4-1987

# Phytoplankton and Zooplankton Composition, Abundance and Distribution: Lake Erie, Lake Huron and Lake Michigan-1983

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## Repository Citation

Makarewicz, Joseph C., "Phytoplankton and Zooplankton Composition, Abundance and Distribution: Lake Erie, Lake Huron and Lake Michigan-1983" (1987). *Government Documents*. 44.
http://digitalcommons.brockport.edu/wr_misc/44

EPA-905/2-87-002
July 1987
GLNPO Report No. 87-06

# Phytoplankton and Zooplankton Composition, Abundance and Distribution: Lake Erie, Lake Huron and Lake Michigan - 1983

## Volume 1 - Interpretive Report

by

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September 1985

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# ABSTRACT

An in-depth comparison of phytoplankton and zooplankton from Lakes Erie, Huron and Michigan is presented based on extensive lake-wide surveys during spring, summer and autumn of 1983. This comparison was achieved by the application of standard and consistent identification, enumeration and data-processing techniques of plankton along north-south transects in Lakes Huron and Michigan and east-west transects in Lake Erie.

For Lakes Erie, Huron and Michigan respectively, 436, 411 and 452 algal taxa and 71, 61 and 73 zooplankton taxa were identified. Based on indicator species and species associations, the plankton assemblage was consistent with a mesotrophic-eutrophic designation for Lake Erie, oligotrophic designation for Lake Huron, and mesotrophic-oligotrophic designation for Lake Michigan.

Species lists for each lake are provided. Original source data for each station visit are provided in the attached microfiche.

# DISCLAIMER

This report has been reviewed by the Great Lakes National Program Office, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

# FORWARD

The Great Lakes National Program Office (GLNPO) of the United States Environmental Protection Agency was established in Region V, Chicago, to focus attention on the significant and complex natural resource represented by the Great Lakes.

GLNPO implements a multi-media environmental management program drawing on a wide range of expertise represented by universities, private firms, State, Federal and Canadian Governmental Agencies and the International Joint Commission. The goal of the GLNPO program is to develop programs, practices and technology necessary for a better understanding of the Great Lakes ecosystem and to eliminate or reduce to the maximum extent practicable the discharge of pollutants into the Great Lakes system. The Office also coordinates U.S. actions in fulfillment of the Great Lakes Water Quality Agreement of 1978 between Canada and the United States of America.

This report presents results of the phytoplankton and zooplankton portions of the water quality surveillance program conducted on Lakes Michigan, Huron and Erie in 1983 by GLNPO. Results of the physical and chemical portions of the surveillance program may be found in a companion report:

> Lesht, Barry M. and David C. Rockwell. 1985. The State of the Middle Great Lakes: Results of the 1983 Water Quality Survey of Lakes Erie, Huron and Michigan. Publication Number ANL/ER-85-2. Argonne National Laboratory, Argonne, Illinois 60439.

GLNPO gratefully acknowledges the contribution to this study of The Bionetics Corporation, with whom GLNPO contracted for assistance in the collection of samples and for the identification and enumeration of the phytoplankton and zooplankton. In particular, we extend appreciation to Norman A. Andresen, Mark A. Lamb, Louis L. Lipsey, Heather K. Trulli, Marc Tuchman and Thomas Morse.

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## ACKNOWLEDGEMENTS

This work would not be possible without the computer skills of Mr. Ted Lewis. I thank him for his continuing effort and dedication.

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# INTRODUCTION

The Laurentian Great Lakes ecosystem occupies a unique position in the development of the United States and Canada and could be considered as presenting one of the most complex water management problems in North America. Individually, the Great Lakes rank among the world's largest with Lakes Huron, Michigan and Erie, the subject of this report, ranking fifth, sixth and twelfth in size of the world's lakes. During the past decades, there has been an enormous population and industrial growth within their watersheds resulting in the accelerated eutrophication of these water bodies.

As a result of the declining water quality of the Great Lakes, Water Quality Agreements were signed in 1972 and 1978 between the United States and Canada. One of the main provisions was to limit the phosphorus in sewage treatment plant effluents. In addition, many states and the Canadian provinces have passed legislation on the water quality of these lakes. These include bans on phosphorus-based detergents in New York and Michigan and reduction in phosphate in detergents in the Province of Ontario.

This project reported here was initiated by the United States Environmental Protection Agency, Great Lakes National Program Office (GLNPO), to analyze phytoplankton and zooplankton samples from Lakes Erie, Huron and Michigan taken in 1983. Because phytoplankton are sensitive to water quality conditions and possess short carbon turnover rates, the determination of phytoplankton abundance and species composition have become established as methods to trace long-term changes in the lakes (Stoermer 1978, Munawar and Munawar 1982). Similarly, zooplankton have value as indicators of water quality and structure of the biotic community and have proved useful for complementing phytoplankton to assess the apparent effects of water quality conditions (Gannon and Stemberger 1978) and of fish populations (e.g. Brooks and Dodson 1965) on biota.

An in-depth planktonic (phyto- and zooplankton) comparison is presented based on extensive lake-wide surveys during spring, summer and autumn of 1983. This comparison was achieved by the application of standard and consistent identification, enumeration and data-processing techniques of plankton along north-south transects in Lakes Huron and Michigan and east-west transects in Lake Erie.

The primary objectives of this report include:

(1) To organize plankton data for use in eutrophication models;

(2) To characterize the composition and abundance of the phytoplankton and zooplankton for comparison with past conditions to the extent that they are known;

(3) To provide firm documentation with which future assessment of the changes in water quality of the lakes can be made; and

(4) To characterize the water quality by studying the abundance and autecology of phytoplankton and zooplankton.

# METHODS AND MATERIALS

Phytoplankton and zooplankton samples were collected by GLNPO personnel from Lakes Erie, Huron and Michigan during seven cruises during the spring, summer and autumn of 1983. Collection dates and station locations of routine plankton sampling are given in Tables 1, 2 and 3 and in Figures 1, 2 and 3. Locations of sampling sites on Lake Michigan were not consistent for the year (Table 3). Every other sampling date alternate east-west stations were sampled (e.g. 5 or 6, 10 or 11; Fig. 3). This selection of sites was based on previous studies which indicated that adjacent east-west sites were within homogeneous areas of the lake (Moll et al. 1985). For analytical purposes, east-west stations were combined, assuming that no significant difference in species abundance and composition existed between east-west stations, to give a single north-south transect. On the last cruise of the year on Lake Huron, samples were taken at a different set of stations (Fig. 2) and were not included in this analysis. All sites are also part of the Great Lakes International Surveillance Program.

An 8-liter PVC Niskin bottle mounted on a General Oceanics Rossette sampler with a guideline electrobathythermograph (EBT) was used to collect phytoplankton. One-liter composite phytoplankton samples were obtained by compositing equal aliquots from samples collected at depths of 1 and 2m above the bottom and at as many 5-meter intervals (5,10,15,20m, etc.) as allowed by total water depth.

Phytoplankton samples were immediately preserved with 10 mL of Lugols solution. 5-6% formaldehyde was added to each sample upon arrival in the laboratory. The settling chamber procedure (Utermöhl

1958) was used to identify (except for diatoms) and enumerate phytoplankton at a magnification of 500x. A second identification and enumeration of diatoms at 1250x was performed after the organic portion was oxidized with 30% $H_2O_2$ and $HNO_3$. The cleaned diatom concentrate was air dried on a #1 cover slip and mounted on a slide (75x25mm) with HYRAX$^{TM}$ mounting medium. Identifications and counts were done by Dr. Norman A. Andresen, Mr. Mark A. Lamb, Dr. Louis L. Lipsey, Ms. Heather K. Trulli, and Dr. Marc Tuchman of the Bionetics Corporation.

The cell volume of each species was computed by applying average dimensions from each sampling station and date to the geometrical shapes that most closely resembled the species form such as sphere, cylinder, prolate spheroid, etc. At least 10 specimens of each species were measured for the cell volume calculation. When fewer than 10 specimens were present, those present were measured as they occurred. For most organisms, the measurements were taken from the outside wall to outside wall. With loricated forms, the protoplast was measured, while the individual cells of filaments and colonial forms were measured. For comparative purposes, biovolume ($\mu m^3/L$) was converted to biomass ($mg/m^3$) assuming the specific gravity of phytoplankton to be 1.0($mm^3/mL=g/m^3$)(Willen 1959, Nauwerck 1963).

### Zooplankton

A Wildco Model 30-E28 conical style net (62-µm mesh net; D:L ratio = 1:3) with 0.5-m opening (radius=0.25m) was used to collect, where possible, two vertical zooplankton samples at each station. Vertical tows were taken from 2m above the bottom to the surface (long tow) and from 20m or from the top of the metalimnion to the surface (short tow). The short tow was analagous to an epilimnetic tow. In some cruises, a third tow (medium tow) from the bottom of the metalimnion to the surface was taken but was not analyzed in this report. Filtration volume and towing efficiency were determined with a Kahl flow meter (Model 00SWA200) mounted in the center of the net. Filtration efficiency averaged 84.5% (range = 33-225), 83.0% (range = 34-277) and 80.6% (range = 28-152), respectively, for Lakes Erie, Huron and Michigan for the entire sampling season. Following collection, the net contents were quantitatively transferred to one-liter sample bottles, narcotized with club soda and preserved with 5% formalin. Identification and enumeration of zooplankton follow Gannon (1971) and Stemberger (1979) and were done by Mr. Tom Morse of the Bionetics Corporation.

Raw counts were converted to number/mL by Bionetics, Inc. With zooplankton, abundances were originally determined based on a sample volume calculated from the depth of tow. All abundance values and sample volumes were recalculated using the volume of water actually filtered.

Abundances and dimensions (phytoplankton only) of each species were entered into a Prime 750 computer using the INFO (Henco Software, Inc., 100 Fifth Avenue, Waltham, Mass.) data management system. Biovolumes were calculated only for phytoplankton and placed into summaries for each sampling station containing density (cells/mL), biovolume ($\mu m^3/mL$) and relative abundance of species. In addition, each division was summarized by station. Summary information is stored on magnetic tape and is available for further analysis.

# RESULTS

## PHYTOPLANKTON

### Annual Abundance of Major Algal Groups

Species lists (Tables A1-A3) and summary tables of abundance (Tables A7-A9) and biovolume (Tables A4-A6) are in Volume 2 - Data Report.

### LAKE ERIE

The phytoplankton assemblage was composed of 436 alga taxa representing 105 genera from eight divisions: Bacillariophyta, Chloromonadophyta, Chlorophyta, Chrysophyta, Cryptophyta, Cyanophyta, Euglenophyta and Pyrrhophyta (Table 4). The Bacillariophyta possessed the largest number of taxa (225) and biovolume (59.9% of the total), while the second largest number (113) and biovolume (14.9%) were observed for the Chlorophyta (Tables 4 and 5). Highest overall densities were attained by the blue-green algae (89.6%). The average density and biovolume for the sampling period were 40,055 cells/mL (range = 27,120 to 49,151) and 1.36 $mm^3$/L (range = 0.63 to 1.80), respectively, for all stations.

### LAKE HURON

The phytoplankton assemblage was composed of 411 alga taxa representing 90 genera from eight divisions. The Bacillariophyta possessed the largest number of taxa (211) and biovolume (68.2% of the total), while the second largest number of taxa (75) was observed for the Chlorophyta (Table 4). The Cryptophyta attained the second highest biovolume (8.29%) (Table 5). Highest overall densities were attained by the blue-green algae (89.5% of total). The average density and biovolume for the sampling period were 19,147 cells/mL (range = 11,700 to 30,085) and 0.38 $mm^3/L$ (range = 0.14 to 0.75), respectively, for all stations.

LAKE MICHIGAN

The phytoplankton assemblage was comprised of 452 taxa representing 106 genera from eight divisions. The Bacillariophyta possessed the largest number of taxa (221) and biovolume (56.41% of the total), while the second largest number of taxa (88) were observed for the Chlorophyta (Table 4). The Cryptophyta accounted for the second highest biovolume (13.43%) (Table 5). Highest overall densities were attained by the blue-green algae (92.2% of total). The annual average density and biovolume were 29,839 cells/mL (range = 14,944 to 40,830) and 0.42 $mm^3/L$ (range = 0.17 to 0.58), respectively, for all stations.

## Seasonal Abundance and Distribution of Major Algal Groups

LAKE ERIE

Seasonally, abundance (cells/mL) increased from April to May (Fig. 4a). In late June-early July, the density was still high (49,151 cells/mL) but was followed by a general decrease till the end of October when abundance increased to 43,966 cells/mL. A different pattern emerged from the seasonal biovolume totals (Fig. 4b). Similar to abundance, biovolume increased from April to early May. Unlike abundance, biovolume decreased to late June-early July and then generally increased to the end of October. The biovolume decrease to late June-early July was due to a decline in the diatoms from 1,109 to

251 cells/mL. Abundance (cells/mL) was maintained by increases in the smaller chrysophytes, cyanophytes and the cryptophytes.

Accounting for 70 to 85% of the phytoplankton community biovolume (Fig. 5), the Bacillariophyta were dominant. By late June the diatoms decreased and remained depressed to late August when they began to increase in importance with the plankton community again. During the summer period, the diatoms were succeeded by the Chrysophyta and Pyrrhophyta in late June and the Chlorophyta in early August. The Cyanophyta peaked in late August but were not major contributors to the biomass of the phytoplankton community.

## LAKE HURON

Seasonally, abundance was bimodal with two peaks (May-July and mid-August). Abundance increased from April to May, was still relatively high in early July (24,716 cells/mL), was lower in early August, reached a second peak in mid-August (30,085 cells/mL) and declined till late October. The second peak was caused by a bloom of small Cyanophyta. A similar seasonal pattern for biovolume was apparent (Fig. 4b) with the exception of the second peak which was absent due to the small biovolume contribution of the abundant blue-green algae.

The Bacillariophyta were dominant throughout the year but had a bimodal distribution accounting for >75% (range = 75-84%) of the plankton biovolume in April, May and late June-early July peak and 59% of the phytoplankton biovolume in late October (Fig. 6). With the decrease in the diatoms in early August, which was a month later than in Lake Erie, a seasonal succession was evident with the Chrysophyta peaking in early July, the Cryptophyta in early August, the Cyanophyta and Pyrrhophyta in late August followed by a second peak of the Cryptophyta in mid-October. The Chlorophyta increased in importance (~19% of the total biovolume) by early August and maintained this level to the end of the study in October.

### LAKE MICHIGAN

Seasonally, abundance (cells/mL) increased from April to early July (36,868 cells/mL), decreased to 14,944 cells/mL in early August and increased to 48,305 cells/mL in late October (Fig. 4a). A completely different biovolume pattern from the abundance pattern was evident. The seasonal abundance pattern in Lake Michigan was dissimilar to the biovolume pattern in late July and October due to the large increase in Cyanophyta which did not contribute heavily to the biomass of the phytoplankton because of their small size. The seasonal biovolume pattern in Lake Michigan was similar to that of Lake Huron's (Fig. 4b).

The Bacillariophyta were dominant accounting for as much as 73% of the phytoplankton biovolume during the spring and autumn bloom (Fig. 7). With the decrease in the diatoms in early and mid August, which was a month later than in Lake Erie, a seasonal succession was evident with the Chrysophyta peaking in early July, the Chlorophyta and Cryptophyta in early August, the Pyrrhophyta and a second peak of the Chrysophyta in late August, the Cyanophyta in mid-October, and a second peak of the cryptophytes in late October.

## Geographical Abundance and Distribution of Major Algal Groups

### LAKE ERIE

The mean phytoplankton abundance for the sampling period was considerably greater at the three western stations (60,000-70,000 cells/mL) than in the rest of the lake (Fig. 8). This higher abundance was caused mostly by the greater abundance of the Cyanophyta in the western end of the lake. However, the Bacillariophyta, Chlorophyta, Chrysophyta and Cryptophyta all possessed a general pattern of decreasing abundance from west to east. The green algae did have a curious increase in abundance at Stations 37 and 73 which was not duplicated in any of the other algal groups. This increase at Stations 37 and 73 was due to a bloom of green algae on the 6-8 August and 22-23 August cruises. Density (cells/mL) on these dates ranged from 1,546 to 3,992 cells/mL as compared to an average of 625 cells/mL for the other cruises.

Seasonally, the pattern of decreasing abundance from west to east occurred on each cruise except on the 27 June-1 July and 21-24 October cruises when the trend was reversed (Fig. 9) with abundance increasing toward the eastern end of the lake. An increase in the Cyanophyta and to a smaller degree in the Cryptophyta at the eastern end of the lake accounted for this pattern.

## LAKE HURON

The mean phytoplankton abundance for the sampling period decreased from north to south to Station 15 (Fig. 10). Abundance increased at Station 15 and then decreased slightly southward. Much of this geographical distributional pattern was determined by the abundance pattern of the Cyanophyta. However, the Chlorophyta and Bacillariophyta had similar, although not as distinct, abundance patterns as did the Cyanophyta from north to south. No distributional pattern was apparent for the Cryptophyta while a general decrease in

Chrysophyta abundance from north to south was evident with the exception of Station 37. Chrysophyte abundance was drastically lower at Station 37.

The seasonal geographical abundance patterns of the algal divisions (Fig. 11) differed significantly from the total abundance patterns (Fig. 10). Abundance was similar from the north to the south but increased slightly from Station 15 southward on the 21-24 April cruise. In the 6-8 May cruise, densities ranged from 10,000-15,000 cells/mL at northern stations (Stations 61 to 27) and increased to ~50,000 cells/mL at the southern stations in the 6-8 May cruise. In early August, the distributional pattern had reversed with the higher abundances occurring at the northern stations (Stations 61 and 54). Higher abundances also occurred at the northern stations during the cruise of 19-21 August.

The seasonal geographical abundance patterns were determined by the abundance pattern of the Cyanophyta and to a lesser degree by the diatoms, chrysophytes and unidentified flagellates in the April and May cruises. The higher densities at the northern stations in early August were predominantly caused by the Cyanophyta and to a lesser degree by the greens and unidentified flagellates. The sharply higher abundances at Stations 61, 45, 37 and 12 on the 19-21 August cruise were due to higher abundances of the diatoms, green algae, blue green algae and the unidentified flagellates.

## LAKE MICHIGAN

The mean phytoplankton abundance for the sampling period generally decreased from north to south with two small peaks at Station 41 and at Station 6 at the most southern sampling point (Fig.

12). This abundance pattern could be attributed mostly to Cyanophyta and to a lesser degree to the Bacillariophyta. The Chlorophyta, Chrysophyta and Cryptophyta had two abundance peaks on the north-south transect: Station 64 and Stations 41 and 34.

Seasonally, the various cruises generally followed the same north-south pattern (Fig. 13) as the mean annual phytoplankton distribution. Abundances were high in the south at Station 6 and at the northern stations (Stations 77, 64, 57) in April, May, early and late August and late October. Only on the 12-15 October cruise did a maximum at Station 6 not occur. On this cruise, two peaks did occur: at Station 77, the northern most sampling point, and at Station 41. Maximum densities were observed for Bacillariophyta, Chlorophyta, Cyanophyta, Chrysophyta and the unidentifed flagellates at Station 77 for this cruise.

## Regional and Seasonal Trends in the Abundance of Common Taxa

### LAKE ERIE

Common species (Table 6) were arbitrarily defined as those possessing a relative abundance of >0.1% of total cells or >0.5% of the total biovolume.

### Cyanophyta

#### Anacystis marina Dr. & Daily

A. marina is widely distributed as plankton in fresh, brackish and sometimes marine waters. It is rarely reported, probably because it is easily overlooked (Humm and Wicks 1980). Cells range in size from 0.5-2.0 µm in diameter. Because a number of varying shaped cells were included as A. marina during identification, it is likely that more than one species are being grouped together (Andresen 1985).

This was the dominant phytoplankter within the study area representing 83% of the total algal abundance (cells/mL) but only ~0.7% of the total algal biovolume. An average density of 33,167 cells/mL was observed for the study period with a maximum density of 141,208 cells/mL observed on 9 May 1985 at Station 55. Abundance was generally higher at the western end of the lake with maximum densities in May and June (Fig. 16a). Makarewicz (1985) reported this species from the mouth of Niagara River and the Oswego River in Lake Ontario. There are no other reports of this species in Lake Erie.

#### Anacystis montana f. minor Dr. & Daily

Humm and Wicks (1980) noted that A. montana was planktonic and possessed a worldwide distribution in freshwater and in brackish water habitats. In Lake Ontario at the mouth of the Oswego River, this species was observed to have a bimodal distribution with a peak in late July and October (Makarewicz 1985). Seasonally in Lake Erie, only one abundance peak was observed in mid-October (Fig. 14a). Average density was 219 cells/mL with a maximum of 5,072 cells/mL on 19 October 1983 at Station 55 (Table 6).

Coccochloris peniocystis Kütz.

According to Humm and Wicks (1980), most reports of this species are from freshwater, but occasionally it is reported from marine habitats. It has a worldwide distribution. In Lake Erie in 1983, this species was the third most abundant species (Table 6) reaching a maximum density of 7,175 cells/mL on 27 July 1983 at Station 15. Seasonally, distribution appeared bimodal with late June and September peaks (Fig. 14b). Stoermer (1978) and Munawar and Munawar (1976) did not include either A. marina or C peniocystis in their lists of abundant, common or "less common" species for Lake Erie.

Aphanizomenon flos-aquae (Lyngb.) Breb.

Ogawa and Carr (1969) and Stoermer (1978) reported A.. flos-aquae to be abundant or occasionally abundant in Lake Erie. In 1970, Munawar and Munawar (1976) observed A. flos-aquae to be a "most common" species accounting for 14% (9-20%) and 8.5% of the mean biomass volume in the western and central basins, respectively. During August 1975 in the western basin, Gladish and Munawar (1980) reported this species as contributing 12.8% of the total biomass.

Seasonally, A. flos-aquae did not appear throughout the lake till late August and steadily increased in abundance to a mean of 437 cells/mL in late October (Fig. 14c). A maximum abundance of 2,561 cells/mL was observed on 21 October at Station 57 (Table 6). The biomass on this date and station was estimated to be 0.23 g/m$^3$, which was considerably lower than the maximum of approximately 1.6 g/m$^3$ reported by Munawar and Munawar (1976) in 1970 for the western basin. The percent of the total biovolume of this species for this study was only 0.5%.

_Coelosphaerium naegelianum_ Unger

Accounting for 0.59% of the total abundance (Table 6), this species reached a maximum density of 5,890 cells/mL on 22 August at Station 79 (mean abundance = 236 cells/mL). Seasonally, two abundance peaks were observed in August and October (Fig. 14b). Geographically, distribution was restricted to the western and central basins.

_Merismopedia tenuissima_ Lemm.

Accounting for 0.83% of the total cells present in this study and less than 0.01% of the total biovolume, the average density was 333 cells/mL with a maximum density of 15,544 cells/mL on 6 August at Station 60. A mid-summer abundance peak at the western end of the lake was evident (Fig. 17a).

_Oscillatoria limnetica_ Lemm.

According to Huber-Pestalozzi (1938), this species is often abundant in polluted waters. It is abundant in Lake Ontario, and its peak abundance is in June and July (Stoermer et al. 1974) although appreciable populations remain into the autumn (Munawar and Nauwerck 1971). Stoermer (1978) reported it as a common element of the Lake

Erie plankton although Munawar and Munawar (1976) did not list it as a common species (>5% of the total biomass) or less common species. This difference may be related to Munawar's use of biomass as an indicator of abundance. For example, in this study O. limnetica represented only 0.24% of the total biovolume but 1.15% of the total cells (Table 6). Seasonally, peak abundance was reached in late August (maximum 11,266 = cells/mL; Station 60) at the western end of the lake (Fig. 16c).

### Oscillatoria subbrevis Schmid.

Although this species had a relatively high abundance (1.01% of the total cells; 1.16% of the total biovolume), it was not commonly found throughout the lake (Fig. 17b). The high relative abundance was due to a single bloom (27,399 cells/mL) on one occassion (21 October) at Station 57. Average density was 404 cells/mL.

### Oscillatoria tenuis C.A. Ag.

This species experienced an isolated bloom of 5,081 cells/mL on 22 August at Station 55. In general, its geographical distribution was restricted to the western end of the lake (Fig. 16b). Average density was 80 cells/mL (Table 6).

## Chlorophyta

### Coelastrum microporum Nag.

Stoermer et al. (1974) reported this species as being widely distributed in the Great Lakes but only reaching appreciable abundance in eutrophic lakes. Taft and Taft (1971) reported it from western Lake Erie. Stoermer (1978) reported it as occasionally abundant.

In 1983, no obvious geographical pattern was observed. Seasonally, it was not observed until early August but steadily increased in abundance to the last sampling date in October (Fig. 14e). Maximum density was 2,291 cells/mL on 21 October at Station 18. With an average density of 135 cells/mL, this was the dominant green alga on a cells/mL basis (Table 6).

### *Cosmarium* sp.

Munawar and Munawar (1976) reported *Cosmarium* sp. as a common species of the eastern basin representing 13.0% and 10.5% of the total biovolume in the eastern basin in late August and September. A maximum of ~ 0.4 $g/m^3$ was observed in this bloom. Gladish and Munawar (1980) reported a relative biomass of 5.6% and 6.3% in the 5 August and 2 September 1975 sampling in the western basin.

Although an average of only 3 cells/mL were observed for the study period, *Cosmarium* sp. did account for 6.12% of the total biovolume (Table 6) for the entire lake. Considering biomass, this was the dominant chlorophyte. Mean maximum density was in early August (Fig. 14d). Maximum biomass (71.4% of the total biomass) for a single station was 1.0 $g/m^3$ (Station 15, 6 August). Mean biomass for all cruises for all stations ranged from 0.03 to 0.23 $g/m^3$, which was slightly lower than Munawar and Munawar's (1976) mean biomass values for 1970. Although Munawar and Munawar (1976) observed *Cosmarium* sp. as a common species only in the eastern basin, this species was common in 1983 throughout all three basins.

### *Monoraphidium contortum* (Thuret) Kom.-Legn.

With an average abundance of 82 cells/mL and a maximum density of

744 cells/mL (Station 78, 9 May), this species accounted for 0.2% of the total cells (Table 6). Seasonally, abundance was greatest in May for the lake (Fig. 14e).

*Mougeotia* sp.

Stoermer (1978) reported this species as being occasionally abundant, while Munawar and Munawar (1976) did not list it as a common or less common species in 1970. In early July and late August (Fig. 14f) of 1983, two peaks in abundance were observed. Mean density was only 14 cells/mL but because of the larger size of the cell, a mean biomass of 12 mg/m$^3$ (0.88% of the total biomass) (Table 6) was observed with a maximum biomass of 200 mg/m$^3$ on 22 August at Station 37.

*Pediastrum simplex* v. *duodenarium* (Bail.) Rabh.

Two abundance peaks, mid-August and mid-October, were observed in 1983 (Fig. 14f) which corresponded well with Munawar and Munawar's (1976) report of maximum mean percent of total biomass of 7.0% and 8.0% between 25-30 August 1970 and between 21-26 October 1970, respectively, for the eastern basin. In the present study, mean percent of the total biomass was 0.53 (Table 6) with a maximum of 11.0% and 6.9% at Station 18 (August, eastern basin) and at Station 79 (October, central basin). Biomass values ranged as high as 312 mg/m$^3$ in the central basin (Station 79, October) with a mean of 7 mg/m$^3$ for the lake. A maximum biomass of ~400 mg/m$^3$ was observed in October 1970 in the central basin (Munawar and Munawar 1976).

Oocystis borgei Snow

Seasonally, a peak abundance in late August (Fig. 14d) was observed. Average density and biomass were 16 cells/mL and 9,465 $\mu m^3$/L (9 mg/$m^3$). Maximum biomass was 87 mg/$m^3$ at Station 37 on 6 August. This species contributed 0.88% of the total biomass in 1983. Stoermer (1978) listed this species as a common element of the plankton, while Munawar and Munawar (1976) did not report it as a common (>5% of the total biomass) or less common species.

Scenedesmus ecornis (Ralfs) Chod.

This species has a seasonal and geographical distribution predominately confined to the central basin (Fig. 17c). A maximum population density of 2,193 cells/mL (300 mg/$m^3$) was observed at Station 37 on 6 August. Average density and biomass for the entire lake were 112 cells/mL and 20 mg/$m^3$, respectively. This species contributed the second largest amount (1.46%) to the total biomass of the Chlorophyta (Table 6).

Staurastrum paradoxum Meyen

Mean seasonal biomass peaked in late August (85 mg/$m^3$) and late October (47 mg/$m^3$). Mean biomass for the study period was 12 mg/$m^3$ for the entire lake. S. paradoxum contributed 1.03% of the total biomass (Table 6) and 2.6% of the biomass in the eastern basin on 21 October. Stoermer (1978) listed this species as a common element of the Lake Erie plankton. In 1970 this species accounted for 8.5% of the total biomass in the eastern basin between 21-26 October (Munawar and Munawar 1976).

### Chrysophyta

*Haptophyte* sp.

Average density was 159 cells/mL with a maximum of 785 cells/mL at Station 42 on 27 July. Seasonally, they are present from mid-May to late August with mean peak abundance in late June (Fig. 15a). This group contributed 0.40% of the total abundance.

### Cryptophyta

*Cryptomonas erosa* Ehr.

*C. erosa* is widely distributed in the Great Lakes (Stoermer et al. 1974), usually in low numbers. According to Huber-Pestalozzi (1968), it is a eurytopic organism, occurring both in oligotrophic lakes and often, in abundance, in eutrophic and slightly saline habitats. Stoermer et al. (1974) listed it as a common element of the Lake Erie plankton. Munawar and Munawar (1976) observed this species to be abundant throughout the year in the western and central basins reaching a biomass as high as ~2 $g/m^3$ in May of 1970 in the western basin. In the western basin, it contributed a maximum of 22% of the biomass on the 3-7 July cruise. In the central basin, *C. erosa* did contribute 34% of the biomass, but this was analagous to a biomass value of ~600 $mg/m^3$. On 1 July 1975, Gladish and Munawar (1980) reported this species to contribute 64.7% of the total biovolume.

In the present study, geographical abundance was greatest in the western basin and lowest in the eastern basin (Fig. 18a). Seasonally, peak density varied geographically. Peak biomass ($\bar{x}$ = 600 $mg/m^3$) occurred in the western basin (Stations 60,57,55) on 6 August. In the central basin (Stations 42,73,37,78,79), mean maximum biomass was 67

$mg/m^3$ during the May-June period with populations near zero by August. Average density and abundance were 31 cells/mL and 66 $mg/m^3$, respectively. For the lake, this species contributed 4.85% of the total biomass. In the western basin, this species accounted for 28.2% of the biomass on the 6 August cruise.

*Chroomonas norstedtii* Hansg.

Mean maximum seasonal abundance (119 cells/mL) was in early August (Fig. 15b). Average density was 31 cells/mL with a maximum of 515 cells/mL at Station 57 on 6 August (Table 6).

*Rhodomonas minuta* v. *nannoplanktica* Skuja

Stoermer (1978) listed this species as a common element of the Lake Erie plankton. From June to late October of 1970, this species was present in the eastern basin contributing as much as 37.5% of the total biomass (~1.6 $mg/m^3$) for a cruise. Seasonally, peak biomass was observed in early June in the eastern basin. Although present in the western and central basin, its contribution historically was never greater than 23% of the biomass for a cruise with biomass not exceeding 0.4 $mg/m^3$ (Munawar and Munawar 1976).

In 1983 mean biomass for the entire lake was 33 $mg/m^3$ with a maximum biomass (143 $mg/m^3$) at Station 79 on 9 May. Mean density was 565 cells/mL. A maximum in May was observed, but abundance was high through the summer (Fig. 15b). The high biomass in the eastern basin reported by Munawar and Munawar (1976) was not observed in this study. In fact, biomass is higher in the central basin than in the eastern basin. This species contributed 2.41% of the total biomass (Table 6).

