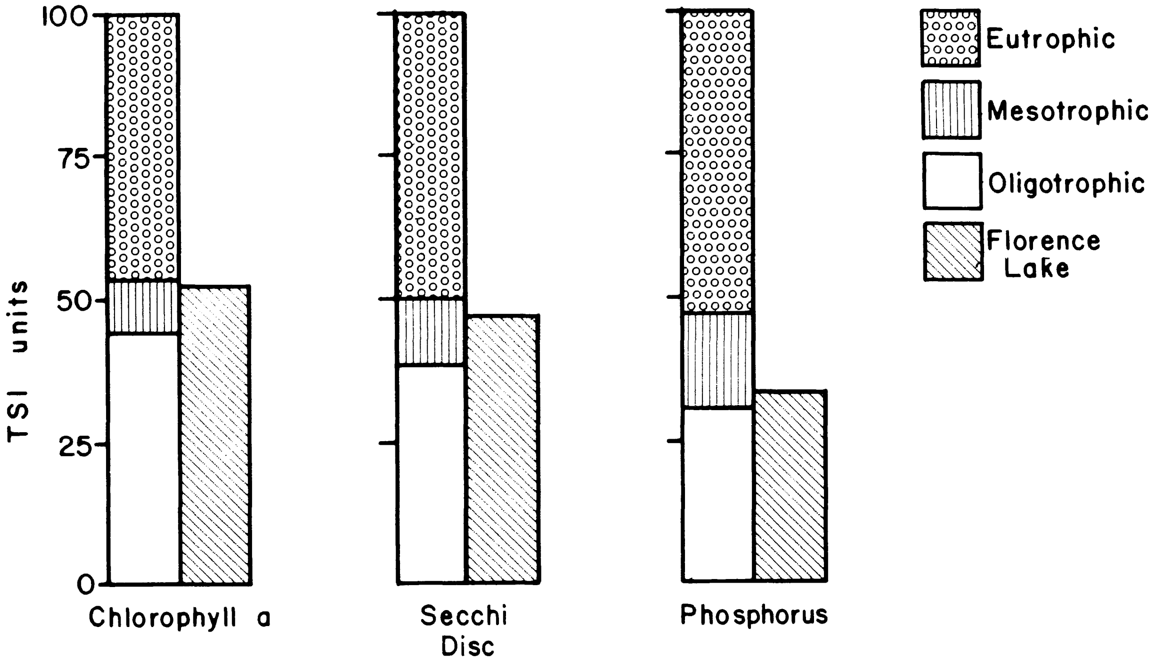

Fig. 11. Carlson's trophic state index (TSI) based on chlorophyll *a*, Secchi disc, and total phosphorus for Florence Lake. Calculations were made using May, 1975 data, the sampling period when the lake was thermally stratified.

The zooplankton community also indicated mesotrophic conditions. Oligotrophic indicator species were lacking and eutrophic forms, such as *Brachionus quadridentatus*, *Cyclops vernalis*, *Trichocerca cylindrica*, and *T. multicrinis* (Gannon and Stemberger, 1978) were rare in Florence Lake.

The composition of the benthic fauna also indicated the generally mesotrophic character of the lake. Pollution-sensitive forms such as many of the Ephemeroptera and Trichoptera were prevalent, but facultative taxa such as *Caenis* and *Cheumatopsyche* were also present. Most chironomid midges were facultative forms but some taxa, such as *Ablabesmyia*, *Pentaneura*, and *Stictochironomus*, are considered pollution-sensitive. The eutrophic indicator, *Chironomus (Chironomus)* and oligochaete worms such as *Limnodrilus* were rare. Other taxa in Florence Lake are essentially facultative species and are therefore found in a wide range of trophic conditions (Olive and Dambach, 1973).

CONCLUSIONS

All available limnological information indicates that Florence Lake is mesotrophic and has well-balanced populations of benthos, plankton, and fish. Since the lake was created by glacial activity thousands of years ago, it has gradually become more productive through natural eutrophication processes. There is no evidence that man's activities have appreciably affected the rate of eutrophication in this lake. Since the National Park Service plans to manage South Manitou Island as a wilderness area, future human impacts on the lake will probably be minimal.

