STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

DIVISION OF THE
NATURAL HISTORY SURVEY
STEPHEN A. FORBES, *Chief*

Vol. XVII. BULLETIN Article IV.

The Plankton of Lake Michigan

BY

SAMUEL EDDY

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
November, 1927

STATE OF ILLINOIS

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SCHNEPP & BARNES, PRINTERS
SPRINGFIELD, ILL.
1927

73484—1200

ERRATA

ges 208, 211, 214, 219—for **Bacellariaceae** read **Bacillariaceae.**

ge 209, middle of table—for **oligactus** read **oligactis.**

ge 211, fifth line in table—for **Aphanotheca** read **Aphanothece.**

ge 213, first line in table—for **oligactus** read **oligactis.**

ge 215, fourth line in table—for **acuminata Ehr.** read **acuminatum (Kutz.) Cl.**

ge 218, sixth paragraph—for **Aphanotheca** read **Aphanothece.**

e 220, fifth paragraph—for **acuminata** read **acuminatum.**

e 224, fourth line from bottom—for **Pandorin** read **Pandorina.**

Omit last line and read **Traverse Bay region.**

e 228, fifth line from bottom—for **Antario** read **Ontario.**

THE PLANKTON OF LAKE MICHIGAN

SAMUEL EDDY

The minute organisms constituting the plankton of the Great Lakes have been studied previously more in connection with investigations of their inter-biotic relations rather than from the primary aspect of the plankton. Perhaps the largest amount of work has been done by investigators who were interested chiefly in the relation of the plankton to the white-fish industry. This is one of the most important phases of plankton work, because the white-fish as well as other fishes of the Great Lakes is dependent upon the plankton for food in its early life (Forbes, 1883)—a fact which has made the study of plankton and plankton production most valuable. Other investigators have made fragmentary studies of the plankton of the Great Lakes for taxonomic purposes; Kellicott, Jennings, and others, for example, devoted their attention to the occurrence of certain groups of organisms and to the number and description of species in those groups as found in the Great Lakes.

The chief purposes of this paper are: (1) to present a general picture of the plankton of Lake Michigan, (2) to determine the relative abundance of its constituent organisms, and (3) to incorporate and summarize the facts now known relating to the plankton of the Great Lakes.

Very little work of a quantitative nature has been published on this subject within the last twenty years. Previous to this period a number of qualitative investigations were made on the plankton of Lake Erie, Lake St. Clair, Lake Michigan, and Lake Superior; and a very important work of both quantitative and qualitative character was done on Lake Michigan in the Traverse Bay region by the Michigan Fish Commission (Ward, 1896). In the latter investigations, which covered both bottom and plankton organisms, the gross quantity of the plankton was estimated from silk-net tows, and some idea of the general character of the plankton was obtained from the relative abundance of the constituent organisms.

Methods and Materials

The data for the present paper were obtained from two series of collections made from Lake Michigan in 1887-1888 and 1926-1927. Fifty silk-net tows (Table I) were made by the Illinois State Laboratory of Natural History from November, 1887 to November, 1888 from the breakwater at Chicago. Quantitative silk-net and filter-paper collections (Table II) were made October 16-17, 1926 at Indiana State Dunes Park and Michigan City, Indiana, and near Sawyer, Michigan. Quantitative collec-

tions (Table III) were also made May 14-15, 1927 at Dunes Park and Gary, Indiana, and July 10, 1927 at Chicago, Illinois. All of these were surface tows near the shore, so that the material in this paper relates only to surface and in-shore conditions. No investigation has been reported on the plankton or the conditions in the central area of the lake.

The material of the older series of collections, which had been preserved in formalin and glycerin, was found to be in excellent condition. Unfortunately, the accession numbers on some of these collections had become illegible, so that it was impossible to secure definite information in regard to the months of January, February, and March of the year 1888. The collections which were assumed to cover these months showed very little variation in the constituent organisms from those of the other months.

PHYSICAL CONDITIONS

Lake Michigan offers a very stable habitat for the production of plankton. Because of its large size and the lack of strong currents, the physical conditions of the water vary but slightly from year to year; therefore, the same constituent organisms may be expected in the plankton over a long period of time. Forbes (1883) found that the conditions of life in Lake Michigan were remarkably uniform throughout the seasons and from year to year and that both plant and animal life exhibited there a regularity and stability in remarkable contrast to their fluctuations in smaller bodies of water and on the surrounding land. There was little change, he found, in the relative number of individuals of the various species or in the absolute number of each. Shelford (Ward and Whipple, 1918) pointed out that Lake Michigan, being a large and deep lake, had none of the seasonal temperature changes extending to the deeper parts. Consequently, as only the surface temperature fluctuates, one would expect the deeper portions to exert a more stabilizing influence on the surface waters than would be found in the waters of more shallow lakes. The stability of the lake as a biotic factor is strikingly demonstrated by our comparisons of data covering a period of forty years, for little or no change has occurred in the composition of the plankton over this long period. Many of the constituent species, though showing slight seasonal variations, are rather constantly abundant throughout the year.

The south end of Lake Michigan is composed of gently-sloping sand beaches exposed to considerable wave action. In the northern portion of the lake there is some rocky shore line. Areas of mud flats and aquatic vegetation are rare. All these conditions are characteristic of a primitive lake. There is little variation in water level or shore line from year to year, and overflow conditions are practically unknown. Cooley (1913) gives the following figures covering the water level for the years 1860-1913:

Greatest yearly range of Lake Michigan.....	1.94 ft.
Least " " " " "	.59 ft.
Average " " " " "	1.21 ft.

At the south end the sandy character of the beaches and the strong wave action prevent the growth of vegetation with its consequent influence on the conditions and life of the water. Practically all the plankton, therefore, must originate within the limnetic area. Shallow breeding areas such as Kofoid (1908) found in the backwaters of Illinois River are practically unknown. Adventitious species so common in the plankton of the shore and bottom areas of rivers and shallow lakes are rare.

Stable conditions are insured still further by the extremely slow removal and renewal of the water in the lake. Speaking generally, Ward (Ward and Whipple, 1918) stated that great depth in a body of water and a large inflow in proportion are unfavorable to the abundant production of plankton, and Ward (1896) computed that there is a change of about one-eighteth of the entire volume of Lake Michigan in one year. In other words, there are no extensive outflows to upset the conditions of life in this lake.

The suspended organic matter and silt so common during overflows in rivers and other plankton-bearing waters—and so detrimental to the production of plankton organisms—seem to be at a minimum in Lake Michigan. (The turbidity was not recorded when the collections were made, but it never seemed to be very high.) All things considered, the conditions for plankton production in Lake Michigan approach those of the sea as near as do those of any body of freshwater.

General Character

The gross bulk of the plankton in the water, determined from the collections made in 1926-1927, is quite large. Ward (1896) reported that the plankton in the upper two meters in the Traverse Bay region ranged from 8.9 to 14.12 c. c. per cubic meter, and that the abundance of the plankton gradually diminished in the lower levels. His data were obtained by allowing the silk-net collections to settle in a graduated cylinder and computing the volume of the plankton per cubic meter. The same method when used on the recent collections showed an even greater bulk for the surface plankton. The collections of October, 1926, averaged 10 c. c., and those of May, 1927, 40 c. c. per cubic meter. Some differences in bulk may be due to time, locality, and seasonal variations. The heavy bulk of the May, 1927, plankton may be due to a spring condition, as Ward's collections were made in summer.

In general, the plankton of Lake Michigan is that which characterizes large and deep lakes. Its specific character consists principally of diatoms of the genera *Asterionella*, *Striatella (Tabellaria)*, and *Fragilaria*. Limnetic algae are not very conspicuous. Zooplanktonts are generally scarce in numbers, but always present to some extent. In the 1887-1888 collections the zooplanktonts, particularly those of the larger sort, were much more abundant than in the recent collections and sometimes comprised nearly half the total number of organisms present. The absence of the smaller organisms in the older series makes it reasonable to as-

sume that a coarser net must have been used, which would account for the loss of many of the smaller organisms and for the relative abundance of the larger forms.

As quantitative methods were not used in making the 1887-1888 collections, it was impossible to calculate the total volume of plankton at any time during that period. Qualitatively, however, the older series was very similar to the recent series.

At all times in the silk-net collections, the phytoplanktonts greatly outnumbered the zooplanktonts; the latter, however, made up for their smallness in numbers by their much larger individual size. Because of their spines and other peculiarities of shape, the plant species actually occupied a great deal less space than they seemed to at first glance, or than their numbers would indicate. Careful measurements, with an ocular micrometer, of the average actual bulk of the various silk-net organisms showed that the zooplanktonts, although present in much smaller numbers than the plant species, often comprised nearly one-half the total bulk. Considerable variation of this ratio between the animal and plant constituents was shown in different collections, depending on seasonal and other factors. This ratio would not apply to the total plankton of the lake, because not enough data were obtained in regard to the smaller organisms (nannoplankton), some of which escaped through the net but were found in the few filter-paper collections.

In all, 119 species were found, most of which were typical plankton species. More data on the nannoplankton would undoubtedly greatly increase this number. Sixty of these species were phytoplanktonts and fifty-nine were zooplanktonts. This is only about one-fifth of the total number of the species listed in the various reports of previous investigators as occurring in the waters of the Great Lakes. Of the 66 species occurring in our 1887-1888 collections, 17 (at least three of which were adventitious) did not occur in our recent collections; most of these were never abundant and could have been easily lost in the later collections. Of the 102 species occurring in our 1926-1927 collections, 53 were not observed in the earlier collections; these were either rare or, as previously mentioned, were so small as to escape through the meshes of the net. Many species of algae which were not noted in the earlier series showed up in the recent series, though none of them were abundant. There is no evidence that any of the missing species did not exist in both periods. Anyone familiar with the methods of plankton study can easily understand how some of the smaller organisms by their scanty distribution can easily escape collection and observation. The 49 species which were common to both periods were usually the larger and most abundant organisms.