Pyrrhophyta

Ceratium hirundinella (O.F. Mull.) Schrank

In 1970 this species was abundant (maximum biomass ~2 mg/m$^3$) in all three basins with biomass reaching a peak in August with a secondary peak in October in the eastern basin (Munawar and Munawar 1976). In 1975 this species accounted for 5.8% of the biomass on 12 August in the western basin (Gladish ad Munawar 1980). In 1983 C. hirundinella reached a peak in early August (Fig. 15f). Mean biomass and mean abundance were 92 mg/m$^3$ and 1.4 cells/mL, respectively. Maximum biomass (0.73 g/m$^3$; 30.5% biomass for the day) occurred at Station 37 on 6 August. For the entire lake, this species accounted for 4.89% of the total biomass (Table 6).

Peridinium aciculiferum Lemm.

Munawar and Munawar (1976) observed this species to be a common species (17% of biomass, central basin; 27% of biomass, eastern basin) with a maximum biomass of ~0.2 g/m$^3$ (central basin) and ~1 g/m$^3$ (eastern basin) in early May. Similarly in 1983, a peak in May was observed in the central basin ($\bar{x}$ = 64 mg/m$^3$) and in the eastern basin ($\bar{x}$ = 53 mg/m$^3$). In May the percent contributing to the biomass in the central and eastern basin was 3.8% and 14%, respectively. For the entire lake, this species accounted for 0.76% of the total biomass.

Bacillariophyta

Actinocyclus normanii f. subsalsa (Juhl.-Dannf.) Hust.

With an average density of 5.8 cells/mL and a maximum density of

88 cells/mL at Station 55 on 6 August, this species contributed 2.65% of the total biomass (Table 6). Two abundance peaks were observed in early August and in mid-October (Fig. 15e).

## Fragilaria capucina Desm.

High population densities of F. capucina are usually associated with eutrophic or disturbed conditions in the Great Lakes (Stoermer and Ladewski 1976). Hohn (1969) reported that it underwent a significant increase in abundance in western Lake Erie during the 40's, 50's and 60's. Verduin (1964) mentioned F. capucina as dominant in 1960-61, whereas Munawar and Munawar (1976) observed it to be common but not dominant in 1970 in the eastern and central basins. A maximum biomass of ~2.4 g/m$^3$ (October) in the central basin and ~0.4 g/m$^3$ (October and November) in the eastern basin was reported.

In the present study, higher abundances were associated with colder temperatures (Fig. 15d). Stoermer and Ladewski (1976) noted that occurrences of F. capucina were at nearly all temperatures, but high absolute and relative abundance was associated with higher temperatures in Lake Michigan.

Geographically, the western basin had the highest biomass (21 mg/m$^3$), followed by the eastern basin (12 mg/m$^3$) and the central basin (6 mg/m$^3$). The maximum biomass observed was 0.13 g/m$^3$ on 27 June at Station 60. Average density was 50 cells/mL (Table 6).

## Fragilaria crotonensis Kitton

This species can tolerate a wide range of ecological conditions

(Stoermer and Tuchman 1979). Munawar and Munawar (1976) observed this species to be abundant with decreasing maximum biomass from the western (7.9 g/m$^3$) to the central (~3.4 g/m$^3$) to the eastern (~1.0 g/m$^3$) basin.

Average biomass in 1983 was 47 mg/m$^3$ with a maximum of 0.27 g/m$^3$ at Station 60 on 25 April. Abundances were greater in the western end of the lake, and blooms tended to occur in April/May and in October (Fig. 18b).

### _Melosira granulata_ (Ehr.) Ralfs

This species is usually considered a member of the classic eutrophic diatom association (Hutchinson 1967). In 1970 distribution of _M. granulata_ was restricted to the western basin (Fig. 19) with a bloom in early August. Maximum biomass was 0.3 g/m$^3$ at Station 57 on 6 August.

### _Rhizosolenia_ sp.

Munawar and Munawar (1976) noted this organism as a less common species of the western basin present in samples from late September to December. In this study, a May bloom was observed (Fig. 15d). A maximum biomass of 3.8 g/m$^3$ was observed at Station 57 on 9 May.

### _Stephanodiscus alpinus_ Hust.

Hohn (1969) reported _S. alpinus_ as being an important component of the spring pulse in the western basin but being fairly abundant throughout the year. Munawar and Munawar (1976) did not observe this species in their 1970 collections.

In 1983 mean abundance and biomass were 9.5 cells/mL and 15

$mg/m^3$, respectively. Seasonal distribution was bimodal with a peak in early May and October with no obvious geographical pattern. This species contributed 1.08% of the total biomass.

Stephanodiscus binderanus (Kütz.) Krieg

This species appears to be most abundant in eutrophic environments during the cold season (Stoermer and Ladewski 1976). Hohn (1969) reported it as having a major increase in abundance in the 50's and 60's. In 1970 Munawar and Munawar (1976) observed M. binderana (= S . binderanus ) to be a common species (>5% of the total biomass) in the western and central basins in the April cruise. A maximum biomass of ~0.5 $g/m^3$ was observed in the western basin.

In 1983 the mean maximum abundance of S. binderanus peaked in May and in October (Fig. 15c). Geographically, abundance decreased from west (101 cells/mL; Station 60) to east (3.4 cells/mL; Station 9). Mean biomass in the western basin was 26 $mg/m^3$ with a maximum of 0.23 $g/m^3$ at Station 60 on 9 May.

Stephanodiscus niagarae Ehr.

In the Great Lakes, this species is abundant in naturally eutrophic areas (Stoermer and Yang 1970). Munawar and Munawar (1976) observed it in the autumn pulse to have a maximum biomass of ~0.6, 2.3 and 1.4 $g/m^3$ in the western, central and eastern basins, respectively. This one species accounted for 54-74% of the total biomass in the autumn in the central basin and 64-80% of the biomass in November and December in the eastern basin.

In the present study, mean biomass for all dates for the western, central and eastern basins was 61 $mg/m^3$, 0.9 $g/m^3$ and 0.29

$g/m^3$, respectively. A maximum biomass of 3.1 $g/m^3$ was recorded at Station 42 on 19 October. Mean biomass for the central basin on 21 October was 1.8 $g/m^3$ which accounted for 76% of the total biomass. A minor peak in abundance occurred in May with a major bloom in October (Fig. 15c). For the lake, this species contributed 37% of the biomass making it the dominant species on a biomass basis (Table 6).

### *Tabellaria flocculosa* (Roth) Kütz.

*Tabellaria fenestrata* was a dominant species prior to 1950 but not in 1960-61 (Verduin 1964). Similarly, Munawar and Munawar (1976) observed *T. fenestrata* not to be important in the 1970 collections. Neither worker mentioned *T. flocculosa*. Differing taxonomic concepts of the *Tabellaria fenestrata* - *T. flocculosa* complex do occur in the literature (e.g. Koppen 1975). Perhaps investigators have been reporting the same entity and simply using differing systematics.

In the present study, although *T. fenestrata* was observed, *T. flocculosa* was more important contributing 3.8% of the total biomass. Mean biomass was 51 $mg/m^3$ with the western (103 $mg/m^3$) and eastern (65 $mg/m^3$) basins being greater than the central (11 $mg/m^3$) basin. Seasonally, a bloom occurred in late April and May (Fig. 18c).

## LAKE HURON

Abundant species (Table 7) were arbitrarily defined as those possessing a relative abundance of >0.1% of the total cells or >0.5% of the total biovolume.

### Cyanophyta

#### Anacystis marina Dr. & Daily

A. marina is widely distributed as plankton in fresh, brackish and sometimes marine waters. It is rarely reported, probably because it is easily overlooked (Humm and Wicks 1980). Cells range in size from 0.5-2.0 µm in diameter. Because a number of varying shaped cells were included as A. marina during identification, it is likely that more than one species is being grouped together (Andresen 1985).

This was the dominant phytoplankter within the study area representing 81% of the total algal abundance (cells/mL) but only 1.9% of the total algal biovolume (8.5 $mg/m^3$). An average density of 18,011 cells/mL was observed for the study period with a maximum density of 55,518 cells/mL (0.23 $mg/m^3$) observed on 19 August at Station 61 (Table 7). Abundance was generally higher at the northern end of the lake with maximum densities in May and August (Fig. 20a). Makarewicz (1985) reported this species from the mouth of Niagara River and the Oswego River in Lake Ontario and from Lake Erie (This Report). There are no other reports of this species in Lake Huron.

#### Anacystis montana f. minor Dr. & Daily

Humm and Wicks (1980) noted that A. montana was planktonic and possessed a worldwide distribution in freshwater and in brackish water habitats. In Lake Ontario at the mouth of the Oswego River, this species was observed to have a bimodal distribution with a peak in late July and October (Makarewicz 1985). Seasonally in Lake Erie, only one abundance peak was observed in mid-October (This Study). Munawar and Munawar (1982) and Stoermer and Kreis (1980) did not report this species. In Lake Huron in 1983, a bimodal pattern was observed, except the spring peak was in May (Fig. 20e). Average density was 380 cells/mL with a maximum of 2,556 cells/mL on 16 October 1983 at Station 12 (Table 7).

### _Anacystis thermalis_ (Menegh.) Dr. & Daily

Stoermer and Ladewski (1976) reported this species as being a common element of phytoplankton assemblages in mesotrophic to eutrophic lakes. Munawar and Munawar (1982) did not list _A. thermalis_ as a common species in their 1971 samples. However, this species is often reported as various species of _Chroococcus_ (Stoermer and Ladewski 1976). Munawar and Munawar (1982) observed three species of _Chroococcus_ that were common (>5% of the biomass). Stoermer (1978) listed this species as present only in minor quantities in Lake Huron. In 1974 maximum abundance was reached in October. Mean abundance in southern Lake Huron was 12 cells/mL.

With an average density of 17 cells/mL (2.4 mg/m$^3$), this species contributed only 0.08% of the relative abundance and 0.54% of the total biomass for the lake (Table 7). Seasonal abundance was highest in October (Fig. 20c). No obvious geographical north-south pattern was obvious.

Coccochloris elabans Dr. & Daily

Munawar and Munawar (1982) did not list this species as a common species (>5%) in their 1971 samples. Stoermer and Kreis (1980) listed a Coccochloris sp. as having a mean density of 0.31 cell/ml with a maximum of 50.3 cells/ml. In 1983 average density was 38 cells/mL accounting for 0.17% of the total cells (Table 7). A maximum abundance of 434 cells/mL was observed on 4 August at Station 61. Seasonal abundance was bimodal with a spring pulse in May and a second summer maximum during August. This seasonal pattern was present at most stations (Fig. 23c).

Coccochloris peniocystis Kütz.

According to Humm and Wicks (1980), most reports of this species are from freshwater, but occasionally it is reported from marine habitats. It has a worldwide distribution. In Lake Erie in 1983, this species was the third most abundant species (This Study). In Lake Huron in 1983, C. peniocystis was the second most abundant species (Table 7) with a maximum density of 7,929 cells/mL (15 mg/m$^3$) on 19 August 1983 at Station 9. Seasonally, distribution appeared unimodal with a late August maximum extending into October (Fig. 20b).

Coelosphaerium naegelianum Unger

Munawar and Munawar (1982) did not list this species as a common species in 1971. Also, Stoermer and Kreis (1980) did not observe this species in 1974. Accounting for 0.33% of the total abundance (Table 7), this species reached a maximum density of 900 cells/mL on 16 October at Station 45 (mean abundance = 74 cells/mL). Seasonally, an abundance peak was observed in October and perhaps in August (Fig. 20c). Geographically, abundance was higher in the northern portion of Lake Huron (Stations 61,54,45).

*Oscillatoria limnetica* Lemm.

According to Huber-Pestalozzi (1938), this species is often abundant in polluted waters. Munawar and Munawar (1982) did not report this species as common in 1971, while Stoermer and Kreis (1980) observed mean densities of only 0.08 cell/mL representing 0.002% of the population. In Lake Huron, it contributed only 0.06% of the total biovolume and 0.39% of the total cells (Table 7). Seasonally, peak abundance was reached in spring (maximum 974 cells/mL; Station 15) (Fig. 23b). No obvious geographical pattern existed (Fig. 23b) although mean station abundance was higher at Stations 9 and 15 ($\bar{x}$ = 151 cells/mL). The discharge of Saginaw Bay into Lake Huron (Schelske et al. 1974, Stoermer and Theriot 1985) may have influenced this abundance pattern. Blue-greens, including *O. limnetica,* contributed 42.7% of the phytoplankton assemblage of Saginaw Bay in 1980.

*Gomphosphaeria lacustris* Chod.

Unlike most species of blue-green algae, *G. lacustris* seems to be common in the offshore waters of the upper Great Lakes (Vollenweider et al. 1974, Stoermer and Ladewski 1976). Stoermer (1978) listed this species as being occasionally abundant. Munawar and Munawar (1982) reported it as a common species (>5% of the biomass) in the fall plankton assemblage in 1971. In 1974 it was quite abundant (91 cells/mL; 4.5% of the population) in southern Lake Huron (Stoermer and Kreis 1980).

In 1983 average density and biomass were 38 cells/mL and 0.2 mg/m$^3$, respectively. Maximum abundance encountered was 920 cells/mL at Station 9 during May and 491 cells/mL at Station 61 during mid-August. Mean abundance without the maximum values of Stations 9 and 61 was only 5.4 cells/mL.

### Chrysophyta

#### *Chrysophaerella longispina* Laut. emend. Nich.

This species is usually a minor component of phytoplankton assemblages in oligotrophic to mesotrophic lakes and small ponds (Huber-Pestalozzi 1941). Stoermer (1978) listed this species as occasionally abundant. Stoermer and Kreis (1980) observed small isolated populations in samples from early May through June in southern Lake Huron. But in August and October, abundance was high along the Michigan coast and at mid-lake stations in southern Lake Huron (maximum ~425 cells/mL). Mean density for southern Lake Huron in 1974 was 40 cells/mL.

In the present study, abundance was near zero to mid-August and steadily increased into October (Fig. 22a). Average abundance for the lake was 13 cells/mL (5.3 mg/m$^3$) (Table 7). Maximum density observed was 74 cells/mL at Station 6 in southern Lake Huron on 16 October. Mean density for stations (27,15,12,9,6) in southern Lake Huron in October was 39 cells/mL.

#### *Dinobryon cylindricum* Imhof

This was not a common species (>5% of the biomass) in 1971 (Munawar and Munawar 1982). In 1974 Stoermer and Kreis (1980) observed a density of 0.04 cell/mL representing only 0.005% of the population in southern Lake Huron at 5m.

In 1983 mean abundance was 16 cells/mL. Mean biomass was 5.8 mg/m$^3$ representing 1.3% of the total biomass. Seasonally, populations increased into May and decreased to near zero by August (Fig. 22b). Mean density for all cruises in southern Lake Huron was 12.3 cells/mL.

### Dinobryon divergens Imhof

This species is apparently widely distributed and may occur in waters of significantly different trophic levels (Stoermer and Kreis 1980). In 1973 Munawar and Munawar (1982) reported this species as a common species in the spring and fall. In 1974 densities of 200 cells/mL were reached in the extreme southern end of Lake Huron. During Stoermer and Kreis's (1980) study, mean abundance was 14.6 cells/mL representing 1.05% of the population.

In 1983 mean abundance for the lake was 16.1 cells/mL representing 0.1% of the total cells. Mean biomass was 4.7 mg/m$^3$ accounting for 1.05% of the total biomass (Table 7). Geographically, mean densities were similar from north to south. A peak in mean abundance occurred in early July (Table 22b).

### Dinobryon sociale var. americanum (Brunnth.) Bachm.

In southern Lake Huron in 1974, mean abundance was 0.094 cell/mL with a maximum density of 12.6 cells/mL. In the present study, mean density and biomass were 49 cells/mL and 6.0 mg/m$^3$, respectively. The species constituted 1.34% of the total biomass. Mean densities for the study were higher in the north (Stations 61 and 54; $\bar{x}$ = 65 cells/mL) as compared to the rest of the lake ($\bar{x}$ = 22 cells/mL).

Haptophyte sp.

Mean density was 168 cells/mL representing 0.75% of the total cells. Seasonally, a single major abundance peak occurred from just south of Saginaw Bay northward. South of Saginaw Bay, abundance was much lower and a May and August peak was evident (Fig. 24b). A maximum abundance of 859 cells/mL was observed at Station 32 on 2 July.

Cryptophyta

Cryptomonas erosa Ehr. and Cryptomonas erosa var. reflexa Marss.

C. erosa is widely distributed in the Great Lakes (Stoermer et al. 1974), usually in low numbers. According to Huber-Pestalozzi (1968), it is a eurytopic organism, occurring both in oligotrophic lakes and often in abundance in eutrophic and slightly saline habitats.

In 1971 it was a common species (>5% of biomass) in the spring, summer and fall (Munawar and Munawar 1982). During June C. erosa and Cryptomonas sp. made up 75% of the biomass (Vollenweider et al. 1974). Stoermer and Kreis (1980) reported it as a minor constituent of the phytoplankton community with an average density of 0.027 cell/mL ( 0.001% of the population) in southern Lake Huron in 1974.

In 1983 C. erosa and C. erosa v. reflexa had an average density of 6.7 cells/mL and mean biomass of 12.7 $mg/m^3$. Although they contributed only 0.03% of the total abundance, they represented 2.8% of the total biomass (Table 6). Seasonally, mean abundance decreased from April to early July, peaked in August, decreased slightly in mid-August and increased slightly into October (Fig. 20f).

### *Cryptomonas pyrenoidifera* Geitl.

Both Stoermer and Kreis (1980) and Munawar and Munawar (1982) observed *Cryptomonas* sp. in 1971 and 1974 but did not list *C pyrenoidifera*. *C. ovata* was reported as accounting for 0.46% of the phytoplankton population in 1974 by Stoermer and Kreis (1980).

In 1983 *C. ovata* was less than 0.1% of the total cells. The average biomass of *C. pyrenoidifera* was 3.5 $mg/m^3$ constituting 0.78% of the total biomass (Table 7). Maximum mean populations were reached in the early spring (Fig. 21a). No north-south gradient or geographical pattern was observed.

### *Rhodomonas minuta* var. *nannoplanktica* Skuja

Munawar and Munawar (1982) reported *R. minuta* as abundant (>5% of the biomass) in the spring, summer and fall of 1971. Between *R. minuta* v. *nannoplanktica* and *R. minuta* , Stoermer and Kreis (1980) observed the variety *nannoplanktica* to be the prevalent form in southern Huron in 1974. Average density in southern Lake Huron was 8.2 cells/mL (0.77% of the population) with a maximum of 54 cells/mL. It was present at most stations throughout the year but appeared to be most abundant during June at offshore stations.

In the present study, *R. minuta* v. *nannoplanktica* was more prevalent than *R. minuta*. Mean density was 204 cells/mL (0.92% of the total cells) with mean biomass being 15.2 $mg/m^3$ (3.4% of the total biomass). Maximum abundance was 311 cells/mL in early May at Station 15. Seasonally, this species was abundant throughout the lake from April till October (Fig. 20d).

## Pyrrhophyta

### *Ceratium hirundinella* (O.F. Mull.) Schrank

*C. hirundinella* was a common species (>5% of the biomass) in the summer of 1971 (Munawar and Munawar 1982). Stoermer and Kreis (1980) reported it as having an average density of only 0.16 cell/mL (0.009% of the population) for the 5-m depth in southern Lake Huron. A maximum of 6.3 cells/mL was reported.

Similarly in 1983, mean abundance was 0.11 cell/mL ( 0.001% of the total cells) with the mean biomass being 5.6 mg/m$^3$ (1.3% of the total biomass) (Table 7). Although this species occurred only at two stations during the 19-21 August cruise, average contribution to the phytoplankton biomass for the cruise was 7.3%.

## Bacillariophyta

### *Asterionella formosa* Hass.

A common species (>5% of the biomass) in the spring, summer and fall of 1971 (Munawar and Munawar 1982), this species is considered a common element of the plankton assemblage (Stoermer 1978). In Stoermer and Kreis's (1980) 1974 work on southern Lake Huron, abundance was generally highest at the nearshore stations and at the Saginaw Bay interface. In mid-July abundance was reduced except at stations in the southern part of Lake Huron (abundance ~100 cells/mL). Abundance in October and November of 1974 generally increased from the summer. Mean abundance was 38.5 cells/mL (2.9% of the population) with a maximum of 394 cells/mL. In 1980-81, *A. formosa* represented 6.7% of the total diatoms in Lake Huron. Abundance was greatest during the spring. Lowest abundance regularly occurred in September except near the Straits of Mackinac (Stevenson 1985).

In the present study, mean density and biomass were 9.7 cells/mL (0.04% of the total cells) and 3.0 mg/m$^3$ (0.66% of the total biomass). Maximum density was 103 cells/mL in July at Station 61. Seasonally, maximum density was observed in the early July sample with abundance greatly higher in the northern part of the lake (Fig. 23a).

*Cyclotella comensis* Grun.

Munawar and Munawar (1982) did not report this species as a common species during 1971. They did list *C. michiganiana*, which can be difficult to distinguish from small *C. comensis* (Stevenson 1985). Stoermer and Kreis (1980) reported that the high abundances attained in southern Lake Huron in 1974 were unprecedented. In August *C. comensis* was in bloom quantities at most stations. Mean density was 150 cells/mL (8.6% of the population with a maximum of 1508 cells/mL). Stevenson (1985) reported a mean relative abundance of 9.7% of the total diatoms.

In 1983 mean abundance increased to early August and decreased slightly into October (Fig. 21b). Abundances were greatest at the northern (Station 61, 45 cells/mL) and southern (Station 6, 82 cells/mL) ends of the lake as compared to the rest of the lake ($\bar{x}$ = 27 cells/mL). Mean abundance was 49 cells/mL with a maximum of 385 cells/mL in early August at Station 6. On a cells/mL basis, this was the dominant diatom representing 0.29% of the total cells (Table 7) and 24.9% of the total diatoms.

*Cyclotella comta* Ehr. (Kütz.)

A common species in the spring, summer and fall of 1971 (Munawar and Munawar 1982), this species is a member of the classic oligotrophic Cyclotella association (Hutchinson 1967). In 1974 average density was 4.7 cells/mL (0.37% of the population) with a maximum of 31.4 cells/mL. Highest overall abundance occurred in August and mid-October in southern Lake Huron (Stoermer and Kreis 1980).

In 1983 mean abundance was 6.4 cells/mL (0.03% of the population). Mean biomass was 17.7 $mg/m^3$ (3.94% of the total biomass) (Table 7). Abundance was higher (4.4 cells/mL) north of Saginaw Bay than south of it (1.5 cells/mL). Highest abundance occurred in August and October (Fig. 21b).

### Cyclotella kuetzingiana var. planetophora Fricke

Munawar and Munawar (1982) reported C. kuetzingiana as a common (>5% of the biomass) element of the summer plankton assemblage. Stoermer and Kreis (1980) reported C. kuetzingiana as having a mean density of 0.02 cell/mL (0.003% of the population) with a maximum of 2.1 cells/mL in southern Lake Huron at 5 m.

In 1983 mean abundance was low throughout the spring and summer and increased to 50 cells/mL in October. Average density was 16.5 cells/mL. Mean biomass was 5.0 $mg/m^3$ representing 1.1% of the total biomass. In October this species contributed 6.1% of the biomass.

### Cyclotella ocellata Pant.

In 1971 this species was a common element (>5% of the biomass) of the spring, summer and fall assemblage (Munawar and Munawar 1982). This species is an important component of phytoplankton assemblages in northern Lake Huron (Schelske et al. 1974, Schelske et al. 1976) and is generally abundant in areas of the Great Lakes which have not undergone significant eutrophication (Stoermer and Kreis 1980).

During 1974 mean abundance was 24.1 cells/mL (2.4% of the population) with a maximum of 169.6 cells/mL. Abundance was generally high in May and June and reduced in August. In 1980 it represented 5.2% of the total diatom abundance (Stevenson 1985).

During the present study, mean abundance increased into early July, was low in August and increased into October (Fig. 21c). Mean abundance and biomass were 29.9 cells/mL (0.13% of the total cells) and 2.3 mg/m$^3$ (0.52% of the total biomass), respectively (Table 7). A maximum abundance of 254 cells/mL occurred at Station 61 in early July. Mean abundance was high (42 cells/mL) at the most northerly station (Station 61) as compared to the rest of the lake ($\bar{x}$ = 18.2 cells/mL). *O. ocellata* represented 8.7% of the total diatom abundance.

*Cymatopleura solea* var. *apiculata* (W. Sm.) Ralfs

Stoermer and Kreis (1980) reported an average abundance of 0.027 cell/mL (0.002% of the population) with a maximum of 2.9 cells/mL. In 1983 density was low (0.2 cell/mL), but biomass was relatively high (13.4 mg/m$^3$, 3.0% of the total biomass).

*Fragilaria crotonensis* Kitton

This species was a common element (>5% of the biomass) in the spring, summer and fall in 1971 (Munawar and Munawar 1982). In 1974 seasonal minimal abundance occurred in August in southern Lake Huron. Average density was 116 cells/mL representing 7.6% of the population. Maximum abundance was 1898 cells/mL (Stoermer and Kreis 1980).

Stevenson (1985) reported *F* *crotonensis* to represent 18.8% of the diatom abundance in 1980 and to be one of the two most common diatoms.

In the present study, *F.* *crotonensis* averaged 27.6 cells/mL (0.12% of the total cells) which represented a biomass of 22.9 mg/m$^3$ (5.1% of the biomass) (Table 7). For the lake, a May maximum extending into July, an August minimum and a second increase into October were evident (Fig. 22d). Similar to Stevenson's (1985) observations, a difference in maxima between regions was observed. South of Saginaw Bay, the spring bloom occurred in early May and collapsed by July. North of Saginaw Bay, a maximum in abundance was not observed till early July. *F.* *crotonensis* represented 9.7% of the total diatom abundance in 1983.

*Fragilaria* *intermedia* var. *fallax* (Grun.) Stoerm. & Yang

Stoermer and Yang (1970) reported this species to reach its maximum relative abundance in the spring in Lake Michigan. In Lake Huron in 1974, a mean abundance of 3.2 cells/mL (0.23% of the population) with a maximum of 279 cells/mL was observed.

In 1983 a mean abundance and biomass of 8.2 cells/mL and 5 mg/m$^3$, respectively, were observed (Table 7). They represented 1.1% of the phytoplankton biomass of the lake. Maximum abundance was 60 cells/mL in May at Station 37. The seasonal maximum occurred in spring with higher abundances at the mid-lake stations (37,32,27) (Fig. 24a). As with *F.* *crotonensis*, the spring bloom occurred earlier south of Saginaw Bay.

*Melosira* *islandica* O. Mull.

This species is a common cold season dominant in boreal and alpine lakes worldwide (Stoermer and Kreis 1980). Munawar and Munawar (1982) noted this species as a common element of the spring and summer plankton. It displayed a spring bloom in most of southern Lake Huron during 1974 (Stoermer and Kreis 1980) and throughout the lake in 1980 (Stevenson 1985) representing 2.8% of the diatom abundance. In 1974 average abundance was 15.2 cells/mL (0.97% of the population) with a maximum of 813 cells/mL.

In the present study, a spring bloom was also observed (Fig. 22c). Mean density and biomass were 12.7 cells/mL and 17 mg/$m^3$, respectively. This species represented 3.8% of the total biomass for the entire sampling area. Maximum abundance was 90 cells/mL at Station 9 in May.

*Rhizosolenia* sp.

Munawar and Munawar (1982) noted *R. eriensis* as a common element of the spring assemblage. Both *R. eriensis* and *R. gracilis* were observed in 1974 by Stoermer and Kreis (1980). Combined mean abundance for these species was 49.7 cells/mL representing 4.4% of the population.

In 1983 abundance was low in April and August-October. In May and July, abundance was high (40 cells/mL; Fig. 21f). Mean abundance was 17.2 cells/mL with a biomass of 127 mg/$m^3$. This represented 28.4% of the total biomass and made this the dominant species on a biomass basis.

*Stephanodiscus niagarae* Ehr. and *S transilvanicus* Pant.

While a common element of the spring plankton in 1971 (Munawar and Munawar 1982), it was not in 1974 (Stoermer and Kreis 1980). In

1974 S. hantzschii and S. minutus were the prevalent species of Stephanodiscus . With a mean abundance of 0.12 cell/mL, S niagarae accounted for only 0.006% of the population.

In 1983 S. niagarae and S. transilvanicus were the prevalent species with a combined abundance of 1.2 cells/mL accounting for 0.005% of the total cells but 3.3% of the total biomass (14.5 mg/$m^3$) (Table 7). Seasonally, a peak in abundance in the spring was observed for S. transilvanicus. A fall peak and a small abundance increase in May were noted for S. niagarae (Fig. 21d).

Tabellaria flocculosa (Roth) Kutz. and T. flocculosa var. linearis Koppen

Munawar and Munawar (1982) reported this species as a dominant in Lake Huron. In 1974 T. flocculosa v. linearis was more prevalent ($\bar{x}$ = 28.8 cells/mL, 2.1% of the population) as compared to T. flocculosa (1.1 cells/mL, 0.09% of the population). Stevenson (1985) reported that although the seasonal abundance pattern was variable from region to region in 1980, it bloomed in most areas of the lake in spring. Similar seasonal patterns were observed in the 1974 study of southern Lake Huron (Stoermer and Kreis 1980).

In 1983 the mean abundance was high in the spring and was low during the rest of the sampling period (Fig. 21e). T. flocculosa (20.3 cells/mL) was more abundant than T. flocculosa v. linearis (1.4 cells/mL). T. flocculosa contributed 13.5% of the total biomass making it the second most dominant species on a biomass basis (Table 7). No obvious geographical pattern was observed.

## LAKE MICHIGAN

Abundant species (Table 8) were arbitrarily defined as those possessing a relative abundance of >0.1% of total cells or >0.5% of the total biovolume.

### Cyanophyta

#### *Anacystis marina* Dr. & Daily

*A. marina* is widely distributed as plankton in fresh, brackish and sometimes marine waters. It is rarely reported, probably because it is easily overlooked (Humm and Wicks 1980). Cells range in size from 0.5-2.0 µm in diameter. Because a number of varying shaped cells were included as *A. marina* during our identification, it is possible that more than one species is being grouped together (Andresen 1985).

This was the dominant phytoplankter within the study area representing 84.6% of the total algal abundance (cells/mL) but only 1.6% of the total algal biovolume (6.3 mg/m$^3$). An average density of 23,607 cells/mL was observed for the study period with a maximum density of 120,019 cells/mL observed on 26 October at Station 77 (Table 8). Mean station abundance was higher (36,315 cells/mL) in the north (Stations 77,64,57) as compared to the rest of the lake (18,850 cells/mL). Differences in seasonal distribution were also evident. The entire offshore region experienced a maximum in October. A second weaker abundance peak was present in the spring or July at most stations (Fig. 28a). Makarewicz (1985) reported this species from the mouth of Niagara River and the Oswego River in Lake Ontario, and from Lake Erie and Huron (This Report). There are no other reports of this species in Lake Michigan.

Anacystis montana f. minor Dr. & Daily

Humm and Wicks (1980) noted that A. montana was planktonic and possessed a worldwide distribution in freshwater and in brackish water habitats. In Lake Ontario at the mouth of the Oswego River, this species was observed to have a bimodal distribution with a peak in late July and October (Makarewicz 1985). Seasonally in Lake Erie, only one abundance peak was observed in mid-October (This Study). In Lake Huron in 1983, a bimodal pattern was observed with the spring peak in May (Fig. 20e). Similar to Lake Erie, only one abundance peak was observed in Lake Michigan in October of 1983 (Fig. 25a). Mean abundance was 451 cells/mL with a maximum of 3,289 cells/mL (Table 8). This species has not been reported before in Lake Michigan.

Anacystis thermalis (Menegh.) Dr. & Daily

Stoermer and Ladewski (1976) reported this species as being a common element of phytoplankton assemblages in mesotrophic to eutrophic lakes. In the 60's, abundance of A. thermalis increased greatly in southern Lake Michigan. Maximum abundance was 460 cells/mL in 1971 (Stoermer and Ladewski 1976). From Rockwell et al.'s (1980) report on southern Lake Michigan, an average density of 397 and 781 cells/mL in August and in September of 1977 can be computed. Stoermer (1978) listed this species as a common element of the plankton assemblage.

