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The Liminology of Oneida Lake - An Interim Report

Phillip E. Greenson

George S. Meyers

STATE OF NEW YORK
CONSERVATION DEPARTMENT
WATER RESOURCES COMMISSION

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U.S. GEOLOGICAL SURVEY

REPORT OF INVESTIGATION
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ABSTRACT

This interim report discusses the general concepts of lake eutrophication and presents the findings of the first year of field investigations on the eutrophication of Oneida Lake, New York. Routine biological and chemical data revealed that the lake has become eutrophic both through the natural processes of lake aging and from the inflow of nutrient-rich water from the fertile drainage basin. The four most important factors affecting the biological activities within the lake are: (1) the high fertility of the drainage basin, (2) the physical position and shallowness of the lake, (3) mixing of the water by wind action, and (4) the inclusion of bottom sediments in the recycling of nutrient materials.

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INTRODUCTION

Oneida Lake, with a surface area of 79.8 square miles (206.7 square kilometers), is the largest lake wholly within New York State, and is used almost exclusively for recreational purposes; it also serves as an important link in the New York State Barge Canal System (fig. 1). During the summer months, Oneida Lake characteristically exhibits a tremendous growth of planktonic, blue-green algae (see Glossary). The production of these organisms is so great that the recreational uses of the lake are hindered, and the decomposition of algae along the shore becomes esthetically unpleasant for lakeside residents.

Although limited control measures for excessive algal growths are practical in certain lakes, the size of Oneida Lake prohibits the practical and economic justification for any of the known methods, such as use of algacides, mechanical harvesting, or biological grazers. There are many gaps in the understanding of lake processes and interactions. With continued study, knowledge increases, relationships are established, and new approaches for lake management become evident.

With this in mind, the Water Resources Division of the U.S. Geological Survey, in cooperation with the Division of Water Resources of the New York State Conservation Department, initiated in April, 1967 a 5-year program to study the eutrophication of Oneida Lake.

The objectives of the program are to provide: (1) physical and chemical descriptions of Oneida Lake and its drainage basin, and (2) an analysis of the interactions between the biology and chemistry of the lake which includes those aspects of basin hydrology, geochemistry, climatology, and cultural activity that may be of importance to the lake processes.

The basis of the study is the determination of the water, mineral, and organic nutrient balances of the entire lake system, including the contribution from: (1) streamflow, (2) precipitation, (3) ground-water inflow, and (4) introduced pollution. The study also includes: (1) an evaluation of the chemical interactions and biological effects within the lake, (2) a description of the type and quantity of organisms present as illustrated by space and time variations, and (3) an attempt to define those chemical and physical conditions of the lake system which appear to give rise to or be associated with the various biological changes within the lake.

In essence, this project critically examines Oneida Lake and its drainage basin in terms of a dynamic system....one of causes and effects. By first describing and understanding the numerous and various scientific bases, it may then be possible in the future to establish a lake management program that will ease the algal problem.

This report describes the general concept of the process of eutrophication and reports the activities of the first year of field investigations. Emphasis is placed on the physical, chemical and biological descriptions of Oneida Lake.

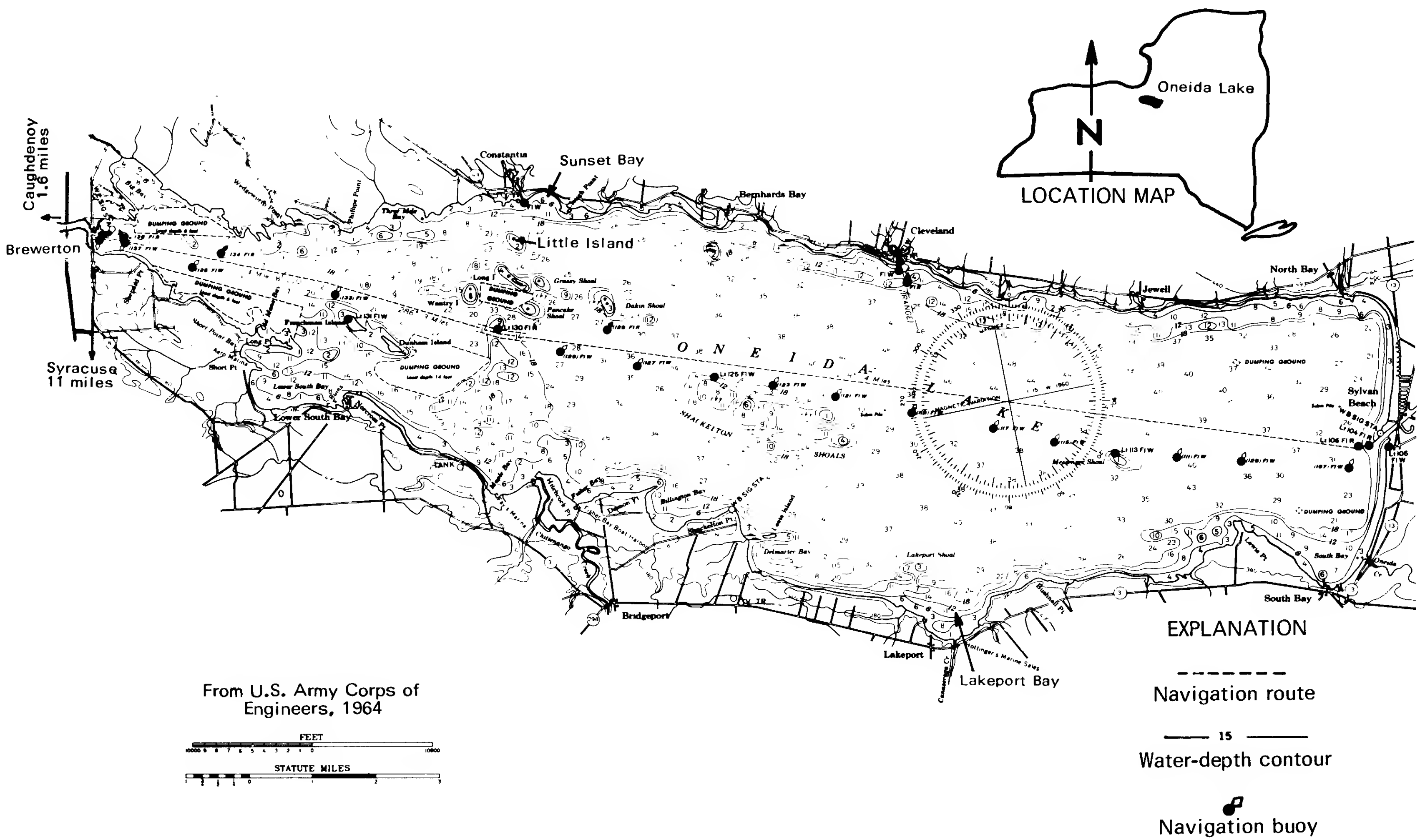

Figure 1.--Oneida Lake.

This interim report accompanies a report by Pearson and Meyers (1969) on the description of the Oneida Lake drainage basin in terms of its physical setting and chemical contributions to the lake.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance of many persons during various phases of the study. Special appreciation is extended to Mr. Henry C. Carroll, New York Division of Water Resources; Dr. John Forney, Cornell University Biological Field Station; Dr. Frederick J. Pearson, Jr., U.S. Geological Survey; Mr. Charles C. Knapp, Bridgeport, New York; and Mr. Millard Rogers, Brewerton, New York.

This report was written under the direction of Garald G. Parker, former District Chief, and under the immediate supervision of Kenneth I. Darmer, Chief, Hydrologic Studies Section, U.S. Geological Survey, Water Resources Division, New York District.

PROCESS OF EUTROPHICATION

Eutrophication is the term applied to the mechanisms and interrelationships of the highly complex processes that contribute to the aging and eventual extinction of lakes, streams, and estuaries. More simply, eutrophication is the natural process of aging of water bodies, the rate of which may be accelerated by cultural activities of man. Figure 2 shows that eutrophication consists of the gradual progression (termed ecological succession) from one life stage into another.

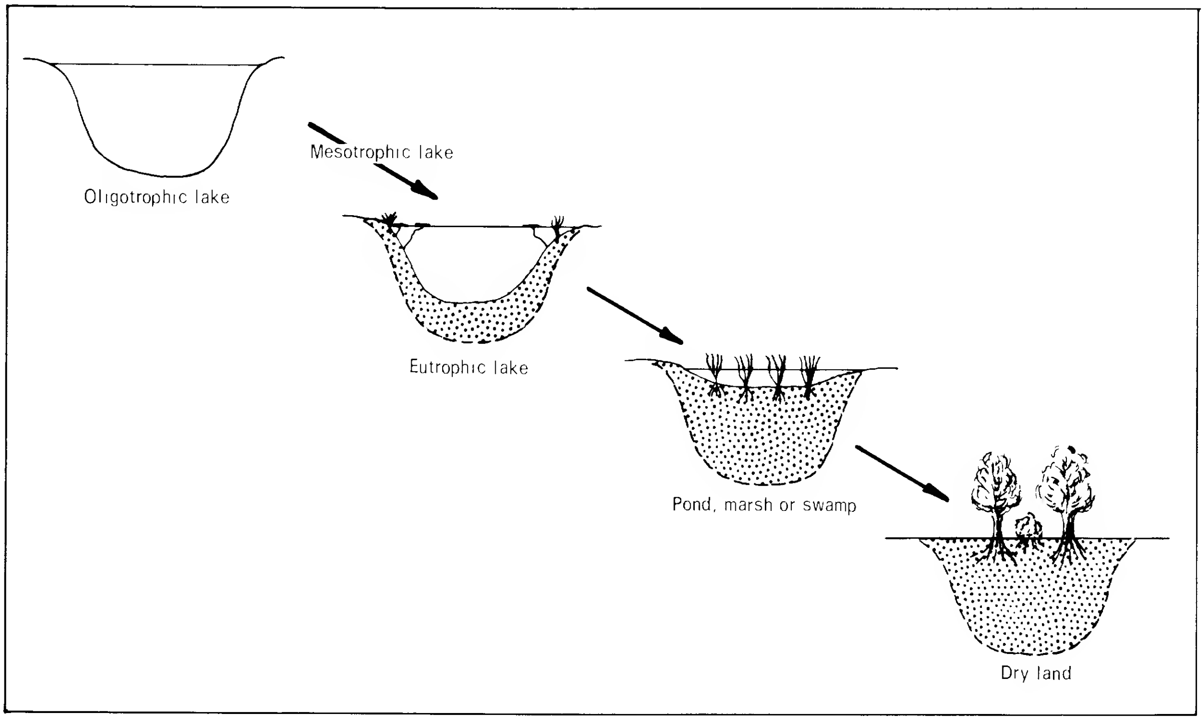

Figure 2.--Eutrophication - the process of aging by ecological succession.

Based on the degree of nourishment or productivity, the youngest stage of the life cycle is called an oligotrophic lake. At some point in the succession, the lake becomes a mesotrophic lake and then a eutrophic lake. The final life stage before the climax extinction is a pond, marsh, or swamp.

As a lake passes through each stage of life, the degree of enrichment by nutritive materials increases. In general, a lake will serve as a trap for nutrients originating in the surrounding drainage basin and entering with the runoff through streams and tributaries, with precipitation, and with ground-water inflow. These entrapped nutrients are recycled during each growing season; they are used and reused by aquatic vegetation. After the concentration of nutrients has become sufficient, a continual supply from the drainage basin is usually not required for sustaining continued plant growth at a high rate of production. It is believed that after an initial stimulus, the recycling of nutrients within a lake might be adequate to sustain highly productive conditions for a period of years (Fruh, 1967). Figure 3 shows that when a lake has reached the eutrophic stage, the changes toward a greater degree of aging are hastened.

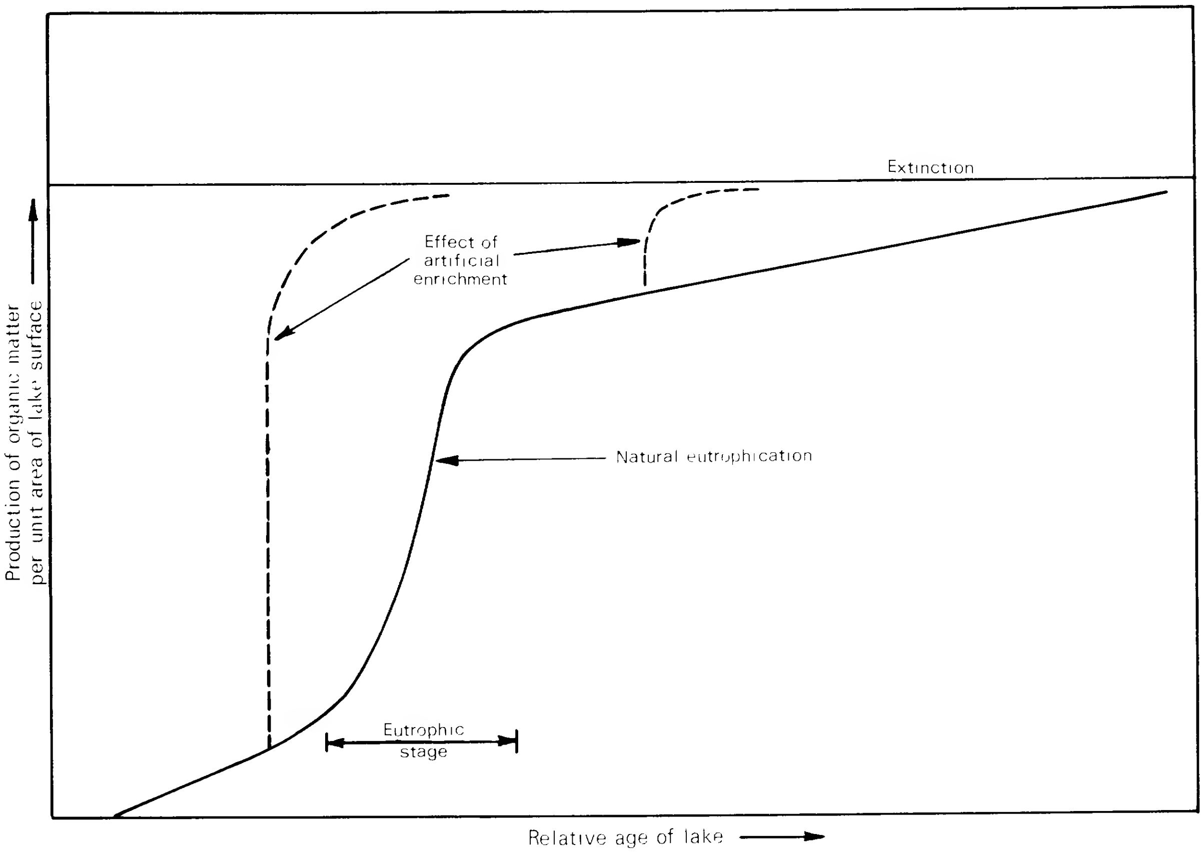

Figure 3.--Hypothetical curve of eutrophication. (Modified from Hasler, 1947.)

Enrichment and sedimentation are the principal contributors to the aging process, which progresses as nutrients and sediments are transported into the lake. The shore vegetation utilizes part of the nutrients, grows abundantly, and in turn, traps the sediment. As the years go by, the lake fills in, not only over its entire bottom by plants and sediments, but also by the invasion of shore vegetation.

As the aging and filling-in continues, the lake's shore encroaches upon the water, the nutrient content increases, plants grow abundantly, and silt, vegetation, and decaying organic matter build up the bottom. The lake eventually becomes dry land. The extinction of the lake is, therefore, a result of enrichment, productivity, decay, and sedimentation.

A eutrophic lake is characterized by a high content of dissolved nutrients and an abundance of aquatic organisms. Plants, particularly algae, are of first concern because they utilize the dissolved inorganic salts (nutrients) directly from the water, and become the primary producers.

The algae of concern are mostly microscopic and free-floating forms called phytoplankton. In an oligotrophic lake, the phytoplankton are usually low in total numbers but rich in variety of forms, whereas the phytoplankton of an eutrophic lake are represented by a large number of a few forms. Table 1 indicates the differences in phytoplankton associated with these two types of lakes.

Table 1.--Plankton of oligotrophic and eutrophic lakes (After Rawson, 1956.)

	Oligotrophic Lake	Eutrophic Lake
Quantity	Poor	Rich
Variety	Many species	Few species
Distribution	To great depths	Upper layer
Diurnal migration	Extensive	Limited
Water-blooms	Very rare	Frequent
Characteristic algal groups and genera	Chlorophyta (Green algae) Staurastrum OR Diatomaceae (Diatoms) Tabellaria Cyclotella Chrysophyta (Yellow-brown algae) Dinobryon	Cyanophyta (Blue-green algae) Anabaena Aphanizomenon Microcystis Diatomaceae (Diatoms) Melosira Fragilaria Stephanodiscus Asterionella

A eutrophic lake is generally characterized by the presence of diatoms (Bacillariophyceae) during the late fall, winter, and spring with numbers being greatest during the spring. Green algae (Chlorophyta) become dominant during late spring but decrease with the oncome of the blue-green algae (Cyanophyta), which are typical of the summer during maximum temperature and light conditions. If all factors are favorable, the blue-green algae grow abundantly to the point of bloom proportions.

An algal bloom (also referred to as "bloom," "water bloom", or "water blossom") is the relatively rapid increase in the total number of phytoplankton per unit time to the extent that their presence hinders the utility of a body of water for whatever the intended use. More simply, an algal bloom is the overabundance of phytoplankton. The concept of an algal bloom is relative and dependent upon its immediate effect on a particular body of water.

The life (metabolic) processes of algae utilize the nutrients in the surrounding medium; with the continued increase in the size of an algal population, there is a progressive decrease of available nutrients. At some point, one or more of the nutrients may become depleted, consequently the growth process of the algae ceases. Thus, other conditions being suitable, the maximum size of an algal bloom or the maximum population that a lake can support is dependent upon the availability of nutritive materials.

Characteristically, a eutrophic lake contains an adequate quantity of nutrients to support an algal bloom, which generally attains a maximum size during early to mid-summer. Subsequent to the initial bloom the population decreases in size to a more or less constant level. Secondary blooms may occur sporadically during the growing season, and a second major bloom may occasionally occur prior to the approach of cooler water temperatures during the fall (fig. 4).

As indicated, the nutrients that support algal growths in lakes originate in the surrounding drainage basin and enter primarily with surface runoff; therefore, the more fertile the soil of the basin, the more abundant are the nutrients.

A nutrient is any substance that is necessary for the continuation of growth, for repair of tissue, or for reproduction. Any chemical element or compound that is required for the normal and healthy existence of an alga is considered to be a nutrient. Those elements that are required in large quantities are known as macrometabolites (macronutrients or major nutrients), while those needed in very minute quantities are called micrometabolites (micronutrients or minor nutrients). The micrometabolites are generally those essential elements that occur in trace quantities in the environment.

Table 2 is a composite list of the 21 essential elements that in some chemical combination are known to be required for the sustenance of algae. The minimum requirements for essential elements are very vaguely understood, but table 2 partially lists those minimum concentrations reported in the literature.