A rich diatom flora predominated in all the collections, the same species occurring in both periods with few exceptions. Those species which were most abundant in the recent series appeared in the same proportions in the earlier series.

The same species of copepods occurred in both periods with the notable exception of *Epischura lacustris* Forbes, which was abundant in the early collections but did not appear at all in the recent ones. The same species of cladocerans were scattered throughout both series. The Protozoa and Rotifera, never abundant, were limited to a few common species occurring in most of the collections, and as they are hard to preserve for identification not enough good determinations could be made of most of them to establish their distribution.

SEASONAL ASPECT

The data are not extensive enough to justify any definite statement of seasonal variations in the bulk of the plankton, although the fall collections of 1926 showed only one-fourth the bulk of the spring collections of 1927. Seasonal variations in constituent species were noticeably lacking, the dominant diatoms running almost uniformly through the collections of 1887-1888. *Asterionella gracillima*, reported as a spring species in the Illinois River by Kofoid (1908), was abundant throughout the different months, as also were *Lysigonium (Melosira)*, *Striatella (Tabellaria)*, *Synedra*, and *Fragilaria*. Other less abundant diatoms generally appeared irregularly in the collections. Forbes (1883) concluded, from his own observations and those of B. W. Thomas over a period of sixteen years, that there was little change in the constituent organisms in Lake Michigan from one season to another, although he noted a slight increase in number of species in the spring and summer months. In the 1887-1888 collections, the zooplanktonts showed a decided decrease in the colder months, being almost entirely absent in the collections of December and in those attributed to January, February, and March.

GENERAL DISTRIBUTION

A fairly uniform distribution of the plankton of Lake Michigan is to be expected, and very little difference has been noticed in the specific character of the plankton at different points. The off-shore waters of Lake Michigan are fairly well mixed by circulation; currents sweep southward on the west side, turn at the south end, and flow northward on the east side (Harrington, 1895), so that the water bearing the plankton at Chicago is, a few days later, off Michigan City, Indiana.

In all the collections examined, the exact number of organisms was never the same, and absolute uniformity has never been reported in plankton investigations. A tendency to swarm is indicated by the variations in abundance in all collections. Reighard (1894) found evidence of plankton swarming in Lake St. Clair. Forbes (1883) found that the plankton was not equally distributed throughout the water and was more dense off the mouths of rivers. These variations, however, were not usually as great as those between different habitats or seasons.

TABLE I.—AVERAGE MONTHLY RELATIVE ABUNDANCE OF PLANKTON ORGANISMS IN LAKE MICHIGAN, 1887-1888, AT CHICAGO

Organisms	1887		1888						
	Nov.	Dec.	Apr.	May	June	July	Aug.	Sept.	Oct.
Cyanophyceae									
Merismopedia glauca (Ehr.) Nag.*	.....	.....	.....	.....	rare	.....	.....	.....	.....
Coeleosphaerium kutzingianum Nag.*	occ.	.....	.....	.....	.....	.....	rare	rare	.....
Anabaena sp.	.....	rare	.....	.....	.....	.....	.....	rare	occ.
Lyngbia sp.	.....	.....	.....	.....	.....	.....	.....	.....	rare
Cscillatoria princeps Vaucher*	.....	.....	.....	.....	.....	.....	.....	.....	rare
Bacellariaceae									
Lysigonium varians Ag.	occ.	occ.	occ.	occ.	occ.	occ.	com.	abd.	com.
Lysigonium granulata (Ehr.) Ralfs.	com.	.....	occ.	abd.	.....	.....	occ.	abd.	com.
Cyclotella sp.	com.	rare	.....	com.	.....	rare	occ.	occ.	.....
Stephanodiscus niagarae Ehr.	occ.	.....	.....	com.	rare	rare	occ.	occ.	.....
Striatella fenestrata (Kütz.) Kuntze	abd.	v. abd.	abd.	abd.	v. abd.	v. abd.	abd.	abd.	v. abd.
Striatella flocculosa (Roth.) Kuntze	com.	occ.	com.	occ.	.....	.....	.....	occ.	com.
Fragilaria crotonensis (Edw.) Kitton	abd.	abd.	com.	abd.	occ.	com.	abd.	abd.	abd.
Fragilaria virescens Ralfs.	occ.	occ.	com.	com.	com.	occ.	com.	com.	occ.
Synedra tenuissima Kütz.	occ.	occ.	.....	abd.	.....	.....	.....	occ.	.....
Synedra ulna (Nitz.) Ehr.	abd.	com.	abd.	abd.	com.	com.	abd.	abd.	abd.
Asterionella gracillima (Hantz.) Heib.	abd.	v. abd.	com.	abd.	.....	.....	occ.	com.	com.
Navicula sp.	.....	.....	.....	occ.	.....	.....	.....	.....	.....
Cocconeis placentula Ehr.	.....	.....	.....	occ.	.....	.....	.....	.....	.....
Gomphonema acuminatum Ehr.	abd.	.....	com.	rare	.....	.....	rare	occ.	occ.
Encyonema prostratum Berk.	occ.	.....	.....	.....	.....	.....	.....	.....	com.
Sphinctocystis librilis (Ehr.) Hass.	rare	.....	.....	.....	rare	rare	rare	rare	.....
Sphinctocystis eliptica (Kütz.) Kuntze	.....	.....	.....	.....	.....	rare	.....	.....	.....
Chlorophyceae									
Spirogyra sp.	.....	.....	occ.	occ.	occ.	.....	.....	.....	.....
Dictyosphaerium pulchellum Wood.	.....	.....	.....	.....	.....	.....	rare	.....	.....
Coelastrum reticulatum (Dangeard.) Senn.*	.....	.....	.....	.....	.....	.....	.....	rare	.....
Pediastrum boryanum (Turpin) Menegh.*	rare	.....	.....	.....	.....	rare	rare	.....	.....

Protozoa									
Centropyxis aculeata Stein	.....	.....	.....	.....	.....	rare	.....	.....	.....
Difflugia globulosa Duj.	.....	.....	.....	.....	rare	occ.	abd.	rare	occ.
Difflugia lebes Penard	.....	.....	.....	.....	.....	.....	.....	rare	occ.
Trachelomonas hispida Stein	.....	.....	.....	.....	.....	.....	.....	occ.	.....
Dinobryon sertularia Ehr.	.....	.....	.....	.....	.....	.....	rare	.....	.....
Peridinium tabulatum Ehr.	.....	.....	.....	.....	.....	.....	occ.	.....	.....
Ceratium hirundinella Müll.	.....	.....	.....	rare	.....	.....	occ.	rare	.....
Codonella cratera (Leidy)	.....	.....	.....	.....	.....	rare	rare	occ.	.....
Vorticella sp.	.....	.....	.....	.....	.....	.....	.....	rare	.....
Thuricola sp.	.....	.....	.....	.....	.....	.....	.....	rare	.....
Podophrya sp.	.....	.....	.....	.....	.....	.....	.....	rare	.....
Acineta sp.	.....	.....	.....	.....	.....	.....	.....	rare	.....
Coelenterata									
Hydra oligactus Pallas	.....	rare	.....	.....	.....	.....	.....	rare	.....
Rotatoria									
Polyarthra trigla Ehr.	.....	.....	.....	rare	.....	rare	.....	rare	.....
Trichocera cylindrica (Imhof.)	.....	.....	.....	.....	.....	.....	.....	rare	.....
Lepadella oblonga (Ehr.)	.....	.....	.....	.....	.....	rare	.....	.....	.....
Trichotria tetractis (Ehr.)	.....	.....	.....	.....	.....	rare	.....	.....	.....
Keratella cochlearis (Gosse)	.....	.....	.....	rare	.....	occ.	occ.	occ.	occ.
Keratella quadrata (Müll.)	.....	.....	.....	.....	.....	rare	.....	.....	.....
Notholca longispina Kellicott	.....	.....	.....	rare	occ.	com.	occ.	occ.	occ.
Notholca striata Müll.	.....	.....	.....	.....	.....	rare	.....	.....	.....
Brachionus capsuliflorus Pallas	.....	.....	.....	.....	.....	.....	rare	.....	.....
Asplanchna priodonta Gosse	.....	.....	.....	.....	.....	.....	occ.	.....	.....
Conochiloides dossuaris (Hudson)	.....	.....	.....	.....	.....	.....	rare	.....	.....

* Filaments or colonies.