Florence Lake may be particularly sensitive to any lakeshore development which would result in phosphorus inputs. Soft-water lakes cannot withstand phosphorus loading as well as hard-water lakes. In hard-water lakes phosphorus co-precipitates into the sediments with marl (calcium carbonate) and becomes unavailable to stimulate plant growth, but soft-water lakes do not have this limiting factor since they are low in calcium carbonate. Consequently, any development that may increase phosphorus loading to Florence Lake should be avoided, since this plant nutrient could readily leach through the porous sands near the lakeshore.

Since the major source of water in Florence Lake is seepage, complete water replacement takes an extremely long time and pollutive inputs would remain for an extended period before being cycled out. Therefore, prevention of pollution through sound management policies is necessary to maintain long-term water quality.

Limnological data in this report provides a benchmark on water quality in Florence Lake. Institution of a monitoring program through the auspices of the National Park Service is recommended for early detection of any adverse changes in water quality.

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APPENDIX A

PHYSICOCHEMICAL AND CHLOROPHYLL α DATA FROM FLORENCE LAKE, 1974-1975

Data is presented for the following variables: temperature (Temp.); dissolved oxygen (D.O.); pH; total alkalinity (T.A.); specific conductance (Sp. Cond.); chlorophyll α (Chlor. α); phaeophytin α (Phaeo. α); chloride (Cl); calcium (Ca); magnesium (Mg); potassium (K); sodium (Na); ammonia-nitrogen (NH_3-N); nitrate-nitrogen (NO_3-N) or nitrite plus nitrate-nitrogen (NO_{2+3}-N); soluble-reactive phosphorus (Sol-P); total phosphorus (Tot-P); and silica (SiO_2).

TABLE A-1. PHYSICOCHEMICAL AND CHLOROPHYLL α ANALYSES OF WATER SAMPLES COLLECTED AT VARIOUS DEPTHS FROM A DEEP, CENTRAL STATION IN FLORENCE LAKE ON 25 MAY 1974

Depth (m)	Temp. (C)	D.O. (mg/L)	D.O. (% sat)	pH	T.A.* (mg/L)	Sp. Cond.† (μmhos/cm)	Chlor. α (μg/L)	Phaeo. α (μg/L)	Cl (mg/L)
0	14.6	10.1	101	8.0	56.0	122	9.3	1.4	2.2
4	14.2	10.0	99	8.0	55.7	119		1.2	2.7
6	12.1	9.0	86	7.6	57.0	121	8.9	5.2	3.5
8	11.2	8.3	78	7.6	57.0	122	8.4	6.0	1.9

Depth (m)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	NH_3-N (μg/L)	NO_3-N (μg/L)	Sol-P (μg/L)	Tot-P (μg/L)	SiO_2§ (μg/L)
0	14.36	6.08	1.25	0.92	23	123	6	7	200
4	14.29	5.57	1.29	0.68	43	114	2	7	230
6	13.53	5.06	1.64		116	109	2	2	40
8		5.16	0.94		169	112	7	9	140

*Total alkalinity as $CaCO_3$.

†Specific conductance is corrected to 25 C.

§Silica is reported as Si.

TABLE A-2. PHYSICOCHEMICAL AND CHLOROPHYLL α ANALYSES OF WATER SAMPLES COLLECTED AT VARIOUS DEPTHS FROM A DEEP, CENTRAL STATION IN FLORENCE LAKE ON 22 MAY 1975

Depth (m)	Temp. (C)	D.O. (mg/L)	D.O. (% sat)	pH	T.A.* (mg/L)	Sp. Cond.† (μmhos/cm)	Chlor. α (μg/L)	Phaeo. α (μg/L)	Cl (mg/L)
0	19.3	9.0	100	8.1	55.0	122	7.5	0	1.12
2	17.5	9.2	99	8.1	55.5	121	7.5	0	1.24
4	16.6	9.1	96	8.0	57.8	122	9.0	0	1.22
6	15.2	8.5	88	7.6	56.1	122	10.6	0	1.16
8	12.0	6.7	64	7.3	58.5	123	6.5	1.4	1.18