In the present study, mean maximum abundance occurred in early October (Fig. 25a). Mean abundance was greater (602 cells/mL) in southern Lake Michigan (Stations 26 and 27 southward) than in the north (325 cells/mL). Average density for the lake was 451 cells/mL

(1.6% of the total cells) with a maximum of 3,289 cells/mL at Station 27 on 12 October. Mean biomass was 3.0 mg/$m^3$.

*Coccochloris peniocystis* (Kütz.)Dr. & Daily

There appears to be no other previous reports of this species in Lake Michigan. According to Humm and Wicks (1980), most reports of this species are from freshwater, but occasionally it is reported from marine habitats. In Lake Erie in 1983, this species was the third most abundant species (This Study); in Lake Huron in 1983, it was the second most abundant species; and in Lake Michigan in 1983, it was the second most prevalent species (Table 8).

Mean abundance and biomass were 1,340 cells/mL (4.8% of the total cells) and 3.0 mg/$m^3$ (0.77% of the total biomass). Populations appeared to build up during the spring and summer reaching a peak in mid-August and then declined into October (Fig. 25a). Abundances were higher ($\bar{x}$ = 2,025 cells/mL) at the far northern stations (57,64,77) than in the rest of the lake (960 cells/mL).

*Coelosphaerium naegelianum* Unger

Parkos et al. (1969) provided abundance estimates for *Coelosphaerium* sp. for different regions of the lake in 1967. Average density for early and late October was 194 cells/mL. Rockwell et al. (1980) reported a mean density of 13.5 cells/mL for *Coelosphaerium kuetzingianum* in late August.

In 1983 average density was 39 cells/mL with a maximum abundance of 1,227 cells/mL on 4 July at Station 64. Distribution was generally limited to the far northern portion of the lake (Stations 77 and 64) and one occurrence at Station 11 at the southern end of the lake.

Seasonally, two mean abundance peaks, July and October, were observed (Fig. 25b).

*Oscillatoria agardhii* Gom.

During the spring of 1963, *Oscillatoria* sp. was observed by Stoermer and Kopczynska (1967a) at densities less than 100 cells/mL. In 1983 *O. agardhii* had a mean abundance and biomass of 14.2 cells/mL and 2.8 mg/m$^3$, respectively. Maximum abundance was 344 cells/mL at Station 64 on 5 May. Seasonally, population density was high in April and May, had collapsed by July and stayed low the rest of the sampling period (Fig. 25b). This species was observed at the far northern end of the lake (Stations 77 and 64) and at mid-lake Stations 23 and 27 only.

*Oscillatoria limnetica* Lemm.

Ahlstrom (1936) and Stoermer and Kopczynska (1967a) listed *O. mougeotii* as the only species of the genus at all abundant in their collections. Stoermer and Ladewski (1976) reported that this species has increased in abundance in Lake Michigan. Rockwell et al. (1980) reported that *O. limnetica* was common throughout the basin in April and June and was especially abundant in September of 1977 at certain stations.

In the present study, an average density and biomass of 139 cells/mL (6.5% of the total cells) and 1.0 mg/m$^3$ (0.26% of the total biomass) were observed, respectively. Mean maximum abundance occurred in July (Fig. 25c). However, differences in maximum abundance were observed within regions of the lake. Peaks in maximum abundance were much greater at mid-lake stations (23,27,34,41) than at the northern and southern stations (Fig 27c).

### Pyrrhophyta

#### *Ceratium hirundinella* (O.F. Mull.) Schrank

Ahlstrom (1936) noted that in his collections *C. hirundinella* did not become abundant until July and later. In 1967, 1.1 cells/mL for the lake were observed (Parkos et al. 1969). Stoermer and Ladewski (1976) reported low abundances (maximum = 3.5 cells/mL) in southern Lake Michigan in 1971.

In 1983 average density was low (0.22 cell/mL), but mean biomass was high (21 mg/m$^3$) representing 5.4% of the total biomass (Table 8). Seasonally, a population maximum of *C. hirundinella* occurred in August. This species was observed only in the southern portion of the lake (Stations 6,11,18,23,27).

### Chlorophyta

#### *Cosmarium* sp.

In October of 1967, this genus attained a density of 0.6 cell/mL in the northern lake region (Parkos et al. 1969). In 1983 this genus had a mean density and biomass of 0.39 cell/mL and 7.0 mg/m$^3$, respectively (Table 8). It contributed 1.79% of the total biomass. In April abundance was low (0.16 cells/mL) but increased to 1.6 cells/mL in May. This abundance was maintained into August. In October the organism was not observed.

#### *Monoraphidium contortum* (Thur.) Kom.-Legn.

This species had a mean density of 38.1 cells/mL (Table 8) with a maximum of 201 cells/mL at Station 18 in April. Seasonally, mean maximum abundance occurred in spring (Fig. 25d). A second peak was observed in October at Stations 34, 41 and 47.

*Stichococcus* sp.

With an average biomass of 2.0 mg/m$^3$ (23 cells/mL), this species contributed 0.50% of the total biomass. Seasonal distribution was described by a late summer maximum that appeared to extend into October. Occurrence was uneven; that is, it occurred only at Stations 6,18,34,41 and 47.

Chrysophyta

*Dinobryon cylindricum* Imhof, *D. divergens* Ehr., *D. sociale* var. *americanum* (Brunnth.) Bachm.

Stoermer (1978) listed *D. cylindricum* as a common element of the Lake Michigan plankton community. In October of 1967, mean abundance was 2.6 cells/mL (Parkos et al. 1969) for *Dinobryon* sp. Stoermer and Kopczynska (1967a) noted that in 1962-63 *Dinobryon* was the most important representative of the Chrysophyta in Lake Michigan. In 1962-63 *D. divergens*, *D. cylindricum* and *D. sociale* were the most common species.

In the present study, these three species accounted for 3.66% of the total biomass (Table 8). Along with *Haptophyte* sp., they were the dominant chrysophytes. A mean biomass of 14.3 mg/m$^3$ occurred for the sampling period. Of the three species, *D. sociale* v. *americanum* was the most prevalent. Maxima for all three species were in July with a second maximum in August for *D. divergens.* Mean abundances for all three species were higher (53.2 cells/mL) at Stations 64 and 77 than in the rest of the lake (21 cells/mL).

### *Haptophyte* sp.

With an average biomass and density of 2.3 mg/m$^3$ and 185 cells/mL, respectively, this group constituted 0.59% of the total biomass and 0.66% of the total cells. A maximum abundance of 785 cells/mL was observed on 4 July at Station 41. Differences in seasonal abundance were evident with geography (Fig. 28b). Abundances tended to be generally low in the south (Stations 6,11,18,23) till the late summer and fall. In the central region (Stations 27,34,41), peaks in abundance occurred in early July and later in August and October. In the northern region (Stations 47,57,64,77), abundance was high during the late spring and in October. Station 47 did not have the spring pulse, but the fall pulse was observed.

### *Stylotheca aurea* (Bachm.) Boloch.

This colorless flagellate was abundant in the spring (Fig. 27b). Mean biomass was 2.1 mg/m$^3$ representing 0.55% of the total biomass. Abundance was especially high (39 mg/m$^3$) at the far northern stations (64 and 77) compared to the rest of the lake (0.5 mg/m$^3$).

## Cryptophyta

### *Chroomonas norstedtii* Hansg.

Average density observed in 1983 was 28.8 cells/mL representing 0.1% of the total cells. Mean seasonal abundance was low in the spring, reached a peak in July and leveled off at ∼30 cells/mL for the rest of the sampling period (Fig. 25f). This trend is somewhat misleading because stations south of 34 did not experience this maximum in abundance. Mean abundance was higher (59 cells/mL) at the far northern stations (Stations 64 and 77) than in the rest of the lake (22 cells/mL).

*Cryptomonas erosa* Ehr. and *C. erosa* var. *reflexa* Marss.

Stoermer (1978) listed this species as present in only minor quantities in Lake Michigan. Stoermer and Kopczynka (1967b) reported cryptomonads as a numerically minor component of the total plankton. Vollenweider et al. (1974) stated that Munawar observed *Cryptomonas* to be commonly found.

Based on three samples in July 1973, Munawar and Munawar (1975) reported that phytoflagellates contributed between 6% and 32% of the biomass. Claflin (1975) also found small flagellates (particularly *Rhodomonas* and *Cryptomonas* )to be abundant in 1970-71. Rockwell et al. (1980) reported an occurrence of *Cryptomonas* spp. of 1,160 cells/mL in 1976.

In 1983 *C. erosa* and *C. erosa* v. *reflexa* had a combined mean abundance and biomass of 7.9 cells/mL and 16.7 mg/m$^3$. On a numerical basis, they represented only 0.02% of the total cells. However, they did contribute 4.3% of the total biomass for the lake.

Seasonally, mean seasonal abundance for *C. erosa* reached a peak in early May, decreased in July, increased to 7.6 cells/mL in August, and remained at this level till late October when mean abundance reached 13.7 cells/mL. Maximum biomass (74 mg/m$^3$) occurred on 4 July at Station 23 and represented 13.4% of the total biomass for that sampling station. No obvious geographic pattern was observed.

*C. erosa* v. *reflexa* displayed a different seasonal abundance pattern with maxima in early August and in late October. Also, stations north of 41 had a mean biomass of 0.2 mg/m$^3$ while the rest had a mean biomass of 3.1 mg/m$^3$.

*Cryptomonas marssonii* Skuja

Stoermer (1978) listed this species as being absent from Lake Michigan. In 1983 this species had a mean abundance and biomass of 2.4 cells/mL and 2.2 mg/m$^3$ (0.57% of the total biomass), respectively (Table 8). A maximum abundance of 25 cells/mL (18.7 mg/m$^3$; 14.9% of the biomass) was observed on 17 August at Station 41. Seasonally, abundance was higher in August through October than in the spring and early summer (Fig. 26a).

*Cryptomonas pyrenoidifera* Geitl.

In 1983 a spring abundance peak was observed (Fig. 26a). Mean abundance was 6.1 cells/mL. Average biomass was 2.8 mg/m$^3$ contributing 0.71% of the total biomass.

*Rhodomonas minuta* var. *nannoplanktica* Skuja

Stoermer (1978) reported this species as occasionally abundant in Lake Michigan. Vollenweider et al. (1974) noted that Munawar and Munawar observed *R. minuta* to contribute up to 5-10% of the biomass for a sampling date in 1971. Some workers believe that *R. minuta* var. *nannoplanktica* is not a distinct variety, but a smaller phase of *R minuta*. Although Munawar and Munawar do not state this, it is possible they lumped the variety *nannoplanktica* into *R. minuta* for this reason or simply for convenience. Claflin (1975) also reported small flagellates (particularly *Rhodomonas* and *Cryptomonas*) to be abundant in 1970-71.

In 1983 peaks in mean abundance were observed in early May and October (Fig. 25f). No obvious geographical pattern was present. Mean abundance and biomass were 269 cells/mL and 22.4 $mg/m^3$, respectively. This species contributed 5.7% of the total biomass to the lake for the year.

Bacillariophyta

*Asterionella formosa* Hass.

Stoermer (1978) reported it as a common element of the Lake Michigan plankton community. Stoermer and Yang (1970) indicated that this species was relatively abundant throughout Lake Michigan and reached its greatest relative abundance in late summer and early fall samples. In 1962-63, *A. formosa* was abundant (ca. 20 cells/mL) in August, declined in September and was abundant again in October (65 cells/mL) (Stoermer and Kopczynska 1967a). In 1967 its relative abundance (numerical basis) was often 5-10% of the diatom assemblage. Holland (1980) reported a maximum density of 226 cells/mL in 1971. Rockwell et al. (1980) observed a mean abundance of 75 cells/mL for southern Lake Michigan in 1976.

In 1983 mean abundance and biomass were 11.8 cells/mL and 3.5 $mg/m^3$, respectively. This species represented 0.91% of the total biomass for the lake. Populations were low in the spring, reached a mean maximum abundance of 49.5 cells/mL in early July, decreased in August and were increasing in mid-October (Fig. 26c). For the sampling period, average densities were higher at Stations 27, 34 and 41 (25.5 cells/mL) and Station 77 (16.3 cells/mL) than in the rest of the lake (5.3 cells/mL). Maximum abundance (206 cells/mL) occurred at Station 32/34 on 4 July 1983. Maximum densities in 1971 (226 cells/mL) and 1983 (206 cells/mL) were similar.

### *Cyclotella comensis* Grun.

In 1962-63 *C. michiganiana* and *C. comta* were the major species in the fall. *C. kutzingiana*, *C. ocellata* and *C. stelligera* were also present but in smaller numbers. Holland (1980) did not report this species. Stoermer and Tuchman (1979) reported this species as a recent introduction to the nearshore southern Lake Michigan in 1977. Abundance was low in June but increased substantially in August and September. Average density was 86.7 cells/mL (1.9% of the population with a maximum of 419 cells/mL) in 1977.

In 1983 mean abundance and biomass for the lake were 52.7 cells/mL and 2.0 mg/m$^3$, respectively (Table 8). A maximum of 834 cells/mL was observed at Station 77 in 3 August 1983. Density was low from April to July, increased in August, and remained high to late October when it increased to a mean abundance of 135 cells/mL for that date (Fig. 26b). Geographically, mean station density was higher at Stations 64 and 77 ($\bar{x}$ = 221 cells/mL) and Station 6 ($\bar{x}$ = 62 cells/mL) at the far northern and southern ends of the lake as compared to the rest of the lake ($\bar{x}$ = 9.5 cells/mL). This species represented 0.24% of the total cells and on a numerical basis was the dominant species of *Cyclotella*.

### *Cyclotella comta* (Ehr.) Kütz.

Previously published works indicate that this species is widely distributed in oligotrophic and mesotrophic lakes (Stoermer and Yang 1970). Stoermer (1978) listed this species as occasionally abundant in Lake Michigan. Schelske et al. (1971) and Holland and Beeton

(1972) reported that *C. stelligera* was among the offshore dominants. In July of 1969, an average density of 422 cells/mL was observed for *C. stelligera* (Schelske et al. 1971).

In 1983 abundance of *C. stelligera* was less than 0.1% of the total cells. On a biomass basis, *C. comta* was the dominant species of *Cyclotella* (4.0% of the total biomass). Mean density and abundance were 6.3 cells/mL and 15.6 $mg/m^3$, respectively. Maximum density was 158 cells/mL. Abundance was low throughout the year reaching a peak in October. Stations 64 and 77 experienced a substantially higher mean station abundance (23.9 cells/mL) than in the rest of the lake (2.3 cells/mL).

*Cyclotella michiganiana* Skv.

Stoermer (1978) listed this species as a common element of the plankton community. Stoermer and Kopczynska (1967a) found it to be a major dominant in collections from southern Lake Michigan in 1962 and 1963. Stoermer and Yang (1970) noted that most modern abundant occurrences came from offshore stations in the extreme northern part of the lake. In 1969 the mean abundance for July was 64 cells/mL (Schelske et al. 1971). In 1965 Holland (1969) observed this species to reach densities of ~300 cells/mL and 100 cells/mL at the offshore Michigan and Wisconsin stations. Highest abundance was in August.

In 1983 mean density and biomass were 12.1 cells/mL and 2.7 $mg/m^3$, respectively. This species represented 0.68% of the total biomass (Table 8). Mean station abundance was low through August and then steadily increased to 38 cells/mL in October (Fig. 26c). Even peak density in 1983 (117 cells/mL) was lower than those abundances observed by Holland (1969) in 1965.

Cymatopleura solea (Breb. & Godey) W. Sm.

Stoermer and Kopczynska (1967a) reported this species as present in small numbers in nearshore stations in 1962-63. Isolated individuals were also occasionally noted in samples from the offshore station. Low densities of 0.2 cell/mL were observed in Green Bay in 1977 (Stoermer and Stevenson 1979). Similarly low densities (0.16 cell/mL) were observed for southern Lake Michigan in 1977 (Stoermer and Tuchman 1979).

In 1983 mean abundance was 0.3 cell/mL with a maximum of 3.7 cells/mL in April. Seasonally, peak abundance occurred in the spring and late October. With a mean biomass of 6.0 mg/m$^3$, this species represented 1.5% of the total biomass.

Entomoneis ornata (J.W. Ball.) Reim.

Stoermer and Tuchman (1979) reported a density of 0.05 cell/mL in the nearshore of southern Lake Michigan in 1977. In 1983 a similar density of 0.15 cell/mL was observed for all sampling stations. Mean biomass (3.3 mg/m$^3$) was relatively high (0.86% of the total biomass).

Fragilaria crotonensis Kitton

During 1962-63 F. crotonensis was the major dominant in the genus. In October of 1967, mean abundance was 1.3 cells/mL (Parkos et al. 1969). Maximum abundance reported by Holland (1969) was ~500 cells/mL. Schelske et al. (1971) reported mean abundances for July and August/September of 1969 of 100 cells/mL and 15 cells/mL, respectively. Stoermer and Yang (1970) stated that this species was the "most consistent major dominant" in the Lake Michigan flora reaching its greatest relative abundance during the summer and early fall. In 1976-77, Rockwell et al. (1980) observed a mean abundance of 325 cells/mL for the June-September period.

In 1983 mean abundance and biomass were 59.4 cells/mL and 42.4 mg/m$^3$, respectively (Table 8). With major abundance peaks in July and October (Fig. 26f), this species contributed 10.9% of the total biomass. Mean station abundance was higher (129 cells/mL) at the northern stations (64 and 77) as compared to the rest of the lake (43.9 cells/mL).

### Fragilaria vaucheriae (Kütz.) Peters.

Stoermer and Ladewski (1976) suspect that this species is primarily benthic in habitat preference. A mean abundance of 0.4 cell/mL was observed in the nearshore of southern Lake Michigan in 1977.

In 1983 mean density and biomass were 10 cells/mL and 4.6 mg/m$^3$, respectively (Table 8). Mean maximum station abundance (31 cells/mL) occurred in the spring (Fig. 26f). Mean station abundance was greatest at the northern stations (57,64,77) (24.3 cells/mL) than in the rest of the lake ($\bar{x}$ = 4.1 cells/mL).

### Melosira islandica O. Mull.

Stoermer (1978) listed this species as a common element of the plankton assemblage. In 1962-63, M. islandica was by far the most abundant member of the genus in the offshore waters of the lake (Stoermer and Kopczynska 1967a). In 1965 maximum abundance in the offshore waters was ~100 cells/mL during the spring (Holland 1969).

In 1970 mean offshore density was 41 cells/mL in May (Holland and Beeton 1972). In the nearshore of southern Lake Michigan in 1977, this species constituted 0.04% of the population (1.5 cells/mL) with a maximum of 27 cells/mL. Rockwell et al. (1980) reported a mean *Melosira* sp. abundance of 186 cells/mL in 1976-77. Stoermer and Yang (1970) reported it as a spring dominant.

In 1983 mean maximum station abundance occurred in the spring (Fig. 27b). Mean abundance and biomass for the sampling period were 12.1 cells/mL and 10.9 mg/m$^3$, respectively. Maximum abundance was 137 cells/mL in May at Station 18. This species represented 2.8% of the total biomass.

*Melosira* *italica* subsp. *subarctica* O. Mull.

Stoermer (1978) listed this species as a common element of the plankton of Lake Michigan. During 1962-63 Stoermer and Kopczynska (1967a) reported *M. islandica* as the dominant species of this genus. Holland and Beeton (1972) noted a mean abundance of 13.7 cells/mL at offshore stations in January of 1971. Stoermer and Ladewski (1976) reported this species as largely restricted to offshore stations. In the nearshore during 1977, mean abundance of *M. italica* was 10 cells/mL with a maximum of 56 cells/mL.

In 1983 mean abundance was 37.6 cells/mL with a maximum abundance of 357 cells/mL at Station 18 in early May (Table 8). Mean station abundance peaked at 161 cells/mL in the spring (Fig. 27a). Abundance in the southern half of Lake Michigan (51.9 cells/mL) was substantially higher than in the northern half (23.9 cells/mL) (Stations 34,41,47,64,77).

### *Rhizosolenia eriensis* H.S. Sm. and *Rhizosolenia* sp.

This species is widely distributed in large oligotrophic to mesotrophic lakes of the world (Stoermer and Yang 1970). In May of 1962-63, relatively high (100 cells/mL) populations were observed in southern Lake Michigan (Stoermer and Kopczynska 1967a). During May and June of 1970, mean abundances for offshore stations were 63 and 611 cells/mL, respectively (Holland and Beeton 1972). Rockwell et al. (1980) reported a mean density of 46.2 cells/mL for *R. longiseta* during 1976-77.

In 1983 mean abundance was only 2.6 cells/mL, and it was essentially absent from the lake except for high abundances in the northern half of the lake in October (Fig. 28c). This species contributed 1.6% of the biomass of the lake. In 1983 *Rhizosolenia* sp. occurred only at Station 77. A small spring peak was observed with a substantial bloom (133 cells/mL) in late October.

### *Stephanodiscus alpinus* Hust.

The most common members of this genus in offshore collections in 1962-63 were *S. transilvanicus* and *S. niagarae* (Stoermer and Kopczynska 1967). In 1970, Holland and Beeton(1972) reported an average of 3.7 cells/mL from the offshore region. Stoermer and Yang (1970) reported that it was widely distributed in Lake Michigan, but abundant occurrences were restricted to nearshore areas of the main lake. In the nearshore zone of southern Lake Michigan during 1977, mean abundance was 9.1 cells/mL with a maximum abundance of 69 cells/ml.

In the present study, mean abundance and biomass were 2.9 cells/mL and 19.4 $mg/m^3$, respectively. Maximum abundance was 22 cells/mL. Mean station abundance was high in the spring ($\bar{x}$ = 7.4

cells/mL) and in late October (3.2 cells/mL). This one species accounted for only 0.01% of the total cells but 4.5% of the total biomass for the sampling period.

*Stephanodiscus niagarae* Ehr.

Stoermer (1978) listed this species as present in minor quantities. In 1962-63 Stoermer and Kopczynska (1967a) noted that the most common members of this genus were *S. transilvanicus* and *S. niagarae* (abundance = 1.0 cell/ml). Stoermer and Yang (1970) reported a high relative abundance in late spring and early fall. Stoermer (1978) listed it as occasionally abundant. Stoermer and Tuchman (1979) reported a mean abundance of 0.07 cell/ml in 1977.

In 1983 abundance was higher in the spring and late October (Fig. 26d). Mean abundance was only 0.79 cell/mL, but biomass averaged 9.9 $mg/m^3$. This species contributed 2.5% of the total biomass.

*Stephanodiscus transilvanicus* Pant.

Stoermer (1978) reported this species as a common element of the plankton assemblage. In 1962-63 this species was a common member of this genus with *S. niagarae* (abundance = 1.0 cell/mL). Stoermer and Yang (1970) reported that the majority of abundant occurrences were found in offshore samples. Stoermer and Tuchman (1979) did not observe this species in the nearshore zone of southern Lake Michigan.

In 1983 mean abundance and biomass were 22.7 cells/mL and 0.3 $mg/m^3$, respectively (Table 8). Maximum abundance attained was 6 cells/mL in early October. Density was highest in the spring (Fig. 26d). This species contributed 1.6% of the total biomass.

Tabellaria fenestrata Kutz.

Schelske et al. (1971) observed a July mean abundance of 72.5 cells/mL in 1969. According to Stoermer and Yang (1970), T. fenestrata is nearly always present in phytoplankton collections from Lake Michigan but usually makes up a minor part of the diatom assemblage. Modern reports of abundant occurrences are essentially restricted to offshore stations in the northeastern part of the lake. In 1977 in the nearshore of southern Lake Michigan, a mean density of 1.4 cells/mL was observed (Stoermer and Tuchman 1979). Rockwell et al. (1980) reported mean abundance of 77.1 cells/mL in 1976-77.

In 1983 mean abundance and biomass were 4.1 cells/mL and 7.2 mg/m$^3$, respectively (Table 8). Seasonally, mean station abundance was high in spring (14.4 cells/mL) but near zero during the rest of the sampling period (Fig. 26e). Abundance (13.1 cells/mL) in the northern region of the lake was higher than in the stations south of Station 57 ($\bar{x}$ = 0.78 cell/mL). Maximum abundance was 79 cells/mL at Station 64 on 4 May 1983 (Fig 27d). This species represented 1.9% of the total biomass.

Tabellaria flocculosa (Roth) Kütz.

Holland (1969) reported a maximum density of ~100 cells/mL in offshore waters of Lake Michigan in 1965. During October, Parkos et al. (1969) observed a mean density of 2 cells/mL. During 1970-72, Holland (1980) reported an offshore mean density of 11.3 cells/mL. In the nearshore of southern Lake Michigan in 1977, mean abundance was 122 cells/mL representing 2.3% of the population (Stoermer and Tuchman 1979).

In 1983 the mean density of T. flocculosa was 16.8 cells/mL with a maximum of 202 cells/mL at Station 64 in May. Mean biomass was 48.9 mg/m$^3$ representing 12.6% of the total biomass (Table 8). On a biomass basin, this was the dominant diatom in the lake in 1983. Peak abundance occurred in May (59.2 cells/mL) (Fig. 26e). Mean station abundance was significantly higher (44.7 cells/mL) in the northern region of the lake (Stations 57,64,77) as compared to the rest of the lake (6.3 cells/mL).

# ZOOPLANKTON

## Annual Abundance of Zooplankton Groups

Species lists (Tables A10-A12) and summary tables of abundance (Tables A13-A18) are in Volume 2 - Data Report.

### LAKE ERIE

The zooplankton assemblage was composed of 71 zooplankton taxa representing 40 genera from the Rotifera, Cladocera, Calanoida, Cyclopoida and Harpacticoida. The Rotifera possessed the largest number of taxa (34) and relative abundance (69.2%), while the second largest number of taxa (19) and abundance were observed for the Cladocera (Table 9). In descending order of relative abundance were the Cyclopoida, Calanoida and the Harpacticoida. The nauplius stage of the Copepoda accounted for 15.8% of the total organisms observed. The average density for the study period for all stations was 288,341 organisms/$m^3$ (Table 10).

### LAKE HURON

The zooplankton assemblage consisted of 61 zooplankton taxa representing 33 genera from the Rotifera, Calanoida, Cyclopoida, Cladocera and the Mysidacea. The Rotifera possessed the largest number of taxa (31) and relative abundance (41.1%). In descending order of relative abundance were the Calanoida, Cyclopoida, Cladocera and Mysidacea (Table 9). The nauplius stage of the Copepoda accounted for 23.1% of the total organisms observed. The average abundance for the study period for all stations was 46,230 organisms/$m^3$ (Table 19).

LAKE MICHIGAN

The zooplankton assemblage consisted of 73 zooplankton taxa representing 43 genera. The Rotifera possessed the largest number of taxa (33) and the highest relative abundance (59.7%). In descending order were the Calanoida, Cyclopoida, Cladocera, Harpacticoida and Cyclopoida (Table 9). The nauplius stage of the Copepoda accounted for 21.3% of the total organisms observed. The average abundance for the study period for all stations was 69,353 organisms/$m^3$ (Table 10).

Seasonal Abundance and Distribution of Major Zooplankton Groups

Seasonal analyses of zooplankton are of interest. Interpretation of seasonal trends of the 1983 data set is limited because of the lack of data from early May to early August.

LAKE ERIE

Seasonally, abundance (organisms/$m^3$) appeared to be unimodal increasing in late April to a summer maximum (~400,000 organisms/$m^3$) which continued till at least late August. By October, abundance decreased to spring densities (Fig. 29). The shape of the seasonal abundance pattern of zooplankton was determined by the overwhelming dominance of rotifers during the spring, summer and fall. The Cyclopoida increased in spring and began to decrease in abundance from August to late October. The Calanoida and Cladocera increased in abundance from April to August and then decreased into the fall (Fig. 30).

## LAKE HURON

Because zooplankton data (short hauls) are available only from the late summer and early fall, seasonal analysis is not warranted.

## LAKE MICHIGAN

Zooplankton abundance was low in April (~25,000 organisms/m$^3$) but appeared to progressively increase to ~150,000 organisms/m$^3$ in mid-October and then decreased by late October (Fig. 29). In the spring, the Copepoda nauplii were the dominant group in the lake. By August the Rotifera increased in abundance and remained the dominant group within the lake to the last sampling date in October. The pattern of distribution exhibited by the Rotifera was not observed in the other zooplankton groups (Fig. 31). The Cyclopoida and Cladocera appeared to increase in abundance from April to mid-October when a slight decrease was evident by late October. The Calanoida appeared to have a bimodal distribution with a summer maxima and late fall peak (Fig. 31).

## Geographical Abundance and Distribution of Major Zooplankton Groups

## LAKE ERIE

Zooplankton abundance during the study period was greatest at the western end of the lake, decreased easterly to Station 73, increased to Station 79 and remained level at ~200,000 organisms/m$^3$ in the eastern end of the lake (Fig. 32). This geographical distributional pattern was primarily determined by the abundance pattern of the Rotifera. The Calanoida copepods generally increased in abundance from west to east, while the Cyclopoida copepods had a higher abundance in the central basin. The Cladocera and the nauplius stage of the Copepoda displayed no discernible geographical pattern.

LAKE HURON

The mean zooplankton abundance for the study period generally decreased from north to south (Fig. 33) with the exception of Station 32. Much of this geographical distributional pattern was determined by the abundance pattern of the Rotifera. Calanoida abundance was lower in the north relative to the rest of the lake. Mean Cyclopoida abundance was higher at the far northern and southern ends of the lake. Cladocera abundance was relatively similar from station to station on the north-south transect.

LAKE MICHIGAN

In comparison to Lakes Erie and Huron, a geographical distributional pattern for zooplankton in Lake Michigan, if any existed, was erratic. There was a suggestion of decreasing zooplankton abundance from north to south (Fig. 34). Rotifera in particular did decrease southward on the transect, while the Calanoida had approximately twice the abundance in the southern half (Stations 34-6) than in the northern half (Stations 77-41) of the lake. The Cladocera ranged from only 1,000 to 2,000/$m^3$ except at Station 64 where a mean density of $\sim$5,500/$m^3$ was observed. No discernible trends in Cyclopoida density were observed.

## Size Frequency Analysis

Size frequency analyses were based on abundances obtained from each lake from the epilimnetic tows (i.e. short hauls) and literature values of length for adult individuals.

### LAKE ERIE

Eighty-four percent of the zooplankton observed were in the 0.1 to 0.3-mm size class. The rotifers and nauplius stage of the copepod fell into this size class. Another peak (6.2%) in size frequency was observed at the 0.6-mm size class. The copepodite stages of the calanoid and cyclopoid copepods were the predominant groups in this size category (Fig. 35).

### LAKE HURON

Over 39% of the zooplankton observed were in the 0.6-mm size class. The calanoid and cyclopoid copepods fell primarily into this size class. Another large group of organisms (rotifers and nauplii) (50%) were observed in the 0.1 to 0.3 size class (Fig. 35). This size class distribution varied little with season or geography.

### LAKE MICHIGAN

Seventy-nine percent of the zooplankton observed were in the 0.1 to 0.3 size class. Rotifers and the nauplius stage of the copepod were the predominant organisms in this size range. Another peak in size frequency was observed in the 0.6-mm size class. The calanoid and cyclopoid copepods were the predominant organisms in this size class (Fig. 35).

## Regional and Seasonal Trends in the Abundance of Common Taxa

### LAKE ERIE

Crustacea were arbitrarily classified as common if they accounted for >0.1% of the total abundance for the study period. Rotifer species were considered common if they accounted for >1.0% of the total abundance.

Copepoda

Copepoda nauplii, Calanoida and Cyclopoida copepodite

Seasonal distribution and summary of average and maximum density and relative abundance are presented in Table 11 and Fig. 36b and c.

Cyclopoida

*Cyclops bicuspidatus thomasi*

On a yearly basis, this is the most important species of crustacean zooplankton in the Great Lakes (Balcer et al. 1984). Mean abundance was 2,825 organisms/$m^3$ representing 1.2% of the total abundance (Table 11). This was the dominant Cyclopoida. Maximum abundance (11,809/$m^3$) occurred on 25 April at Station 37. Abundance was generally higher (mean station abundance = 3,822/$m^3$) in the central basin (Fig. 39b) than in the western (1,254/$m^3$) or eastern (1,636/$m^3$) basins.