TABLE I—Concluded

Organisms	1887		1888						
	Nov.	Dec.	Apr.	May	June	July	Aug.	Sept.	Oct.
Cladocera									
Sida crystallina (Müll.)	.....	.....	.....	.....	.....	.....	.....	rare	.....
Diaphanosoma leuchtenbergianum Fischer	.....	.....	.....	.....	.....	.....	.....	rare	com.
Daphnia retrocurva Forbes	com.	.....	com.	com.	.....	rare	occ.	occ.	rare
Daphnia longispina (Leydig)	rare	.....	.....	com.	.....	rare	.....	occ.	.....
Bosmina longirostris (Müll.)	.....	.....	rare	.....	rare	rare	rare	occ.	rare
Bosmina longispina Leydig	com.	.....	com.	abd.	com.	com.	rare	com.	occ.
Alona sp.	.....	.....	.....	.....	.....	rare	.....	.....	.....
Chydorus sphaericus (Müll.)	.....	.....	.....	.....	.....	occ.	rare	.....	.....
Leptodora kindtii (Focke)	.....	.....	.....	.....	.....	.....	.....	.....	occ.
Copepoda									
Epischura lacustris Forbes	abd.	.....	abd.	abd.	.....	occ.	abd.	abd.	occ.
Diaptomus sicilis Forbes	.....	.....	.....	.....	occ.	.....	occ.	occ.	.....
Diaptomus minutus Lillj.	com.	.....	.....	occ.	.....	abd.	com.	abd.	occ.
Limnocalanus macrurus Sars	.....	.....	.....	.....	.....	.....	.....	occ.	.....
Cyclops bicuspidatus Claus	com.	.....	com.	com.	.....	abd.	com.	com.	occ.
Cyclops prasinus Fischer	rare	.....	abd.	.....	.....	.....	rare	occ.	occ.
Cyclops fimbriatus Fischer	.....	.....	.....	.....	.....	occ.	occ.	com.	occ.
Young Copepods	.....	.....	.....	.....	.....	.....	.....	rare	.....

TABLE II.—ABUNDANCE OF PLANKTON ORGANISMS (PER CUBIC METER) IN COLLECTIONS FROM LAKE MICHIGAN, OCTOBER, 1926

Organisms	Dunes Park, Ind. 10/17/1926 (2 silk-net collections)	Michigan City 10/17/1926 (3 silk-net collections)	Sawyer, Mich. 10/18/1926 (2 silk-net collections)	Michigan City 10/17/1926 (2 filter-paper collections)
Cyanophyceae				
Merismopedia glauca (Ehr.) Nag.*	3,750	200	250	.....
Coelosphaerium kutzingianum Nag.*	52,500	90,000	25,000	.....
Aphanocapsa elachista W. & G. S. West*	11,350	16,000	10,000	.....
Aphanocapsa delicatissima W. & G. S. West*	3,750	8,000	1,250	.....
Aphanotheca sp.*	18,750	12,000	7,500	.....
Chroococcus limneticus Lemm.*	3,750	.....	1,200	.....
Chroococcus dispersus (v. Keiss) Lemm.*	300	.....	100	.....
Anabaena sp.	.....	.....	20,000	.....
Bacillariaceae				
Lysigonium varians Ag.	7,000	400,000	10,000	1,350,000
Lysigonium granulata (Ehr.) Ralfs.	.....	.....	37,500	900,000
Stephanodiscus niagarae Ehr.	11,250	8,000	5,000	200,000
Cyclotella sp.	18,750	20,000	2,500	42,000
Striatella fenestrata (Kütz.) Kuntze	3,750,000	6,000,000	2,000,000	30,000,000
Striatella flocculosa (Roth.) Kuntze	2,310,000	1,000,000	400,000	28,000,000
Fragilaria crotonensis (Edw.) Kitton	60,600,000	48,000,000	12,500,000	16,000,000
Fragilaria virescens Ralfs.	37,500	.....	20,000	40,000,000
Synedra tenuissima Kütz.	562,500	800,000	100,000	7,200,000
Synedra ulna (Nitz.) Ehr.	300,000	800,000	300,000	9,500,000
Asterionella gracillima (Hantz.) Heib.	3,750,000	2,520,000	2,500,000	15,000,000
Amphiprora alata (Ehr.) Kütz.	375	200	250	.....
Sphinctocystis eliptica (Kütz.) Kuntze	1,875	8,000	2,500	4,000
Sphinctocystis librilis (Ehr.) Hass.	3,750	4,000	250	.....

* Per filaments or colonies.

TABLE II—Concluded

Organisms	Dunes Park, Ind. 10/17/1926 (2 silk-net collections)	Michigan City 10/17/1926 (3 silk-net collections)	Sawyer, Mich. 10/18/1926 (2 silk-net collections)	Michigan City 10/17/1926 (2 filter-paper collections)
Chlorophyceae				
Closterium gracile Brèb.	.....	200	25,000	.....
Chrysosphaerella longispina Lauter.*	.....	36,000	5,000	.....
Rhizochrysis limneticus G. M. Smith*	.....	4,000	.....	.....
Dictyosphaerium pulchellum Wood*	48,750	5,000	20,000	.....
Botryococcus sudeticus Lemm.*	1,875	4,000	2,500	.....
Kirchneriella obesa Schmidle	.....	200	.....	.....
Oocystis sp.*	.....	.....	200	.....
Coelastrum reticulatum (Dangeard.) Senn.*	7,500	2,000	7,500	.....
Tetrastrum sp.	.....	.....	200	.....
Scenedesmus quadricauda (Turpin) Brèb.	.....	.....	200	.....
Pediastrum duplex Meyen.*	187	40	2,500	.....
Pediastrum simplex (Bail.)*	350	200	.....	.....
Pediastrum boryanum (Turpin) Menegh.	7,000	100	1,200	.....
Protozoa				
Centropyxis aculeata Stein	.....	.....	200	.....
Difflugia globulosa Duj.	11,250	6,000	25,000	.....
Difflugia pyriformis Perty	.....	100	100	.....
Endorina elegans Ehr.*	.....	100	.....	4,500
Uroglena americana Calkins*	.....	.....	250	.....
Dinobryon sertularia Ehr.	.....	900,000	250,000	860,000
Ceratium hirundinella Müll.	18,750	14,000	7,500	10,300
Codonella cratera (Leidy)	.....	100	2,500	18,000

Coelenterata				
Hydra oligactus Pallas	.....	100	.....	.....
Rotatoria				
Synchaeta stylata Wierz.	23,100	200	1,000	.....
Polyarthra trigla Ehr.	3,750	200	100	.....
Diurella sp.	.....	400	.....	.....
Keratella cochlearis (Gosse)	7,500	2,000	200	18,000
Notholca longispina Kellicott	.....	100	100	.....
Schizocerca diversicornis Daday	.....	50	.....	.....
Cladocera				
Sida Crystallina (Müll.)	370	.....	.....	.....
Daphnia retrocurva Forbes	300	100	.....	.....
Ceriodaphnia lacustris Birge	.....	.....	100	.....
Bosmina obtusirostris Sars	.....	100	.....	.....
Bosmina longispina Leydig	3,750	4,000	5,000	.....
Copepoda				
Diaptomus ashlandi Marsh	.....	500	.....	.....
Diaptomus minutus Lillj.	.....	500	500	.....
Cyclops bicuspidatus Claus	50	50	100	.....
Cyclops prasinus Fischer	400	2,000	1,200	.....

* Per filaments or colonies.

TABLE III.—ABUNDANCE OF PLANKTON ORGANISMS (PER CUBIC METER) IN COLLECTIONS FROM LAKE MICHIGAN, MAY AND JULY, 1927

Organisms	Gary, Ind. May 14, 1927 (2 silk-net collections)	Dunes Park, Ind. May 14, 1927 (2 silk-net collections)	Dunes Park, Ind. May 15, 1927 (2 silk-net collections)	Dunes Park, Ind. May 14, 1927 (2 filter-paper collections)	Chicago, Ill. July 10, 1927 (2 silk-net collections)
Cyanophyceae					
Merismopedia glauca (Ehr.) Nag.*	.....	.....	200	.....	.....
Chroococcus dispersus (v. Keiss) Lenn.*	8,450	6,000	18,000	.....	.....
Chroococcus minutus (Kütz.) Nag.*	.....	300	.....	.....	50,000
Coelosphaerium naegelianum Unger*	.....	.....	.....	.....	112,000
Gomphosphaeria aponina Kütz.*	.....	.....	.....	.....	4,000
Lyngbia sp.	67,600,000	120,000,000	48,000,000	825,000,000	.....
Anabaena sp.	.....	.....	8,000,000	.....	.....
Anabaena circinalis (Kütz.) Rab.	.....	.....	.....	.....	300,000
Bacellariaceae					
Lysigonium varians Ag.	84 500	30,000	40,000	11,000,000	60,000
Lysigonium sp.	67,600	300,000	100,000	.....	.....
Cyclotella sp.	8,450	6,000	6,000	1,760,000	128,000
Stephanodiscus niagarae Ehr.	25,350	12,000	9,000	500,000	60,000
Striatella fenestrata (Kütz.) Kuntze	8,450,000	9,600,000	9,600,000	143,000,000	32,000,000
Striatella flocculosa (Roth.) Kuntze	.....	300	.....	44,000,000	9,000,000
Fragilaria virescens Ralfs.	1,267,500	720 000	40,000	8,250,000	7,680,000
Fragilaria crotonensis (Edw.) Kitton	67,600,000	18,000,000	48,000,000	200,000,000	384,000,000
Synedra tenuissima Kütz.	1,183,000	2,700,000	2,400,000	24,000,000	1,000,000
Synedra ulna (Nitz.) Ehr.	718,650	7,500,000	6,000,000	176,000,000	3,200,000