Depth (m)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	NH_3-N (μg/L)	NO_{2+3}-N (μg/L)	Sol-P (μg/L)	Tot-P (μg/L)	SiO_2§ (μg/L)
0	13.79	5.76	1.09	0.56	140	120	5	6	38
2	12.56	5.63	1.21	0.56	130	119	6	8	29
4	12.05	5.63	1.16	0.59	133	118	4	15	31
6	13.81	5.61	1.16	0.59	164	107	5	17	27
8	14.44	5.68	1.16	0.57	207	108	4	24	33

*Total alkalinity as $CaCO_3$.

†Specific conductance is corrected to 25 C.

§Silica is reported as Si.

TABLE A-3. PHYSICOCHEMICAL AND CHLOROPHYLL α ANALYSES OF WATER SAMPLES COLLECTED FROM THE SURFACE AT NEAR-SHORE STATIONS IN FLORENCE LAKE ON 22 MAY 1975

Station	Temp. (C)	D.O. (mg/L)	D.O. (% sat)	pH	T.A.* (mg/L)	Sp. Cond.† (μmhos/cm)	Chlor. α (μg/L)	Phaeo. α (μg/L)	Cl (mg/L)
North	19.2	9.2	103	8.1	56.0	114	5.1	0.3	1.89
Cabins	19.4	8.9	100	8.2	56.0	120	7.3	0	1.23
South	18.4	8.9	101	8.1	55.9	121	7.3	0	1.18

Station	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	NH_3-N (μg/L)	NO_{2+3}-N (μg/L)	Sol-P (μg/L)	Tot-P (μg/L)	SiO_2§ (μg/L)
North	13.47	5.88	1.17	0.62	128	126	5	6	35
Cabins	14.37	5.74	1.15	0.59	186	130	6		27
South	14.11	5.63	1.13	0.59	141	121	5	6	21

*Total alakalinity as $CaCO_3$.

†Specific conductance is corrected to 25 C.

§Silica is reported as Si.

TABLE A-4. PHYSICOCHEMICAL AND CHLOROPHYLL α ANALYSES OF WATER SAMPLES COLLECTED AT VARIOUS DEPTHS FROM A DEEP, CENTRAL STATION IN FLORENCE LAKE ON 27 SEPTEMBER 1974

Depth (m)	Temp. (C)	D.O. (mg/L)	D.O. (% sat)	pH	T.A.* (mg/L)	Sp. Cond.† (μmhos/cm)	Chlor. α (μg/L)	Phaeo. α (μg/L)	Cl (mg/L)
0	13.2	9.4	91	7.4	57.1	126	27.6	1.7	
3	13.1	9.3	90	7.4	57.2	126	20.0	6.4	
6	13.1	9.3	90	7.5	57.3	124	26.3	-1.9§	
8	13.1	9.2	89	7.5	57.3	127	20.0	0	

Depth (m)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	NH_3-N (μg/L)	NO_{2+3}-N (μg/L)	Sol-P (μg/L)	Tot-P (μg/L)	SiO_2** (μg/L)
0	12.09	5.93	0.92	0.72	200	65	0	21	180
3	11.64	5.89	0.86	0.70	156	76	4	26	180
6	11.79	5.91	0.84	0.68	127	69	5	55	190
8	11.69	5.97	0.84	0.69	67	103	13	22	170

*Total alkalinity as $CaCO_3$.

†Specific conductance is corrected to 25 C.

§Occasionally, low negative values are obtained for phaeophytins. Other chlorophyll degradation products, especially of chlorophyll β, appear after acidification (Loftus and Carpenter, 1971).