*Mesocyclops edax*

Mean abundance was 1,669 organisms/$m^3$ representing 0.7% of the total abundance (Table 11). Mean cruise abundances peaked in early August at 3,960 organisms/$m^3$ which agreed with most workers (Balcer et al. 1984). Maximum abundance was 14,584 organisms/$m^3$ at Station 79 on 6 August. Abundance was greater in the central and eastern basins (Fig. 40a).

### Tropocyclops prasinus mexicanus

Average density in the short hauls (epilimnetic tows) was 748 organisms/$m^3$. Density was considerably higher in the long hauls (1,742/$m^3$). Maximum abundance was 3,300 organisms/$m^3$ in October at Station 9. Abundance increased dramatically from west to east (Fig. 39c). Mean station abundances in the western, central and eastern basins were 112, 617 and 1,104 organisms/$m^3$, respectively. Peak abundance generally occurred in late summer and early fall.

## Calanoida

### Diaptomus oregonensis

Balcer et al. (1984) reported this species as being most abundant in the summer and fall. This agreed well with the 1983 observation of peak mean cruise abundances of 3,558 and 5,505 organisms/$m^3$ on 6 and 22 August (Fig. 39a). Abundance was greatest in the central basin (mean station abundance = 2,385/$m^3$) as compared to the western (116/$m^3$) and the eastern basins (2,011/$m^3$). Mean abundance was 2,034 organisms/$m^3$ making it the dominant Calanoida.

### Diaptomus siciloides

In Lake Erie this species is one of the most abundant calanoid copepods during the summer months, ranking second to D. oregonensis (Davis 1961). Average abundance in July of 1967 was ~1,710 organisms/$m^3$ (Davis 1968) with peaks of 15,800/$m^3$ (Rolan et al. 1973) in 1971 near Cleveland.

In 1983 mean density was 600 organisms/$m^3$ (0.2% of the total organisms) with a maximum of 13,334 organisms/$m^3$ at Station 15 on 6 August. No obvious geographical pattern was observed, but there is a suggestion that abundance in the western and eastern basins was higher than in the central basin. Mean maximum seasonal abundance (1,865/$m^3$) occurred in early August (Fig. 36a).

## Cladocera

### *Bosmina longirostris*

Abundance generally peaks in late summer or early fall (Balcer et al. 1984) which appears to agree with the 1983 observations. Mean seasonal abundance ranged from 1,303 to 1,524 organisms/$m^3$ from April to 19 October. By 24 October, mean seasonal abundance increased to 2,187 organisms/$m^3$ (Fig.38f). For the sampling period, mean station abundance was higher in the western basin (1,939/$m^3$) than in the central (1,139/$m^3$) and eastern basins (1,047/$m^3$). This pattern was especially noticeable during the October maximum when the western basin experienced considerably higher densities (6,182/$m^3$) than in the rest of the lake (689/$m^3$). Mean abundance for the sampling period was 1,628 organisms/$m^3$ representing 0.7% of the total organisms.

### *Eubosmina coregoni*

Balcer et al. (1984) reported that abundance can reach 47,000 organisms/$m^3$. In 1983 mean abundance was 4,505 organisms/$m^3$ with a maximum of 64,384/$m^3$ at Station 57 in late October. Mean station abundance of the western basin (6,213/$m^3$) was greater than in at the rest of the lake (2,738/$m^3$). Seasonally, two abundance peaks were evident in late August and late October (Fig. 36d). This species was the dominant cladoceran in the lake contributing 1.7% of the abundance.

### *Chydorus sphaericus*

This species is occasionally abundant in Lake Erie ($3,000-30,000/m^3$) (Balcer et al. 1984). Mean abundance was low in 1983 ($476/m^3$) (Table 11), but mean seasonal abundance was high in October ($1,309/m^3$) (Fig. 36d). Maximum abundance was $14,902/m^3$ at Station 73 on 19 October.

### *Daphnia retrocurva*

This species is one of the most abundant cladocerans in the Great Lakes. Densities of $4,000-10,000/m^3$ have been reported for Lake Erie with peaks in abundance as early as June in Lake Erie (Balcer et al. 1984). Mean seasonal abundance was low in April and May, was high ($7,150/m^3$) from July to August and decreased in October (Fig. 36e). A maximum abundance of 69,542 organisms/$m^3$ was observed at Station 55 in the western basin on 19 October. Mean abundance was 4,183 organisms/$m^3$ representing 1.4% of the total organisms.

### *Daphnia galeata mendotae*

Historically, this species has been quite abundant (average = $900-5,000/m^3$) with peaks of $270,000/m^3$ (Balcer et al. 1984).
In 1983 mean abundance was 4,055 organisms/$m^3$ representing 1.5% of the total biomass (Table 11). They were not present in April and May and first appeared in our samples in early August (mean abundance for 6 August = $11,453/m^3$) and decreased in abundance till October (Fig. 38e). The western basin had a lower abundance ($298/m^3$) than the rest of the lake ($4,450/m^3$). Maximum abundance was 60,151 organisms/$m^3$ at Station 18 on 6 August.

### *Diaphanosoma leuchtenbergianum*

In Lake Erie, *Diaphanosoma* is most abundant in the western basin in July and in the eastern and central basins during the fall (Balcer et al. 1984). In the 1983 sampling, an abundance peak was observed on 22 August ($\bar{x} = 4{,}323/m^3$) (Fig. 36e). No obvious geographical pattern was observed. Mean abundance for the sampling period was 966 organisms/$m^3$ representing 0.4% of the total organisms (Table 11).

## Rotifera

### *Polyarthra vulgaris*

Mean abundance was 49,739 organisms/$m^3$ representing 18.4% of the total organisms (Table 11). Maximum abundance attained was 334,317 organisms/$m^3$ at Station 57 on 22 August. This was the dominant zooplankter in 1983. Mean seasonal abundance was highest in late August (87,804/$m^3$) (Fig. 38a). Density decreased from the western (60,567/$m^3$) to the central (37,222/$m^3$) to the eastern basin (26,561/$m^3$).

### *Polyarthra dolichoptera*

With a mean abundance of 8,329/$m^3$, this species contributed 2.7% of the total abundance (Table 11). Mean seasonal abundance peaked at 33,900 organisms/$m^3$ in early May (Fig. 38a). No geographical patterns were observed.

### *Polyarthra major*

Mean peak seasonal abundance (~10,000/$m^3$) occurred in the late summer and fall (Fig. 38b). Mean abundance for the sampling period was 6,395 organisms/$m^3$ with a maximum of 24,657/$m^3$ at

Station 42 in late October. Abundance was slightly higher in the long hauls (Table 11).

### *Keratella cochlearis*

With a mean abundance of 19,647 organisms/m$^3$, this species contributed 7.3% of the total organisms. With a maximum of 110,636 organisms/m$^3$ in May at Station 60, this was the third most dominant rotifer and species in the lake. Mean seasonal abundance reached a peak (42,490/m$^3$) in August (Fig. 37c). Abundance in the western basin (24,709/m$^3$) was higher than in the central and eastern basins (12,837/m$^3$).

### *Keratella hiemalis*

With a seasonal mean abundance peak of 47,244 organisms/m$^3$ in May, this species appeared to be restricted in distribution to the central basin (Fig. 42b). Mean abundance for the sampling period was 10,701 organisms/m$^3$ with a maximum of 127,000/m$^3$ at Station 42 in May (Table 11).

### *Keratella crassa*

This species had a mean abundance of 5,384 organisms/m$^3$ during the sampling period representing 1.8% of the total organisms (Table 11). Maximum mean seasonal abundance (19,165/m$^3$) occurred in late August (Fig. 37d). A maximum of 97,000 individuals/m$^3$ was observed on 22 August at Station 57 (Table 11).

### *Keratella earlinae*

Although this species was not a common species, its distribution pattern was of interest. This species generally had a restricted geographical distribution to the western basin with only a few minor occurrences in the central basin (Fig. 41a).

*Synchaeta* sp.

Mean maximum seasonal abundance occurred in early August in the western basin. Abundance was low in the rest of the lake (Fig. 41b). Mean abundance for the sampling period was 29,442 organisms/m$^3$ with a maximum of 370,000/m$^3$ in early August at Station 60. This species was the second most dominant zooplankton and rotifer in the lake contributing 9.5% of the abundance.

*Brachionus* sp. and *B. caudatus*

*Brachionus* sp. contributed 3.0% of the total abundance and had a mean abundance of 9,307 individuals/m$^3$ (Table 11). This species had the highest abundance (540,369/m$^3$) observed of any species in Lake Erie. Distribution was limited to the extreme western end of the western basin with maximum abundance in early August (Fig. 40b). Although *B. caudatus* was not a common species, a similar distribution limited to western basin was observed (Fig. 42c).

*Ascomorpha ecaudis* and *Ascomorpha* sp.

Maximum mean seasonal biomass occurred in August (20,773/m$^3$) (Fig. 38d). Geographically, it was observed in the western and central basin (mean station abundance = 7,252/m$^3$) but not in the eastern basin. Mean abundance was 6,446 individuals/m$^3$. Seasonal distribution of a minor species *Ascomorpha* sp. is given in Figure 38d.

*Notholca laurentiae*

Mean seasonal abundance peaked in early May at 20,632 organisms/$m^3$. Geographically, abundance was low in the eastern basin (mean station abundance = 1207/$m^3$) as compared to the western (9050/$m^3$) and central basins (6383/$m^3$). Mean abundance was 6,964/$m^3$.

*Notholca foliacea*

Abundance varied geographically with mean station abundance low in the eastern basin (184 individuals/$m^3$) as compared to the western (10,357/$m^3$) and central basins (3,399/$m^3$). Maximum mean seasonal abundance occurred in May (18,583/$m^3$) (Fig. 37f) with abundance near zero during the rest of the sampling period. Mean abundance was 5,402 organisms/$m^3$.

*Colletheca* sp.

Abundance was low in April and May, reached a peak (mean August abundance = 18,400/$m^3$) in mid-August and decreased by late October. Mean station abundance was highest (5,917/$m^3$) in the central basin (western basin = 2,158/$m^3$; eastern basin = 3,872/$m^3$). Mean abundance for the sampling period was 5,402 organisms/$m^3$.

*Kellicottia longispina*

Two maxima in abundance were observed (Fig. 37b). The central basin had the highest abundance (mean station abundance = 4,457/$m^3$) followed by the western (2,437/$m^3$) and eastern basins (902/$m^3$).

### Less Common Species

Graphical representations of the seasonal abundance of the following less common species are given: *Asplanchna priodonta* (Fig. 36f), *Conochilus unicornis* (Fig. 37a), *Ploesoma* sp. (Fig. 37b), *Keratella quadrata* (Fig. 37c), *Notholca squamala* (Fig. 37e), *Polyarthra major* (Fig. 38b) and *Gastropus stylifer* (Fig. 38c).

The following less common species of distribution were distinctly limited to the western basin: *Filinia longiseta* (Fig. 40c), *Keratella earlinae* (Fig. 41a), *Trichocerca cylindrica* (Fig. 41c) and *Trichocerca multicrinis* (Fig. 42a).

## LAKE HURON

Crustacea were arbitrarily classified as common if they accounted for >0.1% of the total abundance for the study period. Rotifer species were considered common if they accounted for >1.0% of the total abundance.

### Copepoda

Copepoda nauplii, Calanoida and Cyclopoida copepodite

Seasonal distribution and summary of average and maximum density and relative abundance are presented in Table 12 and Figures 43c and d.

#### *Cyclops biscuspidatus thomasi*

This species is one of the most common and widely distributed copepods in North America. Balcer et al. (1984) reported this species as abundant in Lake Huron. In 1983 this was the dominant cyclopoid in Lake Huron accounting for 1.1% of the total abundance (Table 12). Abundance ($533/m^3$) was slightly higher at the extreme northern end of the lake (Stations 51 and 64) than in the rest of the lake ($230/m^3$). Mean maximum seasonal abundance ($925/m^3$) occurred in early August (Fig. 43d).

#### *Tropocyclops prasinus mexicanus*

Balcer et al. (1984) reported this species as being present in Lake Huron since 1967. Abundance historically has peaked between August and November (Balcer et al. 1984). In 1983 a maximum abundance (mean October density = $267/m^3$) was observed in mid-Octobr (Fig.

43e). No obvious geographical pattern was noted. Mean abundance for the sampling period was 109 organisms/$m^3$ with a maximum of 577/$m^3$ at Station 15 in October (Table 12).

*Mesocyclops edax*

Balcer et al. (1984) reported this species as being most common in Lakes Erie and Michigan. In 1983 this was the third most common cyclopoid with a mean density of 115 organisms/$m^3$ and a maximum density of 930 organisms/$m^3$ at Station 12 in mid-August. Mean maximum seasonal abundance occurred in August (267/$m^3$). Abundance was slightly higher south of Saginaw Bay (99/$m^3$) compared to the area north of it (41/$m^3$).

### Calanoida

*Diaptomus minutus*

This species has been found in all the Great Lakes but is most abundant in Lakes Huron (Patalas 1972) and Michigan (Gannon 1972). In the present study, it was the dominant calanoid with a mean abundance of 465 organisms/$m^3$ representing 0.8% of the total abundance. Mean maximum seasonal abundance (911/$m^3$) occurred in early August (Fig. 46a). Abundance was low in the north and peaked at mid-lake (Stations 37,32,27) and in the southern region of the lake (Stations 12,9,6) (Fig. 46a). Maximum density of 2,063 organisms/$m^3$ occurred at Station 6 on 4 August.

*Diaptomas sicilis*

Balcer et al. (1984) reported this species as occurring in low numbers in Lake Huron. *D. sicilis* is generally found during all seasons, but the adults are generally most abundant between January and June. In 1983 mean minimum seasonal abundance occurred in August with maxima at the first (208/$m^3$) and last (295/$m^3$) sampling dates (Fig. 43b) suggesting a winter maximum. No obvious geographical pattern was observed.

### *Diaptomus oregonensis*

This species is most abundant in the Great Lakes in the summer and fall (Balcer et al. 1984). In 1983 mean maximum seasonal abundance (177/$m^3$) occurred in August. Mean abundance for the sampling period was 140 organisms/$m^3$ with a maximum of 413 individuals/$m^3$ at Station 12 on 19 August.

## Cladocera

### *Daphnia galaeta mendotae*

This species was the dominant cladoceran in the lake with an average density of 1,029 organisms/$m^3$ representing 1.4% of the total abundance (Table 12). Maximum abundance was 4,076 individuals/$m^3$ at Station 9 in early August. Two maxima were observed in August (mean August abundance = 1,328/$m^3$) and October (1,117/$m^3$).

### *Daphnia pulicaria*

Balcer et al. (1984) noted that *D. pulicaria* has not been observed in the Great Lakes. Evans (1985) recently reported that *D. pulicaria* was a new species dominating Lake Michigan. In 1983 in Lake Huron, *Daphnia pulicaria* was observed to be the third most important cladoceran (Table 12). Mean abundance was 363 organisms/$m^3$ with a maximum of 2,791 organisms/$m^3$ at Station 12 on 19 August. Mean maximum seasonal abundance occurred in mid-August (730/$m^3$) (Fig. 44a). Mean station abundance increased from north to south with a mean density for stations south of Saginaw Bay of 431 organisms/$m^3$.

### Daphnia retrocurva

*D. retrocurva* is most common in the nearshore zone of the Great Lakes appearing in the open waters only during peak abundance (Balcer et al. 1984). In 1974-75, McNaught et al. (1980) reported it as an uncommon species in Lake Huron. In 1983 mean abundance was 74/$m^3$. Abundance was generally low for the lake except for the far north where a maximum of 2,148 organisms/$m^3$ was observed at Station 61 in mid-August.

### Daphnia catawba

Balcer et al. (1984) did not list this species as a common or less common species of the Great Lakes. In 1983 it did not appear in the short hauls (Table 12). However, a maximum abundance of 1,610 organisms/$m^3$ was observed from Station 12 in August from the long hauls. Mean maximum seasonal abundance was 442 organisms/$m^3$ in mid-August.

### Holopedium gibberum

Abundance along the western side of Lake Huron ranged from 7-17 individuals/$m^3$ (Basch et al. 1980). In 1983 mean abundance of 58 organisms/$m^3$ with a maximum of 408/$m^3$ occurred at Station 61 in August. Mean seasonal abundance reached a maximum of 125 organisms/$m^3$ in early August. Mean station abundance was higher north of Station 37 (63/$m^3$) than south of it (8.6/$m^3$).

## Rotifera

### *Conochilus unicornis*

This colonial rotifer was the dominant zooplankter in 1983 in Lake Huron (11.2% of the total abundance) (Table 12). Mean seasonal abundance peaked in early August (10,927/$m^3$) with abundance being higher north of Saginaw Bay (Fig. 47a).

### *Kellicottia longispina*

With an average density of 2,088 individuals/$m^3$, this species contributed 8.6% of the total abundance. Maximum density was 7,106/$m^3$ in the short hauls. However, a maximum density of 21,721 organisms/$m^3$ was observed in the long hauls suggesting that this species is found in higher densities in the metalimnion and/or hypolimnion (Table 12). Mean seasonal abundance peaked in early August (Fig. 47b) with abundance being slightly higher north of Saginaw Bay (north: 1,282/$m^3$; south: 838/$m^3$).

### *Keratella cochlearis*

Mean abundance was 2,040 organisms/$m^3$ representing 7.2% of the total abundance (Table 12). Maximum abundance in the short haul (epilimnetic tow) was 5,457/$m^3$, which is considerably less than the maximum abundance (18,633/$m^3$) observed from the long haul. Mean seasonal abundance peaked at 3,521 organisms/$m^3$ in early August (Fig. 44d).

### *Polyarthra vulgaris*

Mean maximum seasonal abundance occurred in mid-August (4,691/$m^3$) (Fig. 45b). This species accounted for 5.3% of the total organisms (2,955/$m^3$) (Table 12).

### *Gastropus stylifer*, *Synchaeta* sp., *Colletheca* sp.

Average abundance and maximum abundance for these common species are presented in Table 12. Mean seasonal abundance is presented in Figures 44c and 45c.

### Less Common Species

The seasonal distributional patterns of less common species are presented in the following figures: *Asplanchna priodonta* (Fig. 44c); *Keratella crassa*, *K. earlinae* and *K. quadrata* (Fig. 44e); *Notholca laurentiae*, *N. squamula* (Fig. 44f); and *Polyarthra major*, and *P. dolichoptera* (Fig. 45a).

## LAKE MICHIGAN

Crustacea were arbitrarily classified as common if they accounted for >0.1% of the total abundance for the study period. Rotifer species were considered common if they accounted for >1.0% of the total abundance.

### Copepoda

Copepoda nauplii, Calanoida and Cyclopoida copepodite

Seasonal distribution and summary of average and maximum density and relative abundance are presented in Table 13 and Figure 48c and d.

### Cyclopoida

#### *Diaptomus ashlandi*

*D. ashlandi* has been reported as the dominant calanoid copepod in the open waters of Lake Michigan usually exceeding 1,000 individuals/m$^3$ (Balcer et al. 1984). In 1983 this species averaged 699 organisms/m$^3$ with a maximum of 6,536/m$^3$ at Station 64 on 3 August. Mean maximum seasonal abundance occurred in early August (2,243/m$^3$) (Fig. 48a). Contributing 1.1% of the total abundance, this species was the dominant calanoid copepod in 1983.

#### *Diaptomus sicilis*

In Lake Michigan, abundance declined between 1954 and 1968 (Wells 1970). It averaged less than 100/m$^3$ in the early 70's in the open lake (Gannon 1972). In 1983 average abundance for the lake was 386 organisms/m$^3$ with a maximum of 4,200 individuals/m$^3$ (Table 12) at Station 32 on 26 October. Mean maximum seasonal abundance (1,282/m$^3$) occurred in late October. Abundance was definitely higher in the southern half of the lake (south of Staton 32) in October (mean station abundance = 2,327/m$^3$) (Fig. 51a).

### *Diaptomus minutus*

Gannon (1972) ranked this species as the second most important calanoid in the early 1970's. Peaks in abundance may exceed a few thousand organisms per cubic meter (Balcer et al. 1984). In 1983 average abundance was 167 organisms/m$^3$ with a maximum of 812/m$^3$ at Station 56 in late April. No obvious geographical or seasonal pattern was observed (Fig. 48b).

### *Diaptomus oregonensis*

*D. oregonensis* was not collected from Lake Michigan in 1927 (Eddy 1927, Beeton 1965) but by the 70's had become the most common diaptomid in Green Bay (Gannon 1972) and may often outnumber *Diaptomus sicilis* in the open waters of the lake (Wells 1960). Peaks of 2,580 individuals/m$^3$ have been observed in the summer in shallow areas of Lake Michigan (Howmiller and Beeton 1971).

In 1983 this species was the fourth most important diaptomid with a mean abundance of 115 organisms/m$^3$. Mean maximum seasonal abundance was 167 organisms/m$^3$ in early August (Fig. 48b). Maximum abundance (1,018/m$^3$) was observed at Station 32 in late October.

### *Limnocalanus macrurus*

Gannon (1972) reported this species as having a low abundance in southern Lake Michigan. In 1983 a mean abundance of 138 organisms/$m^3$ occurred with a maximum of 1,725 organisms/$m^3$ in April at Station 22. Mean seasonal abundance was higher in the spring (257/$m^3$) than during the rest of the sampling period (17/$m^3$). Mean station abundance was low (26/$m^3$) at the far northern stations (Stations 56,64,77) as compared to areas south of Station 56 (155/$m^3$).

### Cyclopoida

#### *Cyclops bicuspidatus thomasi*

On a yearly basis, this species is the most important species of the crustacean zooplankton in the Great Lakes. In the present study, it was the dominant cyclopoid contributing 1.6% of the total abundance ($\bar{x}$ = 1,140/$m^3$). Maximum abundance (5,216/$m^3$) was observed on 3 August at Station 66. No obvious geographical pattern was observed. Two maxima in mean seasonal abundance occurred in early August (1,895/$m^3$) and October (1,459/$m^3$) (Fig. 48e).

#### *Tropocyclops prasinus mexicanus*

In 1983 mean density was 238 organisms/$m^3$ with a maximum of 3,600/$m^3$ on 12 October at Station 10 (Table 12). Mean maximum seasonal abundance peaked in October at 669 organisms/$m^3$.

### Cladocera

#### *Bosmina longirostris*

In 1983 mean abundance was 923 organisms/$m^3$ contributing 1.4% of the total abundance. This was the dominant cladoceran in the lake. Maximum abundance was 17,000/$m^3$ (Table 12) which is considerably less than the 29,000-230,000 reported in Green Bay and the nearshore of Lake Michigan by Gannon (1974) and Stewart (1974). Mean seasonal maximum abundance occurred in early October (3,422/$m^3$) with abundance higher at the northern stations (Fig. 51b).

### *Daphnia galaeta mendotae*

Densities of 100-6,000/$m^3$ have been observed in Green Bay and the nearshore of Lake Michigan in the early 70's. In 1983 two mean seasonal abundance maxima were observed in July (741/$m^3$) and October (1,026/$m^3$) (Fig. 48f). Mean abundance observed was 445 organisms/$m^3$ representing 0.6% of the total abundance (Table 12). No obvious geographical patterns were apparent.

### *Daphnia pulicaria*

Balcer et al. (1974) noted that *D. pulicaria* has not been observed in the Great Lakes. Evans (1985) recently reported that *D. pulicaria* was a new species dominating Lake Michigan. A maximum abundance of 954 organisms/$m^3$ was observed in July.

In 1983 mean abundance for the sampling period was 445/$m^3$ with a maximum of 6,100/$m^3$ at Station 26 on 3 August. Mean seasonal abundance peaked in early August at 1,741 organisms/$m^3$ (Fig. 48f). When both the short and long hauls are considered, this was the dominant species of *Daphnia* in the lake.

### *Daphnia retrocurva*

Abundances were highest in the summer with maximum densities of 2,000-24,000 organisms/$m^3$ during the early 70's (Balcer et al. 1984). In 1983 mean abundance was 115/$m^3$ with a maximum of

3,200/$m^3$ at Station 5 on 12 October. Mean seasonal abundance peaked in early October (430/$m^3$) with density highest in southern Lake Michigan (Fig. 51c).

### Eubosmina coregoni

In April and May, abundance was low. By August, density increased to 167 organisms/$m^3$ and stayed at that approximate abundance to October (Table 12). Abundance was higher at Stations 64 and 77 (356/$m^3$) than in the rest of the lake (21/$m^3$).

### Holopedium gibberum

Abundance peaks generally occur betwen June and October (Balcer et al. 1984). Mean abundance in 1983 was 86/$m^3$. Mean maximum seasonal abundance (679/$m^3$) occurred in early August (Fig. 49a). Abundance at Stations 64 and 77 (395/$m^3$) was much higher than in the rest of the lake (3.4/$m^3$).

## Rotifera

### Polyarthra vulgaris

This species was the dominant zooplankton in Lake Michigan contributing 20.8% of the total abundance ($\bar{x}$ abundance = 16,996/$m^3$). Maximum abundance was 109,000/$m^3$ (Station 46; 17 August). Abundance was low in April and May but by mid-August a mean abundance of 42,598/$m^3$ was observed and maintained into early October (Fig. 50c).

### Synchaeta sp.

With a mean seasonal abundance peak (24,000/$m^3$) in mid-August

(Fig. 49c), this species had a mean abundance for the lake of 8,593 organisms/$m^3$ (Table 12).

### Keratella cochlearis

Mean abundance was 3,463 organisms/$m^3$ in 1983 representing 7.2% of the total abundance (Fig. 50a). Peak abundance occurred in late October (mean October abundance = 8,157/$m^3$). Abundance decreased from north to south (Stations 64 and 77; $\bar{x}$ = 11,470/$m^3$), (Stations 40,46,50; $\bar{x}$ = 2,574/$m^3$), (Stations 5,10,17,22,26,32; $\bar{x}$ = 959/$m^3$).

### Polyarthra major

Mean maximum seasonal abundance occurred in early October (4,856/$m^3$) (Fig. 50b). Mean abundance was 1,928 organisms/$m^3$ with a maximum of 23,000/$m^3$ at Station 40 on 12 October. This species represented 3.1% of the total abundance.

### Kellicottia longispina

Mean abundance was considerably higher in the long tow (4,688/$m^3$) relative to the short tow (981/$m^3$) suggesting that this species was more prevalent in the metalimnion or hypolimnion. Mean maximum seasonal abundance occurred in early August ($\bar{x}$ = 2,446/$m^3$).

### Conochilus unicornis

Mean seasonal abundance reached a peak in August of 4,457/$m^3$ (Fig. 49d). Mean abundance was 1,772/$m^3$ with a maximum of 21,000/$m^3$ on 17 August at Station 77 (Table 12). Mean station abundance was greater at Stations 64 and 77 (4,285/$m^3$) than in the rest of the lake (932/$m^3$).

### Other Common Species

Seasonal distribution patterns and mean and maximum abundances of the following species can be found in Table 12 and the following figures: *Polyarthra dolichoptera* (Fig. 50b), *Keratella crassa* (Fig. 50a), *Gastropus stylifer* (Fig. 49e), *Colletheca* sp. (Fig. 49d), *Keratella earlinae* (Fig. 49f) and *Notholca squamula* (Fig. 52b).

### Less Common Species

Seasonal distribution of the following less common species can be found in the following figures: *Asplanchna priodonta* (Fig. 49b), *Keratella quadrata* (Fig. 49f), *Ascomorpha* sp. and *Ploesoma* sp. (Fig. 50d), and *Notholca laurentiae* and *N. foliacea* (Fig. 52a and c).

## Differences Between the Long and Short Zooplankton Hauls

### LAKE ERIE

*Polyarthra major*, *Mesocyclops edax* and *Cyclops bicuspidatus thomasi* all had mean abundances that were higher in the long hauls (Table 14). Abundances of these species were greater in the metalimnion or hypolimnion.

### LAKE HURON

Significantly higher abundances were observed in the long hauls of the following: Copepoda nauplii, *Keratella cochlearis*, *Synchaeta* sp., *Keratella earlinae*, *Keratella quadrata* and *Notholca laurentiae* (Table 15). Only those organisms observed in either the long or the short hauls are listed in Table 16. Of particular significance are _Daphnia catawba_ and _Notholca squamula_ which were both abundant. _D. catawba_ is not a common species to the Great Lakes.

## LAKE MICHIGAN

Abundance of _Keratella quadrata_ was higher in the long hauls compared to the short hauls (Table 17). Organisms observed only in the short or long hauls are listed in Table 18. Most of these occurrences represent a low abundance and define the rarity of these species.

# DISCUSSION

## PHYTOPLANKTON

## LAKE ERIE

### Changes in Species Composition

#### Division Trends

One hundred twenty-five to 150 species were identified in Lake Erie during 1970 (Munawar and Munawar 1976), which was considerably lower than the 372 species observed in 1983. Also contrary to the 1970 study was the fact that the Bacillariophyta possessed the largest number of species in 1983 rather than the Chlorophyta, which was the second largest group. The diatoms, representing 59.9% of the phytoplankton biomass, were also the dominant group in the lake, while the green algae were the second most important group (14.9% of the biomass).

#### Species Trends - The Entire Lake

Davis (1969b) has reviewed the extensive earlier work on Lake Erie, while Munawar and Munawar (1982), Gladish and Munawar (1980) and Nicholls (1981) discuss the more recent material. Verduin (1964) has concluded that before 1950 the phytoplankton of western Lake Erie had been dominated by Asterionella formosa, Tabellaria fenestrata and Melosira ambigua, whereas in 1960-1961 the dominant forms had been Fragilaria capucina, Coscinodiscus radiatus (probably Actinocyclus normanii f. subsalsa) and Melosira binderana (= Stephanodiscus binderanus).

As with Munawar and Munawar (1976), this study confirms Verduin's observations that those species dominant before 1950 (*A. formosa*, *T. fenestrata* and *M. ambigua*) continued to be less important in the 1983 collections. *Actinocyclus normanii* f. *subsalsa* (= *Coscinodiscus rothii*) and *Stephanodiscus binderanus* were dominant in 1961-1962 (Verduin 1964) and in 1970 (Munawar and Munawar 1976). *Fragilaria capucina* was a dominant in 1961 but not in 1970. By 1983 *Actinocyclus normanii* f. *subsalsa* was only the fifth most prevalent diatom, but on a numerical basis *Fragilaria capucina* was the second most prevalent diatom in the western basin and in the entire lake (Table 6).

Dominant species in 1983 were *Stephanodiscus niagarae*, *Fragilaria crotonensis*, *Fragilaria capucina*, *Coelastrum microporum*, *Cosmarium* sp., *Cryptomonas erosa*, *Rhodomonas* var. *nannoplanktica*, *Anacystis marina*, *Oscillatoria subbrevis*, *Oscillatoria tenuis* and *Ceratium hirundinella* (Table 6). Although occurrence of common and dominant species in 1970 and 1980 were similar, dramatic decreases in abundance of these species were evident (Table 20). This pattern was evident in all three basins. Nicholls et al. (1977b) also observed decreases in abundances of diatoms, especially during the 1967-1975 period.

### Species Trend - Western Basin

Hohn (1969) and Munawar and Munawar (1976), working with data from the western basin of Lake Erie, described long-term changes in the diatoms from 1938 to 1970. (1) Both workers agreed that *Cyclotella stelligera* and *Rhizosolenia eriensis* had decreased in abundance during the period. Both species were present in 1983 but were still relatively unimportant (Table 6). (2) In 1970 *Stephanodiscus binderanus* and *Stephanodiscus* spp. (*S. niagarae*, *S.*

*tenuis* and *S. hantschii*) were frequent but not *S. alpinus* which Hohn (1969) observed to be dominant. In 1983, *S. binderanus*, the dominant *S. niagarae* and *S. alpinus* were all abundant (Table 6) in all three basins.