Asterionella gracillima (Hantzsch.) Heib.	30,420,000	34,000,000	13,600,000	100,000,000	56,960,000
Navicula sp.	.....	.....	.....	2,250,000	8,000
Cocconeis placentula Ehr.	.....	.....	6,000	1,000,000	.....
Gyrosigma acuminata Ehr.	.....	300	400	.....	400
Amphiprora ornata Bailey	.....	.....	.....	300,000	48,000
Gomphonema acuminatum Ehr.	.....	.....	.....	1,200,000	.....
Cymbelia lanceolata (Ehr.) Kirchn.	.....	3,000	800	.....	.....
Encyomema prostatum (Berk.) Kütz.	.....	.....	.....	1,400,000	.....
Cystopleura turgida (Ehr.) Kuntze	.....	12,000	600	700,000	.....
Cystopleura sp.	.....	5,000	.....	.....	.....
Homococladia sigmoidea (Nitz.) Elmore	.....	600	.....	11,000	.....
Sphinctocystis elliptica (Kütz.) Kuntze	.....	6,000	2,000	11,000	2,000
Sphinctocystis librilis (Ehr.) Hass.	.....	12,000	300	.....	64,000
Surirella robusta Ehr.	.....	.....	.....	.....	85
Campylodiscus hibernicus Ehr.	.....	300	.....	.....	.....
Chlorophyceae					
Closterium gracile Brèb.	.....	600	.....	16,500	.....
Closterium moniliferum (Bory.) Ehr.	.....	.....	.....	.....	80
Cosmarium sp.	.....	.....	500	27,000	.....
Spirogyra sp.*	845	600	.....	.....	.....
Rhizochrysis limneticus G. M. S.*	.....	.....	.....	.....	400
Dictyosphaerium pulchellum Wood.*	16,900	12,000	7,000	16,500	112,000
Oocystis sp.	.....	.....	.....	30,000	.....
Sphaerocystis schroeteri Chodat	845	.....	.....	.....	8,000
Ankistrodesmus falcatus (Corda.) Ralfs.	.....	300	2,000	1,350,000	8,000
Coelastrum microporum Nag.*	8,450	.....	.....	11,000	4,000
Scenedesmus bijuga (Turpin) Lag.*	8,450	.....	.....	16,500	.....
Scenedesmus quadricauda (Turpin.) Brèb.*	4,225	600	.....	33,000	.....
Crucigenia sp.	4,225	.....	.....	.....	1,000
Pediastrum boryanum (Turpin.) Menegh.*	.....	300	.....	.....	.....

* Per filaments or colonies.

TABLE III—Concluded

Organisms	Gary, Ind. May 14, 1927 (2 silk-net collections)	DunesPark, Ind. May 14, 1927 (2 silk-net collections)	DunesPark, Ind. May 15, 1927 (2 silk-net collections)	DunesPark, Ind. May 14, 1927 (2 filter-paper collections)	Chicago, Ill. July 10, 1927 (2 silk-net collections)
Protozoa					
Centropyxis aculeata Stein	.....	.....	200	.....	.....
Difflugia globulosa Duj.	.....	.....	300	.....	.....
Difflugia corona Wallich	.....	600	150	.....	.....
Difflugia pyriformis Perty	.....	.....	200	.....	.....
Actinophrys sol Ehr.	.....	.....	200	11,000	.....
Trachelomonas hispida (Perty)	.....	.....	.....	165,000	.....
Euglena oxyuris Schmarda	.....	600	.....	275,000	.....
Chlamydomonas sp.	.....	.....	.....	330,000	.....
Phacus triqueter (Ehr.)	.....	.....	.....	16,500	.....
Cryptomonas ovata Ehr.	.....	.....	.....	110,000	.....
Dinobryon sertularia Ehr.	.....	30,000	.....	7,000,000	320,000
Eudorina elegans Ehr.	.....	1,200	500	.....	.....
Uroglena americana Calkins	4,225	.....	.....	.....	.....
Codonella cratera Leidy	.....	1,200	.....	.....	32,000
Vorticella sp.	.....	.....	.....	220,000	.....
Nemathelminthes					
Nematoda	.....	600	.....	11,000	.....
Rotatoria					
Synchaeta tremula Ehr.	6,336	24,000	3,500	16,500	.....
Polyarthra trigla Ehr.	845	300	.....	16.000	.....
Keratella cochlearis (Gosse.)	100	600	550	17,000	15,000
Keratella quadrata (Müll.)	8,450	.....	300	.....	.....
Notholca striata Müll.	1,690	1,200	2,500	.....	75
Filinia longiseta (Ehr.)	.....	.....	.....	800	.....

Cladocera					
Bosmina longispina Leydig	12,675	.....	1,200	.....	120,000
Leptodora kindtii (Focke)	.....	.....	.....	.....	80
Copepoda					
Diaptomus ashlandi Marsh	.....	.....	200	.....	2,000
Diaptomus minutus Lillj.	845	.....	300	.....	1,600
Cyclops bicuspidatus Claus	4,225	300	200	.....	2,000
Cyclops prasinus Fischer	1,650	600	1,500	.....	6,000
Young Copepoda	16,900	1,200	1,200	.....	4,000
Canthocamptus sp.	4,225	.....	.....	.....	.....

NOTES ON CONSTITUENT ORGANISMS

CYANOPHYCEAE (BLUE-GREEN ALGAE)

The blue-green algae, never very abundant in plankton collections of Lake Michigan, were represented by a few species which were usually present in small numbers in most of our collections. Fourteen species were noted in all. Snow (1902) listed thirty-four species from Lake Erie. Ward (1896) noted several species from the Traverse Bay region. Whipple (Leighton, 1907) found three genera of blue-green algae in Lake Michigan at Chicago.

Merismopedia: *Merismopedia glauca* (Ehr.) Nag. appeared in small quantities in the collections of June, 1888. Fragments of the plate-like colonies occurred in the plankton Oct. 17-18, 1926 at Dunes Park, Michigan City, and Sawyer, and May 15, 1927 at Dunes Park. The colonies were never very abundant, averaging about 200 per c. m., although 3,750 per c. m. were counted in the 1926 collection from Dunes Park. Snow found this species in Lake Erie. Ward recorded *M. convoluta* Breb. at Traverse Bay.

Coelosphaerium: *Coelosphaerium kutzingianum* Nag. occurred in small numbers in the collections of Nov. 1887, Aug. and Sept. 1888, and Oct. 1926. The colonies reached a count of 90,000 per c. m. at Michigan City, Oct. 17, 1926. The absence of this species in all the spring collections suggests that it is not a spring form. Because of its small size and relative scarcity, it appeared to be of no great importance. Colonies of *C. naegelianum* Unger were common (112,000 per c. m.) in the plankton July 10, 1927 at Chicago. Snow recorded *C. Kutzingianum* Nag. and *C. roseum* Snow from Lake Erie.

Gomphosphaeria: Colonies of *Gomphosphaeria aponina* Kutz. occurred only sparingly (4,000 per c. m.) July 10, 1927 at Chicago. This species was reported from Lake Erie by Snow.

Aphanocapsa: Floating colonies of *Aphanocapsa elachista* W. & G. S. West appeared only in the collections made in the fall of 1926, when they were quite common. Colonies of much smaller cells, *A. delicatissima* W. & G. S. West, occurred at the same time but were never as abundant.

Aphanotheca: Colonies of an undetermined species belonging to this genus were quite common in the plankton collections in the fall of 1926.

Chroococcus: Three species of *Chroococcus* occurred in the recent collections. Probably because of the small size of the colonies, none of this genus were found in the earlier collections. Colonies of *C. dispersus* (V. Keiss.) Lemm. were found occasionally in the 1926-1927 collections. *C. minutus* (Kutz.) Nag. and *C. limneticus* Lemm. occurred sparingly in the 1926 collections. Snow reported the latter species and also *C. pallidus* Ehr. and *C. purpureus* Snow from Lake Erie.

Anabaena: Filaments of a very small undetermined species of *Anabaena* occurred sparingly in some of the collections of Dec. 1887, Sept. 1888, Oct. 1888, Oct. 1926, and May 1927. It was never abundant and was probably lost through the meshes of the net in many of the collections. *A. circinalis* (Kutz.) Rab. was common (300,000 per c. m.) in the silk-net collections July 10, 1927 at Chicago. Snow reported this species from Lake Erie. Ward recorded *A. flos-aquae* Kg. from the Traverse Bay region.

Lyngbia: An undetermined species of *Lyngbia* occurred abundantly in all the 1927 collections. This form was found sparingly in the collections of Oct. 1888. Snow found *L. wollei* Farlow in Lake Erie.

Oscillatoria: A few strands of *Oscillatoria princeps* Vaucher occurred in the collections of Oct. 1888. Snow recorded a number of species from Lake Erie but not this same species.

BACELLARIACEAE (DIATOMS)

Diatoms are the most abundant organisms in the plankton of Lake Michigan. Every collection contained them in large numbers. Twenty-six species, chiefly of four genera, were noted in all. Thomas and Chase (1886) collected 215 species of diatoms during a period of sixteen years from the water supply of Chicago, many of which undoubtedly were not plankton diatoms. Thompson (Ward, 1896) found diatoms very abundant at Traverse Bay and listed fourteen species. Whipple (Leighton, 1907) gave eight genera as being common in Lake Michigan at Chicago.

Lysigonium (Melosira): *Lysigonium varians* Ag. was common in all the collections examined. *L. granulata* (Ehr.) Ralfs. occurred occasionally, and a species of this genus resembling *L. arenaria* Moore was abundant in the October 1926 collections. Snow reported *Melosira arenaria* Moore, *M. granulata* (Ehr.) Ralfs., and *M. varians* Ag. from Lake Erie; but neither Whipple nor Ward reported any species of this genus.