**Silica is reported as Si.

TABLE A-5. PHYSICOCHEMICAL AND CHLOROPHYLL α ANALYSES OF WATER SAMPLES COLLECTED FROM THE SURFACE AT NEAR-SHORE STATIONS IN FLORENCE LAKE ON 27 SEPTEMBER 1974

Station	Temp. (C)	D.O. (mg/L)	D.O. (% sat)	pH	T.A.* (mg/L)	Sp. Cond.† (µmhos/cm)	Chlor. α (µg/L)	Phaeo. α (µg/L)	Cl (mg/L)
North	13.7	9.3	91	7.3	57.4	123	22.6	3.1	0.15
Cabins	13.2	9.3	90	7.4	56.5	112	18.8	6.5	3.33
South	12.0	9.0	87	7.4	57.1	124	17.5	0.5	3.24

Station	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	NH_3-N (µg/L)	NO_{2+3}-N (µg/L)	Sol-P (µg/L)	Tot-P (µg/L)	SiO_2§ (µg/L)
North	11.69	5.91	1.42	0.77	79	82	11	20	170
Cabins	12.84	5.95	1.46	0.94	105	69	4	24	190
South	12.49	6.15	1.44	0.77	89	60			210

*Total alkalinity as $CaCO_3$.

†Specific conductance is corrected to 25 C.

§Silica is reported as Si.

TABLE A-6. PHYSICOCHEMICAL AND CHLOROPHYLL α ANALYSES OF WATER SAMPLES COLLECTED AT VARIOUS DEPTHS FROM A DEEP, CENTRAL STATION IN FLORENCE LAKE ON 18 SEPTEMBER 1975

Depth (m)	Temp. (C)	D.O. (mg/L)	D.O. (% sat)	pH	T.A.* (mg/L)	Sp. Cond.† (μmhos/cm)	Chlor. α (μg/L)	Phaeo. α (μg/L)	Cl (mg/L)
0	17.5	9.9	106	8.2	58.2	117	9.2	-1.2	1.21
1.5	17.3	9.7	103	8.2	58.0	114	12.8	-2.2	1.24
3.0	17.0	9.7	102	8.2	58.3	119	9.9	-1.4	1.15
5.0	16.3	9.5	99	8.1	57.9	119	15.2	-3.5	1.27
7.0	16.1	8.4	87	7.8	57.9	119	12.0	-1.4	1.21

Depth (m)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	NH_3-N (μg/L)	NO_{2+3}-N (μg/L)	Sol-P (μg/L)	Tot-P (μg/L)	SiO_2§ (μg/L)
0	12.63	5.73	1.22	0.57	13	2	14	14	128
1.5	12.65	5.73	1.13	0.55	17	2	9	16	138
3.0	12.54	5.75	1.12	0.55	10	1	6	15	124
5.0	12.93	5.79	1.12	0.60	41	3	7	17	178
7.0	13.01	5.81	1.12	0.55	128	2	14	15	168

*Total alkalinity as $CaCO_3$.

†Specific conductance is corrected to 25 C.

§Silica is reported as Si.

TABLE A-7. PHYSICOCHEMICAL AND CHLOROPHYLL α ANALYSES OF WATER SAMPLES COLLECTED FROM THE SURFACE AND NEAR-SHORE STATIONS IN FLORENCE LAKE ON 18 SEPTEMBER 1975

Station	Temp. (C)	D.O. (mg/L)	D.O. (% sat)	pH	T.A.* (mg/L)	Sp. Cond.† (μmhos/cm)	Chlor. α (μg/L)	Phaeo. α (μg/L)	Cl (mg/L)
North	17.6	9.1	98	8.2	58.5	116	7.6	-1.9	1.13
Cabins	17.2	9.2	98	8.2	57.8	117	8.3	-2.2	1.27
South	17.2	9.8	104	8.2	58.2	117	8.3	-0.5	1.18

Station	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	NH_3-N (μg/L)	NO_{2+3}-N (μg/L)	Sol-P (μg/L)	Tot-P (μg/L)	SiO_2§ (μg/L)
North	12.62	5.73	1.19	0.54	11	5	7	15	133
Cabins	12.63	5.73	1.18	0.55	23	2	10	16	138
South	12.69	5.73	1.16	0.53	16	2	6	13	336

*Total alkalinity as $CaCO_3$.

†Specific conductance is corrected to 25 C.

§Silica is reported as Si.