The causes of eutrophication are not fully understood; the cure for eutrophication is still to be developed. In meeting, defining, and attempting to solve the problem, one must look at the entire process as a dynamic system that is gradually undergoing change. The complexity of environmental relationships and the extent of internal biological

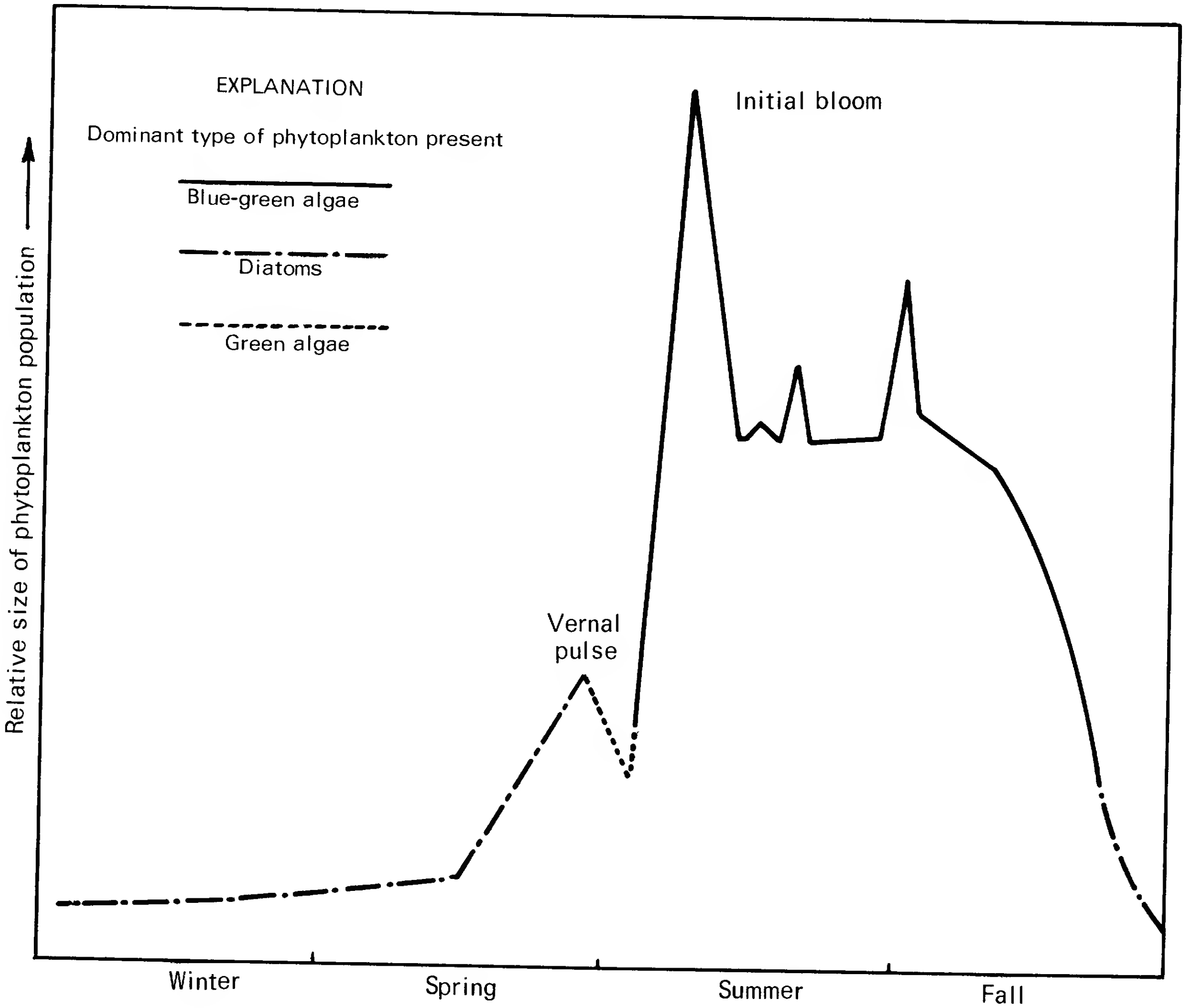

Figure 4.--Hypothetical curve of seasonal phytoplankton distribution in a eutrophic lake.

interactions dictate that the changes of a lake be of a progressive and more or less predictable manner...a system of causes and effects. As one of the numerous influencing factors changes, a response in the lake follows. Thus, at any given moment, a lake is a balanced entity.

Eutrophication is the inevitable process of lake aging. It is a process that probably will never be fully controlled, but the efforts of many investigators may result some day in a retarding effect, and the utility of many lakes will be greatly improved.

Table 2.--Elements essential for the growth of algae

Element	Symbol	Minimum requirements	References
(?) Aluminum	Al	Probably trace quantities	Meyer, et al., 1964.
Boron	B	0.1 mg/l	Eyster, 1965; Provasoli, 1958.
Calcium	Ca	20.0 mg/l	Allen and Arnon, 1955; Walker, 1953.
Carbon	C	(Quantities always sufficient in surrounding medium)	Meyer, et al., 1964.
Chlorine	Cl	Trace quantities	Levin, 1960; Meyer, et al., 1964
Cobalt	Co	0.5 mg/l	Buddhari, 1960 after Miller and Tash, 1967; Pirson, 1937.
Copper	Cu	0.006 mg/l	Walker, 1953.
Hydrogen	H	(Quantities always sufficient in surrounding medium)	Meyer, et al., 1964
Iron	Fe	0.00065 - 6.0 mg/l	Gerloff and Skogg, 1957; Ryther and Kramer, 1961; Schelske, 1962.
Magnesium	Mg	Trace quantities	Kratz and Myers, 1955; Krauss, 1956.
Manganese	Mn	0.005 mg/l	Gerloff and Skoff, 1957; Krauss, 1956; Pirson, 1937.
Molybdenum	Mo	Trace quantities	Bortels, 1940; Cobb and Meyers, 1964; Walker, 1953.
Nitrogen	N	Trace quantities - 5.3 mg/l	Birge and Juday, 1922; Chu, 1943; Hutchinson, 1957; Palmer, 1967; Sawyer, 1947.
Oxygen	O	(Quantities always sufficient in surrounding medium)	Meyer, et al., 1964.

Table 2.--Elements essential for the growth of algae (Continued)

Element	Symbol	Minimum requirements	References
Phosphorus	P	0.002 - 0.09 mg/l	Benoit and Curry, 1961; Chu, 1943; Gerloff and Skogg, 1954; Rodhe, 1949; Sarles, 1961; Sawyer, 1947.
Potassium	K	Trace quantities	Meyer, et al., 1964; Krauss, 1956.
Silicon	Si	0.5 - 0.8 mg/l	Lund, 1950 and 1954; Pearsall, 1932.
Sodium	Na	5.0 mg/l	Phillips, et al., 1965.
Sulphur	S	<5.0 mg/l	Fogg, 1966; Meyer, et al., 1964; Rodhe, 1949.
Vanadium	V	Trace quantites	Provasoli, 1958; Shannon, 1965 after Fruh, 1967.
Zinc	Zn	0.01 - 0.1 mg/l	Provasoli, 1958; Provasoli and Pinter, 1953.

PHYSICAL FACTORS OF ONEIDA LAKE

Dimensions

Oneida Lake lies about 11 miles north of Syracuse in Oneida and Oswego Counties, and is the largest lake wholly within New York State. The lake is regulated by a Tainter-gate dam constructed in 1910 on the Oneida River at Caughdenoy, about 1.6 miles (2.6 kilometers) downstream from Brewerton, the mouth of the lake. The lake drains to the west through the Oneida and Oswego Rivers into Lake Ontario at Oswego.

Table 3 shows that the main axis of the lake is 20.9 miles (33.6 kilometers) in length, extending from the State Highway 13 bridge at Sylvan Beach on the east to the U.S. Highway 11 bridge in Brewerton on the west. The maximum width is 5.5 miles (8.8 kilometers) and the average width is 3.8 miles (6.1 kilometers).

Oneida Lake has a surface area of 79.8 square miles (206.7 square kilometers) at the normal summer stage of 369 feet (112 meters) about mean sea level. The shores are uniformly low, sandy, and, in places, wooded and swampy. On the north shore are the villages of Constantia, Bernhards Bay, Cleveland, and North Bay. The villages of Bridgeport and Lakeport are located on the south shore. The 54.7 miles (88.0 kilometers) of shoreline are dotted with summer cottages and fishing camps.

The lake is shallow, with an average depth of 22.3 feet (6.8 meters) and a maximum depth of 55 feet (16.8 meters) near the north shore off Cleveland. The development of volume (d_V) or the index of bottom uniformity is 1.2 (see Glossary) indicating that the lake bottom is slightly concave (fig. 5).

Oneida Lake, as most lakes, is deeper toward its source (on the east) and shallower toward its mouth (on the west). Numerous shoal areas are located throughout the lake. Figure 6 shows the location of five bottom profiles illustrated in figure 7.

About 25.7 percent of the lake bottom consists of shoal areas or all of the lake bottom shallower than 14 feet (4.3 meters). This depth, shown in figure 8, is considered to be the least depth that will interfere with navigation.

Because the lake is shallow, the waters are readily warmed during the spring and summer, and with the availability of abundant nutrients, the phytoplankton find particularly favorable conditions for luxuriant growth.

History

Oneida Lake was preceded by a large, late glacial lake, Lake Iroquois, which was also the ancestor of Lake Ontario and the Finger Lakes of central New York. Upon the wastage of the continental glacier, the St. Lawrence lowland was opened and Lake Iroquois was drained to the east by way of the Mohawk valley to the Hudson valley (Muller, 1965). One of the undrained

Table 3.--Dimensions of Oneida Lake

NOTE: (See Glossary for definition of terms.)

Factor	Value or remark
Area	
Drainage area	1,382 sq mi (3,579 sq km)
Surface area	79.8 sq mi (206.7 sq km)
Shoal area	20.5 sq mi (53.1 sq km) or 25.7 percent
Length	20.9 mi (33.6 km)
Axis, long	WNW to ESE
Fetch	20 mi (32 km)
Prevailing winds	westerly to northwesterly
Width	
Maximum width	5.5 mi (8.8 km)
Mean width	3.8 mi (6.1 km)
Depth	
Maximum depth	55.0 ft (16.8 m)
Mean depth	22.3 ft (6.8 m)
Shoal depth	14.0 ft (4.3 m)
Volume (at 369 ft stage)	496×10^8 cu ft (140×10^7 cu m)
Development of volume	1.2
Length of shoreline	54.7 mi (88.0 km)
Development of shoreline	1.7
Stage	
Normal summer stage	369 ft (112 m)
Normal winter stage	366 ft (111 m)
Effluent discharge, mean [a]	1,571 million gallons/day (59.5×10^7 cu m/day)
Flow-through time	235 days

a/ U.S. Geological Survey, 1967 (based on 29 years of record).

depressions became Oneida Lake. Radiocarbon dating by Karrow and others (1961) showed that Lake Iroquois existed for about 2,000 years, from 12,500 to 10,500 years ago. Oneida Lake, therefore, has been in existence for about 10,000 years, and its 1,382 square miles (3,579 square kilometers) of watershed was once the bottom of an inland fresh-water sea.

The significance of this physiographic setting is that a large part of the nutrients entering from the drainage basin become entrapped within the lake and, ultimately, become a part of the bottom sediments. Therefore, part of the bottom sediments with the accumulated nutrients of Lake Iroquois

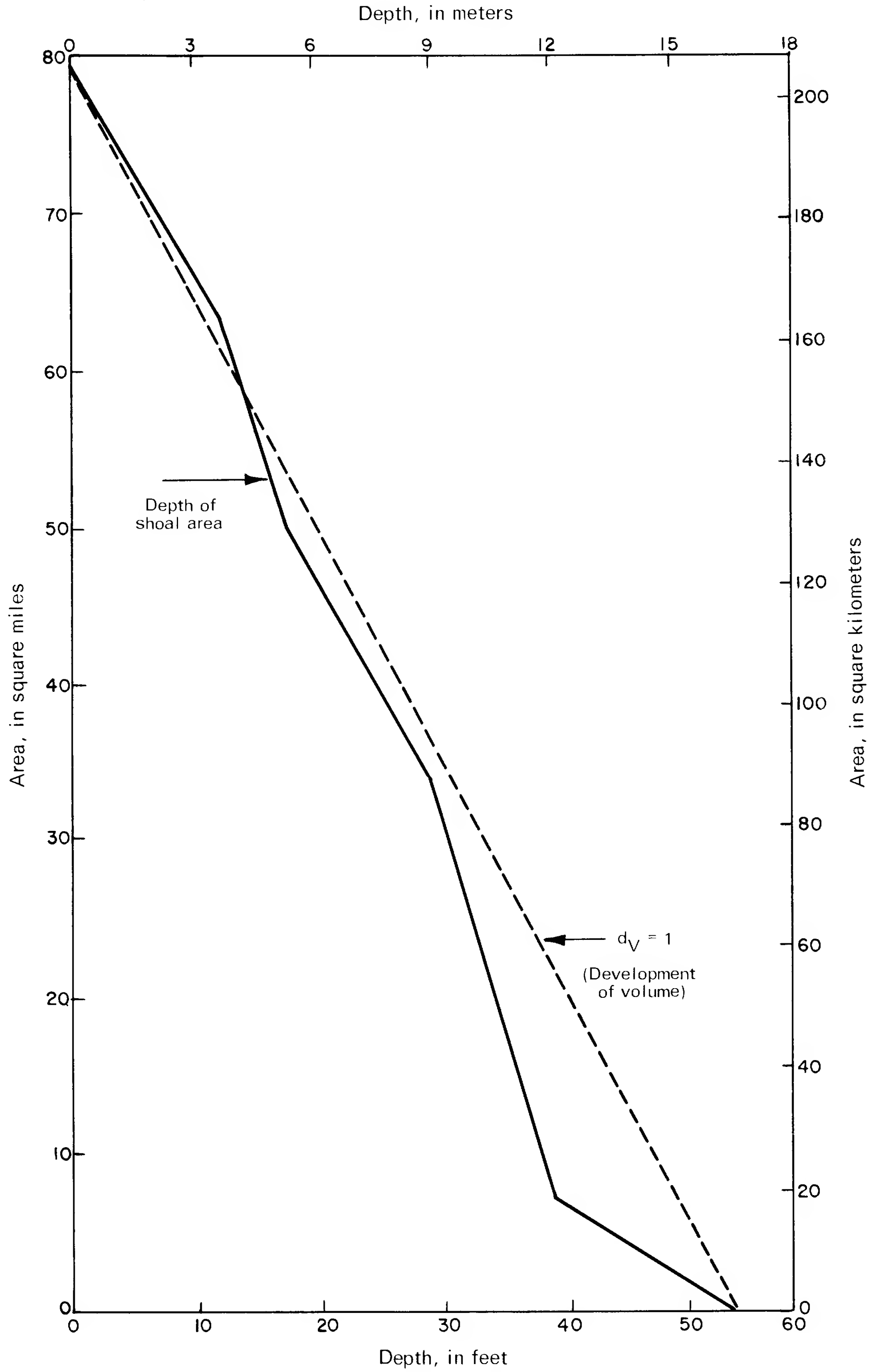

Figure 5.--Area of lake bottom included at various depths.

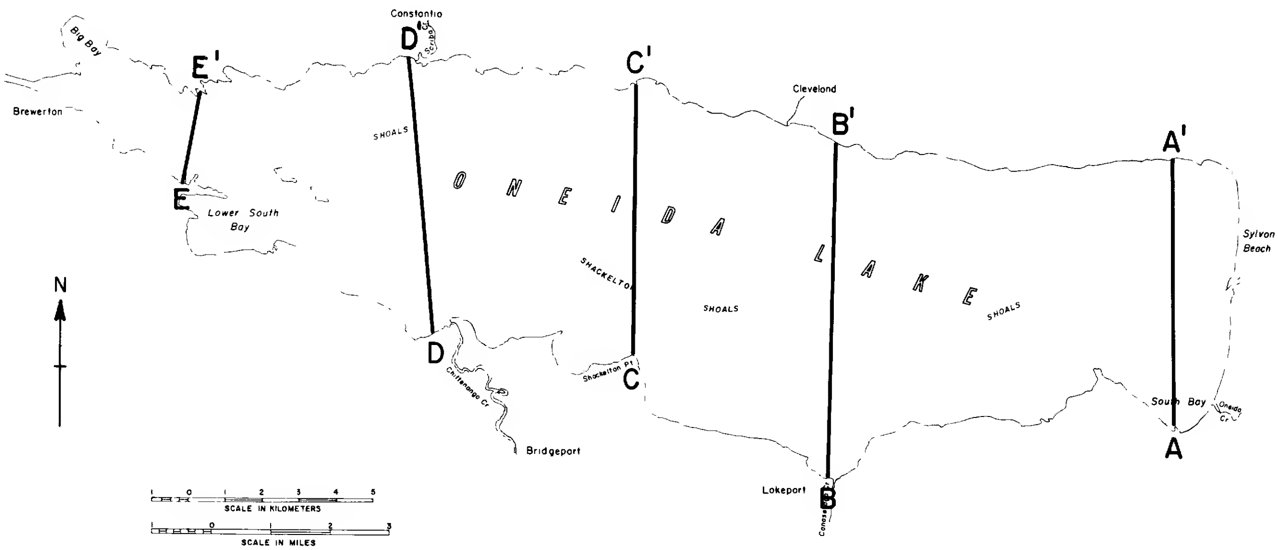

Figure 6.--Transects of bottom profiles as shown in figure 7.

are now the fertile soils of the drainage basin of Oneida Lake. Drainage from these lands brings into the lake an abundance of soluble minerals and dissolved organic materials (Pearson and Meyers, 1969), which become nutritive matter for plants and thus enrich or fertilize the water of the lake, making it a more favorable culture medium for aquatic vegetation.

Oneida Lake, unlike most eutrophic lakes whose aging process is accelerated by the introduction of municipal and industrial wastes, has become eutrophic through natural events. In perspective, the contribution of nutrients into Oneida Lake from cultural activities such as waste discharges and agricultural runoff is small; while, within the framework of existing knowledge, it appears that nutrients from natural sources alone are sufficient to support tremendous quantities of bloom-type algae. The lake has been aging for about 10,000 years and will continue to age for many years to come. The natural rate of aging (eutrophication) can be a very slow process.

It is conceivable that Oneida Lake was eutrophic from the start; it appears, however, that it certainly has been eutrophic for at least 350 years. In the early 1600's, Samuel D. Champlain, believed to be the first white man to see Oneida Lake, described its condition as being what is now known as eutrophic. In 1809, James Fenimore Cooper described the lake as,

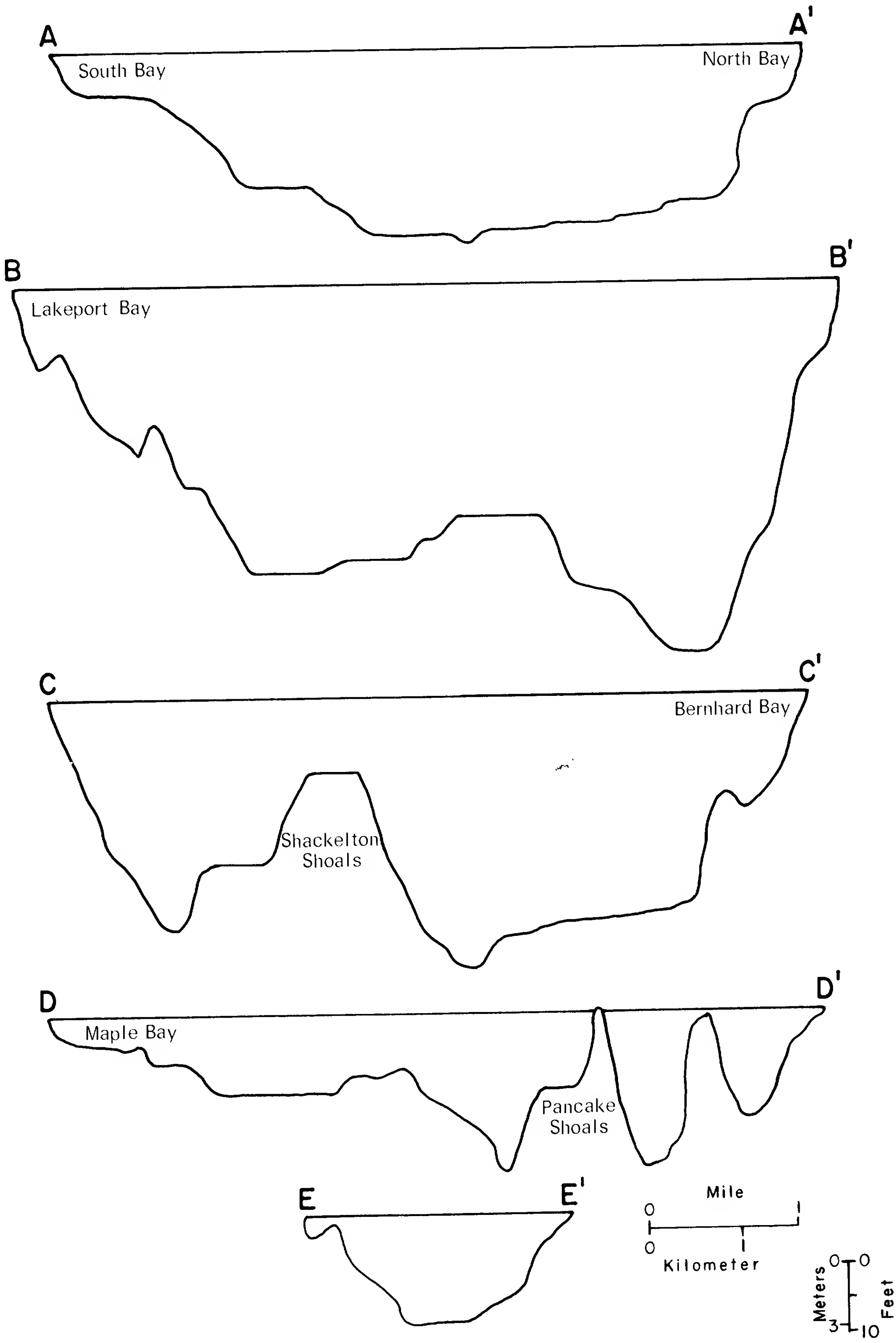

Figure 7.--Bottom profiles. Transects as shown in figure 6.