Cyclotella: A species of *Cyclotella* resembling *C. meneghiniana* Rabh. was common (2,500-1,760,000 per c. m.) in the collections of 1926 and 1927. This small diatom occurred sparingly in the 1887-1888 collections. Snow reported four species of *Cyclotella* from Lake Erie. Ward listed *C. operculata* K. from the Traverse Bay region. Whipple found this genus abundant at Chicago.

Stephanodiscus: *Stephanodiscus niagarae* Ehr. occurred occasionally in most of the collections and was abundant in the 1927 collections, reaching a maximum of 500,000 per c. m. in a filter-paper collection May 14, 1927 at Dunes Park. Snow found *S. niagarae* in Lake Erie. Ward reported this species from Traverse Bay, but Whipple listed it as absent from Lake Michigan at Chicago.

Striatella (Tabellaria): *Striatella fenestrata* (Kutz.) Kuntze was one of the most abundant organisms in the plankton, reaching a maximum of 143,000,000 per c. m. May 14, 1927 at Dunes Park. Every collection throughout the year of 1887-1888 was filled with the zigzag chains of this diatom. *S. flocculosa* (Roth.) Kuntze was plentiful in most of the collections but never as abundant as *S. fenestrata*. Thompson found both species abundant in the Traverse Bay region, Snow reported them from Lake Erie, and Thomas and Chase found them in the Chicago water supply. Whipple listed this genus as abundant in Lake Michigan at Chicago.

Fragilaria: *Fragilaria virescens* Ralfs. and *F. crotonensis* (Edw.) Kitton were abundant at all times. The ribbon-like strands of these diatoms, together with *Striatella*, *Synedra*, and *Asterionella*, composed most of the plankton. The most abundant of all the organisms in the plankton was *F. crotonensis*, which reached a maximum of 384,000,000 per c. m. in a silk-net collection July 10, 1927 at Chicago. Thompson reported *F. capucina* Desm. as very common in Traverse Bay. Snow listed *F. crotonensis* and *F. virescens* from Lake Erie. Whipple found this genus only occasionally in Lake Michigan at Chicago. Chase and Thomas reported six species of this genus, including *F. virescens* but not *F. crotonensis*, from the Chicago water supply.

Synedra: *Synedra ulna* (Nitzsch.) Ehr. and *Synedra tenuissima* Ehr. were abundant in all collections. *S. ulna*, one of the most abundant, reached a maximum of 176,000,000 per c. m. May 14, 1927 at Dunes Park, while *S. tenuissima*, although never so abundant, reached a maximum of 24,000,000 on the same date. Both species appeared to flourish more abundantly in the spring and late fall than in other seasons. Thompson reported *S. ulna* and *S. affinis* Kutz. in Traverse Bay. Snow reported *S. ulna* and *S. oxyrhynchus* Kg. from Lake Erie. Thomas and Chase listed fourteen species of this genus including *S. ulna* but not *S. tenuissima* from the Chicago water supply.

Asterionella: *Asterionella gracillima* (Hantzsch.) Heib., one of the most common diatoms, occurred in all collections except those of June and July, 1888. Its occurrence throughout the rest of the year suggests that it has a longer season of growth in Lake Michigan than in other nearby waters, possibly because of the lower temperatures of Lake Michigan. Kofoid (1908) reported this species as a spring form in Illinois River with a maximum abundance of 891,000,000 per c. m. The greatest abundance observed in Lake Michigan was 100,000,000 May 14, 1927 in a filter-paper collection at Dunes Park. Thompson reported *A. formosa* Hass. from Traverse Bay. Snow also listed *A. formosa* from Lake Erie. Whipple found *Asterionella* to be the most abundant genus at Chicago. Chase and Thomas listed *A. formosa* from the Chicago water supply.

Navicula: Several undetermined species of *Navicula* occurred very sparingly in the collections of 1927. Diatoms of this genus never appeared in any quantity in any of the collections. Ward listed three species of *Navicula* from Traverse Bay, and Whipple found *Navicula* to be common at Chicago. Snow recorded three species from Lake Erie. Forty-nine species of this genus were listed by Thomas and Chase from the Chicago water supply, but many of them undoubtedly were not plankton species.

Cocconeis: *Cocconeis placentula* Ehr. was found rather sparingly May 1888 at Chicago and May 1927 at Dunes Park. This species reached a maximum abundance of 100,000 per c. m. in the filter-paper collections. Snow recorded this species from Lake Erie. Ward found *C. transversalis* Greg. in Traverse Bay. Thompson reported *C. placentula* as being dredged from the bottom of Traverse Bay. Thomas and Chase listed *C. lineata* K. and *C. pediculus* Ehr. from the Chicago water supply.

Gyrosigma (Pleurosigma): *Gyrosigma acuminata* (Kutz.) Cl. was found sparingly at Dunes Park, May 14, 1927, but was not observed in any other collections. *G. attenuatum* Sm. was reported by Snow from Lake Erie but was not among the six species of this genus listed by Thomas and Chase from the Chicago water supply.

Amphiprora: *Amphiprora ornata* Bailey occurred (300,000 per c. m.) in the filter-paper collections May 15, 1927 at Dunes Park and also (48,000) in the silk-net collections July 10, 1927 at Chicago. *A. alata* (Ehr.) Kutz. was found sparingly in the collections made Oct. 17-18, 1926. These species have not been reported by other workers in any of the Great Lakes except by Thomas and Chase who reported *A. calumetica* Thomas and *A. ornata* from the Chicago water supply.

Gomphonema: *Gomphonema acuminatum* Ehr., which occurred very sparingly in the silk-net collections at Dunes Park May 14, 1927, was quite common in the 1887-1888 collections except during the months of June, July, and December. It usually appeared in swarms attached to floating debris. Snow reported this species and three others from Lake Erie. Thomas and Chase listed eighteen species including *G. acuminatum* from the Chicago water supply.

Cymbella: *Cymbella lanceolata* (Ehr.) Kirchn. occurred sparingly in the silk-net collections May 14-15, 1927 at Dunes Park but did not appear in any of the other collections. Snow reported *C. maculata* Kg. and *C. rotundata* H. H. C. from Lake Erie. Thompson found *C. gastroides* to be common in the Traverse Bay region. Thomas and Chase reported twelve species including *C. lanceolata* from the Chicago water supply.

Encyonema: *Encyonema prostratum* (Berk.) Kutz. occurred in the filter-paper collections (1,400,000 per c. m. May 14, 1927) at Dunes Park. This species appeared in collections of Nov. 1887 and Oct. 1888, apparently having Thomas and Chase found it and three others of this genus in the Chicago a fall and spring distribution. Snow reported this species from Lake Erie. water supply.

Cystopleura: *Cystopleura turgida* (Ehr.) Kuntze occurred frequently in the collections May 14-15, 1927 from Dunes Park. An undetermined species of this genus also occurred rather sparingly in the same collections. No species of this genus were observed in any other collections. Snow reported *Cystopleura (Epithemia) turgida* and three other species of this genus from Lake Erie. Thomas and Chase listed six species of this genus including *C. turgida* from the Chicago water supply.

Homoeocladia: *Homoeocladia sigmoidea* (Nitz.) Elmore was found sparingly in some of the collections May 14, 1927 from Dunes Park, but did not appear in any of the other collections. Snow reported this species as *Nitzschia sigmoidea* (Nitzsch.) Sm. and another species, *N. lincaris* Sm., from Lake Erie. Thompson recorded *N. sigmoidea* from Traverse Bay. Whipple listed diatoms belonging to *Nitzschia* as being very abundant at Chicago. Thomas and Chase found eleven species of this genus including *N. sigmoidea* in the Chicago water supply.

Sphinctocystis: *Sphinctocystis cliptica* (Kutz.) Kuntze occurred sparingly in the 1926-1927 collections. It was found only once (in June) in the collections of 1888. *S. librilis* (Ehr.) Hass. was present in small numbers in most of the 1887-1888 collections, not appearing from Dec. to April, and in most of the 1926-1927 collections. Snow reported *S. (Cymatopleura) cliptica* Sm. and *S. solea* Breb. from Lake Erie. Thomas and Chase listed five species of *Cymatopleura*, including *C. cliptica* but not *C. librilis*, from the Chicago water supply.

Surirella: *Surirella robusta* Ehr. occurred very sparingly (85 per c. m.) July 10, 1927 at Chicago. Snow recorded three species of this genus but not this species from Lake Erie. Thomas and Chase listed 10 species of this genus but not *robusta* from Lake Michigan at Chicago.

Campylodiscus: *Campylodiscus hibernicus* Ehr. was found in very small numbers in one silk-net collection from Dunes Park, May 14, 1927. Snow reported *C. cribrosus* Sm. from Lake Erie. Thomas and Chase listed *C. hibernicus* and *C. noricus* Ehr. from the Chicago water supply.

CHLOROPHYCEAE (GREEN ALGAE)

The green algae were never abundant in the plankton of Lake Michigan. Twenty species, some of which were very rare, occurred in the collections. Many of the smaller species which occurred rarely in the recent series did not appear in the earlier series; this may have been due to the use of a coarser net through which most of the smaller forms were lost. Snow (1902) recorded 126 species from Lake Erie. Thompson (Ward,

1896) reported that the green algae were almost entirely absent from the Traverse Bay region, as he found only a few species there. Whipple (Leighton, 1907) listed seven genera as common in Lake Michigan at Chicago.