TABLE A-8. PHYSICOCHEMICAL AND CHLOROPHYLL α ANALYSES OF WATER SAMPLES COLLECTED AT VARIOUS DEPTHS FROM A DEEP, CENTRAL STATION IN FLORENCE LAKE ON 21 MARCH 1975

Depth (m)	Temp. (C)	D.O. (mg/L)	D.O. (% sat)	pH	T.A.* (mg/L)	Sp. Cond.† (μmhos/cm)	Chlor. α (μg/L)	Phaeo. α (μg/L)	Cl (mg/L)
0.5	1.96	12.0	88	7.6	57.2	139	1.2	-0.2	2.19
2.0	3.18	9.4	72	7.5	60.3	144	2.4	0.5	2.37
5.0	4.14	3.9	30	7.4	63.6	146	1.0	1.6	1.51
8.0	4.33	0.2	1	7.2	81.2	157	0.4	4.8	1.52

Depth (m)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	NH_3-N (μg/L)	NO_{2+3}-N (μg/L)	Sol-P (μg/L)	Tot-P (μg/L)	SiO_2§ (μg/L)
0.5	13.97	5.89	1.27	0.64	337	367	5	10	43
2.0	14.78	6.21	1.35	0.63	351	109	7	12	53
5.0	14.84	6.13	1.31	0.62	556	26	18		134
8.0	16.73	6.44	1.51	0.74	1,224	6	12	26	354

*Total alkalinity as $CaCO_3$.

†Specific conductance is corrected to 25 C.

§Silica is reported as Si.

TABLE A-9. PHYSICOCHEMICAL AND CHLOROPHYLL α ANALYSES OF WATER SAMPLES COLLECTED FROM THE SURFACE AT NEAR-SHORE STATIONS IN FLORENCE LAKE ON 21 MARCH 1975

Station	Temp. (C)	D.O. (mg/L)	D.O. (% sat)	pH	T.A.* (mg/L)	Sp. Cond.† (μmhos/cm)	Chlor. α (μg/L)	Phaeo. α (μg/L)	Cl (mg/L)
North	1.46	12.0	84	7.7	56.2	139	1.7	-0.5	5.20
Cabins	1.59	10.8	80	7.6	63.2	134	2.2	0.8	1.62
South	2.10	12.0	88	7.6	63.2	137	0.9	1.0	2.32

Station	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	NH_3-N (μg/L)	NO_{2+3}-N (μg/L)	Sol-P (μg/L)	Tot-P (μg/L)	SiO_2§ (μg/L)
North	14.72	6.17	1.35	0.76	309	234	6	10	22
Cabins	14.84	6.31	1.38	0.65	324	198	12	16	79
South	15.16	6.33	1.40	0.70	304	172	17		46

*Total alkalinity as $CaCO_3$.

†Specific conductance is corrected to 25 C.

§Silica is reported as Si.

APPENDIX B

PHYTOPLANKTON TAXA OF FLORENCE LAKE

The most common taxa are indicated by an asterisk (*).

BACILLARIOPHYCEAE (DIATOMS)

Achnanthes lanceolata (Breb.) Grun.
Achnanthes minutissima Kutz.
Amphora ovalis (Kutz.) Kutz.
Asterionella formosa Hass.
Caloneis amphisbaena (Bory) Cl.
Caloneis bacillum (Grun.) Cl.
Cocconeis pediculus Ehr.
Cocconeis placentula Ehr.
Cocconeis scutellum Ehr.
Cyclotella bodanica Eulenst.
Cyclotella glomerata Bachm.
Cyclotella comta (Ehr.) Kutz.
Cyclotella kuetzingiana Thw.
Cyclotella meneghiniana Kutz.
Cyclotella michigania Skv.
Cymbella affinis Kutz.
Cymbella tumida (Breb.) V.H.
Cymbella turgida Greg.
Cymbella ventricosa Ag.
Diatoma elongatum (Lyngb.) Ag.
Diatoma hiemale (Roth) Heib.
Diatoma vulgare Bory
Epithemia turgida (Ehr.) Kutz.
Eunotia pectinalis (O.F. Müller) Rabh.
Fragilaria capucina Desm.
Fragilaria construens (Ehr.) Grun.
Fragilaria crotonensis Kitton
Fragilaria inflata (Heid.) Hust.
Fragilaria intermedia Grun.
Fragilaria leptostauron (Ehr.) Hust.
Gomphonema angustatum (Kutz.) Rabh.
Gomphonema constrictum Ehr.
Gomphonema olivaceum (Lyngb.) Kutz.
Hantzschia sp.
Melosira islandica O.F. Müller
Meridion circulare (Grev.) Ag.
Navicula canalis Patr.