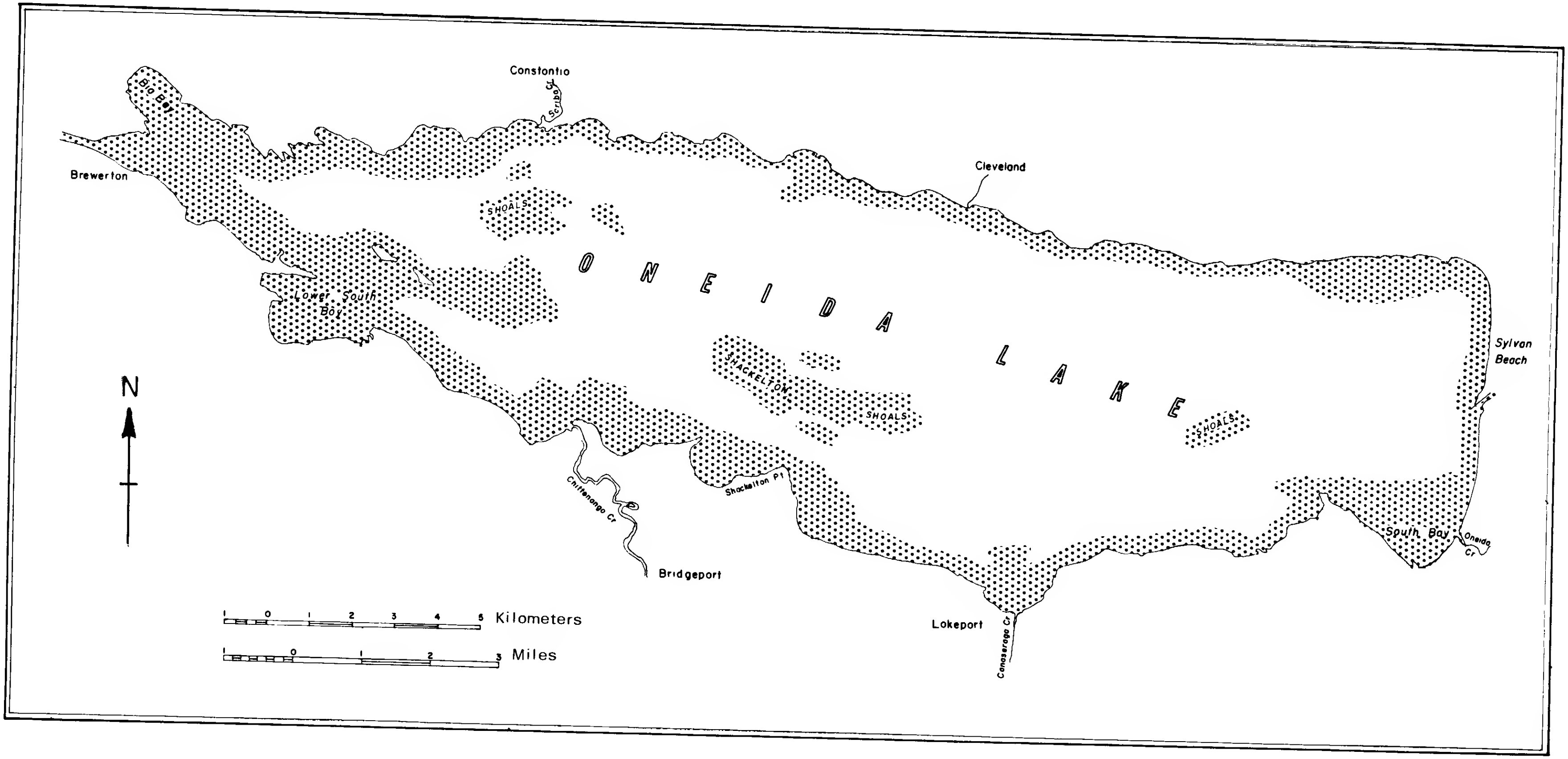

Figure 8.--Hydrographic map showing area (stippled) where water depth is 14 feet or less.

"a broad, dark colored body of water, unwholesome to drink and strongly blended with dark particles which the boatman called lake blossoms" (after N.Y.S. Conservation Department, 1947). These same "lake blossoms" are evidenced today in Oneida Lake.

Stratification

A lake in the temperate zone will generally undergo seasonal variations of temperature throughout the water column. These variations, with accompanying phenomena of thermal stratification, are perhaps the most influential controlling factors within a lake and are the substructure upon which the entire biological framework rests.

Generally and briefly, a lake is homothermous during the spring. As the air temperatures rise, the upper layers of water warm and are mixed with the lower layers. By late spring the differences in thermal resistance cause the mixing to cease and the lake approaches the thermal stratification of the summer season. During this period, the warm upper layer of water (the epilimnion) is isolated from the cold lower layer (the hypolimnion) by the thermocline. When thermal stratification becomes established, the lake enters the summer stagnation period, so named because the hypolimnion becomes stagnated.

With the approach of cooler air temperatures during the fall season, the temperature of the epilimnion decreases. Successive cooling through the thermocline to the hypolimnion results in a total homothermous condition. The lake then enters the fall circulation period (sometimes referred to as "fall turnover") and is again subjected to mixing. The lake remains somewhat homothermous during the winter and into the spring.

The most important phase of the thermal regime of a lake from the standpoint of eutrophication is the summer stagnation period. The hypolimnion, by virtue of its stagnation, becomes the zone of entrapment for inflowing materials and for decaying plant and animal matter, thus decreasing the availability of nutrients for algae during the critical growing season. The hypolimnion becomes anaerobic, or devoid of oxygen, because of its increased content of highly oxidizable material and its separation from the atmosphere. In the absence of oxygen, the conditions for chemical reduction become favorable (Hasler, 1947) and a part of the chemical constituents of the bottom sediments are released into solution. During the fall circulation period, a lake becomes mixed and the nutrients are redistributed throughout the water column for reuse during the following growing season.

Oneida Lake, unlike a typical eutrophic lake, does not thermally stratify during the summer but did exhibit near anaerobic conditions in the lower layers of water during the growing season of 1967. Figure 9 shows that the water temperature gradually declined from surface to bottom with a mean difference of only 4.5° Celsius. Dissolved oxygen, however, stratified sharply at an average depth of about 30 feet (9 meters), below which concentrations averaged 3.35 mg/l (milligrams per liter). A low concentration of 0.77 mg/l was recorded on July 27 (table 4).

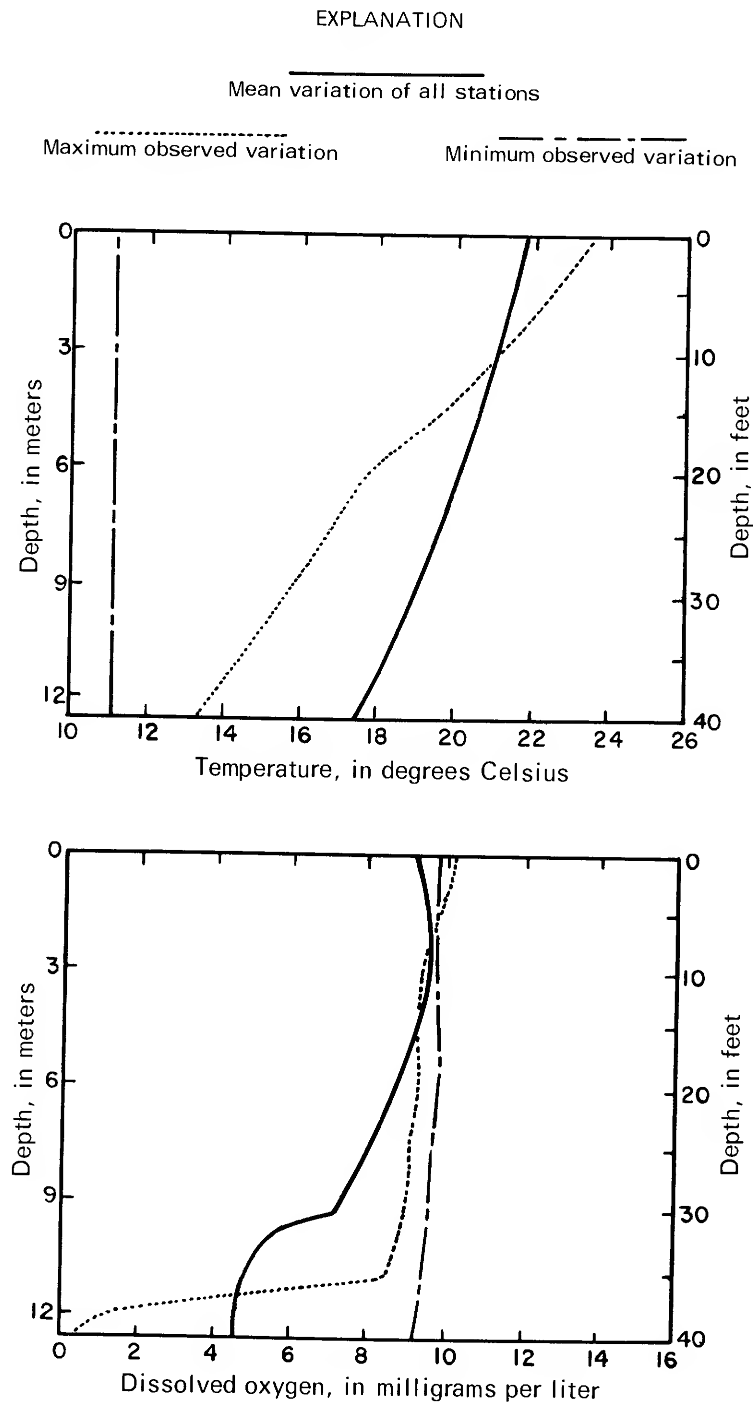

Figure 9.--Vertical profiles of water temperature and dissolved oxygen during the growing season June - September 1967.

The lake underwent an oxygen stratification with the start of increased phytoplankton production and accompanying increase of oxidizable material. Figure 10 shows the depth of stratification, which fluctuated with changes in phytoplankton production.

Table 4.--Vertical profiles of water temperature and dissolved oxygen, June through October 1967

Depth (ft)	Temp. (°C)	D.O. (mg/l)	Depth (ft)	Temp. (°C)	D.O. (mg/l)	Depth (ft)	Temp. (°C)	D.O. (mg/l)
	A. June 6			B. June 13			C. June 20	
0	19.4	9.58	0	23.5	8.19	0	22.0	7.75
10	17.5	9.52	10	21.1	8.45	10	21.4	7.64
20	15.5	9.09	20	17.7	7.74	20	19.9	6.80
30	13.6	7.64	30	15.8	6.46	30	16.4	4.29
40	12.6	6.33	40	13.6	4.33	40	13.8	3.56
	D. June 27			E. June 30			F. July 1	
0	22.4	9.05	0	20.8	9.33	0	22.4	8.33
10	20.8	8.79	10	20.8	9.33	10	21.5	8.05
20	20.1	8.08	20	20.8	9.22	20	21.0	8.00
30	18.9	6.63	30	20.4	9.19	30	21.0	7.81
40	17.0	4.83	40	17.1	2.22	40	18.6	5.05
	G. July 4			H. July 10			I. July 14	
0	21.6	9.43	0	25.2	9.82	0	24.3	7.52
10	21.5	14.72	10	22.9	8.78	10	23.5	7.36
20	21.5	11.17	20	22.2	8.12	20	22.8	6.22
30	20.4	8.11	30	21.8	7.17	30	21.5	4.78
40	18.9	6.37	40	21.0	4.71	40	20.4	3.24
	J. July 18			K. July 27			L. August 1	
0	25.1	9.00	0	25.0	9.57	0	24.8	8.85
10	23.0	10.66	10	23.2	9.07	10	23.9	9.17
20	23.0	8.21	20	22.7	8.12	20	23.2	7.66
30	20.5	3.02	30	22.4	7.18	30	23.0	7.25
40	18.3	1.12	40	17.6	.77	40	21.9	6.77
	M. August 10			N. August 17			O. August 22	
0	23.5	10.09	0	23.8	10.09	0	24.0	8.14
10	23.5	9.13	10	23.0	9.45	10	23.0	8.55
20	23.5	9.22	20	22.6	8.69	20	22.5	8.13
30	23.5	9.13	30	22.1	7.89	30	22.5	7.57
40	21.6	1.07	40	21.2	2.70	40	21.8	1.16
	P. September 27			Q. October 9			R. October 30	
0	18.1	9.92	0	15.8	9.84	0	11.0	10.20
10	17.9	9.68	10	15.8	9.84	10	11.0	10.20
20	17.5	8.97	20	15.8	9.84	20	11.0	10.00
30	17.5	8.66	30	15.8	9.70	30	11.0	10.00
40	17.2	7.66	40	15.8	9.54	40	11.0	9.80

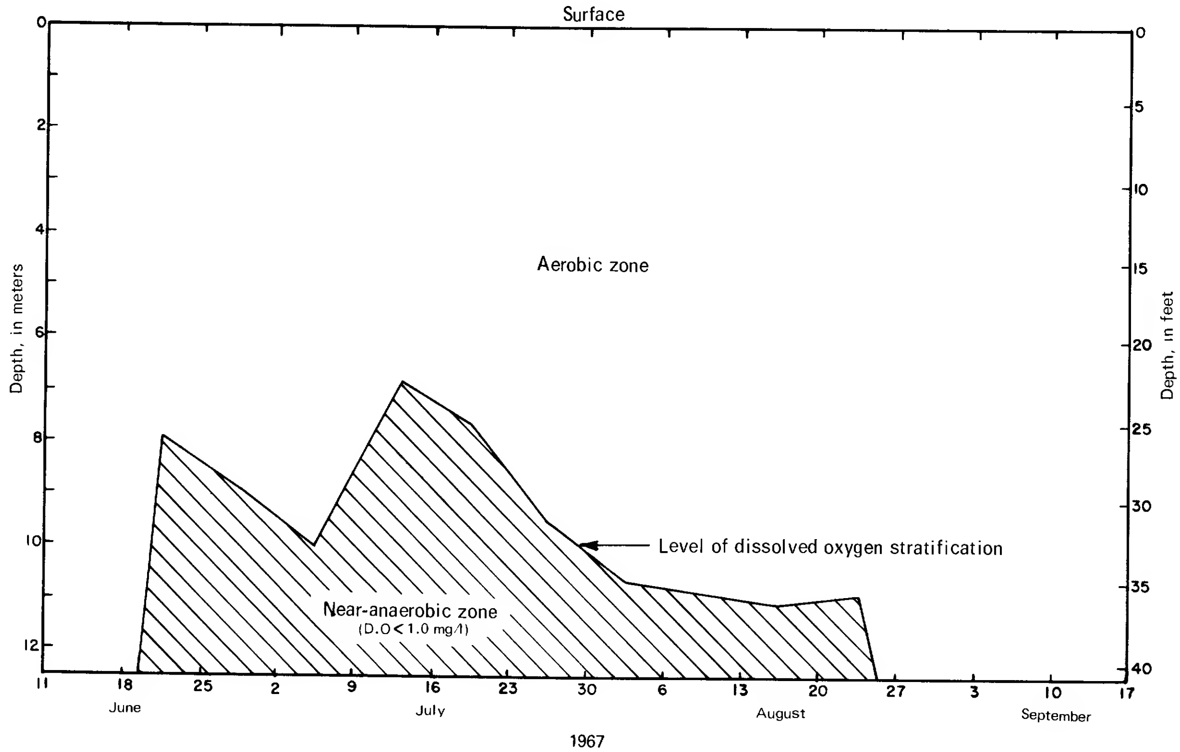

Figure 10.--Mean depth of dissolved oxygen stratification during the growing season of 1967.

Because of possible chemical reduction in the lower layer of water and the bottom sediments, and the lack of thermal stratification, nutrients are continually available in Oneida Lake for recycling and for the growth of phytoplankton.

Waves

One of the principal mechanisms preventing thermal stratification in Oneida Lake and, perhaps, the single most important factor affecting the chemical recycling processes of the lake is wind-generated wave action. Because the long axis of the lake lies in a nearly east-west direction, Oneida Lake is constantly subjected to mixing by the prevailing westerly and north-westerly winds (fig. 11).

Data from the U.S. Weather Bureau at Hancock Field in Syracuse (U.S. Department of Commerce, 1967) show that during 1967 the average wind velocity was 10.6 miles per hour (4.74 meters per second), creating an average wave height of 2.00 feet (0.61 meter) on the lake. During the growing season of June through September, the average wind velocity was 9.1 miles per hour (4.07 meters per second), resulting in an average wave height of 1.48 feet (0.45 meter).