Closterium: *Closterium gracile* Breb., which occurred sparingly in most of the recent collections, was not observed in any of the 1887-1888 collections. *C. moniliferum* (Bory) Ehr. occurred only in the July 1927 collections (80 per c. m.). Snow noted six species of this genus from Lake Erie but did not include *gracile* and *moniliferum*. Whipple reported *Closterium* as occurring occasionally in Lake Michigan at Chicago.

Spirogyra: Fragments of *Spirogyra* (several unidentified species) were found occasionally in the 1927 collections and in the collections of April and June 1888. This genus was not reported by Snow or Thompson, although it was noted by Whipple as "occasional" at Chicago especially around the water supply crib.

Cosmarium: An undetermined species of *Cosmarium* was found only in the filter-paper collections May 14, 1927 at Dunes Park (27,000 per c. m.). This species may have been lost through the meshes in the silk-net collections. Snow listed eleven species of *Cosmarium* from Lake Erie.

Chrysophaerella: Some colonies of green algae agreeing with *Chrysophaerella longispina* Lauterborn were quite common in the collections Oct. 17-18, 1926 at Michigan City and Sawyer and July 10, 1927 at Chicago. This species did not appear in any of the other collections and was not reported from the Great Lakes by any of the previous investigators.

Dictyosphaerium: Colonies of *Dictyosphaerium pulchellum* Wood were quite common in all of the 1926-1927 collections. The greatest abundance recorded was 112,000 colonies per c. m. in a silk-net collection July 10, 1927 at Chicago. This species occurred in small numbers in the collections of August 1888. Snow reported *D. pulchellum* and *D. ehrenbergianum* Nag. from Lake Erie.

Botryococcus: Colonies of *Botryococcus sudeticus* Lemm. occurred in small numbers in the collections of Oct. 17-18, 1926. Snow listed only *B. braunii* Kg. from Lake Erie.

Kirchneriella: A few species of *Kirchneriella obesa* Schmidle occurred sparingly (200 per c. m.) in the collections Oct. 15, 1926 from Michigan City. Snow reported this species and *K. lunaris* (Kirch.) Mob. from Lake Erie.

Oocystis: An undetermined species of *Oocystis* occurred rarely in the collections, 200 per c. m. Oct. 18, 1926 at Sawyer and 30,000 per c. m. May 14, 1927 at Dunes Park. Snow reported three species of this genus from Lake Erie.

Sphaerocystis: A few colonies (845 per c. m.) of *Sphaerocystis schroeteri* Chodat were found in a silk-net collection May 14, 1927 at Gary and also (7,000 per c. m.) July 10, 1927 at Chicago. This species has not been reported for the Great Lakes by any of the other investigators.

Ankistrodesmus: *Ankistrodesmus falcatus* (Corda.) Ralfs. was found only in the collections of May 14-15, 1927 from Dunes Park and July 10, 1927 from Chicago. Clusters of the crescent-shaped cells were quite abundant (1,350,000 per c. m.) in the filter-paper collections, showing that most of the cells passed through the silk net. This species was not mentioned by any of the previous investigators.

Coelastrum: Two species of *Coelastrum* were found in several of the collections. *C. reticulatum* (Dangeard.) Senn. was found occasionally in the collections of Oct. 17-18, 1926 and rarely in the collections of Sept. 1888. *C. microporum* Nag. was found in two silk-net collections, May 14, 1927 at Gary and July 10, 1927 at Chicago, and in a filter-paper collection, May 14, 1927 at Dunes Park. Snow reported four species of this genus, including these two, from Lake Erie.

Tetrastrum: An undetermined species of *Tetrastrum* occurred in small numbers (200 per c. m.) in silk-net collections Oct. 18, 1926 at Sawyer. Species of this genus were not observed in any of the other collections. This genus has not been reported from the Great Lakes by any of the previous investigators.

Scenedesmus: Two species of *Scenedesmus*, which is a very common genus in small lakes and ponds, were found in the 1926-1927 collections. Because of their minute size, these species were probably lost in the earlier collections, and only a few were retained in the recent collections. *S. bijuga* (Turpin) Lag. occurred (8450 per c. m.) May 14, 1927 at Gary and (16,500 per c. m.) in filter-paper collections of the same date at Dunes Park. *S. quadricauda* (Turpin) Breb. occurred in rather small numbers (600-33,000 per c. m.) May 14, 1927 at Gary and Dunes Park and Oct. 18, 1926 at Sawyer. Snow reported ten species of this genus, including these two species, from Lake Erie. Whipple found this genus rather abundant at Chicago.

Crucigenia: A very small undetermined species of this genus occurred (1,000-4,225 per c. m.) in the silk-net collections from Gary and Chicago. This form did not appear in any of the other collections, nor was it mentioned by any of the earlier investigators.

Pediastrum: Although *Pediastrum* is quite a common plankton genus, it was never abundant in our collections. *P. boryanum* (Turpin) Menegh. occurred rarely in the Dec. 1887 and Aug. 1888 collections and appeared in small numbers (100-7,000 per c. m.) Oct. 17-18, 1926 and May 14, 1927 at Dunes Park and July 10, 1927 at Chicago. *P. simplex* var. *duodenarium* (Bail.) Rab. occurred only in the silk-net collections Oct. 17, 1926 from Dunes Park and Michigan City. *P. duplex* Meyen. was present (40-2,500 per c. m.) in the collections of Oct. 17-18, 1926. Thompson reported only *P. boryanum* from Traverse Bay. Snow listed six species of this genus including these three in Lake Erie. Whipple found this genus to be common in the Chicago area.

PROTOZOA

Protozoa, because of their small size and relatively small abundance, were of little importance in the plankton, even in the warmer seasons when they were most numerous. The collections contained at least twenty-one species of protozoans, eleven of which seemed to be typical plankton forms. The others probably were washed up from the bottom or from the vegetation growing on piles and floating timbers. Smith (1894) found ten species in the surface plankton of Lake St. Clair and a number of others from the vegetation and bottom. Kofoid (Ward, 1896) reported eighteen species from the plankton of the Traverse Bay region, but no littoral species. Jennings (1900) listed twenty-two species as limnetic in Lake Erie. Whipple (Leighton, 1907) listed nine genera as present in the waters of Lake Michigan at Chicago.

Centropyxis: *Centropyxis aculeata* Stein occurred sparingly in the July 1888 collections and appeared in small numbers (200 per c. m.) Oct. 17, 1926 at Sawyer and May 15, 1927 at Dunes Park. This species was never abundant enough to form an important element of the plankton. Kofoid reported it from bottom tows in Traverse Bay.

Difflugia: Four species of *Difflugia* were found. *D. globosa* Duj., the most abundant of all the rhizopods, reached a maximum of 25,000 per c. m. in the autumn of 1926 but was rather rare (300 per c. m.) in the spring of 1927. This species was listed as abundant in Traverse Bay by Kofoid and in Lake St. Clair by Smith. *D. lebes* Penard appeared in small numbers in the Sept. and Oct. collections of 1888. *D. corona* Wallich occurred only sparingly (150-600 per c. m.) May 14-15 at Dunes Park. Smith found this species in the shallow waters of Lake St. Clair. *D. pyriformis* Perty was found in very small numbers (200 per c. m.) May 15, 1927 at Dunes Park. Kofoid reported this species as rare in the plankton of Traverse Bay.

Actinophrys: *Actinophrys sol* Ehr. appeared in small numbers (200 per c. m.) May 15, 1927 at Dunes Park. Kofoid reported this species as adventitious in the plankton of Illinois River. Smith found this species in small numbers in the surface tows from Lake St. Clair.

Trachelomonas: *Trachelomonas hispida* Perty was found abundantly (165,000 per c. m.) in the filter-paper collections May 14, 1927 from Dunes Park. This species and others of this genus may have been abundant in the plankton when the older series of collections were made, but because of their size they probably escaped or were impossible to identify in the preserved material. Landacre (1908) reported this species from Sandusky Bay.

Euglena: *Euglena oxyuris* Schmarda occurred frequently May 14, 1927 at Dunes Park, reaching a maximum of 275,000 per c. m. in the filter-paper collections. *E. viridis*, which was reported by both Jennings and Landacre from Lake Erie, was not identified in any of the collections examined.

Chlamydomonas: An undetermined species of *Chlamydomonas* was found abundantly (330,000 per c. m.) in the filter-paper collections May 14, 1927. This form did not appear in any of the other collections, probably escaping through the meshes of the silk net. Snow (1902) listed three species of this genus from Lake Erie.

Phacus: *Phacus triqueter* Ehr. occurred occasionally (16,500 per c. m.) in the filter-paper collections May 14, 1927. This species was not found in any of the silk-net collections. In Lake Erie Jennings reported it from East Harbor, and Landacre listed it from Sandusky Bay.

Cryptomonas: *Cryptomonas ovata* Ehr. was found in the filter-paper collections (110,000 per c. m.) May 14, 1927 at Dunes Park. This form was observed only in fresh living material, and probably because of its minute size it did not appear in the silk-net collections. Whipple reported this genus as present at Chicago.

Eudorina: *Eudorina elegans* Ehr. was found in small numbers (200-1200 per c. m.) in 1926 and 1927. This colonial flagellate has not been reported by previous investigators from the Great Lakes. Kofoid found the closely related form *Pandorin morum* Bory de. St. Vincent in Traverse Bay.

Uroglena: Colonies of *Uroglena americana* Calkins occurred occasionally in two recent collections. Kofoid reported *U. volvox* Ehr. as common in the form *Pandorin morum* Bory de St. Vincent in Traverse Bay.