Navicula crytocephala Kutz.
Navicula cuspidate (Kutz.) Kutz.
Navicula exiqua (Greg.)
Navicula dissipata Hust.
Navicula gastrum (Ehr.) Kutz.
Navicula pupula Kutz.
Navicula pygmaea Kutz.
Navicula radiosa Kutz.
Navicula zanoni Hust.
Nitzschia amphibia Grun.
Nitzschia filiformis (W.Sm.) Schutt
Nitzschia fonticola Grun.
Nitzschia linearis (Ag.) W.Sm.
Nitzschia lorenziana Grun.
Nitzschia palea (Kutz.) W.Sm.
Nitzschia paradoxa (Gmelin) Grun.
Nitzschia parvula W.Sm.
Nitzschia sigmoidea (Nitz.) W.Sm.
Opephora martyi Herib.
Pinnularia borealis Ehr.
Pinnularia gibba Ehr.
Rhoicosphenia curvata (Kutz.) Grun.
Stauroneis phoenicenteron (Nitz.) Ehr.
Stephanodiscus hantzschii Grun.
Stephanodiscus astraea (Ehr.) Grun.
Surirella ovata Kutz.
Synedra acus Kutz.
Syndera pulchella Ralfs
Syndera rumpens Kutz.
Syndera tabulata (Ag.) Kutz.
Synedra ulna (Nitz.) Ehr.
Tropidoneis sp.

CHLOROPHYTA (GREEN ALGAE)

Arthrodesmus sp.
Asterococcus sp.
Botryococcus braunii Kuetzing*
Characium limneticum Lemmermann
Closterium sp.
Cosmarium sp.
Crucigenia quadrata Morren
Crucigenia rectangularis (A. Braun) Gay
Elakatothrix gelatinosa Wille
Gloeocystis major Gerneck *ex* Lemmermann
Gloeocystis planktonica (West & West) Lemmermann
Kirchneriella obesa (W. West) Schmidle
Oocystis parva West & West
Oocystis solitaria Wittrock
Pediastrum biradiatum Meyen
Pediastrum boryanum (Turp.) Meneghini

Pediastrum duplex Meyen
Scenedesmus acutiformis Schroeder*
Scenedesmus arcuatis Lemmermann*
Scenedesmus bijuga (Turp.) Lagerheim*
Scenedesmus denticulatus Lagerheim*
Scenedesmus dimorphus Kuetzing*
Scenedesmus quadricauda (Turp.) de Brébisson*
Sphaerozosma sp.
Spirogyra sp.
Staurastrum sp.
Tetraedron caudatum (Corda) Hansgirg
Tetraedeon minimum (A. Braun) Hansgirg
Tetraedron pentaedricum West & West
Tetraedron regulare Kuetzing

CHRYSOPHYTA (YELLOW-GREEN ALGAE)

Dinobryon bavaricum Imhof
Dinobryon calciformis Bachmann
Dinobryon divergens Imhof
Dinobryon sertularia Ehrenberg
Mallomonas caudata Iwanoff*
Ophicytium capitatum Wolle
Unidentified cryptomonads

CYANOPHYTA (BLUE-GREEN ALGAE)

Anabaena circinalis Rabenhorst
Aphanocapsa elachista West & West
Aphanothece microscopica Naegeli*
Aphanothece nidulans P. Richter*
Chroococcus dispersus (Keissl.) Lemmermann
Chroococcus limneticus Lemmermann
Chroococcus pallidus Naegeli
Coelosphaerium naegilianum Unger
Dactylococcopsis acicularis Lemmermann
Dactylococcopsis smithii Chodat & Chodat
Dictyosphaerium ehrenbergianum Naegli*
Gloeothece linearis Naegeli
Gloeothece rupestris (Lyngb.) Bornet*
Gomphosphaeria aponina Kuetzing*
Holopedium irregulare Lagerheim
Lyngbya birgei G.M. Smith
Microcystis aeruoginosa Kuetz,. *emend.* Elenkin*
Merismopedia glauca (Ehrenb.) Naegeli*
Oscillatoria angustissima West & West
Oscillatoria princeps Vaucher
Pelogloea bacillifera Lauterborn
Phormidium musicola Naumann & Huber-Pestalozzi
Rhabdoderma lineare Schmidle & Lauterborn