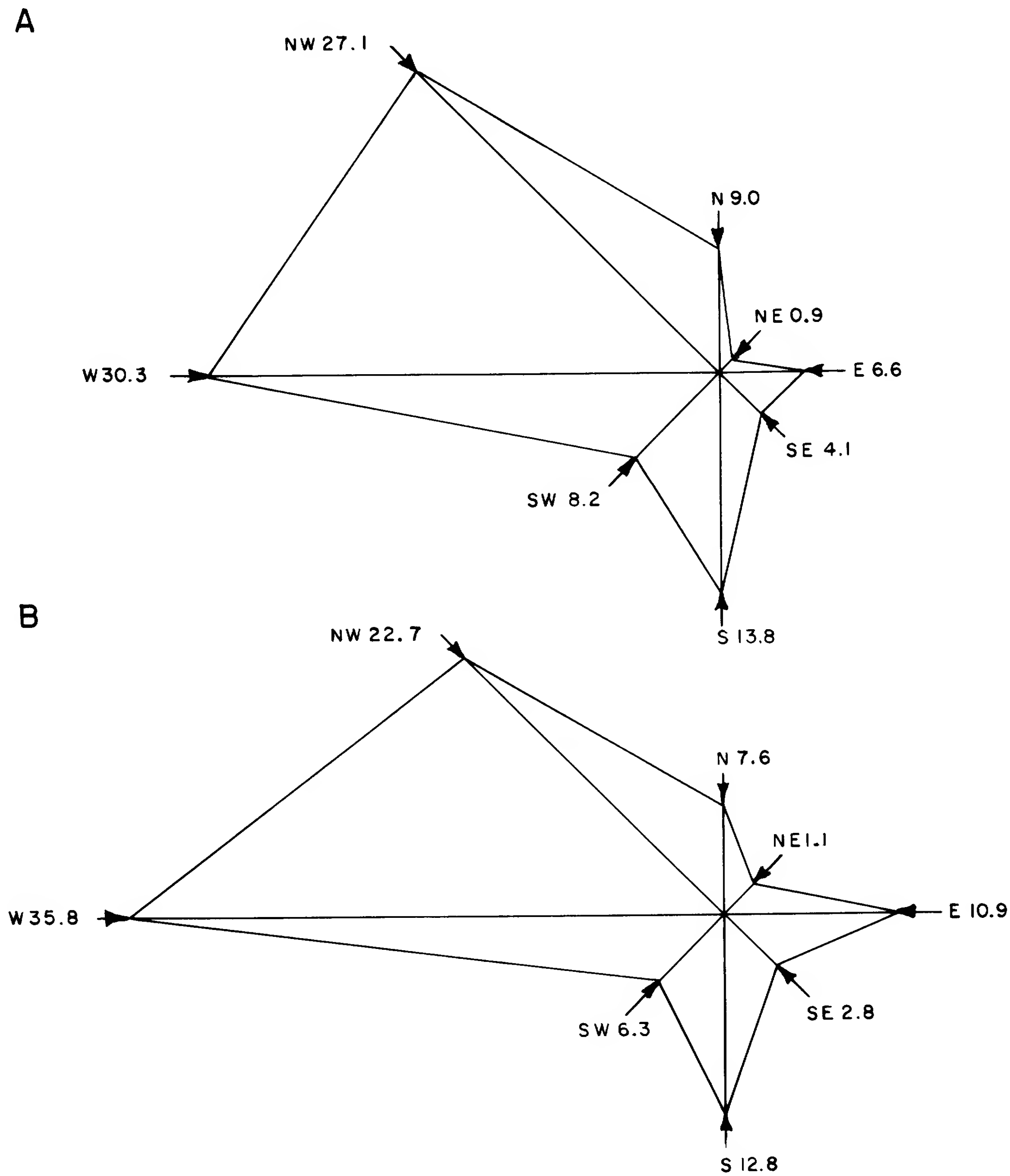

Figure 11.--Wind roses for Hancock Field, Syracuse, New York, showing percentage of time that the wind was recorded from each direction:
A. Growing season, June - September, 1967
B. Calendar year, 1967.
(Data from U.S. Department of Commerce, 1967.)

According to Welch (1952, after Stevenson, 1852), maximum wave height, H_{max}, in meters or the maximum vertical distance between crest and trough (fig. 12) is proportional to the square root of the fetch, F, in kilometers, during optimum wind conditions. The fetch is the downward distance from shore to the location of the wave in question and is equal to a maximum of 20 miles (32 kilometers) for Oneida Lake (table 3). By the formula,

$$H_{max} = 1/3 \sqrt{F},$$

the maximum wave height that can theoretically occur on Oneida Lake was determined to be 6.17 feet (1.88 meters). The actual maximum wave height probably is slightly lower, in the order of about 6 feet (1.8 meters).

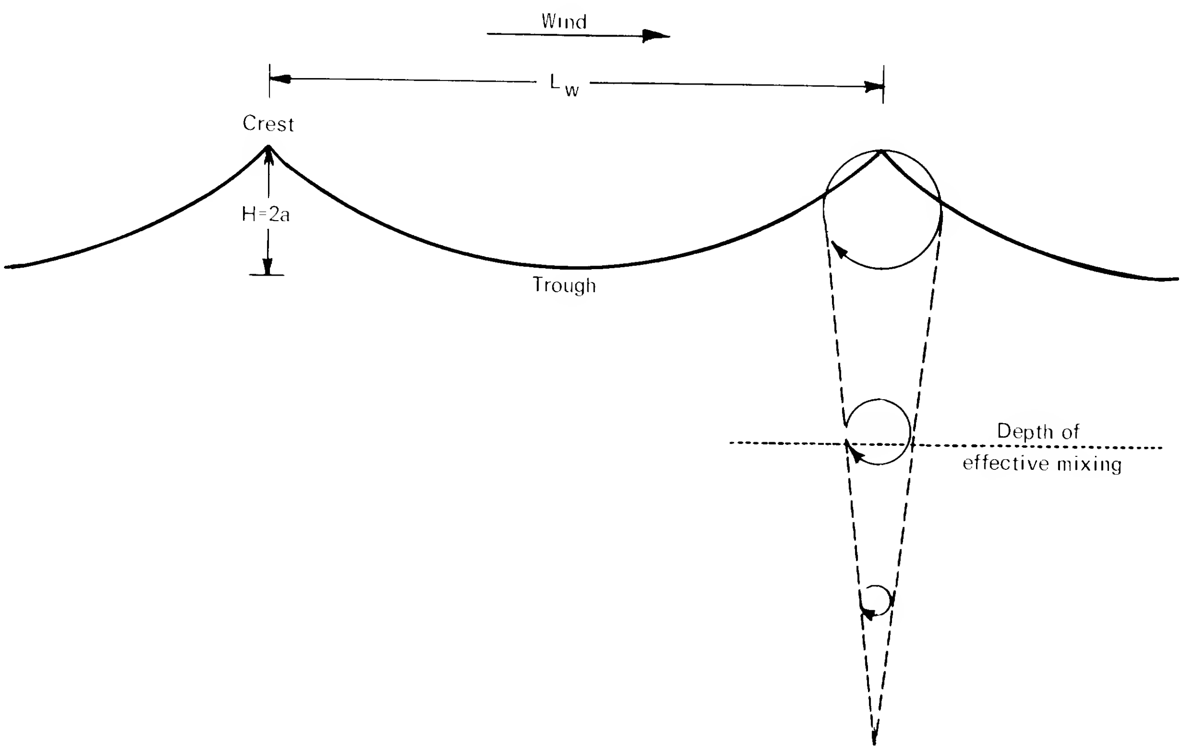

Figure 12.--Wave of oscillation showing circular pattern of water movement in deep water. (L_W = wave length, H = wave height, a = wave amplitude.)

Actual wave height is dependent upon sustained wind velocity (W_v), in meters per second, and is calculated by the formula,

$$H = (0.26/g)\ (W_v^2),$$

where g is the acceleration of gravity (for example, 9.809 meters per second per second) (after Sverdrup and others, 1942). Figure 13 shows the relationship between wave height and wind velocity, and indicates that the maximum theoretical wave height on Oneida Lake can be produced by a persistent westerly wind of about 20 miles per hour (8.96 meters per second). Wind velocities greater than this were recorded on 21.3 percent of the days during the growing season of 1967 (U.S. Department of Commerce, 1967).

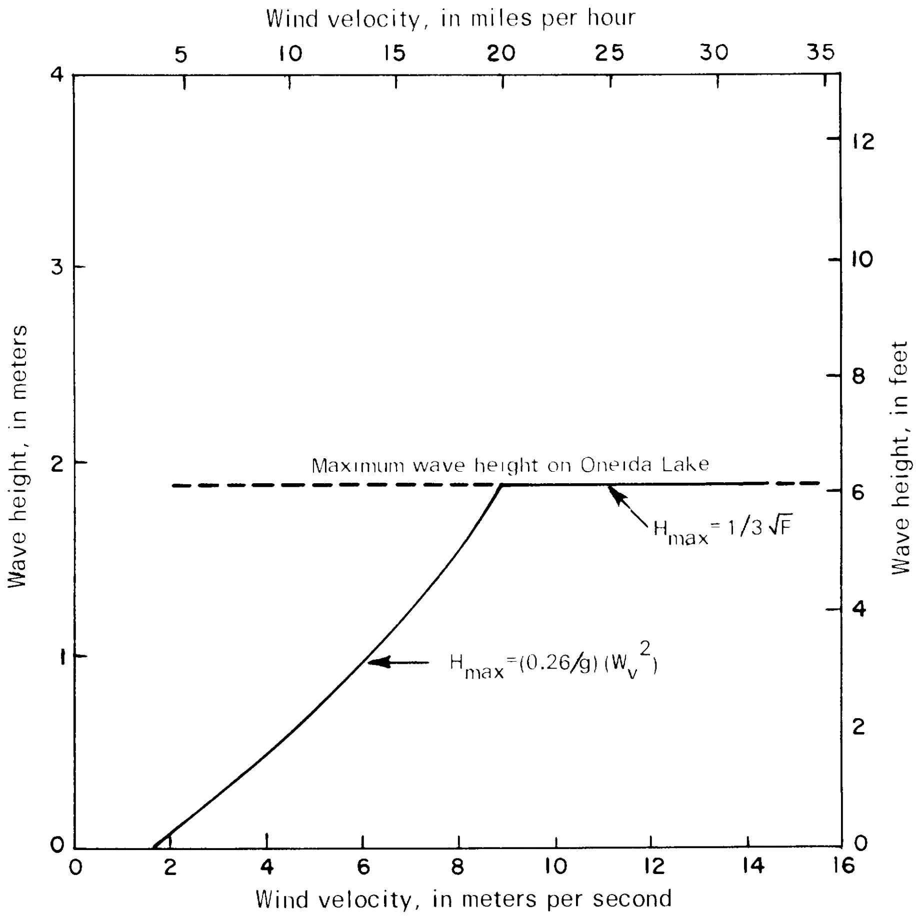

Figure 13.--Development of waves on Oneida Lake.

Wave length, L_w, is the horizontal distance from crest to crest or from trough to trough. Theoretically, the wave height may obtain one-seventh of the wave length (Dapples, 1959), but, generally, there exists sufficient departure from the theoretical form to cause the wave to collapse before this height is reached. In Oneida Lake, however, which is shallow and interrupted by islands and shoal areas, there is a tendency for the wave length to be shortened, thus compacting the waves. The result is to approach the theoretical ratio of wave length to wave height, probably in the order of 10 to 1 ($L_w : H = 10 : 1$). A wave length of about 62 feet (18.8 meters), therefore, can accompany the maximum wave height of 6.17 feet (1.88 meters) in the open spaces of Oneida Lake.

Individual water particles within a wave are considered to revolve in circles (fig. 12). The effect is to produce a movement of water. With increased depth below the surface, according to Dapples (1959), the diameter of circular motion decreases exponentially and diminishes at a depth approximately equal to the wave length. In addition, Dapples implies that effective mixing occurs to about one-half this depth or to a depth equal to about one-half of the wave length.

With a wave length of about 62 feet (18.8 meters), effective mixing by wave action occurs to a depth of about 31 feet (9.45 meters) in Oneida Lake. The significance of this depth was shown during the summer of 1967 when dissolved oxygen sharply stratified at an average depth of about 30 feet (9 meters).

Accordingly, the importance of bottom sediments and their contained chemical nutrients is greatly accentuated because 52 square miles (134 square kilometers) or 65 percent of the lake bottom is shallower than 30 feet (9 meters) and can be subjected to mixing with the overlying water (fig. 14).

Seiches

Additional water mixing and the partial horizontal transfer of nutrient material within Oneida Lake are produced by seiches. A seiche (also called a standing wave) is the oscillation of water about one or more nodal points. It is a localized and periodic shift of the water level in which the water particles advance and return in the same path rather than travel in a circular motion.

A persistent westerly wind on Oneida Lake will push the water of the lake to the east. When the wind subsides, the lake surface rebounds with an alternating rise and fall. The amplitude rapidly diminishes.

Seiches are quite common in Oneida Lake (figs. 15 and 16) and the displacement of water may exceed 1.6 feet (49 centimeters) during a seiche period of 2.4 hours. The full extent of their influence on the processes within the lake is still to be determined.

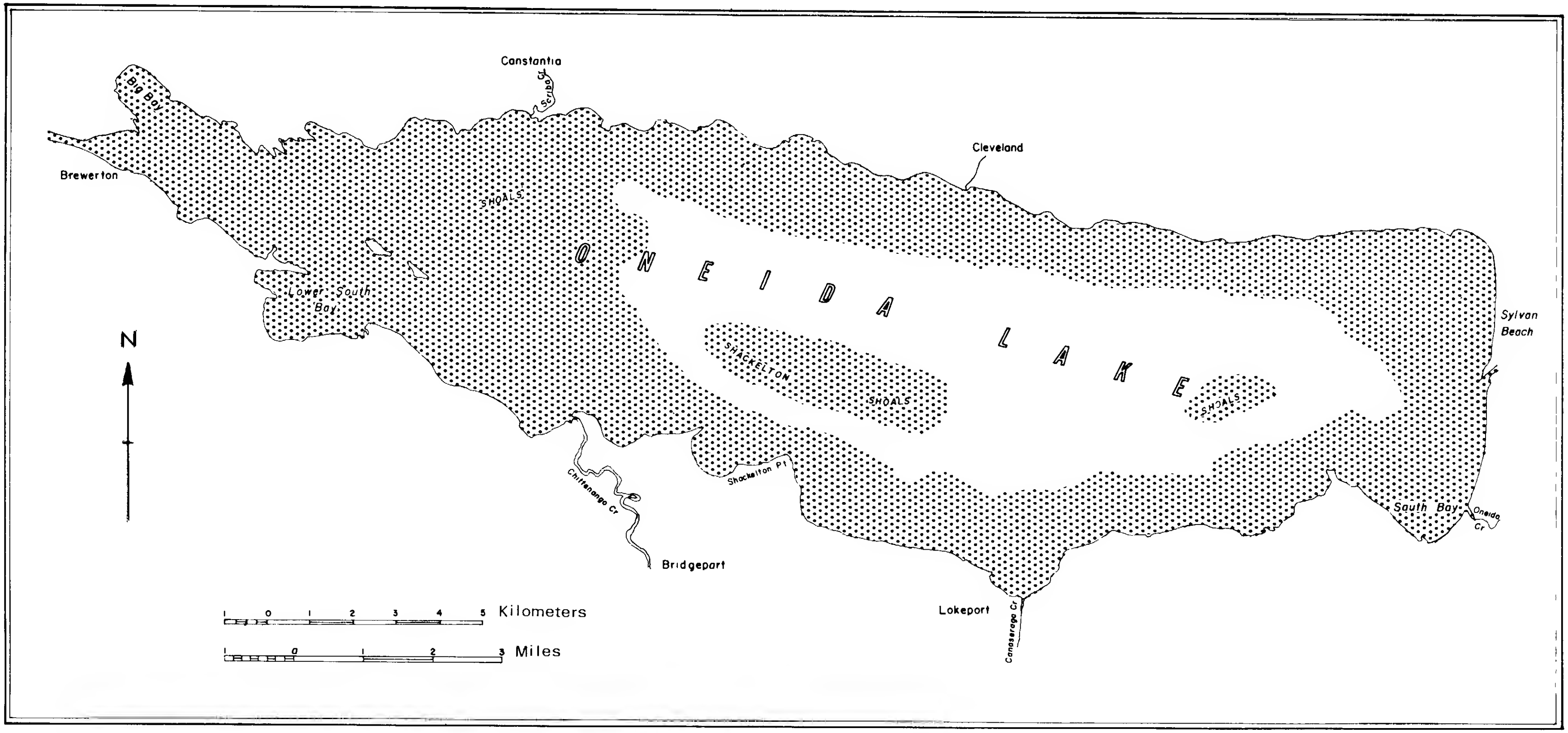

Figure 14.--Hydrographic map showing areas (stippled) where water depth is 30 feet or less.

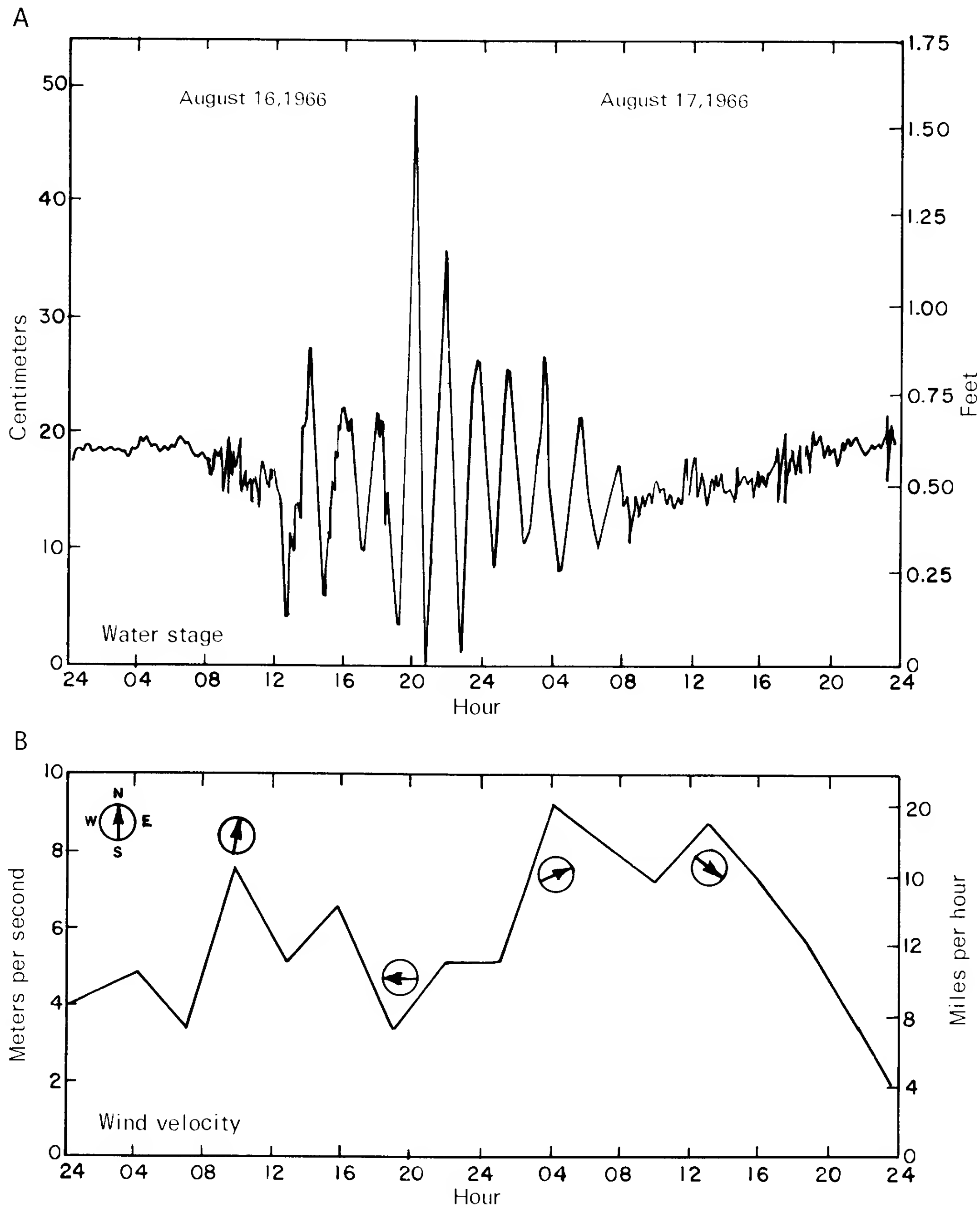

Figure 15.--Development of seiche during August 16-17, 1966. Recording made at outlet of Oneida Lake at Brewerton: A. Water stage. B. Wind velocity and wind direction as indicated by arrows.