Dinobryon: *Dinobryon sertularia* Ehr. was the most abundant protozoan in the plankton. This species seemed to have a swarming tendency, for it was found abundantly in some collections only to be almost absent from others of the same date and place. It was present also in small numbers in the Sept. 1888 collections. In those of Oct. 1926 it reached an abundance of 900,000 per c. m., and in the filter-paper collections of May 14, 1927 it reached an abundance of 7,000,000 per c. m. Kofoid found this species to be abundant in the Traverse Bay region. Smith reported it as abundant in Lake St. Clair, and Whipple listed it as plentiful in Lake Michigan at Chicago.

Ceratium: *Ceratium hirundinella* Müll. was common in the collections of Oct. 1926, and occurred in mall numbers in those of Aug. and Sept. 1888. Kofoid found this species abundant in the Traverse Bay region, and Smith also found it numerous in the surface tows of Lake St. Clair.

Peridinium: *Peridinium tabulatum* Ehr. occurred occasionally in the collections of Aug. 1888 but did not appear in any of the others. As this is a common species in other waters, its apparent scarcity in our collections may be due to its small size and consequent loss through the meshes of the silk net. Kofoid found *P. tabulatum* common in the summer at Traverse Bay, Smith listed it as scarce in Lake St. Clair, and Jennings recorded it from several parts of Lake Erie. Whipple listed this genus as fairly common in July at Chicago.

Codonella: *Codonella cratera* Leidy occurred in small numbers in the collections of July, Aug. and Sept. 1888 and in some of the 1926-1927 collections reaching a maximum abundance of 32,000 per c. m. in a silk-net collection July 10, 1927 from Chicago. This small-shelled ciliate was reported by Kofoid as abundant in the Traverse Bay region. Smith found it abundant in the plaukton of Lake St. Clair and Jennings listed it from Lake Erie.

Vorticella: One or more undetermined species of *Vorticella* occurred occasionally in the collections of Sept. and Oct. 1888. They were found in consider able numbers (220,000 per c. m.) attached to floating debris and diatoms in the filter-paper collections May 14, 1927 at Dunes Park. Kofoid found *Vorticella* in the plankton of the Traverse Bay region. Smith recorded this genus as abundant on diatoms in Lake St. Clair. Jennings found *V. rhabdostyloides* Kellicott common in Lake Erie. Whipple listed this genus as common in Lake Michigan at Chicago.

Thuricola: A few specimens of an undetermined species of *Thuricola* were found attached to floating debris in a collection of Sept. 1888. This form was adventitious in the plankton, belonging more properly to the shore and bottom. Smith found closely related forms to be scarce among the algae in the shallow waters of Lake St. Clair.

Podophrya: An undetermined species of this genus occurred attached to floating debris in a Sept. 1888 collection. Smith reported *P. cyclopum* C. & L. on algae in Lake St. Clair. The same species was found rarely by Kofoid attached to *Epischura lacustris* Forbes in the Traverse Bay region.

Acineta: Several undetermined species of *Acineta* were found attached to algae in the collections of Sept. 1888. Jennings reported finding *A. mystacina* Ehr. attached to floating material in Lake Erie.

COELENTERATA

Several species of *Hydra* are the only coelenterates known to occur in the Great Lakes. *Hydra oligactus* Pallas was found sparingly (100 per c. m.) in a silk-net collection Oct. 17, 1926 from Michigan City. It

occurred in small numbers in the December 1887 and the September 1888 collections. Welch and Loomis (1924) reported the occurrence of *Hydra* in great abundance in Lake Erie and in Lake Michigan near Michigan City, Indiana.

NEMATHELIMINTHES

Free-living nematodes are predominately bottom forms in Lake Michigan. A few undetermined nematodes were found in the collections May 14, 1927 from Dunes Park. These were probably bottom forms washed up from the shallow waters by wave action.

ROTATORIA

Sixteen species of rotifers were found in the plankton of Lake Michigan, although none of them were ever very abundant. These species were all typical plankton forms, several of them being distributed through most of the collections. The rotifers of the Great Lakes as a group have been thoroughly studied by several investigators. Kellicott (1896, 1897) published a long list of the rotifers of Lake Erie in the region of Sandusky Bay, including both bottom, shore, and limnetic forms. Jennings (1894) reported twenty-four limnetic species occurring in Lake St. Clair and referred to the distribution of many species in Lake Erie. In a later and more complete survey covering most of the rotifers of the United States, Jennings (1900, 1902) gave a list of twelve species as occurring in the plankton of Lake Erie and listed seven other species as occurring in the plankton of others of the Great Lakes. Jennings (Ward 1896) found the rotifers less abundant in the Traverse Bay region than in Lake St. Clair; he reported the limnetic forms in the Traverse Bay region to be well represented and listed fourteen limnetic and eight bottom species.

Synchaeta: Two species of *Synchaeta* occurred in our collections, *S. stylata* Wierzejski on Oct. 17-18, 1926 and *S. tremula* Müll. on May 14-15, 1927. No species of this genus were found in the earlier collections; they may have been present but overlooked, as this genus is sometimes very hard to identify in ordinarily preserved collections. *S. tremula* was doubtfully reported by Kellicott from a marsh near Lake Erie. Kellicott found *S. stylata* and *S. pectinata* Ehr. abundantly in Sandusky Bay. Jennings reported *S. stylata* as present in Traverse Bay, rare in Lake Erie, and one of the most abundant species in Lake St. Clair. Whipple listed this genus as present in Lake Michigan at Chicago.

Polyarthra: *Polyarthra trigla* Ehr. (*P. platyptera* Ehr.) was found in small numbers in the May, July, and Sept. collections of 1888. This species also occurred in the collections of Oct. 1926 and May and July 1927, ranging from 100 to 16,000 per c. m. Jennings found this species abundant in Lake Erie and reported it for the Traverse Bay region. Whipple listed it as present in Lake Michigan at Chicago.

Diurella: Small numbers (400 per c. m.) of an undetermined species of *Diurella* were found Oct. 17, 1926 at Michigan City. Jennings found many species of this genus in Lake Erie.

Trichocerca: A few specimens of *Trichocerca cylindrica* (Imhof) *(Rattulus cylindrica* Imhof) occurred in one of the September 1888 collections. Jennings found many species of this genus including *Rattulus cylindricus* Jennings present in Lake Erie.

Lepadella: *Lepadella oblonga* (Ehr.) *(Metopidia lepadella* Levander) was found rarely only in the July 1888 collections. This is not a typical limnetic species but probably a migrant from the bottom. Kellicott reported this species from Sandusky Bay. Jennings found it in Lake St. Clair and also in swamps about Lake Erie.

Trichotria: *Trichotria tetractis* (Ehr.) *(Dinocharis tetractis* Ehr.) was found sparingly in one of the July 1888 collections. This species is probably a migrant from the bottom, as Jennings listed it from the bottom vegetation of Lake Erie and Lake St. Clair.

Keratella: *Keratella (Anuraea) cochlearis* (Gosse) which was found occasionally in the May, July, Aug., Sept., and Oct. collections of 1888 was relatively abundant in all the 1926-1927 collections, reaching a maximum of 17,000 per c. m. in the filter-paper collections of May 14, 1927 from Dunes Park. *K. quadrata* (Müll.) *(A. aculeata* Ehr.) was found (300-8,450 per c. m.) in several of the 1927 collections and more rarely in the July 1888 collections. Jennings found *K. cochlearis* and *K. quadrata* abundant in Lake Erie, Lake Michigan, and Lake St. Clair. *K. cochlearis* was reported by Vorce (1881) from Lake Erie and by Kellicott from Sandusky Bay, as also was *A. stipitata* Ehr. Jennings reported *A. surrulata* Ehr. from Lake St. Clair. Whipple listed this genus as common at Chicago.

Notholca: *Notholca longispina* Kellicott was characteristic of most of the plankton collections, appearing in all except those of Dec. 1887, April 1888, and May and July 1927. Jennings found it in Lake St. Clair and in Lake Michigan. *N. striata* Müll. *(N. acuminata* H. & G.) occurred sparingly in our collections of July 1888 and May and July 1927. Forbes (1883) mentioned this species as occurring in the plankton of Lake Michigan at Chicago.

Brachionus: Only a single species of this common plankton genus was found in our collections, a single specimen of *Brachionus capsuliflorus* Pallas occurring in an Aug. 1888 collection. Kellicott reported two species of this genus, but not including this species, from Sandusky Bay. Jennings found this species and *Brachionus militaris* Ehr. abundant in the shallow parts of Lake Erie.

Schizocerca: A very few (50 per c. m.) specimens of *Schizocerca diversicornis* Daday were found Oct. 17, 1926 at Michigan City. This species, which is more typical of small shallow lakes, has not been reported from the Great Lakes by previous investigators.

Asplanchna: *Asplanchna priodonta* Gosse was found occasionally in the Aug. collections of 1888. Kellicott found this species abundant and *A. herrickii* de Guerne rare in Sandusky Bay. Jennings reported *A. priodonta* from the plankton of Lake Michigan and Lake Erie.

Filinia: *Filinia (Triarthra) longiseta* (Ehr.) occurred sparingly (800 per c. m.) at Chicago, July 10, 1927. Kellicott found this species abundant in Sandusky Bay.