EUGLENOPHYTA (EUGLENOIDS)

Trachelomonas sp.

PYRRHOPHYTA (YELLOW-BROWN ALGAE)

Ceratium hirudinella (O.F. Müller)
Glenodinium sp.
Peridinium sp.

APPENDIX C

ZOOPLANKTON TAXA OF FLORENCE LAKE

Relative abundance is indicated by the following letters: A=abundant; C=common; I=infrequent; R=rare. An asterisk (*) designates littoral or benthic taxa.

ROTIFERA

CLASS MONOGONONTA

Order Ploima

Family Brachionidae

Brachionus quadridentatus Herman	R*
Kellicottia longispina (Kellicott)	C
Keratella cochlearis cochlearis (Gosse)	C
K. cochlearis f. *hispida* (Lauterborn)	R
K. crassa Ahlstrom	A
K. earlinae Ahlstrom	A
K. hiemalis Carlin	R
Lophocharis salpina (Ehrbg.)	R*
Macrochaetus subquadratus Perty	R*
Notholca squamula (O.F. Müller)	R
Trichotria tetractis (Ehrbg.)	R*

Family Lecanidae

Lecane crepida Harring	R*
L. luna (O.F. Müller)	R*
L. stokesi (Pell)	R*
Monostyla bulla Gosse	R*
M. lunaris (Ehrbg.)	I

Family Notommatidae

Cephalodella sp.	R*

Family Trichocercidae

Trichocerca cylindrica (Imhof)	R
T. multicrinis (Kellicott)	R
Trichocerca sp.	R*

Family Gastropidae

Ascomorpha ecaudis Perty	R
A. saltans Bartsch	R
A. ovalis (Bergandal)	R
Gastropus stylifer Imhof	R

Family Asplanchnidae

Asplanchna priodonta Gosse	R

Family Synchaetidae

Ploesoma lenticulare Herrick	R
Polyarthra major Burckhardt	R
P. remata Skorikov	R
P. vulgaris Carlin	C
Synchaeta pectinata Ehrbg.	R
S. stylata Wierzejski	R

Family Testudinellidae

Filinia longiseta (Ehrbg.)	R
F. terminalis (Plate)	C
Testudinella sp.	R*

Family Conochilidae

Conochilus unicornis Rousselet	R

Family Collothecidae

Collotheca mutabilis (Hudson)	I

CRUSTACEA

SUBCLASS COPEPODA

Order Calanoida

Family Diaptomidae

Diaptomus oregonensis Lilljeborg	A

Family Temoridae

Epischura lacustris S.A. Forbes	C

Order Cyclopoida

Family Cyclopidae

Cyclops bicuspidatus thomasi S.A. Forbes	A
C. vernalis Fischer	I
Ectocyclops phaleratus (Koch)	R*
Eucyclops speratus (Lilljeborg)	R*
Macrocyclops albidus (Jurine)	R*
Mesocyclops edax (S.A. Forbes)	C
Tropocyclops prasinus mexicanus Kiefer	A

Order Harpacticoida

Unidentified sp.	R*

SUBCLASS BRANCHIOPODA

Order Cladocera

Family Bosminidae

Bosmina longirostris O.F. Müller	A

Family Chydoridae

Acroperus harpae (Baird)	I*
Alona costata Sars	I*
A. setulosa Megard	R*
Camptocercus rectirostris Schødler	R*
Chydorus sphaericus (O.F. Müller)	A
Eurycercus lamellatus O.F. Müller)	R*