## Picoplankton

The autotrophic nature of picoplankton has been brought to the attention of phycologists in recent years (Johnson and Sieburth 1979, 1982; Li et al. 1983). In the Great Lakes, Sicko-Goad and Stoermer (1984) presented the first evidence of picoplankton, while Caron et al. (1985) documented the occurrence of photosynthetic chroococcoid cyanobacteria (0.7 - 1.3 µm in diameter) in Lake Ontario. The overwhelming abundance of picoplankton (probably *Anacystis marina* and *Coccochloris peniocystis*, Table 6) in the 1983 samples is of interest. Density in Lake Erie during 1983 ($\bar{x}$ = 33,171 cells/mL; maximum of ~141 x $10^3$ cells/mL) was comparable to the picoplankton density in Lake Ontario which ranged from ~1 x $10^3$ to 6.5 x $10^3$ cells/mL. Munawar and Munawar (1976) and Gladish and Munawar (1980), using comparable enumeration and preservation techniques in their studies, did not report these species. It is reasonable to assume that previous Great Lakes' workers ignored this small-sized fraction when enumerating phytoplankton, believing them to be bacterial in nature.

## East-West Species Distribution

Munawar and Munawar (1976) and Davis (1969b) have documented the existence of differences in species abundances from the central, western and eastern basins. In 1983 at least 12 species had higher abundances or abundances restricted to the western basin: *Anacystis marina*, *Oscillatoria tenuis* and *Oscillatoria limnetica* (Fig. 16a–c); *Oscillatoria subbrevis* (Fig. 17a and b); *Cryptomonas erosa*, *Fragilaria crotonensis* and *Tabellaria flocculosa* (Fig. 18a–c) and *Melosira granulata* (Fig. 19), *Fragilaria capucina* and *Stephanodiscus binderanus*. Six species *Coelospharium naegelianum*, *Pediastrum simplex*, *Rhodomonas minuta* var. *nannoplanktica*, *Peridinium aciculiferum*, *Stephanodiscus niagarae* and *Scenedesmus ecornis* (Fig. 17c) had geographical abundance patterns with maxima in the central basin. Only *Peridinium aciculiferum* and *Staurastrum paradoxum* were more abundant in the eastern basin.

Numerically, phytoplankton abundance was greater in the western basin (Fig. 8). Biomass was also greatest in the western basin in April, May and June. However, for the study period, average biomass was similar in the western and central basins (Table 21). This contradiction was due to the greater abundance being caused, in part, by the greater abundance of *Anacystis marina* in the western biomass which contributed little to the biomass because of its small size. However, numerically the Bacillariophyta, Chlorophyta, Chrysophyta and Cryptophyta all possessed a general pattern of decreasing abundance from west to east for the study period.

## Indicator Species

Munawar and Munawar (1982) concluded that the species of phytoplankton found in 1970 usually occurred in mesotrophic and eutrophic conditions. In 1983 a similar conclusion could be drawn even though algal biomass had decreased substantially (see next section). Common species included eutrophic indicators (*Fragilaria* capucina, Melosira granulata, Peridinium aciculiferum, Pediastrum simplex, Scenedesmus ecornis) and mesotrophic indicators (Stephanodiscus niagarae, Fragilaria crotonensis, Tabellaria flocculosa).

A mesotrophic-eutrophic designation agreed reasonably well with the trophic status as determined by the biomass classification scheme of Munawar and Munawar (1982). With a mean biomass of 1.36 g/m$^3$ for the study period for the entire lake, Lake Erie would be classified as mesotrophic.

## Historical Changes in Community Biomass

A very large and consistent increase in the total quantity of phytoplankton in the central basin occurred between 1927 and 1964 (Davis 1964, 1969b). From 1967 to 1975 a decline in the nearshore phytoplankton of the western basin was evident (Nicholls et al. 1977b). Similarly from 1970 to 1980, a number of the common species had decreased in biomass (Table 20), and the total phytoplankton biomass for all three basins had decreased dramatically (Fig. 53). The historically highly productive western basin (Munawar and Burns 1976) has had, in particular, a steady decrease in biomass from 1958 to 1983 (Table 22). In fact, the 1983 mean biomass for the western basin was similar to the central basin (Table 21). The decrease appears to be correlated with reductions in phosphorus loading when average phosphorus loading from the Detroit River in western Lake Erie decreased from about 75 metric tons/day during the 1968-1970 period to about 35 metric tons/day by the early 1970's and was further reduced during 1970 and 1979 (Nicholls 1981, Great Lakes Water Quality Board 1974, Yaksich et al. 1985).

## LAKE HURON

### Changes in Species Composition

The literature pertaining to phytoplankton of the offshore waters of Lake Huron is sparse. Fenwick (1962, 1968) published some qualitative data, and Parkos et al. (1969) listed species observed. Quantitative data from a single offshore station from 1971 exists (Munawar and Munawar 1982, Vollenwider et al. 1974). Stoermer and Kreis (1980) reported on an extensive sampling program in southern Lake Huron including Saginaw Bay during 1974 and provided an extensive bibliography on Huron algal research. An intensive study of the entire lake basin was performed in 1980 (Stevenson 1985).

Since 1971 diatoms have been the dominant division. Dominant diatoms in 1971 included species of *Asterionella formosa*, *A. gracillima*, *Cyclotella comta*, *C. glomerata*, *C. ocellata*, *C. michiganiana*, *Melosira islandica* and *M. granulata*. In addition, species such as *Fragilaria crotonenis* and *Tabellaria fenestrata* were common, while cryptomonads, such as *Rhodomonas minuta* and *Cryptomonas erosa*, contributed very heavily during different seasons.

The following similar common diatoms were observed in 1974 and 1983: *Asterionella formosa*, *Cyclotella comensis*, *C. michiganiana*, *C. ocellata*, *Fragilaria crotonensis*, *Tabellaria fenestrata*, *T. flocculosa* var. *linearis* and *Rhizosolenia* sp.. *Cyclotella stelligera* and *Synedra filiformis* were present in 1983 but were not as common as the 1974 southern Lake Huron plus Saginaw Bay data. *Melosira islandica* was more prevalent in 1983 than in the 1974 data base.

Both *Cryptomonas erosa* and *Rhodomonas minuta* var. *nannoplanktica* were dominant in 1971, 1974 and 1983. Dominant chrysophytes in 1971 were *Dinobryon divergens* and *Chrysosphaerella longispina*. In 1983 these two species were common along with *D. cylindricum* and *D. sociale* var. *americanum* (Table 6). Haptophytes were also numerically abundant. In general, *C. stelligera* and *Synedra filiformis* decreased in abundance after 1974, while *M. islandica*, *D. cylindricum* and *D. sociale* var. *americanum* have increased in abundance.

## Picoplankton

The autotrophic nature of picoplankton has been brought to the attention of phycologists in recent years (Johnson and Sieburth 1979, 1982; Li et al. 1983). In the Great Lakes, Sicko-Goad and Stoermer (1984) presented the first evidence of picoplankton in the Great Lakes, while Caron et al. (1985) documented the occurrence of photosynthetic chroococcoid cyanobacteria (0.7 - 1.3 µm in diameter) in Lake Ontario. The overwhelming dominance of picoplankton (probably *Anacystis marina* and *Coccocholoris peniocystis*, Table 7) in the 1983 samples is of interest. Density in Lake Huron ranged from $\sim$6 x $10^3$ to 5.5 x $10^3$ cells/mL, which was lower but comparable to picoplankton abundance in eutrophic Lake Ontario (range = $\sim$1 x $10^3$ to 6.5 x $10^3$ cells/mL) (Makarewicz 1985). Both Stoermer and Kreis (1980) and Munawar and Munawar (1982) did not report these species. It is reasonable to assume that previous workers ignored this small-sized fraction when enumerating phytoplankton, believing them to be bacterial in nature.

## Dominant and Indicator Species for the Entire Lake

Dominant diatoms in Lake Huron in 1983 were *Rhizosolenia* sp. and

*Tabellara flocculosa* (biomass) and *Cyclotella comensis* (numerically). Four species of *Cyclotella* (*C. comensis*, *C. comta*, *C. kuetzingiana* var. *planetophora* and *C. ocellata*) represented 9.47% of the total biomass (Table 7). Except for *C. comensis*, whose ecological affinities are poorly understood (Stoermer and Kreis 1980), these species are associated with oligotrophic or mesotrophic conditions. Similarly, *Tabellaria flocculosa* is commonly associated with mesotrophic conditions (Tarapchak and Stoermer 1976).

Dominant chrysophytes included *Dinobryon sociale* var. *americanum*, *D. divergens* and *D. cylindricum*, which are often associated with several small members of the genus *Cyclotella* (Schelske et al. 1972, 1974) included in the classical oligotrophic diatom plankton association of Hutchinson (1967). Dominant cryptophytes, cyanophytes and dinoflagellates were *Rhodomonas minuta* var. *nannoplanktica*, *Cryptomonas erosa*, *Anacystis marina* and *Ceratium hirundinella*.

Because of the limited number of studies of the Lake Huron offshore phytoplankton assemblage, there was also a limited basis for evalutating long-term effects of eutrophication. Those studies available (Nicholls et al. 1977a, Schelske et al. 1972, 1974) indicated that the waters of northern Lake Huron generally contained phytoplankton assemblages indicative of oligotrophic conditions. The designation of the offshore waters of southern Lake Huron as oligotrophic based on phytoplankton composition in 1983 was not unlike the trophic status suggested by Stoermer and Kreis (1980) for the offshore waters in 1974. This agreed reasonably well with the trophic status as determined by the biomass classification scheme of Munawar and Munawar (1982). With a mean biomass of 0.38 g/m$^3$ (range =

0.14 to 0.75) for the study period, Lake Huron would be classified as oligotrophic.

## North-South Distribution

Regional variation in water quality was indicated by standing crop and species composition. The mean phytoplankton abundance for the sampling period decreased from north to south to Station 15 (Fig. 10). At Station 15 in southern Lake Huron, abundance increased and remained high into the extreme southern end of Lake Huron. Much of this geographical pattern was determined by the high numerical abundance of *Anacystis marina*.

The north-south pattern still existed, however, when biomass was considered. The diatoms, in particular, had a similar geographic pattern accounting for much of this increase in the northern area (Fig. 56). Diatoms having a distinctly higher abundance and biomass at the northern stations were *Asterionella formosa* (Fig. 23a), *Cyclotella comensis*, *C. comta* and *C. ocellata*. Other species having a higher biomass in the northern stations were *Coelosphaerium naegelianum* and *Dinobryon sociale* var. *americanum*. Except for *C. comensis*, whose ecological affinities are poorly understood or known, the other diatom species common in the north during blooms (*C. comta*, *C. ocellata*, *A. formosa*) are associated with mesotrophic or oligotrophic conditions.

Stoermer and Kreis (1980) suggested that local regions in the northern part of the lake may have shown the effects of nutrient stress. However, these regions did not appear to develop the populations tolerant of highly eutrophic conditions. Our data also suggest that eutrophic conditions were not found. However, the higher biomass and the greater prevalence of *Asterionella formosa* at the far northern stations suggested a more productive status for the northern region. This may be caused by transport of the more productive waters of Lake Michigan into Lake Huron. The physical transport of populations by water currents from Lake Michigan into Lake Huron through the Straits of Mackinac has been demonstrated (Schelske et al. 1976).

The higher abundance of phytoplankton (Fig. 10), especially the higher biomass south of Saginaw Bay, was the result of higher biomass of diatoms in April and May. Diatoms with a higher biomass in this region were *Asterionella formosa*, *Cyclotella ocellata*, *Fragilaria crotonensis*, *Melosira islandica*, *Rhizosolenia* sp. and *Tabellaria flocculosa* var. *linearis*. There are at least two possible causes for the higher biomass observed in April and May south of Saginaw Bay: (1) transport of plankton from the historically more productive Saginaw Bay or (2) higher nutrient loading to southern Lake Huron. Because of the sampling design of the 1983 study, it is impossibe to evaluate transport. In prior years though, tranport from Saginaw Bay affected mid-lake stations (Stoermer and Kreis 1980).

More recently, Stoermer and Theriot (1985) suggested that the direct effects of phosphorus-stimulated phytoplankton overproduction in Saginaw Bay on the rest of the Lake Huron ecosystem have been substantially mitigated. In particular, the injection of eutrophication-tolerant populations from Saginaw Bay to Lake Huron has decreased. This suggests that other species tolerant of less productive waters may currently be transported from the Bay to Lake Huron. The 1983 phytoplankton composition of the southern basin suggested a slight degradation of these waters from 1971. Stevenson

(1985) concluded similarly in 1980. Further study and a different sampling design would be necessary to evaluate the cause of the higher biomass observed in southern Lake Huron in 1983.

## Historical Changes in Community Abundance and Biomass

Quantitative phytoplankton data exist for the offshore waters of Lake Huron from at least 1971. The collections of Stoermer and Kreis (1980) were from 44 stations in southern Lake Huron and Saginaw Bay. Phytoplankton were concentrated on millipore filters rather than by the settling chamber procedure used in this study. Thus, the sets of data were not strictly comparable. However, some patterns are suggested (Fig. 54). Abundances in the early spring and late summer and late summer/early fall of 1977 and 1983 were similar, but abundances during late May and early July of 1983 were considerably lower than those during 1974 in southern Lake Huron. It is difficult to conclude whether these differences were apparent and due to different enumeration techniques or were related to the decrease in transport of phytoplankton from Saginaw Bay due to phosphorus mitigation efforts (Stoermer and Theriot 1985).

Munawar and Munawar (1982) collected with a 20-m integrating sampler from April to December of 1971. Because Utermöhl's (1958) procedure for enumeration of algae was employed, these data offered a better comparison to the 1983 data. Seasonal biomass data for only one offshore station of Lake Huron was available (Munawar and Munawar 1982) (Fig. 55). Average station biomass on all sampling dates in 1983 were lower than every sampling date in 1971. A comparison of the maximum value of the range of the 1983 biomass values on each sampling date with the 1971 biomass data was strikingly similar. Also similar, except at the low range, was the seasonal range of biomass values in 1971 (0.4 - 0.79 $g/m^3$) (Munawar and Munawar 1982) and in 1983 (0.14 - 0.75 $g/m^3$). Again the suggestion is an overall improvement in water quality based on species composition and a decrease in biomass. However, caution is required because of the necessity to compare to one offshore station from 1971.

## LAKE MICHIGAN

### Changes in Species Composition

Although an extensive literature on Lake Michigan phytoplankton exists [see Tarapchak and Stoermer (1976) for a review to the earlier literature], the establishment of long-term trends of phytoplankton in the offshore waters is difficult due to the widely varying methodologies employed. However, studies in 1962-63 and 1976-77 by Stoermer and Kopczynska (1967a and b) and Rockwell et al. (1980), respectively, utilized a settling chamber procedure similar to the technique used in this study. The 1962-63 study was limited to the southern basin, while the 1976-77 study is conservative in its abundance estimate because a magnification of only 400x was used for enumeration.

#### Division Trends

There is no doubt that diatoms have decreased in dominance in Lake Michigan since the 1962-63 study. In the 1976-77 study, phytoflagellates dominated at virtually all stations. In 1983 the blue-greens dominated numerically by virtue of the high abundance of the picoplankton which were not counted in previous studies. However, in addition to the cyanophytes, both the cryptophytes and chlorophytes were still numerically more important than the diatoms (Table 5) in 1983. The numerical decline of the diatoms is probably related to the high phosphorus loading and concomitant silica depletion (Schleske and Stoermer 1971). On a biomass basis, however, diatoms were the dominant group in 1983.

## Species Trends

Evaluation of changes in species is difficult because many of the earlier workers did not report the abundances actually observed. Qualitative comparisons were simply made. Dominant diatoms in 1983 included the numerically dominant Cyclotella comensis, Fragilaria crotonensis and Melosira italica subsp. subarctica ; on a biomass basis, Tabellaria flocculosa was predominant (Table 8). Of the 1983 dominant diatoms, only Fragilaria crotonensis and perhaps T. flocculosa were major components of the diatom assemblage in 1962-63. Stoermer and Kopczynska (1967a) noted taxonomic difficulties with Tabellaria and noted that most populations of Tabellaria "are probably to be referred to T. fenestrata ....." The dominant species of Cyclotella and Melosira in 1962-63 were C. michiganiana and M. islandica.

Rockwell et al. (1980) reported that Cyclotella spp. were common in 1977 but were never dominant. The dramatic decrease in some species of Cyclotella, such as C. michiganiana and C. stelligera, which were offshore dominants in August of 1970, is presented in Table 23. C. comensis, believed to be tolerant of higher nutrient and lower silica concentrations than most members of this genus, is currently the numerically dominant diatom in the offshore.

A change in prevalence of species of Melosira was evident. M. islandica was dominant in 1962-63. In 1983 M. islandica was present ($\bar{x}$ = 12.1 cells/mL), but M. italica subsp. subarctica ($\bar{x}$ = 37.6 cells/mL) was more abundant. Similarly, Synedra acus was common throughout the southern basin in 1977 (Rockwell et al. 1980) but in 1983 represented only 0.1% of the total cells.

R. eriensis had apparently declined in abundance. In May of 1962-63, relatively high (100 cells/mL) populations were observed in southern Lake Michigan (Stoermer and Kopczynska 1967a). During May and June of 1970, mean abundances for offshore stations were 63 and 611 cells/mL, respectively (Holland and Beeton 1972). Rockwell et al. (1980) reported a mean density of 28.7 cells/mL for R. eriensis during June of 1977. Abundance in 1983 was 2.6 cells/mL for the entire lake. A bloom (133 cells/mL) in the far northern station (Station 77) did occur in October.

Ankistrodesmus falcatus increased in abundance to 1977 and had decreased by 1983. Ahlstrom (1936) reported it as rare, but Stoermer and Kopczynska (1967a) noted that it had increased by 1962-63 (range = 20-60 cells/mL). Rockwell et al. (1980) suggested that by 1977 it had increased further (range = 20-610 cells/mL). In 1983 this species was observed only once during the study at Station 32 (6.5 cells/mL).

Dominant chrysophytes in 1962-63 were Dinobryon divergens, D. cylindricum and D. sociale, which were also the common species in 1983. Rockwell et al. (1980) reported these species as dominant or subdominant often in the offshore. D. sociale var. americanum was the prevalent species of Dinobryon in 1983. However, the haptophytes were numerically the dominant group.

Dominant cryptophytes included Cryptomonas erosa var. reflexa, C. erosa and Rhodomonas minuta var. nannoplanktica. Stoermer and Kopczynska (1967b) and Stoermer (1978) reported these species as uncommon in Lake Michigan, but Vollenweider et al. (1974) noted these species as commonly found. Similarly, Munawar and Munawar (1975), Claflin (1975) and Rockwell et al. (1980) had reported C. erosa and R. minuta var. nannoplanktica to be dominant, abundant and perhaps increasing in number. From our 1983 study, it is apparent that *C. erosa* was numerically uncommon but on a biomass basis was the second most important cryptophyte (Table 8). Evaluation of abundance of *R. minuta* in earlier studies was not possible because it was grouped into phytoflagellates, flagellates or simply *Rhodomonas*. What can be said about *Rhodomonas minuta* var. *nannoplanktica* is that in 1983 it was the dominant cryptophyte on a numerical and biomass basis.

*Oscillatoria limnetica* has become more prevalent in the lake. Ahlstrom (1936) and Stoermer and Kopczynska (1967a) listed *O. mougeotii* as the only species of this genus abundant in their collections. Stoermer and Ladewski (1976) reported that *O. limnetica* had generally increased in abundance in Lake Michigan. Rockwell et al. (1980) observed that *O. limnetica* was common throughout the basin in April and June and was especially abundant in September of 1977 at certain stations. Not considering the picoplankton, which were not counted in previous studies, *O. limnetica* was the dominant offshore blue-green algae in 1983 (Table 8).

### Picoplankton

The autotrophic nature of picoplankton has been brought to the attention of phycologists in recent years (Johnson and Sieburth 1979,1982; Li et al. 1983). In the Great Lakes, Sicko-Goad and Stoermer (1984) presented the first evidence of picoplankton, while Caron et al. (1985) documented the occurrence of photosynthetic chroococcoid cyanobacteria (0.7 - 1.3 µm in diameter) in Lake Ontario. The overwhelming abundance of picoplankton (probably *Anacystis marina* and *Coccochloris peniocystis*) (Table 8) in the 1983 samples is of interest. Densities in Lake Michigan ($\bar{x}$ = 23,607; maximum of 1 x

$10^3$ cells/mL) were comparable to the picoplankton densities in Lake Ontario which ranged from ~1 x $10^3$ to 6.5 x $10^3$ cells/mL. No other researchers on Lake Michigan have routinely reported these species. It is reasonable to assume that previous Great Lakes' workers, believing the picoplankton to be bacterial in nature, ignored this small-sized fraction when enumerating phytoplankon.

## Indicator Species

A comparison of modern and historic records by Stoermer and Yang (1970) indicated that taxa characteristic of disturbed situations are rapidly increasing in relative abundance in Lake Michigan. In the nearshore area, a shift in oligotrophic forms to forms which dominate under eutrophic conditions was evident. Occurrence of certain eutrophic forms were also evident in offshore waters (Stoermer and Yang 1970). Dominant diatom species in the offshore waters in 1983 were *Cyclotella comensis*, *C. comta*, *Tabellaria flocculosa*, *Fragilaria crotonensis* and *Melosira italica* subsp. *subarctica*. *C. comta*, *T. flocculosa* and *F. crotonensis* are mesotrophic forms, while the ecological affinities of *C. comensis* and *M. italica* are poorly understood.

## North-South Distribution

Regional variation in water quality was indicated by the geographical variation in abundance and the variable species composition. The mean station phytoplankton abundance for the sampling period generally decreased from north to south with two small peaks at Stations 41 and 6 at the most southern sampling point (Fig. 12). Much of the increase was due to picoplankton abundance.

However, diatoms, cryptophytes, chrysophytes and chlorophytes all had higher abundances at the northern stations (Stations 77 and 64) and at the southern station (Station 6). The peak at Station 41 was primarily due to chrysophytes but also to cryptophytes and chlorophytes.

Species having a distinctly higher abundance at the northern stations were *Tabellaria flocculosa*, *Tabellaria fenestrata*, *Fragilaria vaucheriae*, *Fragilaria crotonensis*, *Cyclotella comta*, *C. comensis*, *Chroomonas norstedtii*, *Oscillatoria agardhii* and *Coelosphaerium naegelianum*. Except for *C. comensis*, whose ecological affinities are poorly known, the other diatom species common at Stations 64 and 77 are generally associated with mesotrophic conditions. The peak in abundance at Station 41 was primarily due to haptophytes and *Dinobryon cylindricum.* Besides picoplankton, the peak at Station 6 at the far southern end of the lake was due to increases in *Dinobryon sociale* var. *americanum*, *D. divergens* and species of haptophytes.

Species composition and abundance suggest that the far northern stations, in particular, showed some indication of nutrient stress. There are at least two possible causes for the higher biomass observed north of Green Bay: higher nutrient loading to these northern waters and the transport of plankton from the historically more productive Green Bay. Because of the sampling design of the 1983 study, it is impossible to evaluate transport. Water that does escape the bay most commonly flows south along the Wisconsin shore. However, high conductivity values in north-central Lake Michigan have been attributed to Green Bay (Stoermer and Stevenson 1980). Also, substantial exchange may exist because the Bay de Noc complex alone has been estimated to contributed 12% of the total phosphorus loaded to Lake Michigan (Upchurch 1972).

## Historical Changes in Community Abundance

A comparison of abundance trends over the entire lake was not possible because of the non-availability of comparable offshore data prior to 1983. A reasonably valid comparison can be made of the offshore of the southern extreme of Lake Michigan from 1962-63 to 1976-77 to 1983. From 1962-63 to 1976, abundance appeared to increase (Table 24) with Rockwell et al. (1980) reporting a conservative maximum density of ~6,000 cells/mL.

Because picoplankton were not counted in previous years, they have been removed from the 1983 data allowing comparison to previous years (Table 24). Abundance was higher in 1983 than in 1962-63 but similar to the abundance in 1976. This observation confirms that an increase has taken place since 1962-63. Because of the conservative nature of the 1976 abundance data, the suggestion could be made that abundances decreased from 1976 to 1983. However, there is no evidence to substantiate the suggestion.

# DISCUSSION

## ZOOPLANKTON

### LAKE ERIE

### Changes in Species Composition

Brooks (1969) suggested that a shift in the Lake Erie cladoceran assemblage was evident by 1948-49 with smaller cladocerans, such as *Daphnia galeata mendotae*, *D. retrocurva* and *Diaphanosoma*, being more abundant than in 1938-39. In 1970 the most commonly found *Daphnia* species were *D. retrocurva*, *D. galeata mendotae* and *D. longiremis* (Watson and Carpenter 1974). However, *Bosmina longirostris* and *Eubosmina coregoni* were more abundant (Watson and Carpenter 1974). Predominant cladoceran species in 1983 were small forms similar to those observed in 1970. In 1983 the predominant Cladocera in descending order were *Eubosmina coregoni*, *Daphnia galeata mendotae*, *Daphnia retrocurva*, *Bosmina longirostris*, *Diaphanosoma leuchtenbergianum* and *Chydorus sphaericus* (Table 11).

*Chydorus sphaericus* has established itself as a common species in Lake Erie. A rare species in the offshore waters of the western basin in 1929-30 (Tidd 1955), this species was a prominent constituent in the 1950's (Davis 1962) and in 1970 with a higher abundance in the western basin (Watson and Carpenter 1974). In 1983 this species contributed only 0.2% of the total abundance and had no observable abundance peak in the western basin.

*Cyclops vernalis* has exhibited a dramatic increase in abundance and distribution (Gannon 1981). In the 30's, *C. vernalis* was found only in the extreme western end of Lake Erie at the mouth of the Detroit and Maumee Rivers (Tidd 1955). By 1967 it had spread throughout the lake (Davis 1969a). Patalas (1972) and Watson (1976) reported it as numerous in the western basin of Lake Erie during the late 60's and 70's. In 1983 *C. vernalis* was not observed at any of the sampling stations.

The dominant cyclopoid copepod in 1970 was *Cyclops bicuspidatus thomasi* with *Mesocyclops edax* common in the summer. *Tropocyclops prasinus* was present in low numbers (Watson and Carpenter 1974). In 1983 the same three species ( *C. bicuspidatus thomasi*, *M. edax* and *T. prasinus* ) predominated (Table 11).

Abundance of *Diaptomus siciloides* has increased in Lake Erie (Gannon 1981). It was most prevalent in the western basin and western portion of the central basin in the late 60's and 70's (Patalas 1972, Watson 1974). Abundant diaptomids in the eastern and central basins in 1970 were *Diaptomus oregonensis* and *D. siciloides*. *D. oregonensis* and *D. siciloides* were also the predominant calanoids in Lake Erie in 1983. In 1983 *D. oregonensis* was more prevalent in the central and eastern basins, while *D. siciloides* was more prevalent in the eastern and western basins.

Davis' studies (1968, 1969a) of the zooplankton of Lake Erie did include rotifers. Certain soft-bodied rotifers were not identified nor are the samples quantitative for rotifers. A #20 net was employed. However, it is apparently the only lake-wide study of the offshore that included the rotifers. Species observed to be abundant in 1967 were *Brachionus angularis*, *B. calyciflorus*, *Conochilus unicornis*, *Keratella cochlearis*, *K. quadrata*, *Kellicottia longispina*, *Synchaeta stylata* and *Polyarthra vulgaris* (Davis 1968, 1969a). In 1983 a similar group of abundant rotifers was found. In decreasing order of relative abundance (% of total abundance), the abundant species were: Polyarthra vulgaris (18.4%), Synchaeta sp. (9.5%), Keratella cochlearis (7.3%), Conochilus unicornis (5.3%), Keratella hiemalis (3.5%), Brachionus sp. (3.0%), etc. (see Table 11). Although it was only the fourteenth most abundant rotifer, Kellicottia longispina was still prevalent in 1983 representing 1.3% of the total abundance (Table 11). Only Keratella quadrata is apparently not as abundant in 1983 as it was in 1967. K. quadrata was observed in 1983 but was not common ( <1% of total abundance).

## East-West Species Distribution

Numerous researchers (e.g. Davis 1969a, Watson 1974, Patalas 1972, Gannon 1981) have documented the existence of differences in species composition and abundance from the central, western and eastern basins. In 1983 at least 13 species had higher abundances or distributions restricted (see Indicator Species) to the western basin (Table 25). Five species Diaptomus oregonensis (Fig. 39a), Cyclops bicuspidatus thomasi (Fig. 39b), Colletheca sp., Kellicottia longispina and Keratella hiemalis (Fig. 42b) had geographical abundance patterns with maxima in the central basin. Only the cyclopoid Tropocyclops prasinus mexicanus was more prevalent in the eastern basin. From Fig. 39c, a west to east buildup in T. prasinus is evident. Both Daphnia galeata mendotae and Mesocyclops edax were abundant in the eastern and central basins.

## Indicators of Trophic Status

Zooplankton have potential value as assessors of trophic status (Gannon and Stemberger 1978). Rotifers, in particular, respond more quickly to environmental changes than do the crustacean plankton and appear to be more sensitive indicators of changes in water quality (Gannon and Stemberger 1978). Brachionus angularis, B. calyciflorus, Filinia longiseta and Trichocerca multicrinis are four rotifer species indicative of eutrophy. Species in the genus Brachionus are particularly good indicators of eutrophy in the Great Lakes (Gannon and Stemberger 1978).

The eutrophic rotifers Brachionus caudatus, Brachionus sp., Filinia longiseta, Synchaeta sp., Trichocerca cylindrica, Trichocerca multicrinis and Keratella earlinae had abundances restricted to or significantly higher in the western basin (Figs. 40b & c; 41a,b & c; 42a & c). Total zooplankton abundance was also higher in the western basin. Both rotifer abundance and species composition indicated a greater degree of eutrophy of the western basin than of the central or eastern basins.

The calanoid/cyclopoid plus cladoceran ratio (plankton ratio) has been employed as a measure of trophic condition in the Great Lakes (Gannon and Stemberger 1978, McNaught et al. 1980). Calanoid copepods generally appear best adapted for oligotrophic conditions, while cladocerans and cyclopoid copepods are relatively more abundant in eutrophic waters (Gannon and Stemberger 1978). In Lake Erie this ratio increased from west to east (Table 26). The productive status (primary production) of the western basin as compared to the central and eastern basins (Glooschenko et al. 1974a, Glooschenko 1974b) was correlated in the abundance of zooplankton, species composition and the calanoid to cyclopoid plus cladoceran ratio. Compared to Lakes Huron and Michigan in 1983, abundance of zooplankton was greatest, and the plankton ratio was lower in Lake Erie (Table 19) indicating the eutrophic nature of Lake Erie.

## Historical Changes in Abundances

Zooplankton data exists for the western basin of Lake Erie from 1939 to 1983. Gannon (1981) noted that the collections in 1939, 1949 and 1961 were made with a 10-liter Juday trap in the islands region, and the 1970 collections were obtained at the extreme western end of the lake with an 8-liter Van Dorn bottle. The data were not strictly comparable with each other or the 1983 data. In particular, the 1970 data were from the far western end of the western basin and probably are not representative of the entire western basin. Also, samples from the late spring to the early summer and from the late summer of 1983 were lacking, but some trends were suggested.

In comparing the 1970 data to the 1939, 1949 and the 1961 zooplankton data, Gannon (1981) concluded that an increase occurred in the cladocerans, copepods and rotifers of the western basin of Lake Erie. However, a comparison to the 1983 August data for Cladocera and Copepoda suggested that abundances were more comparable to the 50's (Figs. 58 and 59). Cladocera data from October suggested a slighly higher abundance in 1983 than in previous years. Without sampling points in June, July and September at times of zooplankton maxima in Lake Erie, no firm conclusions could be made on crustacean populations. The increase in numbers of rotifers was sufficiently large and consistent to indicate an abundance increase from 1970 to 1983 (Fig. 60).

Watson and Carpenter (1974) utilized a 64-µm mesh net in 1971 to collect vertical hauls of zooplankton from the entire lake basin. These data are comparable to 1983 collections and are presented in Fig. 57. Again, the lack of a sampling point between mid-May through

July did not allow a comparison during what was the peak abundance period of zooplankton in 1970. However, the April-May and August-October periods were comparable and suggested that total zooplankton abundance was similar from 1970 to 1983 during those periods.