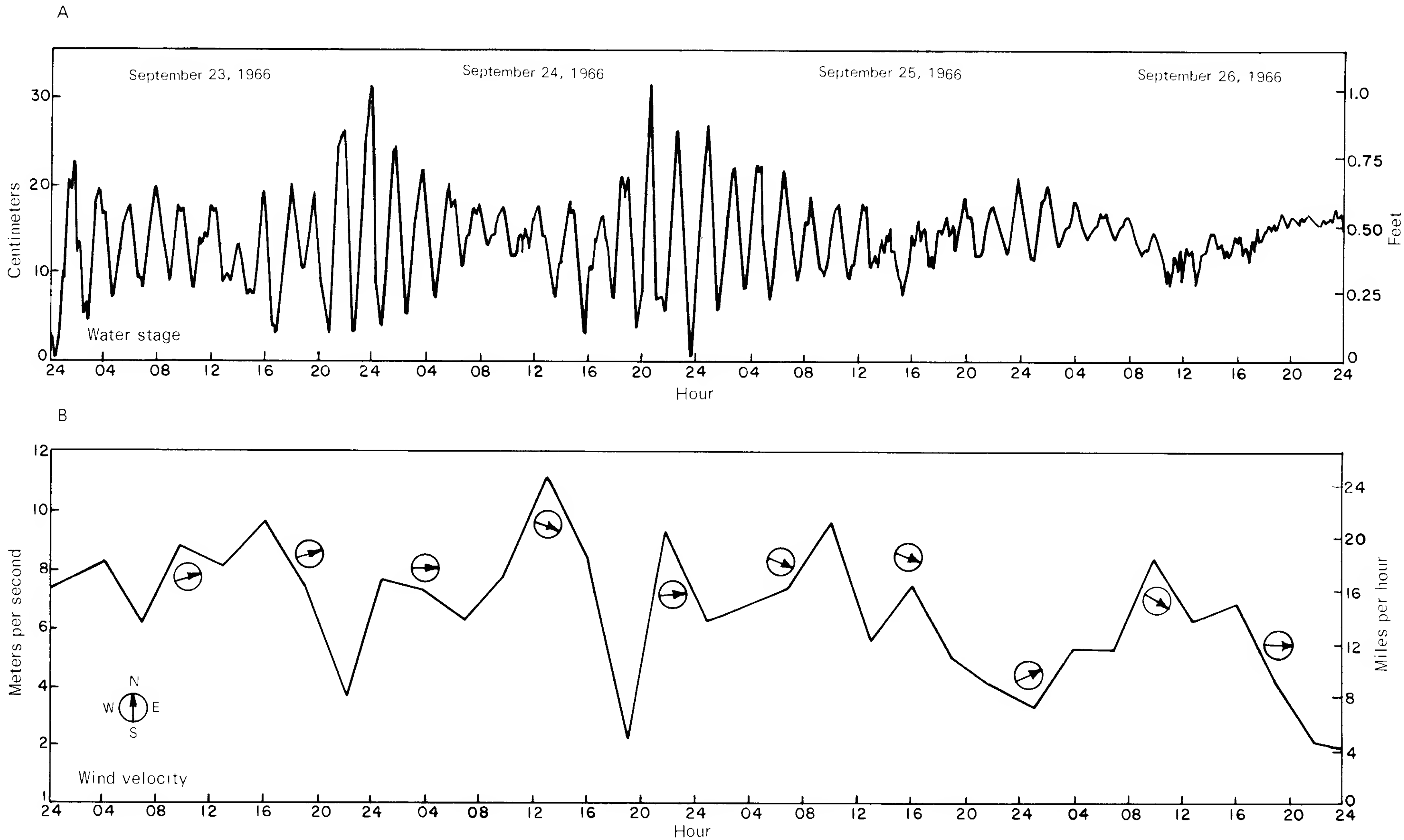

Figure 16.--Harmonic train of seiches during September 23-26, 1966. Recording made at outlet of Oneida Lake at Brewerton: A. Water stage. B. Wind velocity and wind direction as indicated by arrows.

BIOLOGICAL CHARACTERISTICS OF ONEIDA LAKE

Methods of Routine Investigations

Routine field investigations of the phytoplankton of Oneida Lake were started in May, 1967 and included weekly sampling of phytoplankton for qualitative and quantitative evaluations. Figure 17 shows the 15 sampling stations and table 5 gives their approximate locations.

Phytoplankton samples were treated upon collection with 40-percent formaldehyde solution for preservation, with a concentrated solution of cupric sulfate for maintaining color of cells, and with a 20-percent detergent solution for prevention of coagulation of settled material. The resultant solution was of a 3 to 4 percent concentration. Straight water samples were used for the quantitative evaluations, and net samples or concentrates were used for qualitative identifications.

A Sedgwick-Rafter counting cell and a Whipple ocular micrometer were employed for counting at 100X magnification. A 21X objective and a "dynazoom" lens were used for scanning fields and for greater magnification. The counting cell was filled 3 times from each sample, counted and the results averaged. Twenty to 100 fields were normally counted, depending on the number of algal cells present. When concentrations were too thick for proper counting, samples were diluted with distilled water and counts repeated. Final counts were expressed in number of cells per milliliter of sample.

Temporary wet mounts of sample concentrates were used for identifications. Diatoms (Bacillariophyceae) were cleared by the method of Prescott (1962). Identifications to species were made when possible.

Because microscopic evaluations of phytoplankton are very time consuming, attempts are now being made to determine the applicability of correlating phytoplankton cell counts with chlorophyll concentrations and total suspended matter (termed total seston). Additional efforts are being made to determine the feasibility of using remote sensing (for example, aerial photography) for evaluating phytoplankton populations both qualitatively and quantitatively. The results of these studies will be in the final report.

Special Studies

Three major special studies have been and are being made in addition to the routine sampling. Because most of these studies are of a continuing nature encompassing 2 to 3 years of investigation, the detailed results will be included in the final report. Following is an annotated listing of the special biological studies:

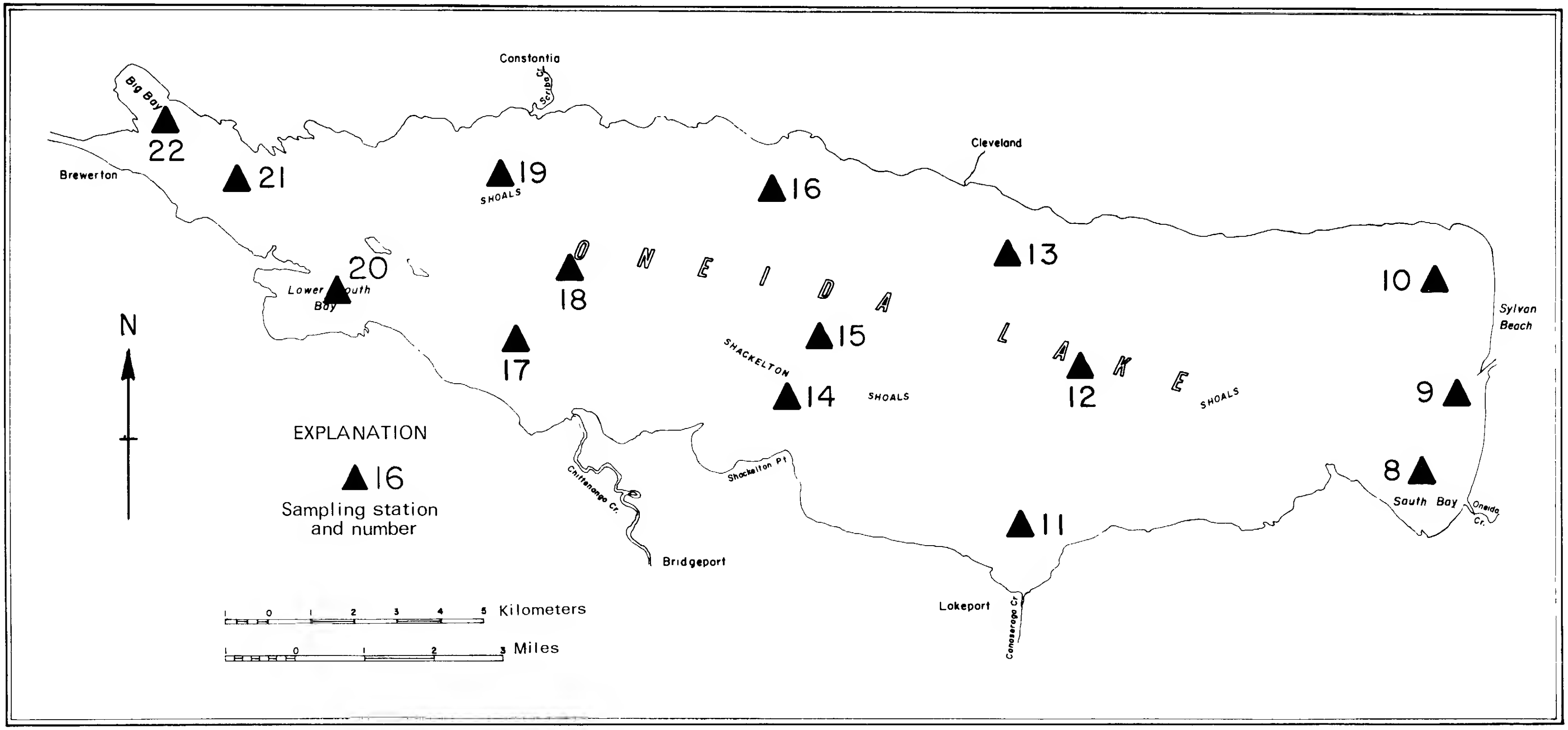

Figure 17.--Location of sampling stations. (Numbers refer to station numbers in table 5.)

Table 5.--Approximate locations of sampling stations on Oneida Lake

Station number	Location
8	75°45'W, about 1 mile north of south shore (South Bay)
9	75°45'W, midlake at Buoy 107-F1W
10	75°45'W, about 1 mile south of north shore (North Bay)
11	75°50'W, about 1 mile north of south shore (Lakeport Bay)
12	75°50'W, midlake at Buoy 117-F1W
13	75°50'W, about 1 mile south of north shore
14	75°55'W, about 1 mile north of Shackelton Point
15	75°55'W, midlake at Buoy 123-F1W (Shackelton Shoals)
16	75°55'W, about 1 mile south of north shore
17	76°00'W, about 1 mile north of south shore (Maple Bay)
18	76°00'W, midlake at Buoy 127-F1W
19	76°00'W, about 1 mile south of north shore midway between Little Island and Long Island
20	about geographical center of Lower South Bay
21	76°05'W, midlake at Buoy 134-F1R
22	about geographical center of Big Bay

1. During the spring, summer and fall of 1967, bottom samples were obtained from stations 8 through 10, 14 through 16, and 20 through 22. Samples were preserved at time of collection, and later examined for contained macrobenthic organisms. A continuation of benthal sampling will be made during the summers of 1968 and 1969 to establish short-term yearly changes and to provide comparison data for an extensive benthological study made by Baker (1916 and 1918).

2. Ground collections and aerial surveys of higher aquatic plants are being made to delineate the extent of vegetation beds and to determine the degree of their importance in the lake community. Similar collections and surveys are being made of the benthal algae (for example, attached and filamentous forms). If and when the phytoplankton populations of Oneida Lake are controlled, the importance of higher plants and benthal algae may be greatly accentuated because of their role as primary producers.

3. Diurnal (24-hour) studies are being conducted routinely at station 15 to correlate the seasonal variations of phytoplankton productivity with changes in the physical and chemical environments.

Phytoplankton

Ninety-seven species of algae were observed in the phytoplankton of Oneida Lake during 1967 (table 6). Their types and distribution followed the general pattern for a eutrophic lake. Figure 18 shows that the green algae (Chlorophyta) were the dominant forms when the investigation was started in May. These were replaced by the blue-green algae (Cyanophyta) during late June. Subsequent to the initial bloom, the population declined until a second bloom occurred during early September. The diatoms (Bacillariophyceae) became dominant by mid-October and remained dominant through the winter. Figure 19 shows the relative abundances of the major groups of algae and table 7 lists those genera observed on two or more occasions.

The algae that hamper recreation most are the blue-green algae because their great abundances occur when recreation is at a maximum. These forms became dominant by June 20 when Anabaena flos-aquae comprised 92.1 percent of the standing crop (table 8). During the initial bloom on July 10, the phytoplankton consisted almost entirely of blue-green algae. The average concentration was 71,300 cells per milliliter. A maximum concentration of 201,900 cells per milliliter was observed at station 12.

Anabaena flos-aquae and Anabaena circinalis were the two most common species during the summer. They dominated 79 percent of the collections. Aphanizomenon holsaticum was the dominant species in the other 21 percent of the collections. Other abundant blue-green algae included Anabaena spiroides, Gloeotrichia echinulata, Microcystis aeruginosa, Microcystis incerta and Lyngbya Birgei.

A second bloom was observed on August 22 when the average concentration reached 39,700 cells per milliliter. The maximum concentration of 94,400 cells per milliliter was recorded at station 22 in Big Bay. The dominant species was Anabaena flos-aquae.

Phytoplankton concentrations were never uniform over the entire lake. Heavy concentrations in bay areas and localized blooms were quite common. In one instance, a bloom consisting entirely of Microcystis aeruginosa reached a concentration of over a million cells per milliliter in Sunset Bay, west of Constantia on the north shore.

Figure 20 shows the longitudinal variations of the mean standing crop of phytoplankton during 1967. Cell concentrations were almost always heavier in the west end of Oneida Lake. Great concentrations were also observed in the open lake east of Shackelton Shoals between stations 12 and 15.

Table 6.--Composite list of algae observed in the phytoplankton of Oneida Lake from May 1967 through January 1968

(A = abundant, C = common, R = rare)

CHLOROPHYTA

Actinastrum gracillimum Smith (R)
Actinastrum Hantzchii Lagerheim (C)
Ankistrodesmus falcatus (Corda) Ralfs (R)
Carteria Klebsii (Dangeard) (R)
Cateria sp. (R)
Characium sp. (R)
Chlamydomonas sp. (C)
Chlorella sp. (R)
Chlorogonium elongatum (Dangeard) Franzé (R)
Cladophora glomerata (Linnaeus) Kützing (C)
Cladophora sp. (R)
Closterium Archerianum Cleve (R)
Closterium Leibleinii Kützing (R)
Coelastrum microporum Nägeli (R)
Coronastrum aestivale Thompson (R)
Cosmarium Boeckii Wille (R)
Cosmarium sp. (R)
Crucigenia rectangularis (Braun) Gay (R)
Dictyosphaerium pulchellum Wood (C)
Eudorina elegans Ehrenberg (C)
Golenkinia radiata (Chodat) Willie (R)
Hydrodictyon reticulatum (Linnaeus) Lagerheim (R)
Kirchneriella lunaris (Kirchner) Möbius (R)
Micractinium pusillum Fresenius (R)
Microspora Loefgrenii (Nordstedt) Lagerheim (R)
Microspora stagnorum (Kützing) Lagerheim (R)
Microspora Willeana Lagerheim (A)
Microthamnion strictissimum Rabenhorst (R)
Mougeotia sp. (C)
Pandorina morum (Müller) Bory (A)
Pediastrum biradiatum Meyen (R)
Pediastrum Boryanum (Turpin) Meneghini (R)
Pediastrum duplex Meyen (A)
Platydorina caudata Kofoid (R)
Pleodorina californica Shaw (R)
Scenedesmus arcuatus Lemmermann (R)
Scenedesmus bijuga (Turpin) Lagerheim (R)
Scenedesmus longus Meyen (R)
Scenedesmus quadricauda (Turpin) DéBrebisson (R)
Sorastrum spinulosum Nägeli (R)
Sphaerocystis Schroeteri Chodat (C)
Spirogyra sp. (R)
Staurastrum paradoxum Meyen (A)
Ulothrix aequalis Kützing (R)
Ulothrix subconstricta West (R)

Table 6.--Composite list of algae observed in the phytoplankton of Oneida Lake from May 1967 through January 1968 (Continued)

CHLOROPHYTA (Continued)
- Ulothrix variabilis Kützing (R)
- Volvox aureus Ehrenberg (R)

EUGLENOPHYTA
- Phacus sp. (R)

CHRYSOPHYTA (including Bacillariophyceae)
- Asterionella formosa Hassall (A)
- Cyclotella sp. (R)
- Cymbella sp. (R)
- Dinobryon bavaricum Imhof (R)
- Dinobryon cylindricum Imhof (R)
- Fragilaria sp. (A)
- Fragilaria sp. (C)
- Fragilaria sp. (C)
- Gomphonema sp. (R)
- Gyrosigma sp. (R)
- Gyrosigma sp. (R)
- Melosira distans (Ehrenberg) Kützing (A)
- Melosira granulata (Ehrenberg) Ralfs (A)
- Melosira varians Agardh (A)
- Melosira sp. (C)
- Navicula sp. (R)
- Nitzchia sp. (R)
- Stephanodiscus niagarae Ehrenberg (C)
- Suriella sp. (R)
- Synedra sp. (C)
- Synura uvella Ehrenberg (R)
- Tabellaria sp. (C)
- Tabellaria sp. (C)

PYRROPHYTA
- Ceratium hirundinella (Müller) Schrank (C)
- Glendinium Gymnodinium Penard (R)
- Peridinium cinctum (Müller) Ehrenberg (R)

CYANOPHYTA
- Anabaena circinalis Rabenhorst (A)
- Anabaena flos-aquae (Lyngbye) DeBrébisson (A)
- Anabaena spiroides Klebahn (A)
- Aphanizomenon holsaticum Richter (A)
- Chroococcus limneticus Lemmermann (C)
- Cylindrospermum stagnale (Kützing) Bornet & Flahault (R)
- Entophysalis lemaniae (Agardh) Drouet & Daily (R)
- Gloeotrichia echinulata (Smith) Richter (A)
- Lyngbya aestuarii (Mertens) Liebmann (R)
- Lyngbya Birgei Smith (A)

Table 6.--Composite list of algae observed in the phytoplankton of Oneida Lake from May 1967 through January 1968 (Continued)

CYANOPHYTA (Continued)

Lyngbya contorta Lemmermann (R)
Lyngbya limnetica Lemmermann (R-C)
Merismopedia elegans Braun (R)
Microcystis aeruginosa Elenkin (A)
Microcystis incerta Lemmermann (A)
Nostochopsis lobatus Wood (R)
Oscillatoria lacustris (Klebahn) Geitler (R)
Oscillatoria limnetica Lemmermann (R)
Oscillatoria limnosa (Roth) Agardh (R)
Oscillatoria subbrevis Schmidle (R)
Oscillatoria tenius Agardh (R)
Pelogloea bacillifera Lauterborn (R)
Synechococcus aeruginosa Nägeli (C)

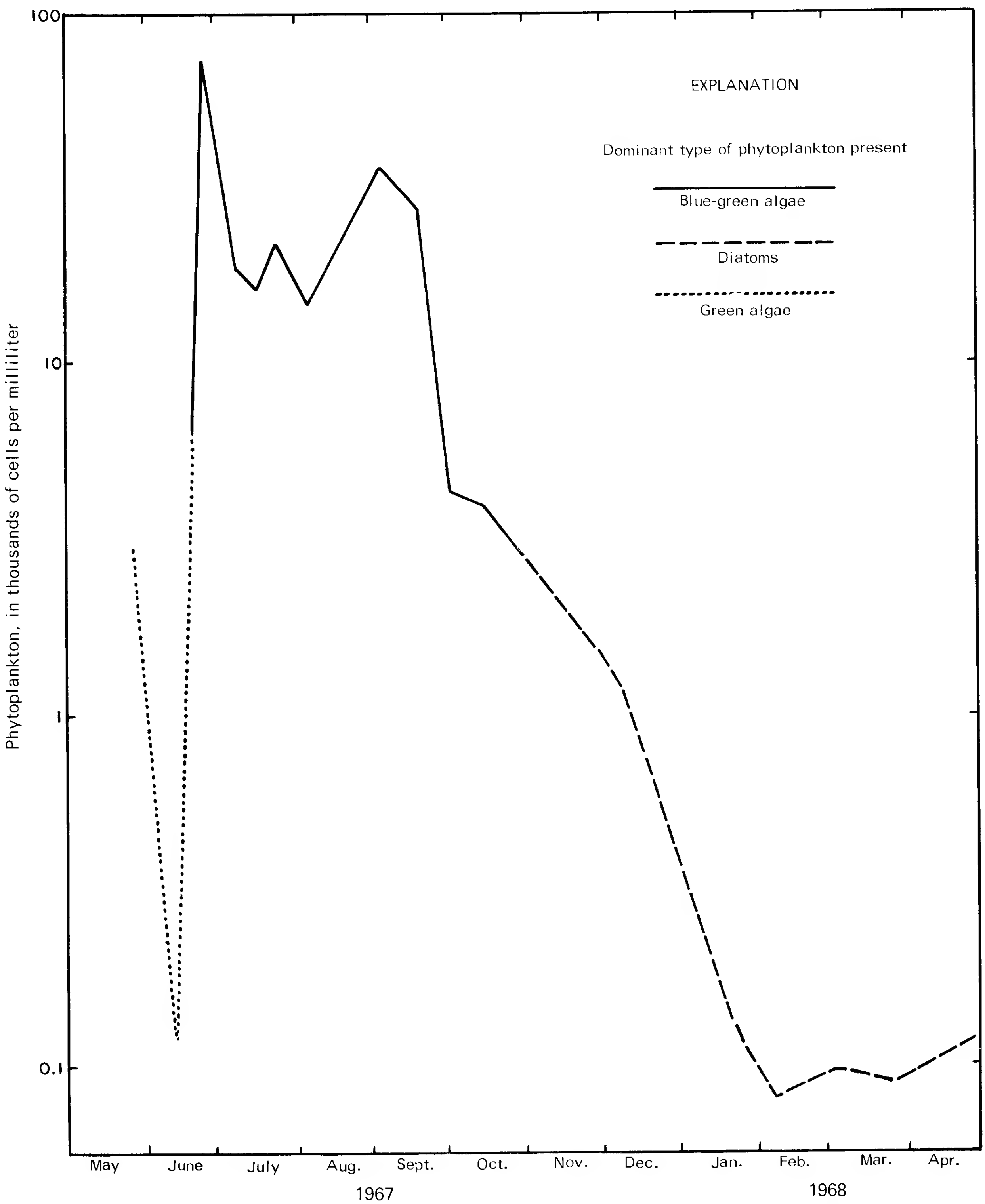

Figure 18.--Variations of mean standing crop of phytoplankton in Oneida Lake.