Conochiloides: *Conochiloides dossuaris* (Hudson) was found in small numbers in the Aug. 1888 collections. This species was reported from Lake Erie by Kellicott, but not in any other of the Great Lakes by other workers. The

closely related form *C. hippocrepis* (Schrank) *(C. volvox* Ehr.) has been reported from Lake St. Clair by Jennings and from Lake Erie by Kellicott. Another similar form *C. unicornis* Rousselet was common in tows from Lake Erie (Jennings) (Kellicott) and from Lake St. Clair (Jennings).

CLADOCERA

Eleven species of cladocerans occurred in our collections. Their relative abundance was greater in the older series than in the recent series, undoubtedly because of the type of net used for collecting. Two species, *Daphnia retrocurva* Forbes and *Bosmina longispina* Leydig, seemed to be generally typical of the plankton, as they occurred in most of the collections. Smith (1871) reported two species from Lake Superior. Birge (Reighard, 1894) found four species in the plankton of Lake St. Clair. Ward (1896) stated that the Cladocera formed an important element of the fauna of Lake Michigan in the Traverse Bay region; he found 25 or 30 species in this region but did not state how many of them belonged to the plankton. Whipple reported finding only one genus in the plankton of Lake Michigan at Chicago. Nine species of Cladocera were listed by Birge (1881) from the Chicago Water Supply, nine species by Sars (1916) from the Georgian Bay region, and twenty-seven species by Bigelow (1922) from Lake Ontario, Lake Erie, and Georgian Bay.

Sida: *Sida crystallina* (Müll.) occurred rarely in the Sept. 1888 collections and also (370 per c. m.) Oct. 17, 1926 at Dunes Park. Forbes found this species occasionally in Lal e Superior. Birge found it abundant in Lake St. Clair. Sars and Bigelow both reported it from Georgian Bay. Bigelow found it fairly common in the shallow parts of Lake Erie.

Diaphanosoma: *Diaphanosoma leuchtenbergianum* Fischer was occasional in the Sept. 1888 collections, but was common in the Oct. 1888 collections. Bigelow found *D. brachyurum* (Liêven) fairly common in Georgian Bay and Lake Erie. He reported that *D. leuchtenbergianum* was not as common in the waters of Georgian Bay.

Daphnia: *Daphnia retrocurva* Forbes occurred in nearly all the collections except those of 1927, running nearly throughout the year in the 1887-1888 collections. Because of its large size, it seemed to be quite common (100-300 per c. m.) *D. longispina* (Leydig) occurred in small numbers in the collections of Nov. 1887 and July and Sept. 1888. The species of *Daphnia* reported from the Great Lakes by the early investigators are rather confused, because of the use of synonyms and European specific names. Smith reported *D. galeata* Sars and *D. pellucida* Müll. from Lake Superior. Forbes (1881) reported *D. longispina* var. *hyalina* Leydig from Lake Michigan, and later (1887) he reported *D. retrocurva* from Lake Superior. Birge listed *D. kahlbergiensis* var. *intexta* Forbes and *D. retrocurva* from Lake St. Clair. Whipple reported this genus as occurring in Lake Michigan at Chicago. Sars found *D. retrocurva* in Georgian Bay. Bigelow reported *D. pulex* (de Geer), *D. retrocurva*, and *D. longispina* from Lake Erie and Lake Antario.

Ceriodaphnia: *Ceriodaphnia lacustris* Birge occurred in small numbers (100 per c. m.) in the Sawyer collections only. Sars found *C. scitula* Forbes in the plankton of Georgian Bay. Bigelow reported four species of this genus from Georgian Bay, including *C. lacustris* as "uncommon."

Bosmina: *Bosmina longispina* Leydig, the most abundant cladoceran of Lake Michigan, was one of the conspicuous organisms of the plankton. It was common in nearly all the collections, being entirely absent only from those of Dec. 1888, and reached a maximum of 120,000 per c. m. July 10, 1927 at Chicago. Birge reported this species as abundant in Lake St. Clair. *B. obtusirostris* Sars, which has not been reported previously from the Great Lakes, occurred (100 per c. m.) Oct. 17, 1926 at Dunes Park. *B. longirostris* (Müll.) occurred rarely from April until Nov. in the 1888 collections. This species was found occasionally by Forbes in the plankton of Lake Superior. Sars and Bigelow both reported this species from Georgian Bay, and Bigelow also found it in Lake Erie.

Alona: An undetermined species of *Alona* was found once in a collection of Aug. 1888. Forbes reported an undetermined species of this genus from Lake Superior. Birge found four species of *Alona* in Lake St. Clair. Bigelow found *A. affinis* (Leydig) abundantly in the plankton from shallow waters of Georgian Bay.

Chydorus: *Chydorus sphaericus* (Müll.) occurred occasionally July 1888 and rarely Sept. 1888 but was not found in any of the 1926-1927 collections. Forbes found *C. sphaericus* and *C. gibbus* Lillj to be common in Lake Superior. Birge reported *C. sphaericus* and *C. globosus* Baird in Lake St. Clair. Bigelow found three species of this genus, including *C. sphaericus*, in Georgian Bay.

Leptodora: *Leptodora kindtii* (Focke) occurred occasionally in the collections of Oct. 1888 and July 1927. This large form was reported by Forbes as occasional in Lake Superior and in Lake Michigan, by Birge as occasional in Lake Michigan and in Lake St. Clair, by Sars as common in Georgian Bay, and by Bigelow as common in Georgian Bay and in Lake Erie.

COPEPODA

Nine species of copepods, all typical limnetic forms, were found, three of them occurring in a majority of the collections. Like the cladocerans, they were more abundant in the earlier collections than in the recent. Smith (1871) mentioned the occurrence of several species of copepods in Lake Superior but did not designate the species or indicate their abundance. Forbes (1882) found four species abundant in Lake Michigan, and in Lake Superior (1887) he found nine species, most of which were common. (Marsh (1895) found nine species of copepods in the plankton of the Traverse Bay region which were the same as those of the other Great Lakes; he reported six species from Lake Erie, nine species from Lake Michigan, and sixteen species from the plankton of Lake St. Clair.

Epischura: *Epischura lacustris* Forbes occurred quite abundantly in all the early collections except those of Dec. 1887 and July 1888. For some unknown reason this species, which because of its abundance and large size was very prominent in the earlier series, did not appear at all in the recent series. Forbes found this species abundant in Lake Michigan at Chicago and Traverse Bay and also in Lake Superior. Marsh reported it as common in Lake St. Clair, Lake Erie, and Lake Michigan.

Diaptomus: Three species of *Diaptomus* were found in our collections. *D. minutus* Lillj. was common in the collections of Nov., July, Aug., Sept., and Oct. 1887-1888, and in those of 1926-1927. This species was quite conspicuous, ranging in abundance from 300 to 1600 per c. m. *D. ashlandi* Marsh was found (200-2,000 per c. m.) in 1926-1927. Marsh found both species in Lake Michigan and

Lake St. Clair and reported *C. minutus* as the most common copepod in the Great Lakes. *D. sicilis* Forbes occurred occasionally in the June, Aug., and Sept. collections of 1888. Forbes found this species abundant in Lake Michigan and in Lake Superior. Marsh found it common in both Lake Michigan and Lake St. Clair. Marsh also reported *D. oregonensis* Lillj. as occurring occasionally in Lake Michigan and in Lake Erie.

Limnocalanus: *Limnocalanus macrurus* Sars was found occasionally in the collections of Sept. 1888. Forbes found this species abundant in Lake Michigan at Chicago and also in Lake Superior. Marsh reported it from Lake Michigan and Lake St. Clair.

Cyclops: Three species of *Cyclops* occurred in our collections from Lake Michigan. *C. bicuspidatus* Claus was the most abundant, occurring in all the collections except those of Dec. 1887 and June 1888. This species was reported by Forbes as abundant in Lake Michigan and Lake Superior. Marsh mentioned it as the common *Cyclops* of the Great Lakes occurring in Lake Michigan, Lake St. Clair, and in Lake Erie. *C. prasinus* Fischer was abundant in the 1926-1927 collections and was fairly common in all the 1887-1888 collections except those of Dec., June, and July. Marsh (Ward and Whipple, 1918) stated that this species was common in the Great Lakes. *C. fimbriatus* Fischer was found occasionally in the July, Aug., Sept., and Oct. collections of 1888. This species was not mentioned, at least not under this name, by any of the previous investigators. A total of fourteen species have been reported from the Great Lakes by previous investigators, but many of these are synonyms.

Canthocamptus: An undetermined species of *Canthocamptus* occurred (4,225 per c. m.) in the collections of May 14, 1927 from Gary. Forbes found this genus to be rare in Lake Superior and Lake Michigan.

Summary

The uniformity of the plankton from year to year and from season to season strikingly demonstrates the stability of Lake Michigan as a fresh-water habitat. Comparisons of recent collections with those made forty years ago show that very little change has occurred in the general composition of the plankton and justify the inference that there have been no changes in temperature, currents, depth, and chemical composition of the water sufficient to influence the production of plankton. Of the species which were abundant in the 1887-1888 collections, only one, *Epischura lacustris* Forbes, was absent in the recent series. From the examination of the seasonal collections, there appeared to be a fairly constant and uniform phytoplankton throughout the year, although the zooplankton showed some response to seasonal conditions. Diatoms predominate at all times and constitute the majority of the organisms of the plankton, the same species being conspicuous in all the collections examined.

Acknowledgment

The writer wishes to thank Mr. R. E. Richardson and Mr. H. C. Oesterling, both of the Illinois State Natural History Survey, for much valuable criticism and assistance in preparing this paper.

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