## LAKE HURON

### Changes in Species Composition

Crustacean studies of the entire Lake Huron basin are few in number. Patalas (1972) sampled 51 stations including Saginaw Bay in August of 1968 with a 77-µm mesh net. In 1971, eleven stations on a transect from the Straits of Mackinac to the origin of the St. Clair River were sampled from May to November with a 64-µm net (Watson and Carpenter 1974). A 64-µ mesh net was used to sample 18 stations on eight dates from April to October of 1974 in southern Lake Huron including Saginaw Bay (McNaught et al. 1980). The 1983 research included 10 stations sampled (62-µm mesh net) for each of the three sampling dates between August and September.

In August of 1968 calanoids were dominated by *Diaptomus sicilis*, *D. ashlandi* and *D. minutus* (Patalas 1972). These same three species were dominant in 1971, 1974/75 and 1983 with the addition of *Diaptomus oregonensis* (Table 27). Although not strictly comparable, mean abundance for the major calanoid species were similar for the 1971 and 1983 samples. The 1974 calanoid abundance was higher than either the 1971 or 1983 samples. However, the 1971 and 1983 data were only from offshore sites, while 1974 data included samples from the eutrophic waters of Saginaw Bay. The oligotrophic indicator species, *Limnocalanus macrurus*, appeared to be decreasing in abundance (Table 27).

In 1968, 1971, 1974/75 and 1983, the dominant cyclopoid was *Cyclops bicuspidatus thomasi* (Table 27). *Tropocyclops prasinus mexicanus* and *Mesocyclops edax* appeared to have increased in abundance from 1971 to 1983. *Cyclops vernalis*, often associated with eutrophic conditions in Lake Erie, was higher in abundance in the 1974 data. This higher abundance again may have been due to the inclusion of Saginaw Bay stations in the 1974 data set.

Dominant cladoceran species in August of 1968 were *Bosmina longirostris* and *Holopedium gibberum*, while in 1974 *Holopedium gibberum*, *B*. *longirostris* and *Eubosmina coregoni* were dominant in August-October. Comparison of the 1971 and 1983 August data suggested decreases in abundance of *B*. *longirostris*, *E*. *coregoni* and *H*. *gibberum*.

Quantitative data on species of daphnids were not available for 1971, but *Daphnia retrocurva*, *Daphnia galeata mendotae* and *D*. *longiremis* were commonly found in Lake Huron (Watson and Carpenter 1974). The dominant daphnid species in 1983 was *D*. *galeata mendotae*.

Evans (1985) recently reported that *Daphnia pulicaria* was a new species dominating Lake Michigan. In 1983 in Lake Huron, *D*. *pulicaria* was observed to be the third most important cladoceran (Table 12). Mean station abundance increased from north to south with a mean density of 431 organisms/m$^3$ for stations south of Saginaw Bay.

*D*. *catawba* also appeared to be a new dominant from the deeper waters of Lake Huron. This species was not thought to be either common or less common species of the Great Lakes (Balcer et al. 1984). It appeared exclusively in the long hauls from Lake Huron in 1983. A maximum abundance of 1,610 organisms/m$^3$ was observed in August at Station 12.

Stemberger et al. (1979) collected rotifers with a Nisken bottle at 5-m intervals to 20m followed by 10-m intervals to the bottom of the lake. Samples were pooled and filtered through a 54-µ mesh net on the vessel. Greatest abundance of rotifers in Lake Huron in 1974 occurred in late spring and early summer (Stemberger et al. 1979), a period in which no samples were taken in 1983. Comparison of the August-October of 1983 to April-November of 1974 suggested the following between the 1974 and 1983 data. Abundant rotifer species in both studies were *Conochilus unicornis*, *Polyarthra vulgaris*, *Keratella cochlearis*, *Kellicottia longispina* and *Gastropus stylifer*. *C. unicornis* was the dominant rotifer in 1983 while *Keratella cochlearis* was dominant in 1974 (Table 29).

## North-South Distribution

Horizontal distribution of zooplankton in Lake Huron is affected by the physical limnology of the lake (McNaught et al. 1980). In the warmer inshore areas, cladocerans grow best, while calanoids tend to be found in offshore waters (McNaught et al. 1980). Movement of the zooplankton-rich eutrophic waters from Saginaw Bay also influenced zooplankton abundance in the nearshore waters of Lake Huron south of the Bay. In general, inshore densities were greater than offshore densities (McNaught et al. 1980).

The 1983 data did suggest a trend of increasing total zooplankton abundance from south to north (Fig. 33) with the exception of Station 32, located northeast of the mouth of Saginaw Bay. However, Station 32 would appear to be too far offshore to be influenced by the higher abundances of the Bay. However, Stoermer and Kreis (1980) have observed midlake stations in southern Lake Huron to be affected by populations of phytoplankton from Saginaw Bay in 1974. Although the transport of eutrophication-tolerant algal populations into Lake Huron from Saginaw Bay has been mitigated in recent years (Stoermer and

Theriot 1985), the transport of zooplankton could still take place.

Total abundance was slightly higher in the extreme south at Stations 9 and 6 due to increases in rotifer, cyclopoid and copepoda nauplii abundances. McNaught et al. (1980) also observed abundance increases of the cyclopoid copepodites, *C. bicuspidatus* and *T. prasinus* north to south in southern Lake Huron. In 1983 rotifers decreased in abundance from north to south to Stations 9 and 6 when a slight increase was evident (Fig. 33).

A number of species possessed horizontal distributions that varied along the north-south axis. *Diaptomus minutus* abundance was lower in the northern portion of the lake (Fig. 46a), while *Daphnia retrocurva* had a maxima limited to the far northern station (Fig. 46b). Abundance of both *Conochilus unicornis* and *Kellicottia longispina* decreased from north to south. *Holopedium gibberum* had a higher abundance north of Saginaw Bay, while *Mesocyclops edax* abundance was higher south of Saginaw Bay. *Cyclops bicuspidatus thomasi* was more abundant at the far northern stations (Stations 51 and 64) than in the rest of the lake.

## Indicators of Trophic Status

Zooplankton have potential value as assessors of trophic status (Gannon and Stemberger 1978). Rotifers, in particular, respond more quickly to environmental changes than do the crustacean plankton and appear to be more sensitive indicators of changes in water quality. Composition of the rotifer community, as well as species, have been employed to evaluate trophic status. A rotifer community dominated by *Polyarthra vulgaris*, *Keratella cochlearis*, *Conochilus unicornis* and *Kellicottia longispina* have been considered to be indicative of an oligotrophic lake (Gannon and Stemberger 1978). Even during a period when rotifers were not abundant, these were the dominant rotifers in Lake Huron from August to September of 1983 (Table 12).

The calanoid/cyclopoid plus cladoceran ratio (the plankton ratio) has been employed as a measure of trophic status in the Great Lakes (Gannon and Stemberger 1978, McNaught et al. 1980). Calanoid copepods generally appear best adapted for oligotrophic conditions, while cladocerans and cyclopoid copepods are relatively more abundant in eutrophic waters. Using this ratio, McNaught et al. (1980) identified the offshore waters of southern Lake Huron to have the highest quality water. Because the 1983 samples were all from the offshore, no such comparison could be made. However, the plankton ratio was high and similar from north to south (Table 28) indicating a similar high water quality over the entire lake except for the far northern Station 61. The low zooplakton abundance, compared to those of Lakes Erie and Michigan (Table 19), the presence of the oligotrophic rotifer association, the domination of the calanoids, and the fairly abundant presence of the oligotrophic _Diaptomus sicilis_ (McNaught et al. 1980) suggested oligotrophic offshore waters for Lake Huron in 1983.

The lower ratio for Station 61 reflected the higher population of _Daphnia retrocurva_ in this area. This station might have been influenced by waters from Lake Michigan. The plankton ratio at Station 61 in Lake Huron was similar to that of the Straits of Mackinac (Schelske et al. 1976) and northern Lake Michigan (see Zooplankton, Lake Michigan).

## Historical Changes in Abundances

Little can be concluded on quantitative changes in zooplankton because of the lack of data for the period early May to August, 1983. Maximum zooplankton abundance occurred during this period in 1974 (Fig. 61). In comparing mean seasonal abundance patterns in 1972 and 1983, densities in August and October of 1983 were similar to those in 1972 (Fig. 61). The higher abundance of crustaceans in 1974 is probably due to the inclusion of Saginaw Bay samples with this data set.

Rotifer densities were more perplexing. Abundance was an order of magnitude higher in 1974 than in 1983 (Table 29; Fig. 62). At present, no explanation for such a difference can be provided.

## LAKE MICHIGAN

### Changes in Species Composition

Numerous studies (Williams 1966; Johnson 1972; Gannon et al. 1982a, 1982b; Evans et al. 1980) of the nearshore region of Lake Michigan exist from as far back as 1927 (Eddy 1927). Several researchers have compared the nearshore with the offshore zooplankton in discussions of eutrophication of the entire lake. Comparisons of the inshore with the offshore stations should be viewed with caution because effects are not necessarily due to eutrophication or fish predation (Evans et al. 1980).

Although no intensive zooplankton studies of the offshore waters of the entire lake basin have taken place, some offshore studies of Lake Michigan zooplankton do exist. Wells (1960, 1970) sampled Crustacea on four dates in June, July and August in 1954, 1966 and 1968 from the offshore region off Grand Haven, Michigan, with a #2 (366 µm) net. During 1969-70 on six dates (March 1969 to January 1970), Gannon (1975) collected crustaceans from the offshore and inshore of Lake Michigan along a cross-lake transect from Milwaukee to Ludington with a 64-µm mesh net. In September of 1973, northern Lake Michigan was sampled with a 250-µm mesh net (Schelske et al. 1976). Also, Stemberger and Evans (1984) provided abundance data (76-µm net) for a few zooplankters from offshore waters of the southeastern Lake Michigan area.

The data of Wells' (1960, 1970) and Gannon (1975) are useful but have to be used with caution. A 366-µm and a 250-µm net are probably quantitative for larger crustaceans but certainly would not be for smaller crustaceans such as _Chydorus sphaericus_, _Bosmina longirostris_, _Eubosmina coregoni_, _Ceriodaphnia_ spp., _Tropocyclops_ *prasinus*, cyclopoid and calanoid copepods (Makarewicz and Likens 1979).

The zooplankton populations in Lake Michigan underwent striking size-related changes between 1954 and 1966 (Wells 1970). Species that declined sharply were the largest cladocerans (*Leptodora kindtii*, *Daphnia galeata mendotae* and *D. retrocurva*) , the largest calanoid copepods (*Limnocalanus macrurus*, *Epischura lacustris* and *Diaptomus sicilis*) and the largest cyclopoid copepod (*Mesocyclops edax*). Medium-sized or small species (*D. longiremis*, *H. gibberum*, *Polyphemus pediculus*, *Bosmina longirostris*, *Ceriodaphnia* sp., *Cyclops bicuspidatus*, *Cyclops vernalis*, *Diaptomus ashlandi*) increased in number, probably in response to selective alewife predation. After the alewife dieback, *M. edax* and *D. galeata mendotae* were still rare in 1968 when the composition of the zooplankton community shifted back toward one similar of 1954 (Wells 1970).

In northern Lake Michigan during September of 1973, predominant species were *Daphnia galeata mendotae*, *D. retrocurva*, *Limnocalanus macrurus*, *Diaptomus oregonensis*, *Eubosmina coregoni* and *Diaptomus sicilis*. Cyclopoid copepods were a minor component of the fauna in 1973 (Schelske et al. 1976).

The changing nature of the zooplankton community of Lake Michigan was further evident in 1983. *Daphnia galeata mendotae*, *D. pulicaria* and *D. retrocurva* were the second, third and fourth most important cladocerans in the lake (Table 13). Abundances of *D. galeata* in August of 1983 were half of those in 1954 (1,200/$m^3$) (Table 30). Perhaps as important, densities as high as 2,700/$m^3$ were observed at certain stations in August. Abundance of the large cladoceran *Leptodora kindtii* in 1983 was similar to abundance in 1954.

The 1983 abundance of *Daphnia retrocurva* was similar to the August 1966 abundance rather than to those of 1954 or 1968. However, maximum abundance in October of 1983 (3,161/$m^3$) was comparable to the 1954 or 1968 observations. Perhaps related to the low abundance of *D. retrocurva* in August of 1983 was the appearance of the large (~2 mm) (Evans 1985) cladoceran *Daphnia pulicaria*, which reached a maximum abundance in August.

Evans (1985) recently reported that *D. pulicaria* was first observed in Lake Michigan in 1978. Abundance remained low in southeastern Lake Michigan until 1982 and 1983, when they dominated the offshore summer *Daphnia* community and at an offshore station southeast of Grand Haven, Michigan. In 1983 this species was the dominant cladoceran in Lake Michigan from the short and long hauls (Table 13). Mean abundance reached 1,741 organisms/$m^3$ in early August with a maximum of 6,056/$m^3$. *Daphnia dubia*, another new species for the lake, had a mean station abundance of 49 organisms/$m^3$ in early October.

*Eubosmina coregoni*, *B. longirostris* and the larger *Holopedium gibberum* appeared to have increased in abundance since 1954 (Table 30). The increase in *H. gibberum* was probably real. It is doubtful that this large cladoceran would pass through a 366-µm mesh net like that used in Wells' (1960, 1970) studies of 1954-68. However, the net employed by Wells' would not have been quantitative for *E. coregoni* and *B. longirostris*.

*Cyclops bicuspidatus* was the dominant cyclopoid with *Diaptomus ashlandi* being the dominant calanoid in 1983. Abundance of

*Mesocyclops edax* was low in August of 1983 compared to 1954, but abundance in early October reached 151 organisms/$m^3$ (mean station abundance). *Diaptomus minutus* appeared to have decreased in abundance since 1968 while there was some suggestion that *D. oregonensis* had increased steadily since 1954 (Table 31). *D. sicilis* had increased dramatically since 1968. Abundance of *Limnocalanus macrurus* was lower during August of 1983 than in 1954-68. However, abundance in April of 1983 was 1,724/$m^3$. The abundance of *Epischura lacustris* in August was still low in 1983 relative to 1954, but mean station abundance was 111 organisms/$m^3$ in late October. By 1983 the large cladocerans, calanoids and cyclopoid copepods, observed by Wells (1970) to have decreased sharply in the early 60's, had increased in abundance to denities similar to those in August of 1954. In some instances, abundance was not as high in August but was as high at other times of the year. In addition, two new species were observed including the large and now dominant *Daphnia pulicaria*.

The resurgence of larger zooplankton in Lake Michigan is probably related to the sharp decline in the abundance of the planktivorous alewife in 1982 and 1983. The lakewide catch of adult alewifes was only 31% that of 1982 and only 12% of the 1981 catch. Bloater chubs are replacing the alewifes and have been experiencing a dramatic increase in abundance since 1970 (Wells and Hatch 1983). Bloaters above ™18 cm in size primarily feed on *Mysis* and *Pontoporeia*. Only smaller individuals feed on zooplankton (Wells and Beeton 1963).

## Rotifera

Rotifer studies reported in the literature are primarily from the nearshore region of the lake. In the nearshore, *Keratella* cochlearis, Polyarthra vulgaris, Kellicottia longispina, Synchaeta stylata and Synchaeta tremula were dominant in 1926-27 (Eddy 1927). Keratella and Polyarthra were the dominant genera in 1962 (Williams 1966), while K. cochlearis and P. vulgaris were dominant in 1970 (Johnson 1972). Gannon et al.(1982a) noted that the following rotifers were predominant in 1977: K. cochlearis, K. crassa, P. vulgaris, Conochilus unicornis, K. longispina and P. remata.

Abundance of rotifers in Lake Michigan generally decreased from the nearshore into the offshore (Gannon et al. 1982a, Stemberger and Evans 1984). It is also of interest that the species composition of the nearshore and offshore was similar. In 1983 the predominant offshore rotifers were in descending order: Polyarthra vulgaris, Synchaeta sp., Keratella cochlearis, Polyarthra major, Kellicottia longispina, Keratella crassa, Gastropus stylifer and Colletheca sp. (Table 13), which are similar to nearshore and to Ahlstrom's (1936) offshore observations of predominant species (K. cochlearis, Synchaeta stylata and P. vulgaris).

## North-South Trophic Status

In comparison to Lakes Erie and Huron, the geographical distributional pattern of total zooplankton was erratic. This may be related to the alteration of east-west sampling stations on every other trip (see Methods and Materials). There was a suggestion of decreasing zooplankton abundance from north to south (Fig. 34). Rotifera, in particular, did decrease southward on the transect, while the Calanoida had approximately twice the abundance in the southern half (Stations 34 to 6) than in the northern half (Stations 77 to 41) of the lake. The distribution of the calanoid *Diaptomus sicilis* was restricted essentially to the southern half of the lake (Fig. 51a). Cladocera abundance ranged from 1,000-2,000 organisms/m$^3$ except at Station 64 where a mean abundance of 5,000/m$^3$ was observed.

Geographical abundance of *Eubosmina coregoni* and *Bosmina longirostris* had inverse distributional patterns from *Limnocalanus macrurus* (Fig. 63). Also, *Notholca laurentiae*, *N. squamula*, *N. foliacea* (Fig. 52a-c) and *Holopedium gibberum* all had abundance peaks at the far northern end of the lake and were not abundant in the southern half of Lake Michigan. *Daphnia retrocurva* was observed in maximum abundance at the extreme southern end of the lake (Fig. 51c).

## Indicators of Trophic Status

Zooplankton have potential value as assessors of trophic status (Gannon and Stemberger 1978). Rotifers, in particular, respond more quickly to environmental changes than do the crustacean plankton and appear to be more sensitive indicators of changes in water quality. Composition of the rotifer community (Gannon and Stemberger 1978), as well as species, have been employed to evaluate trophic status. A rotifer community dominated by *Polyarthra vulgaris*, *Keratella cochlearis*, *Conochilus unicornis* and *Kellicottia longispina* have been considered to be an association indicative of an oligotrophic community by Gannon and Stemberger (1978).

In 1983 the six predominant rotifers in descending order of relative abundance were *P. vulgaris*, *Synchaeta* sp., *K. cochlearis*, *P. major*, *K. longispina* and *C. unicornis*. The 1983 rotifer community appeared to be an oligotrophic association.

The high relative abundance of *Diaptomus sicilis* and

*Limnocalanus macrurus* (Table 13), both oligotrophic indicators (Gannon and Stemberger 1978, McNaught et al. 1980), also suggested oligotrophic offshore conditions.

The calanoid/cyclopoid plus cladoceran ratio has been used as a measure of trophic status in the Great Lakes (Gannon and Stemberger 1978, McNaught et al. 1980). Calanoid copepods generally appear best adapted for oligotrophic waters, while cladocerans and cylopoid copepods are relatively more abundant in eutrophic waters. On the north-south transect, the plankton ratios were high and similar, except at the far north and the southern extreme of the lake (Table 32). This distribution of the ratios suggested that the highest quality water existed from Station 57 to Station 11. With a zooplankton abundance between those of Lakes Erie and Huron (Table 19), the presence of the oligotrophic rotifer association, a plankton ratio between those of Huron and Erie, the domination of the calanoids, and the fairly abundant presence of the oligotrophic indicator species, *Diaptomus sicilis* and *Limnocalanus macrurus*, Lake Michigan's waters in 1983 are best characterized as mesotrophic/oligotrophic.

The low plankton ratios (0.37 and 0.41) at the far northern end of Lake Michigan (Stations 64 and 77) were very similar to those observed in 1973 at the Straits of Mackinac (Gannon and Stemberger 1978). Gannon and Stemberger (1978) implied that more eutrophic conditions existed within this area of a low calanoid to cladoceran plus cyclopoid ratio. Abundance of the oligotropic *Limnocalanus macrurus* and *Diaptomus sicilis* was significantly lower in these far northern stations, while the eutrophic species *Eubosmina coregoni* and *Bosmina longirostris* increased at the far northern stations (Fig.

63). Similarly, the eutrophic rotifer species *Notholca squamula*, *N. laurentiae* and *N. folicacea* were only abundant at the far northern area. Several indicators suggest that the northern end of Lake Michigan near the Straits of Mackinac have waters often associated with eutrophic conditions.

# RECOMMENDATIONS

1. Because much of the historical data that exists is from the spring and summer periods, samples for zooplankton should be taken during the period of greatest population growth; i.e. late May, June and July. The lack of zooplankton data during this period in 1983 compromised the use of the data set for historical comparisons. Furthermore, as the scientific community becomes more interested in food web relationships, zooplankton abundance and diversity during periods of maximum abundance will become of interest.

2. The same stations need to be sampled routinely. The rotation of sampling sites in Lake Michigan only complicated the analysis and interpretation.

3. A better understanding of the nature of the picoplankton is required for the Great Lakes. In the current work, the decision was made to enumerate blue-green algae even though direct observation as to the autotrophic nature of the organism was inconclusive. Fluorescence microscopy failed to reveal the presence of chlorophyll in the objects because iodine (Lugol's fixative) quences fluorescence. Great Lakes' material, fixed with glutaraldehyde, on membrane filters, subjected to fluorescence microscopy autofluoresced, suggesting chlorophyll containing objects (Andresen 1985). Further research is suggested as below.

a. Taxonomic identification of the picoplankton.

b. Appropriate preservation of samples to utilize fluorescence microscopy and TEM examination for elucidation of biochemical and structural characters.

c. Examination of the pigment distribution by size fraction

- chlorophyll and phycobilins (Stewart and Farmer 1984).

d. Productivity based on size fractions.

e. Examination of the potential use of cyanobacterium as a food source for rotifers. Caron et al. (1985) suggests that rotifers and microflagellates may be important consumers.

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TABLE 1. Plankton sampling dates for Lakes Erie, Huron and Michigan in 1983.

| Lake | Cruise | Cruise Date |
|---|---|---|
| ERIE | 1 | 4/25 - 4/26 |
| | 2 | 5/9 - 5/10 |
| | 3 | 6/27 - 7/1 * |
| | 4 | 8/6 - 8/8 |
| | 5 | 8/22 - 8/23 |
| | 6 | 10/19 - 10/21 |
| | 7 | 10/21 - 10/24 |
| HURON | 1 | 4/21 - 4/24 * |
| | 2 | 5/6 - 5/8 |
| | 3 | 7/2 - 7/4 * |
| | 4 | 8/4 - 8/6 |
| | 5 | 8/19 - 8/21 |
| | 6 | 10/16 - 10/18 |
| | 7 | 10/24 - 10/26 |
| MICHIGAN | 1 | 4/17 - 4/21 |
| | 1a | 4/26 - 5/1 ** |
| | 2 | 5/4 - 5/6 |
| | 3 | 7/4 - 7/5 * |
| | 4 | 8/3 - 8/4 |
| | 5 | 8/17 - 8/19 |
| | 6 | 10/12 - 10/15 |
| | 7 | 10/26 - 10/30 |

* No zooplankton sample

** No phytoplankton sample

TABLE 2. Latitude and longitude of plankton sampling stations, 1983.

| Station # | Latitude | Longitude |
|---|---|---|
| LAKE ERIE | | |
| LE60 | 41°53'30" | 83°11'48" |
| LE57 | 41 49 54 | 83 01 06 |
| LE55 | 41 44 18 | 82 44 00 |
| LE42 | 41 57 54 | 82 02 30 |
| LE73 | 41 58 40 | 81 45 25 |
| LE37 | 42 06 36 | 81 34 30 |
| LE78 | 42 07 00 | 81 15 00 |
| LE79 | 42 15 00 | 80 48 00 |
| LE18 | 42 25 18 | 80 04 48 |
| LE15 | 42 31 00 | 79 53 36 |
| LE09 | 42 32 18 | 79 37 00 |
| LAKE HURON | | |
| LH61 | 45 45 00 | 83 55 00 |
| LH54 | 45 31 00 | 83 25 00 |
| LH45 | 45 08 12 | 82 59 00 |
| LH37 | 44 45 42 | 82 47 00 |
| LH32 | 44 27 12 | 82 20 30 |
| LH27 | 44 11 54 | 82 30 12 |
| LH15 | 44 00 00 | 82 21 00 |
| LH12 | 43 53 24 | 82 03 24 |
| LH09 | 43 38 00 | 82 13 00 |
| LH06 | 43 28 00 | 82 00 00 |
| LAKE MICHIGAN | | |
| LM06 | 42 00 00 | 87 00 00 |
| LM10 | 42 23 00 | 87 25 00 |
| LM18 | 42 44 00 | 87 00 00 |
| LM22 | 43 08 00 | 87 25 00 |
| LM27 | 43 36 00 | 86 55 00 |
| LM32 | 44 08 24 | 87 14 00 |
| LM41 | 44 44 12 | 86 43 18 |
| LM46 | 45 13 24 | 86 36 48 |
| LM64 | 45 57 00 | 85 35 12 |
| LM77 | 45 47 24 | 84 49 24 |

TABLE 3. Sample dates and stations for Lake Michigan, 1983.

| Station Number | Sample Dates | | | | | | |
|---|---|---|---|---|---|---|---|
| | 4/17-21 | 4/26-5/1 | 5/4-6 | 8/3-4 | 8/17-19 | 10/12-15 | 10/26-30 |
| 5 | | X | X | | | | X |
| 6 | X | | | X | X | X | X |
| 10 | X | | X | | | | X |
| 11 | | X | | X | X | X | X |
| 17 | | | X | | | | X |
| 18 | X | X | | X | X | | |
| 22 | X | | X | X | X | X | X |
| 23 | | X | | | | | X |
| 26 | | | X | X | X | | |
| 27 | X | | | | | | X |
| 32 | X | | X | X | X | X | X |
| 34 | | X | | | | | X |
| 40 | | | X | | X | X | X |
| 41 | X | | | X | | | |
| 46 | X | | X | | | | X |
| 47 | | X | X | X | X | X | X |
| 56 | | X | | | | | X |
| 57 | | | X | X | X | X | X |
| 64 | | X | X | X | X | X | X |
| 77 | | X | X | X | X | | X |

TABLE 4. Number of taxa and genera observed in each algal division or grouping, 1983.

| | LAKE ERIE | | LAKE HURON | | LAKE MICHIGAN | |
|---|---|---|---|---|---|---|
| | Taxa | Genera | Taxa | Genera | Taxa | Genera |
| Bacillariophyta | 225 | 31 | 211 | 31 | 221 | 33 |
| Chlorophyta | 113 | 38 | 75 | 28 | 88 | 34 |
| Chrysophyta | 29 | 11 | 56 | 10 | 53 | 13 |
| Cryptophyta | 20 | 3 | 25 | 3 | 29 | 4 |
| Cyanophyta | 18 | 9 | 13 | 6 | 28 | 10 |
| Colorless flagellates | 15 | 6 | 13 | 4 | 16 | 6 |
| Pyrrhophyta | 10 | 4 | 10 | 4 | 10 | 4 |
| Euglenophyta | 2 | 2 | 4 | 3 | 1 | 1 |
| Unidentified | 3 | - | 3 | - | 5 | - |
| Chloromonadophyta | 1 | 1 | 1 | 1 | 1 | 1 |
| TOTAL | 436 | 105 | 411 | 90 | 452 | 106 |

TABLE 5. Relative abundance of major phytoplankton divisions in Lakes Erie, Huron and Michigan. BAC=Bacillariophyta, CAT=Chloromanophyta, CHL=Chlorophyta, CHR=Chrysophyta, COL=Colorless Flagellates, CRY=Cryptophyta, CYA=Cyanophyta, EUG=Euglenophyta, PYR=Pyrrhophyta, UNI=Unidentified.

LAKE ERIE

| Division | % Biovolume/mL | % Cells/mL |
|---|---|---|
| BAC | 59.93 | 1.38 |
| CAT | 0.01 | 0.01 |
| CHL | 14.91 | 1.95 |
| CHR | 0.88 | 0.61 |
| COL | 0.10 | 0.07 |
| CRY | 9.13 | 1.73 |
| CYA | 4.14 | 89.58 |
| EUG | 0.04 | 0.01 |
| PYR | 8.40 | 0.03 |
| UNI | 2.47 | 4.65 |

LAKE HURON

| Division | % Biovolume/mL | % Cells/mL |
|---|---|---|
| BAC | 68.20 | 1.16 |
| CAT | 0.02 | 0.01 |
| CHL | 3.45 | 0.42 |
| CHR | 7.11 | 1.60 |
| COL | 0.14 | 0.06 |
| CRY | 8.29 | 1.13 |
| CYA | 4.31 | 89.53 |
| EUG | 0.11 | 0.01 |
| PYR | 3.25 | 0.01 |
| UNI | 5.11 | 6.09 |

LAKE MICHIGAN

| Division | % Biovolume/mL | % Cells/mL |
|---|---|---|
| BAC | 56.41 | 1.07 |
| CAT | 0.02 | 0.01 |
| CHL | 5.25 | 0.65 |
| CHR | 6.53 | 1.49 |
| COL | 0.75 | 0.13 |
| CRY | 13.43 | 1.24 |
| CYA | 5.56 | 92.21 |
| EUG | 0.04 | 0.01 |
| PYR | 7.32 | 0.01 |
| UNI | 4.68 | 3.20 |

TABLE 6. Summary of major phytoplankton species occurrence in Lake Erie during 1983. Summary is based on all samples analyzed. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Major species were arbitrarily defined as having an abundance of >0.1% of the total cells or >0.5% of the total biovolume.

| Taxon | Maximum cells/mL | Average cells/mL | % of Total Cells | Mean Biovolume $\mu m^3/mL$ | % of Total Biovolume |
|---|---|---|---|---|---|
| BACILLARIOPHYTA | | | | | |
| Actinocyclus normanii f. subsalsa | 88 | 5.8 | .01 | 36129 | 2.65 |
| Fragilaria capucina | 603 | 49.8 | .12 | 11645 | .85 |
| Fragilaria crotonensis | 554 | 76.7 | .19 | 47360 | 3.47 |
| Melosira granulata | 555 | 25.2 | .06 | 11522 | .85 |
| Rhizosolenia sp. | 507 | 7.2 | .02 | 53354 | 3.91 |
| Stephanodiscus alpinus | 78 | 9.7 | .02 | 14736 | 1.08 |
| Stephanodiscus binderanus | 234 | 17.9 | .04 | 9836 | .72 |
| Stephanodiscus niagarae | 169 | 25.3 | .06 | 507424 | 37.22 |
| Tabellaria flocculosa | 376 | 20.8 | .05 | 51064 | 3.75 |
| CHLOROPHYTA | | | | | |
| Coelastrum microporum | 2291 | 135.5 | .34 | 11054 | .81 |
| Cosmarium sp. | 49 | 3.0 | .01 | 83415 | 6.12 |
| Monoraphidium contortum | 744 | 82.0 | .20 | 704 | .05 |
| Mougeotia sp. | 352 | 13.4 | .03 | 11991 | .88 |
| Oocystis borgei | 155 | 15.3 | .04 | 9465 | .69 |
| Pediastrum simplex v. duodenarium | 376 | 11.5 | .03 | 7172 | .53 |
| Scenedesmus ecornis | 2193 | 111.7 | .28 | 19837 | 1.46 |
| Staurastrum paradoxum | 16 | .8 | .01 | 14024 | 1.03 |
| CHRYSOPHYTA | | | | | |
| Haptophyte sp. | 785 | 158.6 | .40 | 1781 | .13 |
| CRYPTOPHYTA | | | | | |
| Chroomonas norstedtii | 515 | 53.4 | .13 | 1289 | .09 |
| Cryptomonas erosa | 286 | 30.4 | .08 | 66183 | 4.85 |
| Rhodomonas minuta v. nannoplanktica | 1890 | 564.8 | 1.41 | 32813 | 2.41 |
| CYANOPHYTA | | | | | |
| Agmenellum quadruplicatum | 3305 | 70.1 | .18 | 19 | .01 |
| Anacystis marina | 141208 | 33171.1 | 82.81 | 8893 | .65 |
| Anacystis montana v. minor | 5072 | 219.1 | .55 | 1650 | .12 |
| Aphanizomenon flos-aquae | 2561 | 91.5 | .23 | 6844 | .50 |
| Coccochloris peniocystis | 7175 | 697.3 | 1.74 | 1826 | .13 |
| Coelosphaerium naegelianum | 5891 | 235.9 | .59 | 2785 | .20 |
| Merismopedia tenuissima | 15544 | 333.2 | .83 | 104 | .01 |
| Oscillatoria limnetica | 11266 | 460.1 | 1.15 | 3295 | .24 |
| Oscillatoria subbrevis | 27399 | 404.4 | 1.01 | 15796 | 1.16 |
| Oscillatoria tenuis | 5081 | 79.5 | .20 | 4466 | .33 |
| PYRRHOPHYTA | | | | | |
| Ceratium hirundinella | 16 | 1.4 | .01 | 66724 | 4.89 |
| Gymnodinium sp. #2 | 16 | .7 | .01 | 6932 | .51 |
| Peridinium aciculiferum | 16 | 1.0 | .01 | 10300 | .76 |
| Peridinium sp. | 106 | 3.8 | .01 | 19741 | 1.45 |
| UNIDENTIFIED | | | | | |
| Unidentified flagellate - ovoid | 3960 | 1296.0 | 3.24 | 24405 | 1.79 |
| Unidentified flagellate - spherical | 1301 | 564.3 | 1.41 | 9238 | .68 |
| | | TOTAL | 97.51 | TOTAL | 86.98 |