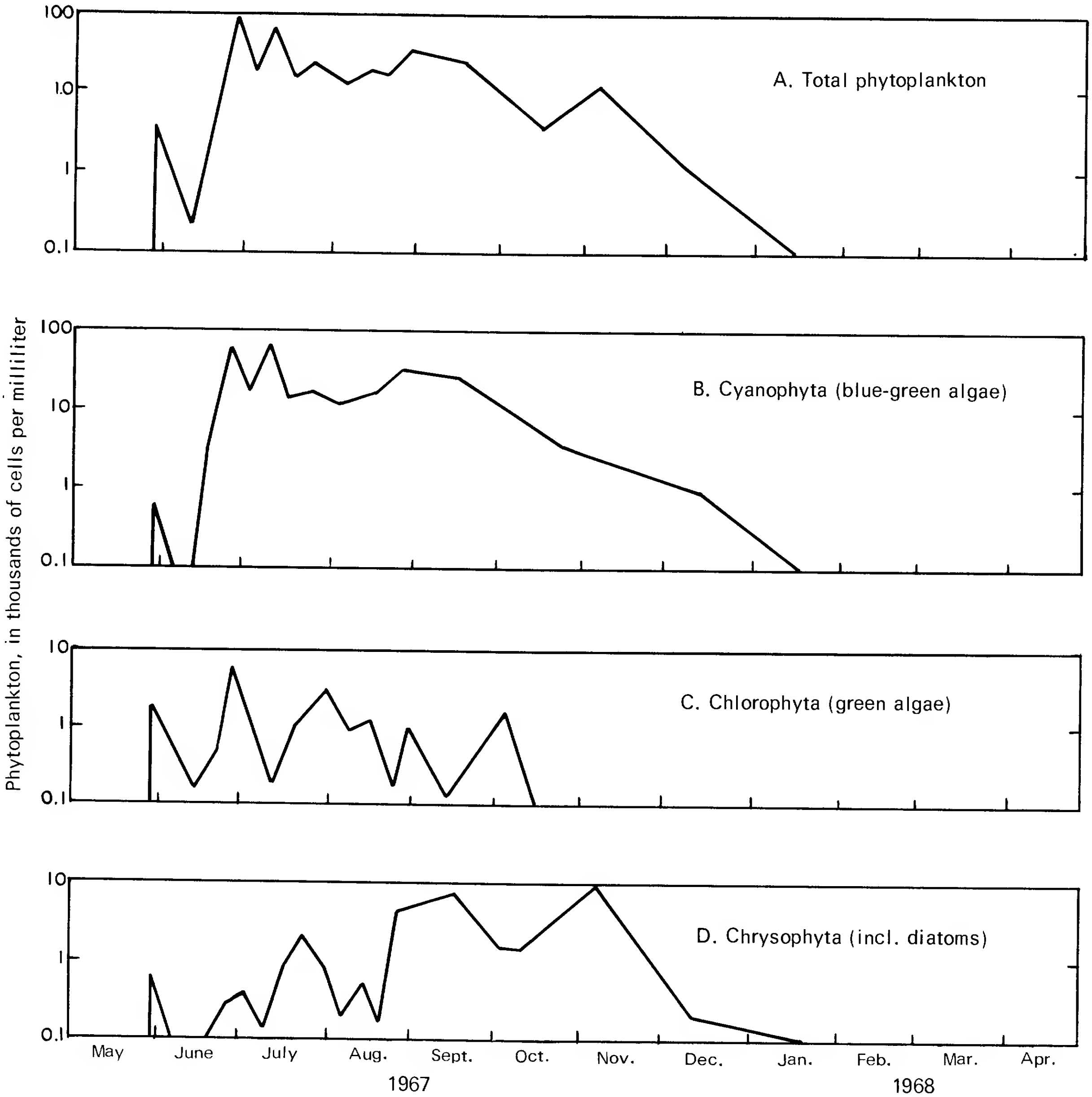

Figure 19.--Relative abundances of the major groups of algae comprising the phytoplankton of Oneida Lake.

Big Bay was the site of first occurrence of blue-green algae on June 20, 1967, when 6 of the 16 recorded species were of that type. An increase in cell concentrations in the bay preceeded the two major blooms and most of the pulses of the phytoplankton population. The extent of importance of Big Bay and other bays on the phytoplankton variations in the lake is now being investigated.

The blue-green algae declined with the start of the fall season. Most species had disappeared by mid-October and only Anabaena flos-aquae remained by the first of December. Diatoms formed the entire phytoplankton by mid-December.

Table 7.--Distribution of phytoplankton organisms of Oneida Lake from May 30, 1967 through January 17, 1968

Genus of Alga	May 30	June 7	June 13	June 20	June 27	July 2	July 6	July 10	July 14	July 18	July 27	Aug. 1	Aug. 9	Aug. 17	Aug. 22	Sept. 13	Sept. 27	Oct. 9	Oct. 30	Nov. 14	Dec. 4	Dec. 18	Jan. 17
Chlorophyta																							
Actinastrum							x	x	x	x	x	x	x	x	x	x	x	x					
Ankistrodesmus																x			x				
Carteria														x	x	x							
Chlamydomonas						x	x	x	x	x	x	x	x	x	x	x	x	x		x	x		
Chlorella																x		x					
Cladophora						x									x		x						
Closterium	x				x																		
Coelastrum		x					x									x							
Coronastrum									x	x	x	x											
Cosmarium						x						x	x		x				x				
Dictyosphaerium									x	x	x	x	x	x		x	x						
Eudorina					x		x							x									
Micractinium							x				x												
Microspora					x		x	x	x	x	x	x	x	x	x			x	x		x		
Mougeotia				x			x							x	x		x		x	x			
Pandorina				x		x		x	x	x	x	x	x	x	x		x			x			
Pediastrum				x	x		x	x	x	x		x		x	x		x	x	x	x	x		
Scenedesmus				x							x	x					x		x				
Sphaerocystis	x	x	x	x	x	x	x	x	x	x	x												
Spirogyra														x					x		x		
Staurastrum					x	x		x	x	x	x	x	x	x	x	x	x	x	x	x			
Ulothrix	x				x		x					x											
Volvox								x	x	x	x												
Chrysophyta																							
Asterionella	x	x		x					x	x	x	x	x	x	x	x	x	x	x	x	x		
Cymbella													x								x		
Dinobryon					x			x	x	x				x		x							
Fragilaria	x				x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Gyrosigma																	x		x		x		
Melosira			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Navicula	x									x			x								x		
Nitzschia													x				x						
Stephanodiscus			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
Synedra	x						x				x		x	x	x	x	x	x	x	x	x		x
Synura															x						x		
Tabellaria																x					x		x
Pyrrophyta																							
Ceratium				x					x	x	x	x	x		x	x	x						

Table 7.--Distribution of phytoplankton organisms of Oneida Lake from May 30, 1967 through January 17, 1968 (Continued)

Genus of Alga	May 30	June 7	June 13	June 20	June 27	July 2	July 6	July 10	July 14	July 18	July 27	Aug. 1	Aug. 9	Aug. 17	Aug. 22	Sept.13	Sept.27	Oct. 9	Oct. 30	Nov. 14	Dec. 4	Dec.18	Jan. 17
Cyanophyta																							
Anabaena				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Aphanizomenon					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Chroococcus							x			x	x	x	x	x	x	x							
Entophysalis									x	x	x								x				
Gloeotrichia				x	x	x	x	x	x	x	x	x	x	x	x								
Lyngbya				x	x		x	x	x	x	x	x	x	x	x	x	x	x	x		x		
Microcystis				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Oscillatoria				x								x				x		x	x		x		
Pelogloea															x	x							
Synechococcus				x	x	x	x	x	x														

Table 8.--Dominant phytoplankton organisms of Oneida Lake from May 30, 1967 through January 17, 1968

(Approximate values represent cells per milliliter and percent of standing crop)

May 30, 1967
Ulothrix 1,600, 44.7%; Lyngbya 660, 18.1%; Asterionella 460, 12.8%; Fragilaria 440, 12.1%.

June 6, 1967
Sphaerocystis 1,300, 76.0%; Coelastrum 260, 15.4%; Asterionella 150, 8.6%

June 13, 1967
Sphaerocystis 4,400, 93.6%; Melosira 200, 4.2%.

June 20, 1967
Anabaena 16,200, 92.1%; Sphaerocystis 1,200, 6.9%; Melosira 110, 0.6%.

June 27, 1967
Anabaena 11,400, 87.7%; Microcystis colonies; Sphaerocystis 900, 5.5%; Gloeotrichia colonies.

July 6, 1967
Anabaena 14,900, 79.0%; Aphanizomenon 1,140, 6.2%; Gloeotrichia colonies; Microcystis colonies; Coelastrum 240, 1.3%.

July 10, 1967
Anabaena 49,000, 71.1%; Aphanizomenon 19,900, 28.5%; Gloeotrichia colonies; Microcystis colonies; Synechococcus 150, 0.2%.

July 14, 1967
Aphanizomenon 6,850, 45.4%; Gloeotrichia colonies; Anabaena 6,670, 44.3%; Microcystis colonies; Melosira 630, 4.2%.

July 18, 1967
Anabaena 10,500, 44.6%; Aphanizomenon 9,700, 41.2%; Gloetrichia colonies; Microcystis colonies; Melosira 1,350, 5.7%.

July 27, 1967
Anabaena 11,900, 50.7%; Gloeotrichia colonies; Aphanizomenon 6,500, 27.7%; Microcystis colonies; Pandorina 900, 10.7%.

August 1, 1967
Anabaena 14,900, 63.8%; Aphanizomenon 6,200, 26.8%; Pandorina 500, 2.3%; Microcystis colonies.

August 9, 1967
Aphanizomenon 11,350, 63.0%; Anabaena 6,100, 27.7%; Microcystis colonies; Dictyosphaerium 650, 2.9%.

Table 8.--Dominant phytoplankton organisms of Oneida Lake from May 30, 1967 through January 17, 1968 (Continued)

August 17, 1967
Aphanizomenon 10,900, 55.2%; *Anabaena* 8,360, 42.3%; *Microcystis* colonies; *Pandorina* 830, 4.2%.

August 22, 1967
Anabaena 19,700, 49.3%; *Aphanizomenon* 16,900, 42.2%; *Microcystis* colonies; *Fragilaria* 100, 2.7%.

September 13, 1967
Anabaena 12,300, 46.0%; *Aphanizomenon* 7,900, 29.4%; *Microcystis* colonies; *Melosira* 360, 15.8%; *Fragilaria* 160, 6.7%.

September 27, 1967
Anabaena 490, 46.3%; *Melosira* 190, 18.6%; *Fragilaria* 100, 9.5% *Aphanizomenon* 90, 8.7%.

October 9, 1967
Anabaena 560, 41.5%; *Fragilaria* 410, 30.9%; *Melosira* 100, 15.8%; *Aphanizomenon* 70, 11.1%.

October 30, 1967
Melosira 200, 56.5%; *Anabaena* 80, 22.5%; *Fragilaria* 50, 19.8%.

December 4, 1967
Melosira 200, 80.0%; *Anabaena* 40, 16.0%.

January 17, 1968
Melosira 25, 50.0%; *Synedra* 25, 50.0%.

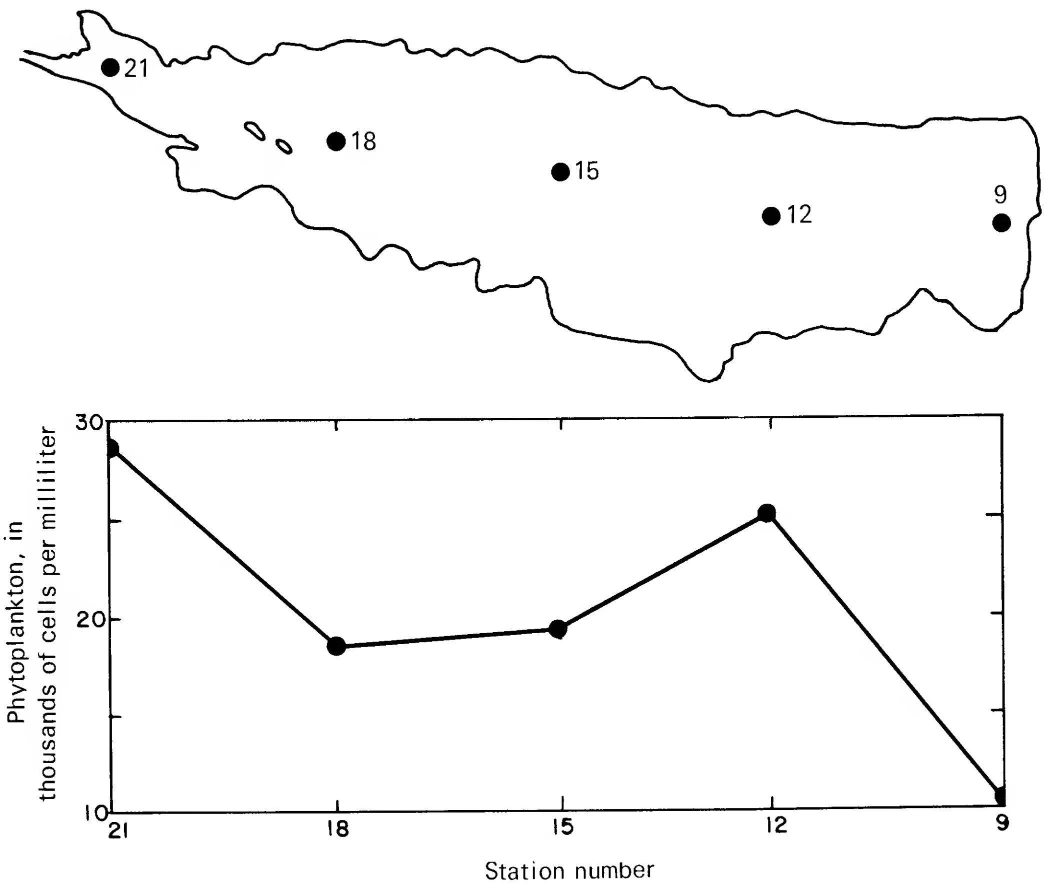

Figure 20.--Longitudinal variations in the mean standing crop of phytoplankton during 1967.

Although the number of diatoms decreased during the summer, they were present during the entire year. The persistent species were Asterionella formosa, Fragilaria sp., Melosira distans, Melosira granulata and Melosira varians. Tabellaria sp. appeared during the winter.

Commonly occurring green algae included Pediastrum duplex, Microspora Willeana, Pandorina morum and Staurastrum paradoxum. Ceratium hirundinella, a dinoflagellate of Pyrrophyta, was common during the spring, summer, and fall.

CHEMISTRY OF ONEIDA LAKE

Methods of Routine Investigations

The biweekly collection of water samples for chemical analyses started in June, 1967. Samples were obtained routinely at stations 8 through 22 (fig. 17) and filtered with a water sample filtration unit (Skougstad and Scarbro, 1968) through a 0.45 micron membrane filter. Periodic unfiltered samples also were obtained.

Samples for the determination of nitrogen species (for example, nitrate, nitrite, ammonia, and organic nitrogen) were preserved with mercuric chloride ($HgCl_2$). Samples for phosphate analysis were stored in glass citrate bottles.

All samples were returned to the U.S. Geological Survey laboratory in Albany for processing. Standard chemical methods were used (American Public Health Association, 1965 or Rainwater and Thatcher, 1960). The following constituents were determined: silicon dioxide (SiO_2), calcium (Ca,) magnesium (Mg), sodium (Na), potassium (K), bicarbonate (HCO_3), carbonate (CO_3), fluoride (F), nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), organic nitrogen (org-N), total phosphate (tot-PO_4) and dissolved solids (DS).

In situ measurements for dissolved oxygen, water temperature and specific conductance were made during each visit to a sampling station. Field measurements for pH and alkalinity were made intermittently.

Periodic water samples were obtained at station 12 for the spectrographic analysis for trace elements. The analyses were made by the U.S. Geological Survey laboratory in Denver, Colorado, and results were reported in micrograms per liter ($\mu g/l = mg/l \times 10^{-3}$).

Secchi disc readings for determining the relative extent of light penetration were taken routinely at stations 12 and 20 according to the method of Welch (1948).

Special Studies

As with biological investigations, several special chemical studies have been and are being made in addition to routine sampling. The results of these studies and a comprehensive evaluation of the chemical cycles and interactions within Oneida Lake will be included in the final report. A list of some of the special chemical studies follows:

1. A map of bottom sediments indicating type, distribution and chemical quality is being prepared.

2. Data from routine chemical samples, from the geochemical investigation of the drainage basin, from the chemical evaluation of various biological groups, and from the chemical quality of sediments will form the basis for establishing nutrient cycles within the lake.

3. Daily and hourly samples are being collected prior to and during bloom conditions to determine the influence of phytoplankton productivity on the chemical quality of the water and vice versa.

4. Efforts are being made to determine the sources of trace element contributions into the lake.

Nutrients

General

Oneida Lake lies within a fertile drainage basin. According to Pearson and Meyers (1969), on an average day in 1967 about 1,250 tons (about 1,130 metric tons) of dissolved solids (DS) were carried into the lake by surface streams. Ten to 15 percent, or about 150 tons per day (about 135 metric tons) of these materials were retained or entrapped within the lake. Because the streams of the basin contain primarily calcium sulfate bicarbonate water, a large part of the dissolved solids flowing into the lake is of nutritional value.