Graptoleberis testudinaria (Fischer)	R*
Pleuroxis procurvus Birge	R*

Family Daphnidae

Ceriodaphnia lacustris Birge	C
C. quadrangula (O.F. Müller)	R
Daphnia galeata mendotae Birge	I
D. retrocurva S.A. Forbes	C
Simocephalus serrulatus (Koch)	R*

Family Holopedidae

Holopedium gibberum Zaddach	C

Family Leptodoridae

Leptodoridae kindtii Focke	R

Family Macrothricidae

Ilyocryptus spinifer Herrick	R*

Family Sididae

Diaphanosoma leuchtenbergianum Fischer	C
Latona setifera (O.F. Müller)	R*
Sida crystallina (O.F. Müller)	I*

APPENDIX D

MACRO-INVERTEBRATES OF FLORENCE LAKE

ANNELIDA

HIRUDINEA

Oligochaeta

Branchiobdellidae
Lumbriculidae
Naididae

Dero digitata (Müller)
Nais bretscheri Michaelsen
N. communis Piguet
Pristina foreli (Piguet)
P. longiseta Ehrenberg
P. osborni (Walton)
Slavina appendiculata (d'Udekem)
Specaria josinae (Vejdovsky)
Stylaria fossularis Leidy
S. lacustris Michaelsen
Uncinais uncinata (Ørsted)
Vejdovskyella comata (Vejdovsky)

Tubificidae

Limnodrilus hoffmeisteri Claparède
L. udekemianus Claparède

ARTHROPODA

ARACHNOIDEA

Hydracarina

Elyais
Hydrachna

CRUSTACEA

Amphipoda

Gammarus
Hyalella azteca (Saussure)

Decopoda

Orconectes virilis (Hagen)

INSECTA

Coleoptera

Acilius
Agabus
Bidessus
Coptotomus
Dineutus
Gyrinus
Haliplus
Hygrotus
Laccophilus
Peltodytes
Steltodytes
Stenelmis
Tropisternus
Unidentified Hydrophilidae

Diptera

Ceratopogonidae

Alluaudomyia
Dasyhelia
Palpomyia
Stilobezzia
Unidentified member of the *Probezzia-Bezzia* group

Chaoboridae

Chaoborus

Chironomidae

Ablabesmyia

Calopsectra querla Roback
Calopsectra van der wulpi Edwards
Calopsectra #5 (Roback, 1957)
Calopsectra #6 (Roback, 1957)
Chironomus (Anth asinus)
Chironomus (Chironomus) thummi group
Chironomus (Salinaris)
Corynoneuria taris Winnertz
Cricotopus
Cryptochironomus
Cryptochironomus vulneratus (Zetterstedt)
Dicrotendipes
Endochironomus
Harnischia
Hydrobaenus
Lauterborniella
Microtendipes
Paralauterborniella
Paratendipes
Phaenopsectra (Tribelos)
Polypedilum
Polypedilum (Tripodura) halterale Coquillett
Procladius adumbratus Johannsen
Pseudochironomus (Pentapedilum) tritum Walker
Stenochironomus
Tanytarsinae, Tribe Calopsectrini
Tanytarsus
Tanytarsus #6 (Roback, 1957)
Thienemanninyia Series
Xenochironomus

Rhagionidae

Atherix

Ephemeroptera

Caenis
Ephemerella
Siphlonurus
Stenonema
Unidentified Baetidae

Hemiptera

Hesperocorixa
Lethocerus
Mesovelia

Notonecta (two species)
Plea
Ranatra
Unidentified Belastomatidae

LEPIDOPTERA

Nymphula

ODONATA

Aeshna
Anax
Anomalogion
Enallagma (two species)
Gomphus
Plathemis
Stylurus
Tetragoneuria

Trichoptera

Agrypnia
Cheumatopsyche
Glyphotaelius
Leptocella
Molanna
Mystacides
Oecetis
Oxyethira
Phryganea
Polycentropus
Triaenodes
Unidentified Hydroptilidae
Unidentified Phryganeidae

MOLLUSCA

GASTROPODA

Amnicola
Gyraulis

PELECYPODA

Pisidium

DO NOT REMOVE
OR
MUTILATE CARD