TABLE 7. Summary of major phytoplankton species occurrence in Lake Huron during 1983. Summary is based on all samples analyzed. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Major species were arbitrarily defined as having an abundance of >0.1% of the total cells or >0.5% of the total biovolume.

| Taxon | Maximum cells/mL | Average cells/mL | % of Total Cells | Mean Biovolume $\mu m^3/mL$ | % of Total Biovolume |
|---|---|---|---|---|---|
| BACILLARIOPHYTA | | | | | |
| Asterionella formosa | 103 | 9.7 | .04 | 2957 | .66 |
| Cyclotella comensis | 385 | 49.2 | .29 | 1698 | .9 |
| Cyclotella comta | 51 | 6.4 | .03 | 17659 | 3.94 |
| Cyclotella kuetzingiana v. planetophora | 80 | 16.5 | .07 | 4975 | 1.11 |
| Cyclotella ocellata | 254 | 29.9 | .13 | 2330 | .52 |
| Cymatopleura solea v. apiculata | 3 | .2 | .01 | 13446 | 3 |
| Fragilaria crotonensis | 123 | 27.6 | .12 | 22889 | 5.11 |
| Fragilaria intermedia v. fallax | 60 | 8.2 | .04 | 5019 | 1.12 |
| Melosira islandica | 90 | 12.7 | .06 | 16985 | 3.79 |
| Rhizosolenia sp. | 143 | 17.2 | .08 | 127442 | 28.44 |
| Stephanodiscus niagarae | 3 | .3 | .01 | 5755 | 1.28 |
| Stephanodiscus transilvanicus | 8 | .9 | .01 | 8838 | 1.97 |
| Tabellaria flocculosa | 133 | 20.3 | .09 | 60602 | 13.52 |
| Tabellaria flocculosa v. linearis | 21 | 1.4 | .01 | 2554 | .57 |
| CHRYSOPHYTA | | | | | |
| Chrysosphaerella longispina | 74 | 13.5 | .06 | 5276 | 1.18 |
| Dinobryon cylindricum | 164 | 16.1 | .07 | 5850 | 1.31 |
| Dinobryon divergens | 141 | 21.6 | .10 | 4704 | 1.05 |
| Dinobryon sociale v. americanum | 524 | 49.1 | .22 | 5997 | 1.34 |
| Haptophyte sp. | 859 | 168.0 | .75 | 1571 | .35 |
| CRYPTOPHYTA | | | | | |
| Cryptomonas erosa | 16 | 5.4 | .02 | 10213 | 2.28 |
| Cryptomonas erosa v. reflexa | 8 | 1.3 | .01 | 2472 | .55 |
| Cryptomonas pyrenoidifera | 33 | 6.1 | .03 | 3497 | .78 |
| Rhodomonas minuta v. nannoplanktica | 311 | 204.4 | .92 | 15173 | 3.39 |
| CYANOPHYTA | | | | | |
| Anacystis marina | 55518 | 18010.5 | 80.63 | 8456 | 1.89 |
| Anacystis montana v. minor | 2556 | 379.9 | 1.70 | 1667 | .37 |
| Anacystis thermalis | 115 | 17.3 | .08 | 2425 | .54 |
| Coccochloris elabans | 434 | 37.7 | .17 | 421 | .09 |
| Coccochloris peniocystis | 7929 | 1332.4 | 5.96 | 3336 | .74 |
| Coelosphaerium naegelianum | 900 | 73.7 | .33 | 332 | .07 |
| Gomphosphaeria lacustris | 920 | 37.6 | .17 | 204 | .05 |
| Oscillatoria limnetica | 974 | 87.2 | .39 | 281 | .06 |
| PYRRHOPHYTA | | | | | |
| Ceratium hirundinella | 2 | .1 | .01 | 5590 | 1.25 |
| Gymnodinium sp. | 8 | .3 | .01 | 2735 | .61 |
| Gymnodinium sp. #2 | 2 | .2 | .01 | 3374 | .75 |
| UNIDENTIFED | | | | | |
| Unidentified flagellate - ovoid | 1135 | 489.3 | 2.19 | 10434 | 2.33 |
| Unidentified flagellate - spherical | 5211 | 870.5 | 3.90 | 12335 | 2.75 |
| | | TOTAL | 98.72 | TOTAL | 89.66 |

TABLE 8. Summary of major phytoplankton species occurrence in Lake Michigan during 1983. Summary is based on all samples analyzed. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Major species were arbitrarily defined as having an abundance of >0.1% of the total cells or >0.5% of the total biovolume.

| Taxon | Maximum cells/mL | Average cells/mL | % of Total Cells | Mean Biovolume $\mu m^3/mL$ | % of Total Biovolume |
|---|---|---|---|---|---|
| BACILLARIOPHYTA | | | | | |
| Asterionella formosa | 206 | 11.8 | .04 | 3541 | .91 |
| Cyclotella comensis | 834 | 52.7 | .24 | 1958 | .97 |
| Cyclotella comta | 158 | 6.3 | .02 | 15647 | 4.01 |
| Cyclotella michiganiana | 117 | 12.1 | .04 | 2664 | .68 |
| Cymatopleura solea | 5 | .3 | .01 | 5991 | 1.54 |
| Entomoneis ornata | 4 | .2 | .01 | 3346 | .86 |
| Fragilaria crotonensis | 755 | 59.4 | .21 | 42373 | 10.86 |
| Fragilaria vaucheriae | 115 | 10.0 | .04 | 4572 | 1.17 |
| Melosira islandica | 137 | 12.1 | .04 | 10920 | 2.80 |
| Melosira italica subsp. subarctica | 357 | 36.6 | .13 | 6667 | 1.71 |
| Rhizosolenia eriensis | 53 | 2.6 | .01 | 6165 | 1.58 |
| Rhizosolenia sp. | 133 | 1.7 | .01 | 7204 | 1.85 |
| Stephanodiscus alpinus | 22 | 3.0 | .01 | 19375 | 4.96 |
| Stephanodiscus niagarae | 18 | .8 | .01 | 9876 | 2.53 |
| Stephanodiscus transilvanicus | 6 | .3 | .01 | 6326 | 1.62 |
| Tabellaria fenestrata | 79 | 4.1 | .01 | 7247 | 1.86 |
| Tabellaria flocculosa | 202 | 16.8 | .06 | 48991 | 12.55 |
| CHLOROPHYTA | | | | | |
| Cosmarium sp. | 8 | .4 | .01 | 6985 | 1.79 |
| Green coccoid - bacilliform | 376 | 39.5 | .14 | 832 | .21 |
| Monoraphidium contortum | 201 | 38.1 | .14 | 310 | .08 |
| Stichococcus sp. | 761 | 23.0 | .08 | 1969 | .50 |
| CHRYSOPHYTA | | | | | |
| Dinobryon cylindricum | 311 | 17.8 | .06 | 5732 | 1.47 |
| Dinobryon divergens | 258 | 15.5 | .06 | 2317 | .59 |
| Dinobryon sociale v. americanum | 802 | 47.7 | .17 | 6227 | 1.60 |
| Haptophyte sp. | 785 | 185.0 | .66 | 2306 | .59 |
| Unidentified coccoids | 540 | 46.5 | .17 | 478 | .12 |
| Stylotheca aurea | 172 | 6.7 | .02 | 2142 | .55 |
| CRYPTOPHYTA | | | | | |
| Chroomonas norstedtii | 202 | 28.8 | .10 | 653 | .17 |
| Cryptomonas erosa | 25 | 6.7 | .02 | 14345 | 3.68 |
| Cryptomonas erosa v. reflexa | 11 | 1.2 | .01 | 2464 | .63 |
| Cryptomonas marssonii | 25 | 2.5 | .01 | 2249 | .58 |
| Cryptomonas pyrenoidifera | 49 | 6.1 | .02 | 2783 | .71 |
| Rhodomonas minuta v. nannoplanktica | 777 | 268.8 | .96 | 22375 | 5.73 |
| CYANOPHYTA | | | | | |
| Anacystis marina | 120019 | 23607.8 | 84.61 | 6329 | 1.62 |
| Anacystis montana v. minor | 3289 | 451.2 | 1.62 | 2994 | .77 |
| Coccochloris peniocystis | 11437 | 1339.7 | 4.80 | 3014 | .77 |
| Coelosphaerium naegelianum | 1227 | 39.3 | .14 | 165 | .04 |
| Gomphosphaeria lacustris | 818 | 37.9 | .14 | 265 | .07 |
| Oscillatoria agardhii | 344 | 14.2 | .05 | 2791 | .72 |
| Oscillatoria limnetica | 2266 | 139.3 | .50 | 1033 | .26 |
| PYRRHOPHYTA | | | | | |
| Ceratium hirundinella | 8 | .2 | .01 | 20898 | 5.36 |
| Gymnodinium sp. #2 | 16 | .3 | .01 | 3765 | .96 |
| Peridinium sp. | 8 | .4 | .01 | 2584 | .66 |
| UNIDENTIFIED | | | | | |
| Unidentified flagellate - ovoid | 1630 | 393.4 | 1.41 | 9707 | 2.49 |
| Unidentified flagellate - spherical | 1859 | 499.2 | 1.79 | 8415 | 2.16 |
| | | TOTAL | 98.62 | TOTAL | 87.34 |

TABLE 9. Relative abundance of taxa and number of taxa and genera observed in each zooplankton grouping, 1983.

| | LAKE ERIE | | | LAKE HURON | | | LAKE MICHIGAN | | |
|---|---|---|---|---|---|---|---|---|---|
| | Taxa | Genera | % of Total Abundance | Taxa | Genera | % of Total Abundance | Taxa | Genera | % of Total Abundance |
| Rotifera | 34 | 18 | 69.2 | 31 | 17 | 41.1 | 33 | 20 | 59.7 |
| Cladocera | 19 | 13 | 6 | 15 | 8 | 4.8 | 23 | 13 | 3.2 |
| Calanoida | 10 | 5 | 3.7 | 9 | 4 | 19.8 | 10 | 5 | 10.1 |
| Cyclopoida | 7 | 4 | 5.4 | 5 | 3 | 11.2 | 5 | 4 | 5.7 |
| Harpacticoida | 1 | - | <0.1 | 0 | 0 | 0 | 1 | - | <0.1 |
| Mysidacea | 0 | 0 | 0 | 1 | 1 | <0.1 | 1 | 1 | <0.1 |
| Copepoda nauplii | - | - | 15.8 | - | - | 23.1 | - | - | 21.3 |
| Total | 71 | 41 | | 61 | 33 | | 73 | 43 | |

TABLE 10. Mean abundances of zooplankton groups during the study period.

| | Lake Erie | Lake Huron | Lake Michigan |
|---|---|---|---|
| Rotifera | 195,966 | 17,035 | 41,331 |
| Cladocera | 16,224 | 2,448 | 2,143 |
| Copepoda Nauplii | 41,515 | 5,924 | 11,893 |
| Cyclopoida | 12,759 | 5,072 | 3,924 |
| Calanoida | 9,115 | 10,677 | 6,138 |
| Mysidacea | 0 | 0 | 0.33 |
| Harpacticoida | 4.2 | 0 | 0.10 |
| Mean | 288,341<br>(195,344) | 46,230<br>(44,502) | 69,353<br>(35,087) |

TABLE 11 Summary of common zooplankton species occurrence in Lake Erie during 1983.[1] Values are from the short zooplankton hauls. Summary includes the maximum population density encountered, the average density and the relative abundance. Parentheses indicate values from the long haul.

| Taxon | Maximum Organisms/$m^3$ x 1000 | Average Density #/$m^3$ | % of Total Organisms[2] |
|---|---|---|---|
| ROTIFERA | | | |
| Polyarthra vulgaris | 334.0 | 49739 | 18.44 |
| Synchaeta sp. | 370.0 | 29442 | 9.54 |
| Keratella cochlearis | 111.0 | 19647 | 7.27 |
| Conochilus unicornis | 112.0 | 14006 | 5.34 |
| Keratella hiemalis | 127.0 | 10701 | 3.53 |
| Brachionus sp. | 540.0 | 9307 | 2.98 |
| Polyarthra dolichoptera | 155.0 | 8329 | 2.70 |
| Polyarthra major | 24.0 (26) | 6395 (8558) | 2.62 |
| Ascomorpha ecaudis | 64.0 | 6446 | 2.33 |
| Notholca laurentiae | 83.0 | 6964 | 2.27 |
| Colletheca sp. | 59.0 | 5298 | 2.03 |
| Keratella crassa | 97.0 | 5384 | 1.82 |
| Notholca foliacea | 59.0 | 5402 | 1.75 |
| Kellicottia longispina | 37.0 | 3590 | 1.29 |
| CLADOCERA | | | |
| Eubosmina coregoni | 64.0 | 4505 | 1.66 |
| Daphnia galaeta mendotae | 60.0 | 4055 | 1.54 |
| Daphnia retrocurva | 70.0 | 4183 | 1.42 |
| Bosmina longirostris | 8.0 | 1628 | .65 |
| Diaphanosoma leuchtenbergianum | 9.0 | 966 | .38 |
| Chydorus sphaericus | 14.0 | 476 | .16 |
| COPEPODA | | | |
| Copepoda nauplii | 133.0 | 41515 | 15.76 |
| Cyclopoida | | | |
| Cyclopoid copepodite | 22.0 (25) | 7512 (10895) | 3.13 |
| Cyclops bicusbidatus thomasi | 12.0 | 2825 | 1.23 |
| Mesocyclops edax | 15.0 | 1669 | .67 |
| Tropocyclops prasinus mexicanus | 3.3 (6.0) | 748 (1782) | .36 |
| Calanoida | | | |
| Calanoid copepodite | 40.0 | 6120 | 2.54 |
| Diaptomus oregonensis | 12.0 | 2034 | .82 |
| Diaptomus siciloides | 13.0 | 600 | .19 |
| TOTAL | 94.4 | | |

1. Species were arbitrarily classified as common if they accounted for >0.1% of the total abundance for the study period except for the Rotifera. Rotifer species were considered common if they accounted for >1.0% of the total abundance.

2. Short and long hauls are grouped together.

TABLE 12 Summary of common zooplankton species in Lake Huron during 1983.[1] Summary includes the maximum population density encountered, the average density and the relative abundance. Values are from the short zooplankton hauls. Parentheses indicate values from the long haul.

| Taxon | Maximum Organisms/$m^3$ | Average Density Number/$m^3$ | Percent of Total Organisms [2] |
|---|---|---|---|
| ROTIFERA | | | |
| Conochilus unicornis | 19,750 | 7,050 | 11.2 |
| Kellicottia longispina | 7,106 (21,721) | 2,088 (176) | 8.6 |
| Keratella cochlearis | 5,457 (18,633) | 2,040 (356) | 7.2 |
| Polyarthra vulgaris | 8,249 | 2,955 | 5.3 |
| Gastropus stylifer | 4,244 (6,815) | 1,132 (81) | 2.6 |
| Synchaeta sp. | 1,277 | 175 | 1.7 |
| Colletheca sp. | 2,196 | 848 | 1.5 |
| CLADOCERA | | | |
| Daphnia galaeta mendotae | 4,076 | 1,029 (16) | 1.4 |
| Bosmina longirostris | 1,598 (2,813) | 518 (409) | 1.2 |
| Daphnia pulicaria | 2,791 | 363 | .7 |
| Daphnia retrocurva | 2,148 (2,423) | 74 (82) | .6 |
| Eubosmina coregoni | 998 | 229 | .4 |
| Daphnia schodleri | 1,630 | 164 | .2 |
| Daphnia catawba | 0 (1,610) | 0 (70) | .2 |
| Holopedium gibberum | 408 (468) | 58 | .1 |
| COPEPODA | | | |
| Copepoda nauplii | 11,766 (38,290) | 5,924 (962) | 23.1 |
| Cyclopoida | | | |
| Cyclopoid copepodite | 8,608 | 4,397 | 9.8 |
| Cyclops bicuspidatus thomasi | 2,346 | 452 | 1.1 |
| Tropocyclops prasinus mexicanus | 577 | 109 | .2 |
| Mesocyclops edax | 930 | 115 | .1 |
| Calanoida | | | |
| Calanoid copepodite | 19,707 | 9,666 | 17.6 |
| Diaptomus minutus | 2,063 | 465 | .8 |
| Diaptomus ashlandi | 802 (1,008) | 206 (332) | .6 |
| Diaptomus sicilis | 1,141 | 145 | .4 |
| Diaptomus oregonensis | 413 | 140 | .3 |
| | | TOTAL | 97.0 |

1. Species were arbitrarily classified as common if they accounted for >0.1% of the total abundance for the study period with the exception of the Rotifera. Rotifer species were considered common if they accounted for >1.0% % of the total abundance.

2. Short and long hauls are grouped together.

TABLE 13 Summary of common zooplankton species occurrence in Lake Michigan during 1983.[1] Values are from the short zooplankton hauls. Summary includes the maximum population density encountered, the average density and the relative abundance. Parentheses indicate values from the long haul.

| Taxon | Maximum Organisms/$m^3$ x 1000 | Average Density Number/$m^3$ | Percent of Total Organisms[2] |
|---|---|---|---|
| ROTIFERA | | | |
| Polyarthra vulgaris | 109 | 16992 | 20.8 |
| Synchaeta sp. | 84 | 8593 | 11.6 |
| Keratella cochlearis | 58 | 3463 | 7.2 |
| Polyarthra major | 23 | 1928 | 3.1 |
| Kellicottia longispina | 10 (15) | 981 (4,688) | 2.6 |
| Conochilus unicornis | 21 | 1772 | 2.5 |
| Polyarthra dolichoptera | 33 | 1368 | 2.1 |
| Keratella crassa | 12 (23) | 982 (63) | 1.9 |
| Gastropus stylifer | 12 (31) | 917 (972) | 1.7 |
| Colletheca sp. | 6.0 (6.5) | 1083 (391) | 1.6 |
| Keratella earlinae | 19 | 837 | 1.0 |
| Notholca squamula | 11 | 594 | 1.0 |
| CLADOCERA | | | |
| Bosmina longirostris | 17 | 923 | 1.4 |
| Daphnia galaeta mendota | 3.5 | 445 | .6 |
| Daphnia pulicaria | 6.1 | 376 | .7 |
| Daphnia retrocurva | 3.2 | 115 | .2 |
| Eubosmina coregoni | 1.2 | 95 | .1 |
| Holopedium gibberum | 2.1 | 86 | .1 |
| COPEPODA | | | |
| Copepoda nauplii | 39 | 11893 | 21.3 |
| Cyclopoida | | | |
| Cyclopoid copepodite | 27 | 2516 | 3.7 |
| Cyclops bicuspidatus thomasi | 5.2 | 1140 | 1.6 |
| Tropocyclops prasinus mexicanus | 3.6 | 238 | .3 |
| Calanoida | | | |
| Calanoid copepodite | 14 (43) | 4589 (5,099) | 7.7 |
| Diaptomus ashlandi | 6.5 | 699 | 1.1 |
| Diaptomus sicilis | 4.2 | 386 | .6 |
| Diaptomus minutus | .8 | 167 | .2 |
| Diaptomus oregonensis | 1.0 (1.1) | 115 (88) | .2 |
| Limnocalanus macrurus | 1.7 | 138 | .2 |
| | | TOTAL | 97.7 |

1. Species were arbitrarily classified as common if they accounted for >0.1% of the total abundance for the study period with the exception of the Rotifera. Rotifer species were considered common if they accounted for >1.0% of the total abundance.

2. Short and long hauls are grouped together.

TABLE 14. Zooplankton species having major differences in abundances between the long and short hauls, Lake Erie.

| Taxon | short | | long | |
|---|---|---|---|---|
| | #/m³ | % | #/m³ | % |
| Rotifera | | | | |
| Synchaeta sp. | 29442 | 10.68 | 1447 | 0.82 |
| Keratella hiemalis | 10701 | 3.88 | 1514 | 0.86 |
| Polyarthra dolichoptera | 8329 | 3.02 | 488 | 0.04 |
| Notholca laurentiae | 6964 | 2.52 | 616 | 0.35 |
| Polyarthra major | 6394 | 2.32 | 8558 | 4.87 |
| Notholca foliacea | 5402 | 1.96 | 300 | 0.17 |
| Keratella crassa | 5384 | 1.95 | 1426 | 0.81 |
| Notholca squamula | 1916 | 0.69 | 71 | 0.04 |
| Keratella earlinae | 1672 | 0.61 | 229 | 0.12 |
| Cladocera | | | | |
| Daphnia retrocurva | 4183 | 1.52 | 1239 | 0.70 |
| Chydorus sphaericus | 476 | 0.17 | 64 | 0.04 |
| Cyclopoida | | | | |
| Cyclops bicuspidatus thomasi | 2825 | 1.02 | 4857 | 2.76 |
| Mesocyclops edax | 1669 | <0.01 | 2011 | 1.11 |

TABLE 15. Zooplankton species having major differences in abundances between the long and short hauls, Lake Huron.

| Taxon | short #/m³ | short % | long #/m³ | long % |
|---|---|---|---|---|
| Rotifera | | | | |
| Conochilus unicornis | 7050 | 17.13 | 2492 | 6.17 |
| Polyarthra vulgaris | 2955 | 7.18 | 1506 | 3.75 |
| Keratella cochlearis | 2040 | 4.96 | 3637 | 9.01 |
| Synchaeta sp. | 174 | 0.42 | 1105 | 2.70 |
| Keratella earlinae | 82 | 0.20 | 168 | 0.41 |
| Keratella quadrata | 74 | 0.18 | 609 | 1.50 |
| Notholca laurentiae | 27 | 0.07 | 330 | 0.80 |
| Cladocera | | | | |
| Daphnia galaeta mendotae | 1029 | 2.51 | 181 | 0.45 |
| Daphnia retrocurva | 74 | 0.18 | 388 | 0.96 |
| Daphnia schodleri | 164 | 0.40 | 20 | <0.01 |
| Eubosmina coregoni | 229 | 0.56 | 97 | 0.24 |
| Copepoda | | | | |
| Copepoda nauplii | 5924 | 14.39 | 12319 | 30.50 |
| Cyclopoida | | | | |
| Mesocyclops edax | 115 | 0.28 | 55 | 0.14 |
| Tropocyclops prasinus mexicanus | 109 | 0.26 | 52 | 0.13 |
| Calanoida | | | | |
| Calanoid copepodite | 9666 | 23.50 | 5100 | 12.60 |
| Diaptomus minutus | 465 | 1.13 | 190 | 0.47 |

TABLE 16. Zooplankton species observed in either the long or short hauls, Lake Huron.

| | Mean $\#/m^3$ | % of Total Abundance | Type of Haul |
|---|---|---|---|
| Cladocera | | | |
| Daphnia catawba | 70.0 | .37 | long |
| Daphnia dubia | 1.9 | .005 | short |
| Diaphanosoma leuchtenbergianum | 0.36 | <.001 | short |
| Cyclopoida | | | |
| Cyclops vernalis | 0.49 | .001 | short |
| Mysidacea | | | |
| Mysis relicta | 0.26 | <.001 | long |
| Rotifera | | | |
| Notholca squamula | 72.0 | .41 | long |
| Notholca foliacea | 29.0 | .073 | long |
| Polyarthra remata | 10.0 | .027 | short |
| Keratella hiemalis | 10.0 | .025 | long |
| Keratella cochlearis hispida | 2.9 | .007 | short |
| Cephalodella sp. | 3.1 | .007 | short |
| Monostyla lunaris | 1.7 | .004 | short |
| Euclanis sp. | 0.42 | .001 | long |

TABLE 17. Zooplankton species having major differences in abundances between the long and short hauls, Lake Michigan.

| Taxon | short | | long | |
|---|---|---|---|---|
| | #/m³ | % | #/m³ | % |
| Rotifera | | | | |
| Polyarthra vulgaris | 16992 | 25.97 | 2662 | 7.96 |
| Kellicottia longispina | 980 | 6.50 | 1756 | 5.25 |
| Keratella earlinae | 836 | 1.27 | 141 | 0.42 |
| Keratella quadrata | 144 | 0.22 | 391 | 1.17 |
| Copepoda | | | | |
| Copepoda nauplii | 11893 | 18.17 | 9662 | 28.91 |

TABLE 18. Zooplankton species observed in either the long or short hauls, Lake Michigan.

| | Mean #/m$^3$ | % of Total Abundance | Type of Haul |
|---|---|---|---|
| Rotifera | | | |
| Lecane tunuiseta | 2.7 | .008 | long |
| Notholca striata | 1.0 | .003 | long |
| Encentrum sp. | 0.85 | .003 | long |
| Notholca acuminata | 0.38 | .001 | long |
| Euclanis sp. | 0.28 | <.001 | long |
| Brachionus quadridentatus | 0.19 | <.001 | long |
| Monostyla sp. | 0.13 | <.001 | short |
| Cladocera | | | |
| Ceriodaphnia lacustris | 0.79 | .001 | short |
| Daphnia longiremis | 0.78 | .001 | short |
| Daphnia middendorffiana | 0.04 | <.001 | short |
| Camptocercus rectirostris | 0.04 | <.001 | long |
| Diaphanosoma leuchtenbergianum | 0.27 | <.001 | short |
| Cyclopoida | | | |
| Eucyclops prionophorus | 0.01 | <.001 | short |

TABLE 19. Comparison of average abundance and biomass of plankton in Lakes Erie, Huron and Michigan, April-October, 1983

| | Algal Abundance (cells/ml) | Algal Biomass ($g/m^3$) | Zooplankton Abundance ($\#/m^3$) | Calanoid Cyc.+Clad. |
|---|---|---|---|---|
| Lake Erie | 40,055 | 1.36 | 288,341 | 0.33 |
| Lake Huron | 19,147 | 0.38 | 46,230 | 1.43 |
| Lake Michigan | 29,839 | 0.42 | 69,353 | 1.02 |

TABLE 20. Mean maximum abundance of selected common phytoplankton species in 1970 and 1983, Lake Erie. Data from Munawar and Munawar (1976) and this study. 1970 data - graphical accuracy.

| | BASIN | 1970 $g/m^3$ | 1983 $g/m^3$ |
|---|---|---|---|
| Actinocyclus normanii | Western | 4.7 | 0.30 |
| Stephanodiscus niagarae | Eastern | 1.4 | 1.05 |
| | Central | 2.3 | 1.90 |
| | Western | 0.6 | 0.12 |
| Stephanodiscus tenuis | Western | 1.8 | 0.001 |
| Stephanodiscus binderanus | Western | 0.5 | 0.11 |
| Fragilaria crotonensis | Eastern | 1.0 | 0.15 |
| | Central | 3.4 | 0.11 |
| | Western | 7.9 | 0.18 |
| Fragilaria capucina | Central | 2.4 | 0.03 |
| | Eastern | 0.4 | 0.006 |
| Peridinium aciculiferum | Central | 0.2 | 0.06 |
| | Eastern | 1.0 | 0.05 |
| Ceratium hirundinella | Central | 1.8 | 0.35 |
| | Eastern | 2.0 | 0.31 |
| Rhodomonas minuta | Eastern | 1.6 | 0.04 |
| | Central | 0.4 | 0.10 |
| Cryptomonas erosa | Western | 2.0 | 0.63 |
| Pediastrum simplex | Central | 0.4 | 0.06 |
| Staurastrum paradoxum | Central | 0.4 | 0.07 |
| Aphanizomenon flos-aquae | Western | 2.0 | 0.10 |
| Oscillatoria subbrevis | Western | * | 0.35 |

* Not listed as a common or uncommon species by Munawar and Munawar (1976)

TABLE 21. Total mean phytoplankton biomass for the western, central and eastern basins, 1983, Lake Erie.

| | Western Basin | Central Basin | Eastern Basin |
|---|---|---|---|
| Biomass ($g/m^3$) | 1.49 | 1.59 | 0.84 |

TABLE 22. Comparison of phytoplankton biomass values between 1956 and 1983 in western Lake Erie. Modified from Gladish and Munawar (1980).

| AUTHOR(S) | TIME AND LOCATION OF STUDY | BIOMASS $g/m^3$ |
|---|---|---|
| Davis (1958) | 1956, Bass Island region | 6.1 |
| Verduin (1964) | June 1957 to August 1958 Bass Islands region | 4.1 |
| Munawar & Munawar (unpublished) | April to December 1970 Off tip of Pt. Pelee | 3.8 |
| Munawar & Munawar (unpublished) | April to December 1970 Near Detroit River mouth | 4.9 |
| Gladish & Munawar (1980) | June 1975 to September 1976 Northern waters | 2.5 |
| This study | April to October 1983 | 1.5 |

TABLE 23. Comparison of abundance of selected species at offshore sites in August of 1970 and 1983. Data from Holland and Beeton (1972) and this study.

| | 11 August 1970 (Offshore Stations) cells/mL | 17 August 1983 (Stations 22 & 27) cells/mL |
|---|---|---|
| Cyclotella michiganiana | 92,182,71 | 0.44,6.8 |
| Cyclotella stelligera | 300,467,613 | 0.17,2.2 |

TABLE 24. Phytoplankton abundance in 1962, 1977 and 1983 in southern Lake Michigan. Data from Stoermer and Kopczynska (1967a and b), Rockwell et al. (1980) and this study.

| Year | Site | Abundance cells/mL | Sampling Dates |
|---|---|---|---|
| 1962-63 | Offshore<br>Nearshore | 125-1,170<br>? -2,770 | April,May,June,July<br>August,September |
| 1976-77 | Offshore (?) | 1,190-6,000 | April,June,August, September |
| 1983 | Offshore | 14,944-48,305 (with picoplankton) | April,May,July,August |
|  | (Mean of all Stations) | 1,895-4,276 (without picoplankton) | late August,mid-October, late October |
| 1983 | Offshore (Station 6) | 1,244-6,398 (without picoplankton) | late August,mid-October, late October |

TABLE 25. Species having peak abundances in the western, central or eastern basin of Lake Erie, 1983.