The cycling of individual nutrients within a lake system is poorly understood. Part of the nutrients become incorporated into living matter (for example, phytoplankton, zooplankton, vascular plants, and fish) and upon death and decay of the organism, the nutrients are liberated for reuse. Part of the nutrients remain in solution, while some become permanently incorporated within the bottom sediments or flow out of the lake. Attempts are now being made to define, at least partially, these cycles of inorganic nutrients in Oneida Lake, and, as previously stated, the results of this study will be included in the final report.

Nutrients accumulate within a lake and, after a period of years, become available in concentrations sufficient to support algal blooms. Table 2 shows the essential elements of algae and the respective minimum required concentrations. Table 9 shows the mean concentrations of dissolved essential elements in Oneida Lake for the period of May 1967 through March 1968.

All but four of these elements exhibited more than adequate quantities for algal nutrition, according to findings reported in the literature. Observed copper (Cu) and sodium (Na) concentrations were equal to reported minimum requirements, but boron (B) and cobalt (Co) were considerably below the minimum. The mean concentrations of these latter two elements were 0.025 mg/l and $<$0.003 mg/l, respectively, as compared with the estimated minimum requirements of 0.1 mg/l and 0.5 mg/l, respectively. The observed low concentrations of boron and cobalt had no perceptible effect on the phytoplankton.

Of those studied, no particular element, ion or compound appeared to be a limiting factor on the growth processes of algae or the extent of bloom formation in Oneida Lake. Even during the large bloom on July 10, mean concentrations of nutrients dissolved in the water were above the minimum requirements for the healthy existence of phytoplankton. Variations in concentrations of dissolved nutrients cannot be correlated, at present, with changes in the phytoplankton population.

Table 9.--Essential elements in Oneida Lake. Values represent mean concentrations at station 12 for the period of May 1967 through March 1968

Element	Chemical form	Mean value (mg/l)	Element	Chemical form	Mean value (mg/l)
Aluminum	Al	0.035	Nitrogen	Total as N	0.364
Boron	B	.025		NO_3	.6
Calcium	Ca	38		NO_2	.01
Carbon	--	--		NH_4	.11
Chlorine	Cl	9		Organic N	.14
Cobalt	Co	<.003	Oxygen	--	--
Copper	Cu	.006	Phosphorus	Total PO_4	.18
Hydrogen	--	--	Potassium	K	.9
Iron	Fe	.041	Silicon	SiO_2	2.5
Magnesium	Mg	8.6	Sodium	Na	5
Manganese	Mn	.022	Sulphur	SO_4	48
Molybdenum	Mo	<.0006	Vanadium	V	<.003
			Zinc	Zn	<.015

Table 10 summarizes the results of the chemical investigation of Oneida Lake by showing the biweekly mean values of the chemical constituents from June, 1967 to May, 1968. Table 11 shows the concentrations of various trace elements at station 12.

Nitrogen and Phosphorus

Nitrogen and phosphorus have long been considered to be key elements required by phytoplankton. In many lakes, the concentrations of these two nutrients are vitally important in controlling the extent of biological productivity. When concentrations are high, algal blooms generally occur, whereas, when concentrations are low, no problems of productivity are experienced.

Table 10.--Biweekly mean values of the chemical constituents of Oneida Lake at all stations from June 6, 1967 to May 8, 1968 (Values represent milligrams per liter)

Date	Water Temperature (°C)	Dissolved Oxygen	pH	SiO_2	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F*	NO_3 (as NO_3)	NO_2 (as NO_2)	NH_4 (as NH_4)	Organic N (as N)	Total P (as PO_4)	Dis-solved solids	Specific Con-duct-ance **
6/ 6/67	19.6	9.53	7.8	0.2	40	9.1	5.2	0.8	102	0	53	9.4	0.2	0.2	0.01	0.64	--	0.03	169	282
6/20/67	22.2	7.51	8.0	.9	41	9.6	5.3	.8	104	0	54	8.9	.1	.1	.02	.07	--	.02	172	281
7/ 6/67	21.6	8.71	7.8	2.2	41	9.0	5.1	1.0	104	0	54	8.9	.1	.1	.01	.21	--	.05	173	289
7/14/67	24.2	7.88	8.0	2.3	40	9.2	5.1	.9	100	0	54	9.2	.0	.1	.00	.06	--	.17	170	299
7/28/67	24.6	9.28	8.1	3.1	38	9.6	5.2	.9	92	1	54	9.7	.1	.1	.02	.17	--	.11	173	278
8/10/67	23.8	9.17	7.1	2.3	41	9.1	6.8	1.3	104	0	53	8.3	.2	.1	.00	.07	0.03	.06	173	291
8/15/67	24.1	9.83	8.6	3.2	40	9.2	5.4	.9	94	6	52	8.4	.1	.1	.00	.02	.14	.07	171	292
8/22/67	23.1	8.13	8.0	2.8	41	8.7	5.1	.9	104	1	46	8.8	.0	.0	.00	.11	.25	.39	169	290
9/17/67	18.9	10.04	7.9	2.7	40	9.0	5.2	.9	103	0	52	8.9	.1	.0	.00	.10	.30	.30	170	289
9/27/67	16.6	10.35	8.0	1.9	43	9.4	5.5	1.0	107	0	54	9.3	.1	.3	.00	.10	.63	.22	178	289
10/ 9/67	15.7	10.21	7.9	.9	43	10	5.4	.8	108	0	53	9.2	.1	.3	.00	.00	.03	.33	177	298
10/30/67	10.3	10.00	7.8	.8	39	8.8	5.4	1.2	106	0	52	9.4	.1	.3	.00	.11	.06	.41	169	300
11/15/67	2.8	11.45	7.8	1.0	39	8.4	5.4	1.0	100	0	47	9.1	.1	.4	.01	.08	.10	.40	156	298
12/ 4/67	1.1	13.30	7.8	2.9	32	7.4	4.6	1.0	90	0	39	9.1	.1	1.0	.02	.00	.17	.40	142	305
12/18/67	.0	13.62	7.3	3.8	32	6.5	3.1	.4	90	0	45	8.2	.1	1.1	.01	.00	.21	.16	138	300
1/16/68	.0	--	7.7	3.4	38	7.5	4.0	.9	98	0	47	7.3	.1	1.2	.01	.00	.01	.20	136	--
1/30/68	.0	--	7.6	3.4	37	7.5	4.2	.6	100	0	48	8.5	.1	1.2	.01	.09	.09	.13	131	--
2/13/68	.0	13.33	7.4	3.7	27	6.1	3.9	.8	77	0	35	8.0	.2	1.5	.00	.00	.23	.12	126	260
2/27/68	.0	14.60	7.6	4.5	38	9.6	4.4	.8	126	0	28	8.7	.0	2.4	.00	.27	.09	.02	159	275
3/12/68	.0	13.90	7.6	3.0	36	8.6	5.2	1.0	97	0	44	10.0	.1	1.4	.03	.04	.08	.13	158	300
3/20/68	.0	--	7.5	2.8	36	8.3	5.5	1.2	93	0	47	11	.1	1.1	.06	.10	.14	.16	160	--
4/ 2/68	7.8	--	7.4	2.6	34	7.5	4.3	1.0	88	0	40	9	.1	1.0	.04	.00	.10	.28	143	--
4/18/68	9.3	11.43	7.8	1.5	34	6.9	4.8	1.0	85	0	41	9	.2	.7	.00	.00	.19	.09	143	259
5/ 8/68	11.2	10.82	8.0	.6	38	8.0	4.3	1.1	99	0	47	9.6	.2	.2	.03	.02	.17	.04	158	250

* Not considered to be an essential element.

** Expressed as micromhos per centimeter at 25°C.

Table 11.--Trace elements in Oneida Lake and their respective concentrations

(Samples collected at station 12. Values represent micrograms per liter.)

Date	Al*	Ba	Be	Bi	B*	Cd	Cr	Co*	Cu*	Ga	Fe*	Pb	Li	Mn*	Mo*	Ni	Rb	Ag	Sr	Sn	Ti	V*	Zn*	Zr
5/29/67	45	35	<0.2	ND	30	ND	1	<2	3	ND	35	<2	3	5	<0.5	<2	<1	<0.2	500	<2	2	<2	<25	ND
6/ 6/67	70	33	<.2	ND	19	ND	9	<3	5	ND	70	8	4	13	<.6	.9	<1	<.2	530	2	3	<3	<20	ND
6/13/67	30	31	<.2	ND	22	ND	9	<3	4	ND	11	22	4	13	<.6	<.6	<1	<.2	490	9	.3	<3	<20	ND
6/20/67	40	31	<.2	ND	14	ND	14	<3	7	ND	14	7	4	9	<.6	<.6	<1	<.2	540	<2	.6	<3	<20	ND
6/27/67	41	34	<.2	ND	22	ND	7	<3	5	ND	20	5	3	25	<.6	<.6	<2	<.2	560	<2	.6	<3	<20	ND
6/29/67	43	32	<.2	ND	18	ND	13	<3	3	ND	8	7	4	4	<.6	<.6	<2	<.2	540	<2	.4	<3	<20	ND
7/ 1/67	28	35	<.2	ND	26	ND	12	<3	10	ND	28	6	3	8	<.6	<.6	<1	<.2	600	2	2	<3	<20	ND
7/ 3/67	60	34	<.2	ND	21	ND	8	<3	6	ND	65	4	3	7	<.6	<.6	<1	<.2	590	<2	.7	<3	<20	ND
7/ 6/67	13	35	<.2	ND	26	ND	8	<3	4	ND	6	19	3	3	<.6	<.6	<1	<.2	570	10	.3	<3	<20	ND
7/10/67	54	40	<.2	ND	25	ND	12	<3	4	ND	33	9	4	14	<.6	<.6	<1	<.2	550	<2	.5	<3	<20	ND
7/14/67	41	35	<.2	ND	27	ND	21	<3	4	ND	55	7	4	14	<.6	1	<1	<.2	550	<2	1	<3	<20	ND
7/18/67	28	30	<.2	ND	25	ND	12	<3	--	ND	--	9	3	25	<.6	1	<1	<.2	550	4	1	<3	--	ND
7/27/67	30	31	<.2	ND	26	ND	8	<3	3	ND	45	3	3	8	<.6	.7	<1	<.2	550	<2	2	<3	<20	ND
8/ 1/67	60	31	<.2	ND	25	ND	10	<3	5	ND	75	5	3	140	<.6	.8	<1	<.2	530	<2	4	<3	22	ND
8/10/67	23	32	<.2	ND	31	ND	8	<3	5	ND	18	5	4	8	<.6	<.6	<1	<.2	590	<2	.9	<3	<20	ND
8/18/67	18	35	<.2	ND	34	ND	3	<3	3	ND	45	18	4	17	<1	.9	<1	<.2	500	7	2	<2	<15	ND
8/22/67	18	38	<.2	ND	30	ND	5	<3	4	ND	9	3	4	4	<1	.7	<1	<.2	510	<2	<1	<2	<15	ND
9/27/67	50	30	<.2	ND	20	ND	6	<3	11	ND	9	2	3	2	<.6	<.9	.8	<.2	690	<2	<2	<2	<3	ND
10/ 9/67	--	40	<.2	<3	25	<2	--	<2	6	<2	--	3	3	5	<.6	2	.9	<.2	580	<3	8	<3	10	ND
10/14/67	30	33	<.1	<3	20	<15	13	<2	5	<2	70	12	3	12	<.6	.7	1	<.2	430	<3	<2	<2	12	ND
10/30/67	8	40	<.2	<3	24	<2	1	<2	3	<2	4	8	4	2	<.6	<.6	1	<.2	660	<3	<2	<3	<15	ND
12/18/67	25	30	<.1	<3	20	<15	3	<2	7	<2	50	17	3	11	<.6	1	.8	<.5	490	<3	<2	<2	17	ND
1/ 3/68	20	--	<1	ND	30	ND	7	<5	10	ND	27	6	4	18	<5	<7	.8	<.2	--	<9	<5	<5	ND	ND
2/13/68	30	30	<.6	ND	40	ND	4	<8	10	ND	110	10	4	95	<.6	2	.9	<.3	210	<8	<2	<1	ND	ND
2/27/68	25	31	<.7	ND	23	ND	8	<5	--	ND	85	20	3	40	<.5	4	.9	<.4	350	<5	<2	<2	ND	ND
3/13/68	35	30	<.6	ND	20	ND	7	<4	6	ND	100	9	2	60	<.4	3	.6	<.3	200	<4	<1	1	ND	ND

* Essential element of algae.
ND Not detected.

The minimum requirements for nitrogen and phosphorus by algae in the natural environment are topics of debate, because little is known about their roles (cycles) in lake systems. The discrepancies are reflected in table 2 by the wide range of minimum requirements as reported in the literature.

The values of 0.30 mg/l for nitrogen and 0.01 mg/l for phosphorus, generally are considered to be closest to the actual minimum requirements. Sawyer (1947) stated that when concentrations exceeded these values, nuisance conditions could be expected.

In Oneida Lake, the mean concentrations of nitrogen and phosphorus during May, 1967 through March 1968 were 0.36 mg/l and 0.18 mg/l, respectively. During the initial bloom of July 10, mean concentrations were 0.39 mg/l and 0.10 mg/l, respectively, quite adequate to support algal blooms.

Figures 21, 22, and 23 show the mean variations of total dissolved nitrogen, total dissolved phosphate and various nitrogen species in Oneida Lake during the first year of study.

Spatial Variations

The dissolved nutrients of Oneida Lake were essentially uniform in concentration, both vertically and areally; only subtle differences were detected during the first year of study. Upon entering the lake, waters from the tributaries are subjected to the ever present winds and are mixed almost immediately.

During periods of dissolved oxygen stratification, concentrations of dissolved nutrients were only very slightly higher in the near-anerobic layer of water at the bottom (below 30 ft in depth). Table 12 shows the mean differences.

Because there were no appreciable vertical variations in dissolved nutrients, chemical reduction in the lower layers of water was most likely of minor significance during 1967. Investigations are now being made to determine the exact role of chemical reduction on the nutrient cycles in the lake.

Significantly larger amounts of only the ammonium ion and total dissolved phosphate were noted in the deep zone. In both cases, the increased amounts were probably due to bacterial and biochemical decomposition of organic materials.

Maximum differences in dissolved nutrients between the surface and bottom were recorded on August 17. Winds of up to 18 mph (8 m per sec) on August 19 (U.S. Department of Commerce, 1967) mixed the waters of the lake and replenished nutrients for reuse by the phytoplankton. The result was the second major algal bloom on August 22.

During periods when the lake did not stratify, concentrations of dissolved materials were essentially uniform through the entire water column.

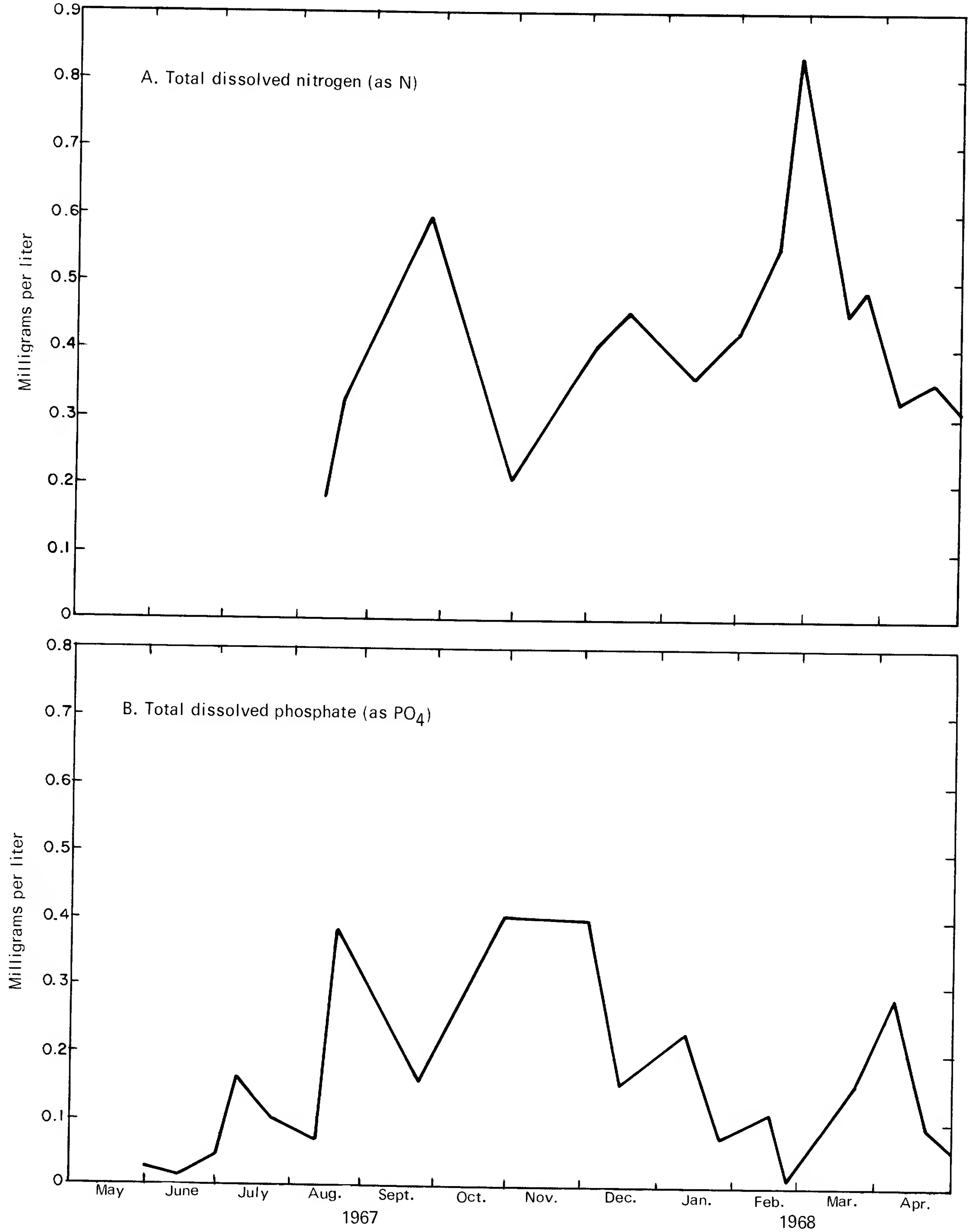

Figure 21.--Mean variations of total nitrogen and total phosphate in Oneida Lake.

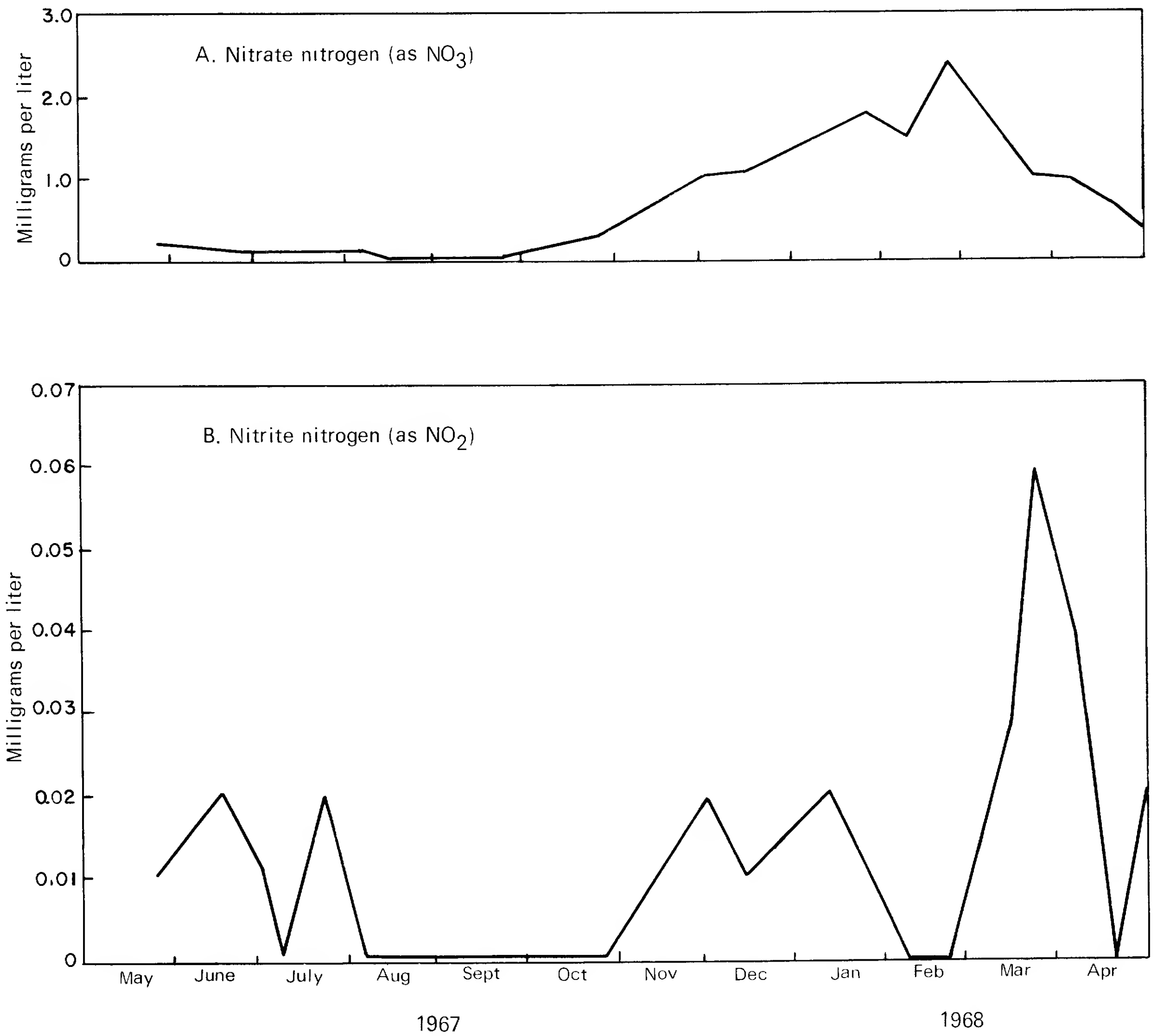

Figure 22.--Mean variation of nitrate nitrogen and nitrite nitrogen in Oneida Lake.

The average Secchi disc reading during 1967 was 6.21 feet (1.89 meters). Readings ranged from 5.06 feet (1.54 meters) to 8.67 feet (2.64 meters). Greater depths were recorded in the open lake at station 12 and lesser depths were observed at the western end of the lake at station 21; the mean readings were 6.81 feet (2.08 meters) and 5.62 feet (1.71 meters), respectively.

Areal variations of dissolved nutrients were minimal. Slightly higher concentrations were recorded at the western stations (numbers 17 through 22). The lowest concentrations of specific nutrients were observed at station 9, resulting from the inflow of low-mineralized water in Fish Creek from the north and northeast. Table 13 shows the mean concentrations of chemical factors for each of the sampling stations.

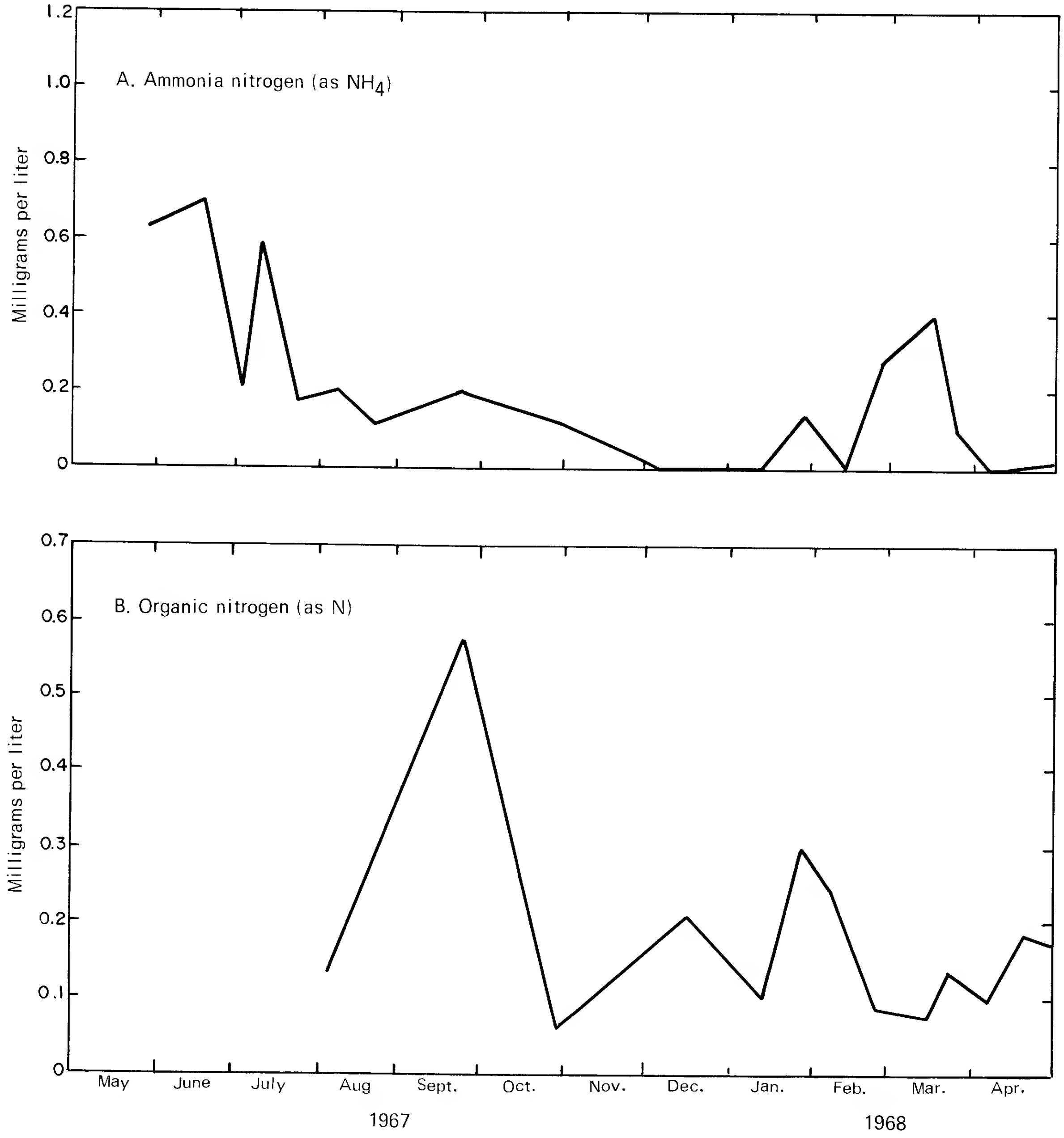

Figure 23.--Mean variations of ammonia nitrogen and organic nitrogen in Oneida Lake.

Table 12.--Variations of major ions between surface and bottom during period of dissolved oxygen stratification and periods of no dissolved oxygen stratification

(Values represent mean concentration in milligrams per liter)

	pH	Specific conductance*	SiO_2	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F**	NO_3 (as NO_3)	NO_2 (as NO_2)	NH_4 (as NH_4)	Total P (as PO_4)	Dissolved solids
Stratification																	
Surface	8.0	302	2.2	40	9.1	5.2	0.9	102	1	54	9.1	0.1	0.1	0.02	0.09	0.07	172
Bottom	7.5	304	5.5	41	9.2	5.2	1.0	109	0	51	8.9	.1	.1	.01	.38	.22	176
No Stratification																	
Surface	8.0	306	1.1	42	9.2	5.3	.9	105	0	55	9.4	.1	.1	.00	.28	.09	176
Bottom	7.6	303	1.4	42	9.2	5.1	.9	104	0	53	9.4	.1	.1	.00	.23	.09	173

* Expressed in micromhos per centimeter at 25°C.
** Not considered to be an essential element.

Table 13.--Mean values of chemical constituents at each sampling station on Oneida Lake

(Values represent milligrams per liter)

Station number	Water Temperature (°C)	Dissolved oxygen	pH	SiO_2	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F*	NO_3 (as NO_3)	NO_2 (as NO_2)	NH_4 (as NH_4)	Organic N (as N)	Total P (as PO_4)	Dis-solved solids	Specific con-duct-ance**
8	20.9	9.42	8.0	1.2	41	9.2	5.1	0.9	103	1	55	9.5	0.1	0.1	0.01	0.07	0.15	0.08	173	284
9	19.9	9.60	7.9	1.8	35	7.9	4.8	.9	93	1	42	8.6	.1	.4	.03	.19	.13	.21	145	268
10	21.5	9.50	7.9	1.4	41	9.2	5.1	.9	101	0	54	8.9	.1	.1	.01	.10	.18	.11	171	275
11	20.9	9.79	7.9	1.3	40	9.0	5.1	.9	103	1	54	9.4	.1	.1	.01	.11	.16	.09	171	286
12	20.0	9.87	7.9	1.8	40	8.9	5.2	1.0	102	1	51	9.2	.1	.2	.01	.12	.14	.15	169	297
13	21.6	9.21	8.1	1.6	41	9.2	4.2	.9	103	1	54	9.3	.1	.1	.01	.16	.33	.12	174	286
14	19.6	9.42	7.9	1.8	39	8.8	4.9	.9	100	0	51	9.2	.1	.4	.01	.14	.35	.04	164	280
15	18.1	10.25	7.9	1.8	38	8.5	4.9	.9	97	1	46	9.1	.1	.5	.00	.11	.16	.14	157	283
16	22.0	9.14	8.1	1.7	41	9.3	5.2	.9	102	1	54	9.1	.1	.1	.01	.21	.22	.13	172	291
17	21.5	9.30	8.0	1.7	41	9.2	5.0	.9	103	1	54	9.3	.1	.2	.01	.20	.15	.11	173	286
18	20.1	9.86	8.1	1.1	41	9.1	5.2	1.0	104	1	42	9.6	.1	.2	.01	.19	.12	.18	173	305
19	21.1	9.02	8.1	1.9	40	8.9	5.0	.9	102	1	51	9.3	.1	.2	.01	.17	.25	.09	167	284
20	21.5	9.52	8.1	1.8	40	9.0	5.3	.9	99	2	53	9.5	.1	.1	.00	.16	.23	.13	170	272
21	19.5	10.68	8.0	1.2	41	9.1	5.1	.9	103	1	53	9.4	.1	.1	.00	.20	.38	.13	171	300
22	21.6	9.85	8.1	1.7	37	8.7	5.1	1.0	95	2	49	9.4	.1	.1	.01	.17	.37	.10	162	268

* Not considered to be an essential element.

** Expressed in micromhos per centimeter at 25°C.

SUMMARY AND CONCLUSIONS

A 5-year study of the annual nuisance algal blooms of Oneida Lake was begun in April, 1967 by the U.S. Geological Survey, Water Resources Division, in cooperation with the Division of Water Resources of the New York State Department of Conservation.

The objectives of the study are to examine critically Oneida Lake and its drainage basin in terms of a dynamic system --- one of causes and effects. The study attempts to define those chemical and physical conditions of the lake system that appear to give rise to, or be associated with, the various biological phases that are of importance; and, ultimately, to present the necessary interpretations upon which a proper lake management program can be based.

This interim report describes the general concepts of lake eutrophication and reports the activities of the first year of field investigations.

The following summaries and conclusions are made within the framework of existing knowledge:

1. Oneida Lake is a eutrophic lake which has been in existence for about 10,000 years. The fertile drainage basin of the lake was once the bottom of an inland fresh-water sea, and drainage from this area brings into the lake an abundance of soluble minerals and dissolved organic materials.

2. Oneida Lake has become eutrophic through natural events. The nutrients entering the lake from natural sources alone appear to be of sufficient quantity to support the annual algal blooms.

3. The lake has been eutrophic for at least 350 years. This is apparent from the description by early settlers that the algae observed in the lake were of a bloom-forming type. These same forms are still evident in Oneida Lake today.

4. Oneida Lake does not stratify thermally during the summer but did exhibit near-anaerobic conditions in the lower layers of water during the growing season of 1967. A sharp dissolved-oxygen stratification at about 30 feet accompanied the increase in phytoplankton productivity in the upper layers of water.

5. One of the most influential factors among the processes within the lake is wind-generated wave action. Prevailing westerly winds can create a maximum wave height exceeding 6 feet on Oneida Lake, with effective mixing to a depth of about 30 feet.

6. The importance of nutrient-rich bottom sediments as a continual source of dissolved materials within the lake is greatly accentuated. Sixty-five percent of the lake bottom is shallower than 30 feet and can be subjected to mixing with the overlying water.

7. Seiches are quite common in the lake and assist in the horizontal transfer of nutrient materials. The vertical displacement of water may exceed 1.6 feet during a period of about 2.4 hours.

8. Higher aquatic plants and benthic algae are common in Oneida Lake. They are a potential source of future "productivity" problems if and when the phytoplankton populations are controlled.

9. Anabaena flos-aquae, a blue-green alga, was the dominant species of bloom-forming algae in 79 percent of the collections.

10. Other important bloom-forming blue-green algae included Aphanizomenon holsaticum, Anabaena circinalis, Anabaena spiroides, Microcystis aeruginosa, Microcystis incerta, Gloeotrichia echinulata and Lyngbya Birgei.

11. Algal concentrations were never uniform over the entire lake. Bay areas and shoal areas often were sites of localized blooms.

12. No particular nutrient appeared to be a limiting factor on the growth processes of algae or the extent of bloom formations in Oneida Lake.

13. The concentrations of nutrients dissolved in the waters of Oneida Lake were more than adequate for the healthy existence of phytoplankton, even during large algal blooms. Nitrogen and phosporus never approached growth-limiting concentrations.

14. The dissolved nutrients of the lake were essentially uniform in concentrations, both vertically and areally. Slightly higher values were reported for the western end of the lake and in the deeper layers of water during periods of dissolved oxygen stratification.

15. The four most important factors affecting the processes in Oneida Lake are: (1) high fertility of the drainage basin, (2) the physical position and shallowness of the lake, (3) mixing as caused by wind, and (4) fertility of the bottom sediments.

GLOSSARY

ALGAE: the group of simple or primitive plants that generally are microscopic in size and live in wet or damp places.

ALGAL BLOOM: the relatively rapid increase in the total number of phytoplankton per unit time to the extent that their presence hinders the utility of a body of water for whatever the intended use.

ANAEROBIC: devoid of oxygen.

BENTHIC ALGAE: algae which grow in or on the bottom.

BENTHOS: organisms that live in or on the bottom of a body of water.

BIOLOGICAL GRAZERS: animal organisms that feed on vegetation; herbivores.

BLOOM: (see Algal Bloom).

CHEMICAL CYCLE: the circular path of an element in its various combinations from the environment to the organism and back to the environment.

CHEMICAL REDUCTION: the addition of hydrogen to or the subtraction of oxygen from a substance; a reaction opposite to the chemical oxidation.

DEVELOPMENT OF SHORELINE: the uniformity index of the shoreline. The index of 1 represents a circle.

DEVELOPMENT OF VOLUME: the uniformity index of volume. The index of 1 represents a cone.

DIATOMS: a group of algae characterized by a cell wall of pectic materials impregnated with silica, giving it a glass-like appearance and texture.

DRAINAGE AREA: the land and water surfaces from which a lake derives its inflow of water.

DRAINAGE BASIN: (see Drainage Area).

ECOLOGICAL SUCCESSION: the gradual progression from one life stage into another.

ENRICHMENT: the addition or accumulation of nutrients within a body of water.

EPILIMNION: the upper layer of water during periods of thermal stratification in a lake.

ESSENTIAL ELEMENT: any element which in some chemical form is required for the nutrition of an organism.

EUTROPHICATION: the natural process of aging of a body of water through ecological succession and enrichment.

EUTROPHIC LAKE: a lake having an abundant amount of dissolved nutrients.

FETCH: the uninterrupted, straight-line distance from the shore to the point of interest; usually associated with wave formation.

FILAMENTOUS ALGAE: thread-like forms of algae having a linear arrangement of cells. These forms are generally macroscopic and benthic.

FLOW-THROUGH TIME: the time necessary for the volume of a lake to be replaced by inflowing water, assuming that there is a complete mixing of the lake water.

GEOCHEMISTRY: the science of the chemical characteristics and properties of the earth.

HIGHER PLANTS: (see Vascular Plants).

HOMOTHERMOUS: uniform or equal in temperature.

HYDROGRAPHIC MAP: a chart of the lake bottom indicating various depth contours.

HYDROLOGY: the earth science that relates to the occurrence of water in the earth, its physical and chemical reactions with the rest of the earth, and its relation to living organisms.

HYPOLIMNION: the bottom layer of water during period of thermal stratification in a lake.

LENGTH: the long axis of a lake.

LIMITING FACTOR: any substance or condition that approaches or exceeds the upper or lower tolerance limits of an organism.

LIMNOLOGY: the science of fresh waters, especially of ponds and lakes, including the physical, chemical, and biological conditions.

LONG AXIS: the greatest length of a lake.

MACROBENTHOS: large, nonmicroscopic organisms that live in or on the bottom of a body of water.

MACROMETABOLITE: a nutrient that is required in relatively large quantities.

MESOTROPHIC LAKE: a lake with a moderate content of dissolved nutrients.

MICROMETABOLITE: a nutrient that is required in relatively small or trace quantities.

NUTRIENT: any substance that is required by an organism for the continuation of growth, for repair of tissue, or for reproduction.

OLIGOTROPHIC LAKE: a lake with a low content of dissolved nutrients.

ORGANISM: a living plant or animal.

PHYTOPLANKTON: plant organisms of the plankton.

PLANKTON: passively floating or weakly swimming aquatic organisms of relatively small size that are at the mercy of the water currents.

PREVAILING WINDS: the average or normal winds.

PRIMARY PRODUCERS: the plant organisms that utilize dissolved nutrients directly from the water.

PRODUCTIVITY: the total amount of organic matter that is formed from raw materials.

SEDIMENTATION: the deposition of suspended or dissolved materials on the bottom of a lake or stream.

SEICHE: the oscillation of water about one or more nodel points within a lake. It is a localized and periodic shift of the water level in which the water particles advance and return in the same path.

SHOAL: (see Shoal Area).

SHOAL AREA: the part of the lake that is shallower than 14 feet in depth.

SHORELINE: the margin of land surrounding the lake surface.

STAGE: the elevation of the surface of a body of water.

STANDING CROP: the total quantity of living material at any moment in time.

STANDING WAVE: (see Seiche).

SUMMER STAGNATION PERIOD: the period of thermal stratification in a lake when the hypolimnion is anaerobic.

SURFACE AREA: the expanse of the lake surface.

THERMAL RESISTANCE: the resistance to mixing because of thermally-produced density differences between the upper and lower layers of water.

THERMAL STRATIFICATION: the distinct layering of a body of water because of thermal differences.

THERMOCLINE: the layer of water between the epilimnion and the hypolimnion where the temperature rapidly declines per unit depth from the upper margin to the lower margin.

TRACE ELEMENT: an element that exists in very minute quantities in the environment.

VASCULAR PLANTS: highly developed plants with a water conducting system. Generally, those plants with leaves, stems, and roots.

VERNAL: of or in the spring.

VERNAL PULSE: the increase in standing crop of plankton during the spring season.

VOLUME: the amount or quantity of water in a lake.

WATER COLUMN: the vertical profile in a lake from surface to bottom.

WATERSHED: (see Drainage Area).

WAVE HEIGHT: the maximum vertical distance between crest and trough of a wave.

WAVE LENGTH: the linear distance from crest to crest or from trough to trough between successive waves.

WAVE OF OSCILLATION: the vertical rise and fall of the water at successive positions in which the water particles move in a circular path.

WIDTH: the short axis of a lake.

ZOOPLANKTON: animal organisms of the plankton.

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