---

WESTERN BASIN

*Bosmina longirostris*
*Eubosmina coregoni*
*Diaphanosoma leuchtenbergianum*
*Brachionus caudatus*
*Brachionus* sp.
*Filinia longiseta*
*Keratella cochlearis*
*Keratella earlinae*
*Notholca foliaceae*
*Notholca laurentiae*
*Synchaeta* sp.
*Trichocerca cylindrica*
*Trichocerca multicrinis*

CENTRAL BASIN

*Diaptomus oregonensis*
*Cyclops bicuspidatus thomasi*
*Daphnia galeata mendotae*
*Colletheca* sp.
*Kellicottia longispina*
*Keratella hiemalis*

EASTERN BASIN

*Daphnia galeata mendotae*
*Mesocyclops edax*
*Tropocyclops prasinus mexicanus*

TABLE 26. Ratio of calanoids to cladocerans plus cyclopoids in Lake Erie, 1983.

| | WESTERN BASIN | CENTRAL BASIN | EASTERN BASIN | MEAN |
|---|---|---|---|---|
| $\frac{\text{Calanoid}}{\text{Cladoceran + Cyclopoid}}$ | 0.19 | 0.31 | 0.45 | 0.32 |

TABLE 27. Comparison of mean crustacean abundance for the sampling period in 1971 (April-November), 1974/75 (April-November) and 1983 (August-October). 1971 data modified from Watson and Carpenter (1974), 1974/75 data from McNaught et al. (1980). NF = not found. Values are number/ m$^3$.

| SPECIES | 1971 | 1974/75** | 1983 |
|---|---|---|---|
| Cladocera | | | |
| Bosmina longirostris | 553 (1047)* | 4109 | 518 |
| Eubosmina coregoni | 330 (765)* | 2084 | 229 |
| Daphnia retrocurva | | 361 | 74 |
| Daphnia galeata mendotae | 339 (852)* | 692 | 1029 |
| Daphnia longiremis | | | |
| Daphnia pulicaria | 0 (0) | 0 | 363 |
| Chydorus sphaericus | 18 | 391 | NF |
| Holopedium gibberum | 229 (580)* | 576 | 58 |
| Cyclopoida | | | |
| Cyclops bicuspidatus thomasi | 3764 (3274)* | 1271 | 2346 |
| Cyclops vernalis | 7.5 (5)* | 117 | .5 |
| Tropocyclops prasinus mexicanus | 63 (61)* | 310 | 577 |
| Mesocyclops edax | 5 (6.7)* | 91 | 115 |
| Calanoida | | | |
| Diaptomus ashlandi | 246 (37)* | 745 | 206 |
| Diaptomus minutus | 462 (322)* | 966 | 465 |
| Diaptomus sicilis | 117 (77)* | 496 | 145 |
| Diaptomus oregonensis | 109 (92)* | 192 | 140 |
| Limnocalanus macrurus | 64 (44)* | 34 | 9.3 |

* August, September and October average

** Includes Saginaw Bay

TABLE 28. Ratio of Calanoida to Cladocera plus Cyclopoida in Lake Huron, 1983.

| Station | | $\frac{\text{Calanoida}}{\text{Cyclopoida + Cladocera}}$ |
|---|---|---|
| 61 | (North) | 0.67 |
| 54 | | 1.11 |
| 45 | | 1.19 |
| 37 | | 1.57 |
| 32 | | 2.13 |
| 27 | | 1.37 |
| 15 | | 1.60 |
| 12 | | 1.98 |
| 09 | | 1.31 |
| 06 | (South) | 1.23 |

TABLE 29. Mean abundance of rotifers in Lake Huron in 1974 and 1983. Data from Stemberger et al. (1979) and this study. NF = not found in short tow.

| | 1974<br>April-Nov.<br>#/L | 1983<br>Aug.-Oct.<br>#/L |
|---|---|---|
| Colletheca sp. | 0.8 | 0.90 |
| Conochilus unicornis | 15.0 | 7.10 |
| Filinia longiseta | 3.4 | 0.004 |
| Gastropus stylifer | 5.2 | 1.10 |
| Kellicottia longispina | 6.8 | 2.10 |
| Keratella cochlearis | 41.9 | 2.00 |
| Keratella earlinae | 10.9 | 0.08 |
| Notholca squamula | 7.4 | NF |
| Polyarthra dolichoptera | 3.0 | 0.07 |
| Polyarthra remata | 6.8 | 0.01 |
| Polyarthra vulgaris | 17.6 | 3.00 |
| Synchaeta kitina | 8.1 | NF |
| Synchaeta stylata | 7.1 | NF |
| Synchaeta sp. | 2.4 | 0.10 |

TABLE 30. Cladoceran abundance in 1954, 1966, 1968 and 1983 in Lake Michigan. Data from Wells (1970) and this study. Dashes indicate that no collections were made. Values are number/m$^3$.

| Species and Year | Early June | Late June-Early July | Mid-July | Early August |
|---|---|---|---|---|
| Leptodora kindtii | | | | |
| 1954 | 0 | 12.0 | 13.0 | 29.0 |
| 1966 | 0 | 0.2 | 2.9 | 3.5 |
| 1968 | - | - | 9.8 | 16.0 |
| 1983 | - | - | - | 33.5 |
| Daphnia galeata | | | | |
| 1954 | 2.3 | 160.0 | 580.0 | 1200.0 |
| 1966 | 0 | 0.1 | 0 | 0 |
| 1968 | - | - | 2.5 | 0.4 |
| 1983 | - | - | - | 514.0 |
| Daphnia retrocurva | | | | |
| 1954 | 0 | 270.0 | 1400.0 | 1400.0 |
| 1966 | 0 | 2.4 | 17.0 | 79.0 |
| 1968 | - | - | 1200.0 | 2100.0 |
| 1983 | - | - | - | 82.0 |
| Diaphanasoma brachyurum | | | | |
| 1954 | 0.1 | 4.5 | 4.3 | 1.6 |
| 1966 | 0 | 0 | 0 | 0 |
| 1968 | - | - | 0 | 0 |
| 1983 | - | - | - | 0.9 |
| Daphnia longiremis | | | | |
| 1954 | 0 | 0 | 0 | 0 |
| 1966 | 6.1 | 5.7 | 1.2 | 16.0 |
| 1968 | - | - | 0.1 | 0 |
| 1983 | - | - | - | 0 |
| Daphnia pulicaria | | | | |
| 1954 | - | - | - | - |
| 1966 | - | - | - | - |
| 1968 | - | - | - | - |
| 1983 | - | - | - | 1011 |
| Holopedium gibberum | | | | |
| 1954 | 0 | 0 | 0 | 0 |
| 1966 | 0 | 0.5 | 2.1 | 2.3 |
| 1968 | - | - | 5.8 | 4.6 |
| 1983 | - | - | - | 456.0 |
| Polyphemus pediculus | | | | |
| 1954 | 0 | 0.5 | 0.6 | 2.0 |
| 1966 | 0 | 4.4 | 82.0 | 15.0 |
| 1968 | - | - | 170.0 | 9.7 |
| 1983 | - | - | - | 12.6 |
| Bosmina longirostris | | | | |
| 1954 | 7.1 | 250.0 | 40.0 | 26.0 |
| 1966 | 30.0 | 320.0 | 240.0 | 98.0 |
| 1968 | - | - | 130.0 | 16.0 |
| 1983 | - | - | - | 342.0 |
| Eubosmina coregoni | | | | |
| 1954 | 0 | 0 | 0 | 0 |
| 1966 | 0 | 0.1 | 0.3 | 0.6 |
| 1968 | - | - | 72.0 | 16.0 |
| 1983 | - | - | - | 159.0 |
| Ceriodaphnia quadrangula | | | | |
| 1954 | 0 | 0 | 0 | 0 |
| 1966 | 0 | 0 | 3.4 | 3.7 |
| 1968 | - | - | 0.3 | 0.5 |
| 1983 | - | - | - | 0 |

TABLE 31. Copepod abundance in 1954, 1966, 1968, and 1983 in Lake Michigan. Data from Wells (1970) and this study. Dashes indicate that no collections were made. Values are number/$m^3$.

| Species and Year | Early June | Late June-Early July | Mid-July | Early August |
|---|---|---|---|---|
| Limnocalanus macrurus | | | | |
| 1954 | 460.0 | 160.0 | 71.0 | 91.0 |
| 1966 | 15.0 | 22.0 | 5.6 | 34.0 |
| 1968 | - | - | 89.0 | 270.0 |
| 1983 | - | - | - | 18.0 |
| Epischura lacustris | | | | |
| 1954 | 3.7 | 20.0 | 140.0 | 41.0 |
| 1966 | 0 | 17.0 | 3.2 | 6.6 |
| 1968 | - | - | 84.0 | 21.0 |
| 1983 | - | - | - | 18.5 |
| Diaptomus sicilis | | | | |
| 1954 | 190.0 | 72.0 | 12.0 | 3.0 |
| 1966 | 0 | 3.0 | 2.0 | 1.0 |
| 1968 | - | - | 2.0 | 3.0 |
| 1983 | - | - | - | 79.0 |
| Mesocyclops edax | | | | |
| 1954 | 0 | 260.0 | 460.0 | 200.0 |
| 1966 | 0 | 0 | 0 | 0 |
| 1968 | - | - | 1.0 | 0 |
| 1983 | - | - | - | 12.5 |
| Senecella calanoides | | | | |
| 1954 | 0 | 0.6 | 0.4 | 0.2 |
| 1966 | 0 | 0.2 | 0 | 0.2 |
| 1968 | - | - | 0.2 | 0.1 |
| 1983 | - | - | - | 1.4 |
| Cyclops bicuspidatus | | | | |
| 1954 | 1100.0 | 630.0 | 770.0 | 310.0 |
| 1966 | 1700.0 | 1300.0 | 1900.0 | 1000.0 |
| 1968 | - | - | 1200.0 | 860.0 |
| 1983 | - | - | - | 1457.0 |
| Diaptomus ashlandi | | | | |
| 1954 | 25.0 | 160.0 | 200.0 | 140.0 |
| 1966 | 320.0 | 280.0 | 150.0 | 220.0 |
| 1968 | - | - | 67.0 | 13.0 |
| 1983 | - | - | - | 1256.0 |
| Cyclops vernalis | | | | |
| 1954 | 0 | 0 | 0 | 0 |
| 1966 | 1.0 | 8.0 | 0 | 0 |
| 1968 | - | - | 1.0 | 0 |
| 1983 | - | - | - | 0 |
| Eurytemora affinis | | | | |
| 1954 | 0 | 0 | 0 | 0 |
| 1966 | 0 | 4.0 | 6.0 | 33.0 |
| 1968 | - | - | 55.0 | 3.0 |
| 1983 | - | - | - | 0 |
| Diaptomus oregonensis | | | | |
| 1954 | 10.0 | 17.0 | 73.0 | 63.0 |
| 1966 | 38.0 | 10.0 | 110.0 | 58.0 |
| 1968 | - | - | 15.0 | 100.0 |
| 1983 | - | - | - | 138.0 |
| Diaptomus minutus | | | | |
| 1954 | 82.0 | 220.0 | 110.0 | 39.0 |
| 1966 | 320.0 | 400.0 | 88.0 | 25.0 |
| 1968 | - | - | 660.0 | 1500.0 |
| 1983 | - | - | - | 151.0 |

TABLE 32. The ratio of calanoids to cyclopoids plus cladocerans geographically in Lake Michigan, 1983.

| Station | | $\frac{\text{Calanoida}}{\text{Cyclopoida + Cladocera}}$ |
|---|---|---|
| 77 | (North) | 0.37 |
| 64 | | 0.41 |
| 57 | | 1.74 |
| 47 | | 1.52 |
| 41 | | 1.10 |
| 34 | | 1.03 |
| 27 | | 1.53 |
| 23 | | 1.15 |
| 18 | | 3.01 |
| 11 | | 1.71 |
| 6 | (South) | 0.87 |

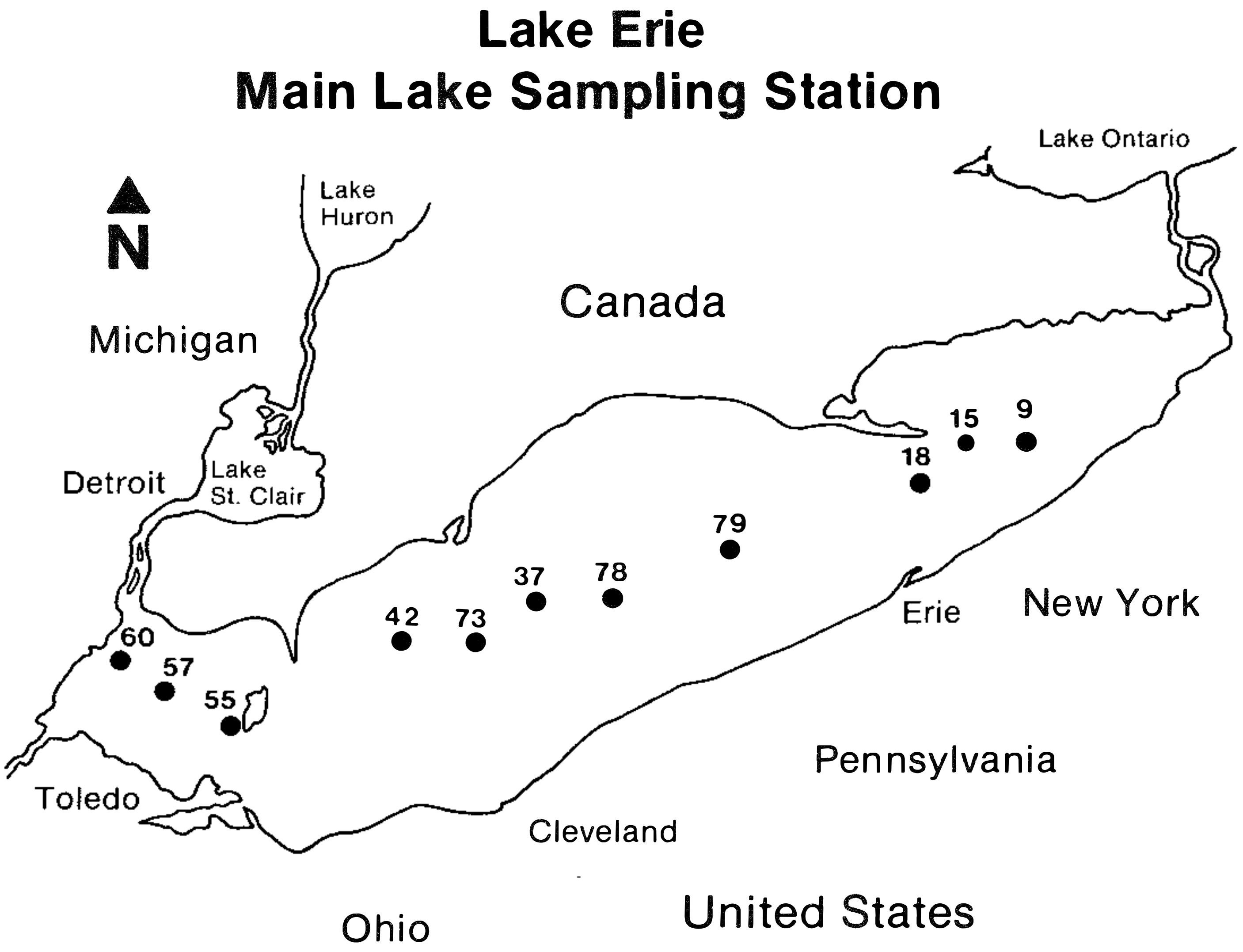


FIGURE 1 Lake Erie plankton sampling stations, 1983

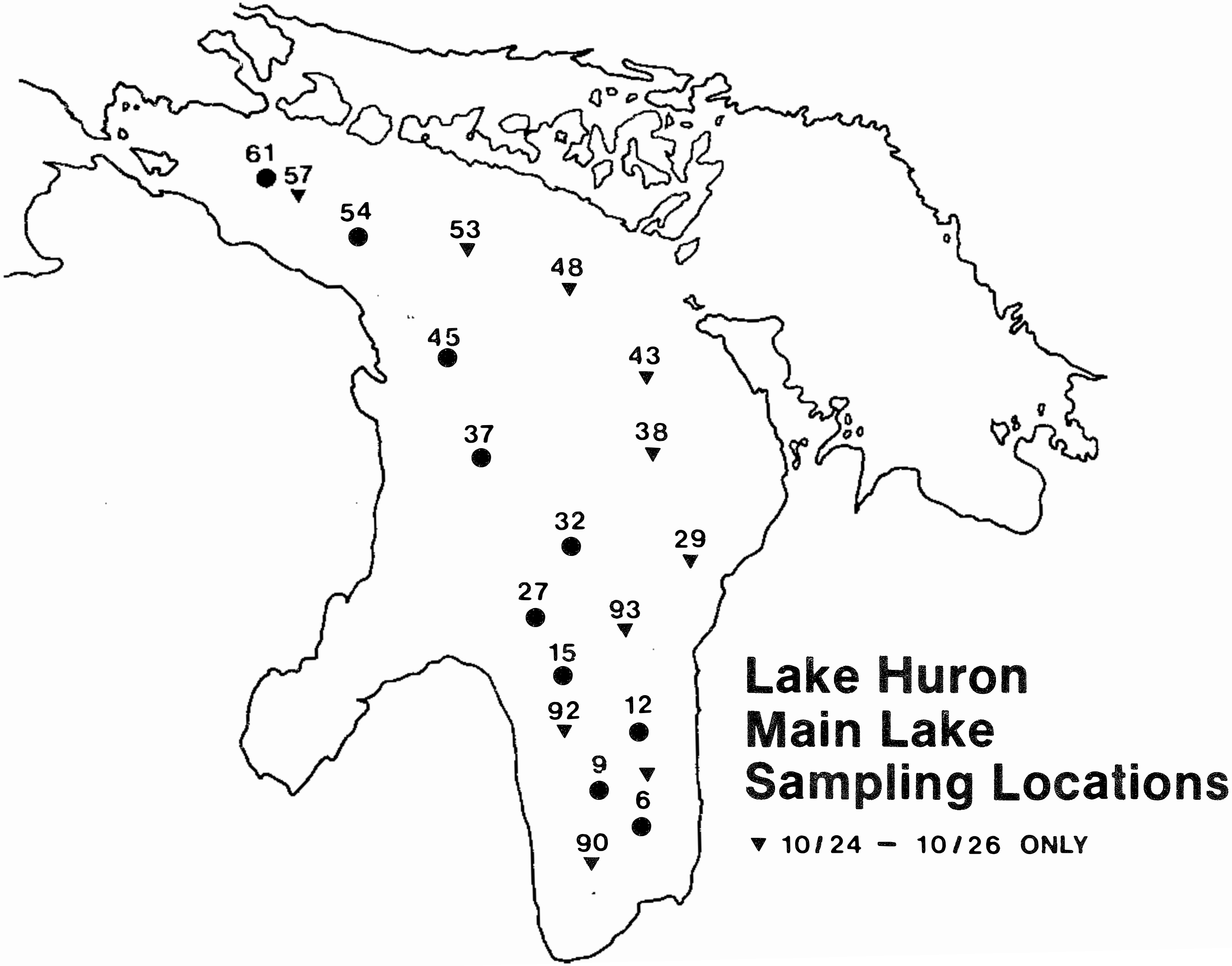


FIGURE 2 Lake Huron plankton sampling stations, 1983

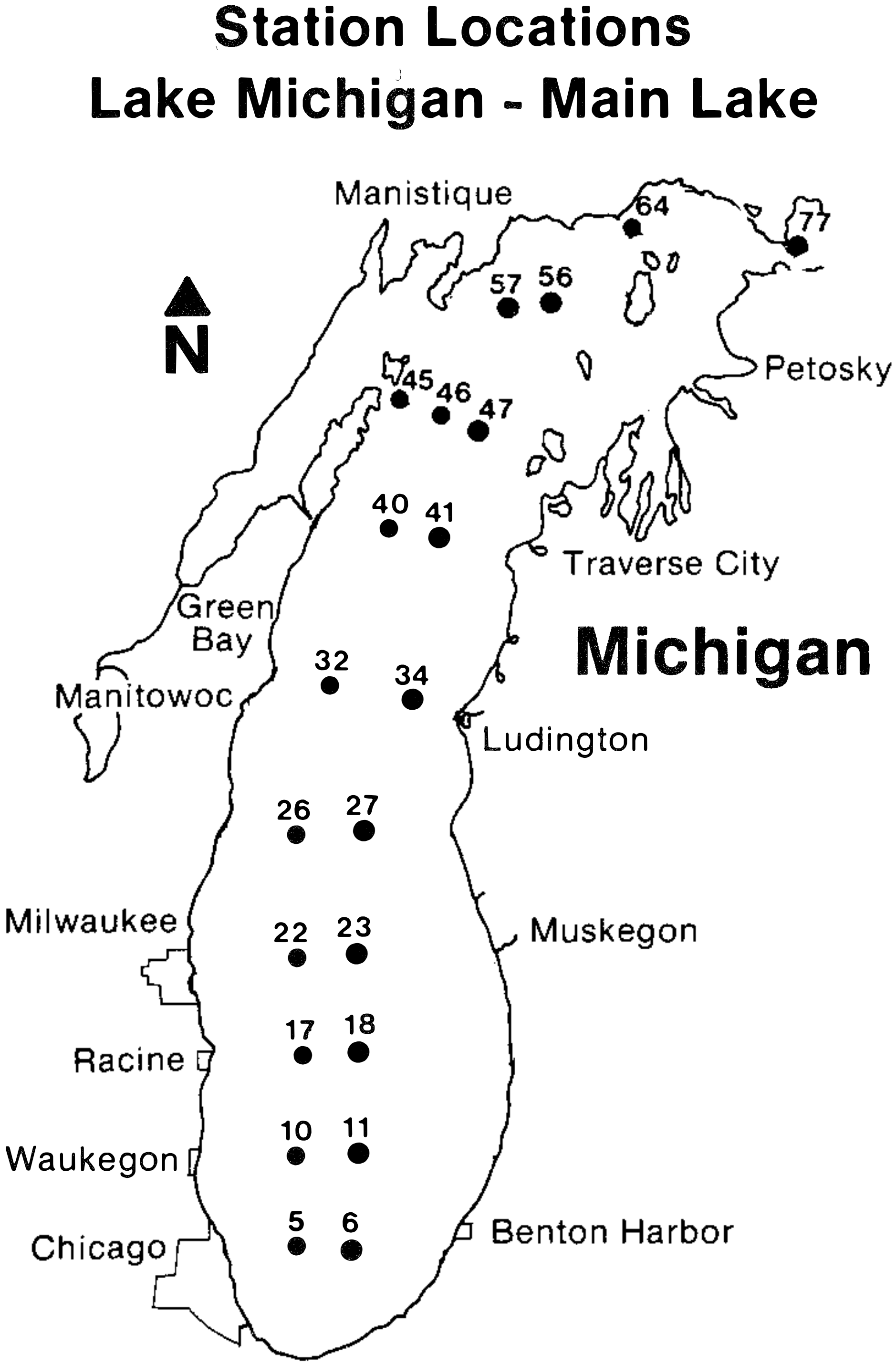


FIGURE 3 Lake Michigan plankton sampling stations, 1983

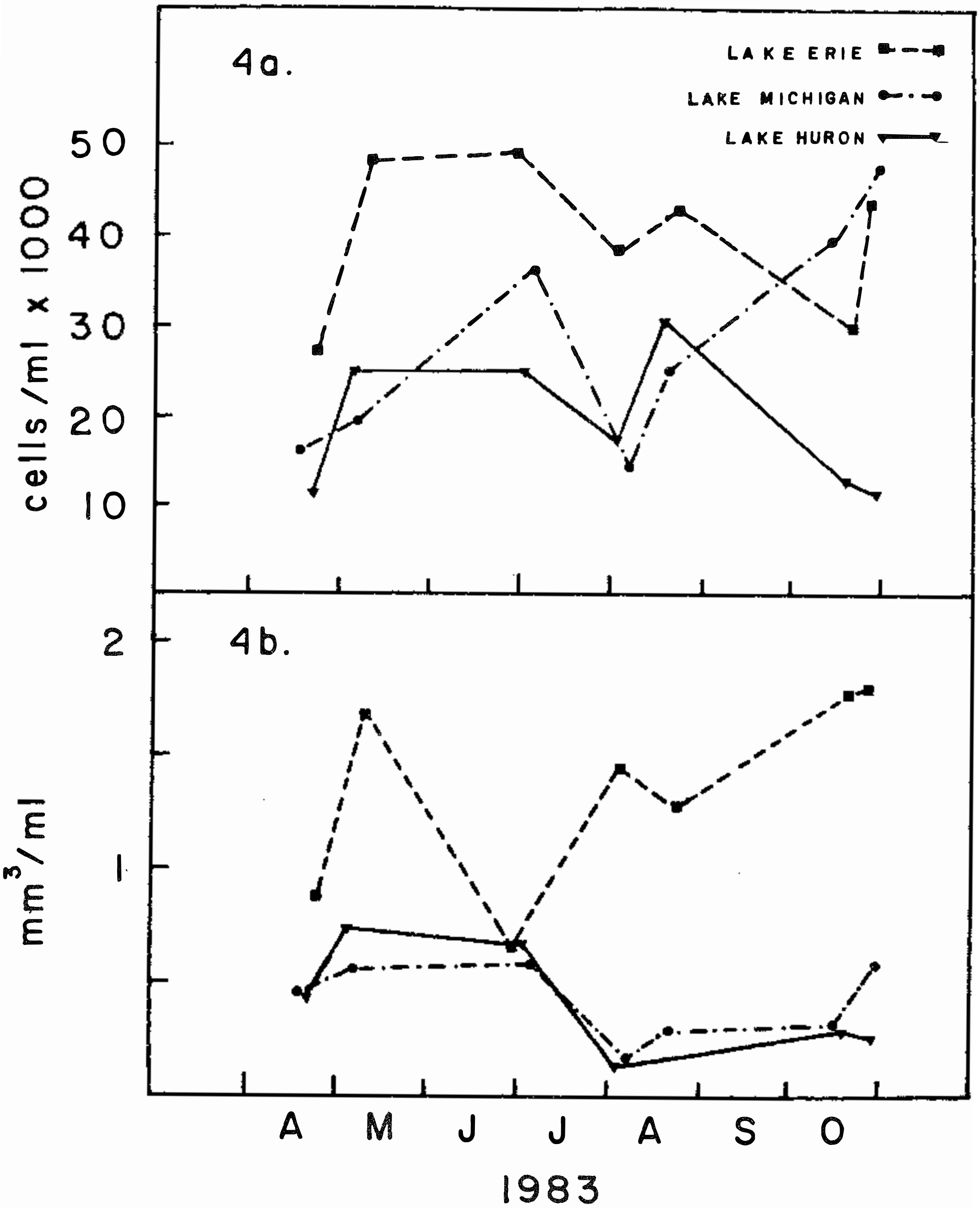


FIGURE 4 Seasonal phytoplankton abundance (4a) and biovolume (4b) trends in Lakes Erie, Huron and Michigan

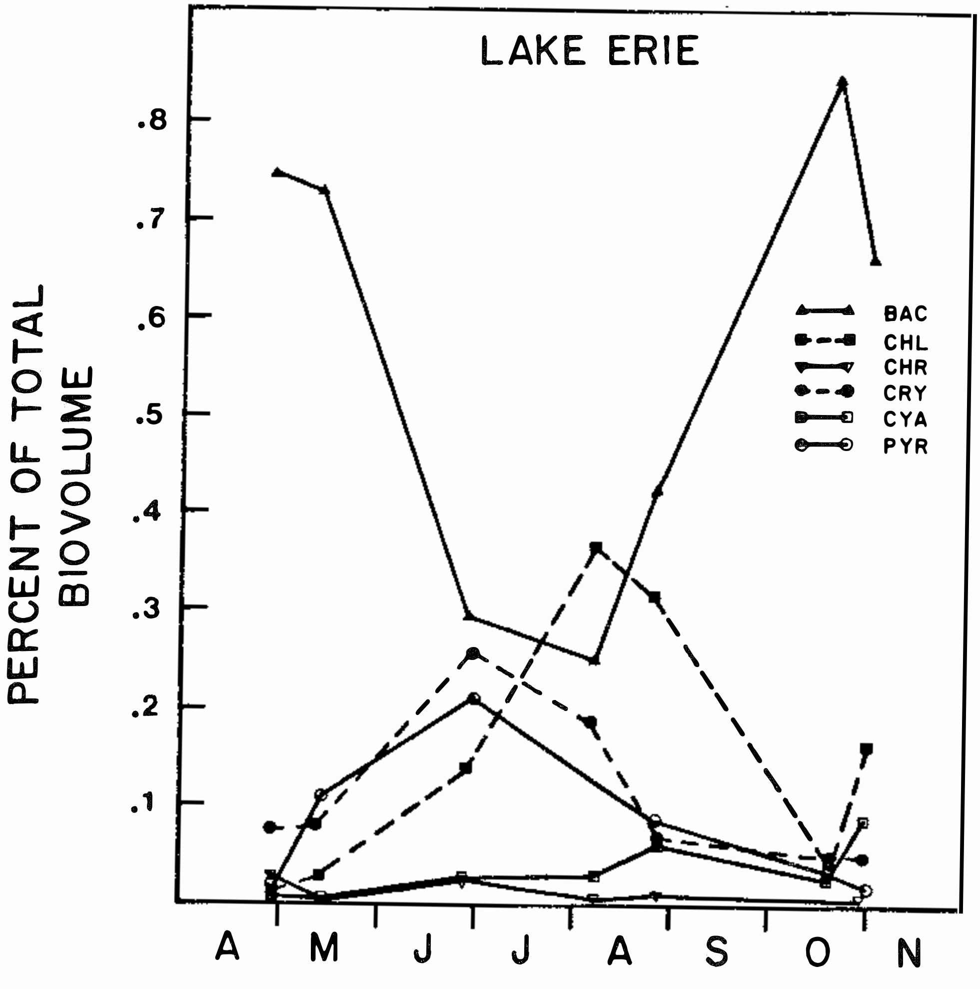


FIGURE 5 Seasonal distribution of algal divisions in Lake Erie. BAC = Bacillariophyta, CHL = Chlorophyta, CHR = Chrysophyta, CRY = Cryptophyta, CYA = Cyanophyta, PYR = Pyrrhophyta.

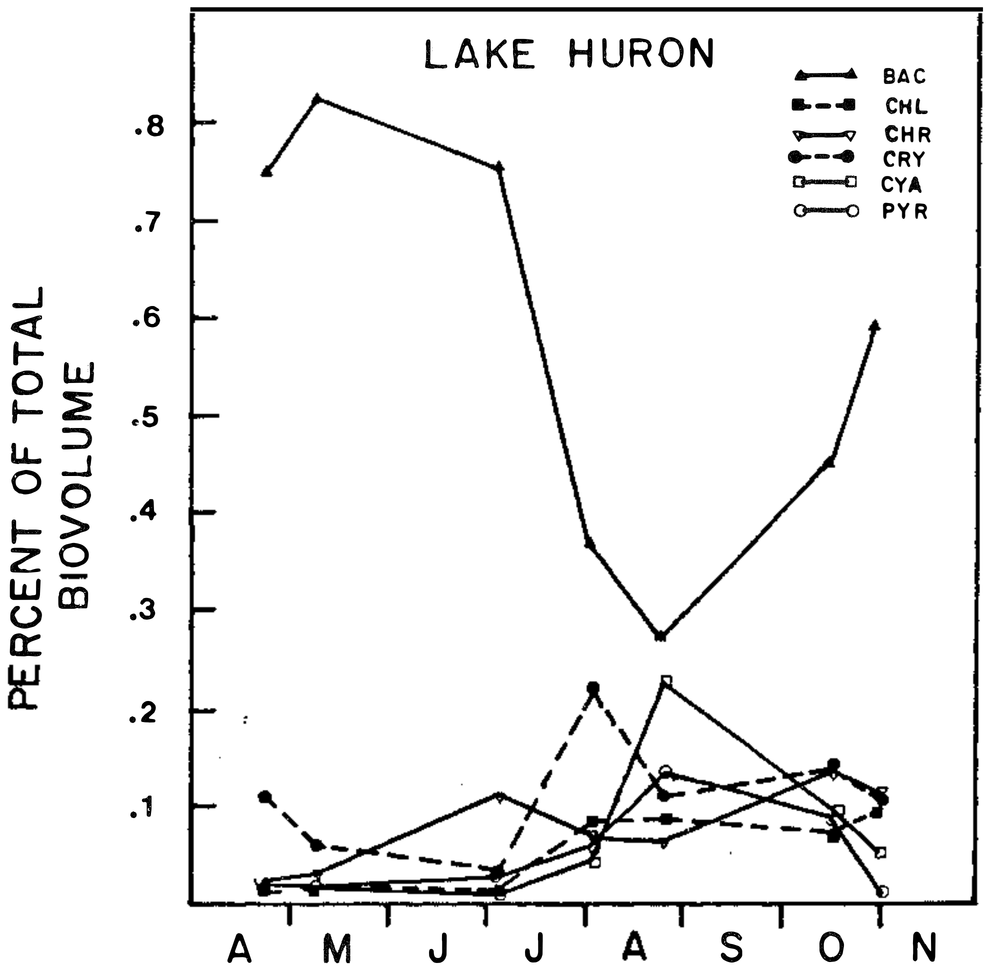


FIGURE 6 Seasonal distribution of algal divisions in Lake Huron. BAC = Bacillariophyta, CHL = Chlorophyta, CHR = Chrysophyta, CRY = Cryptophyta, CYA = Cyanophyta, PYR = Pyrrhophyta.

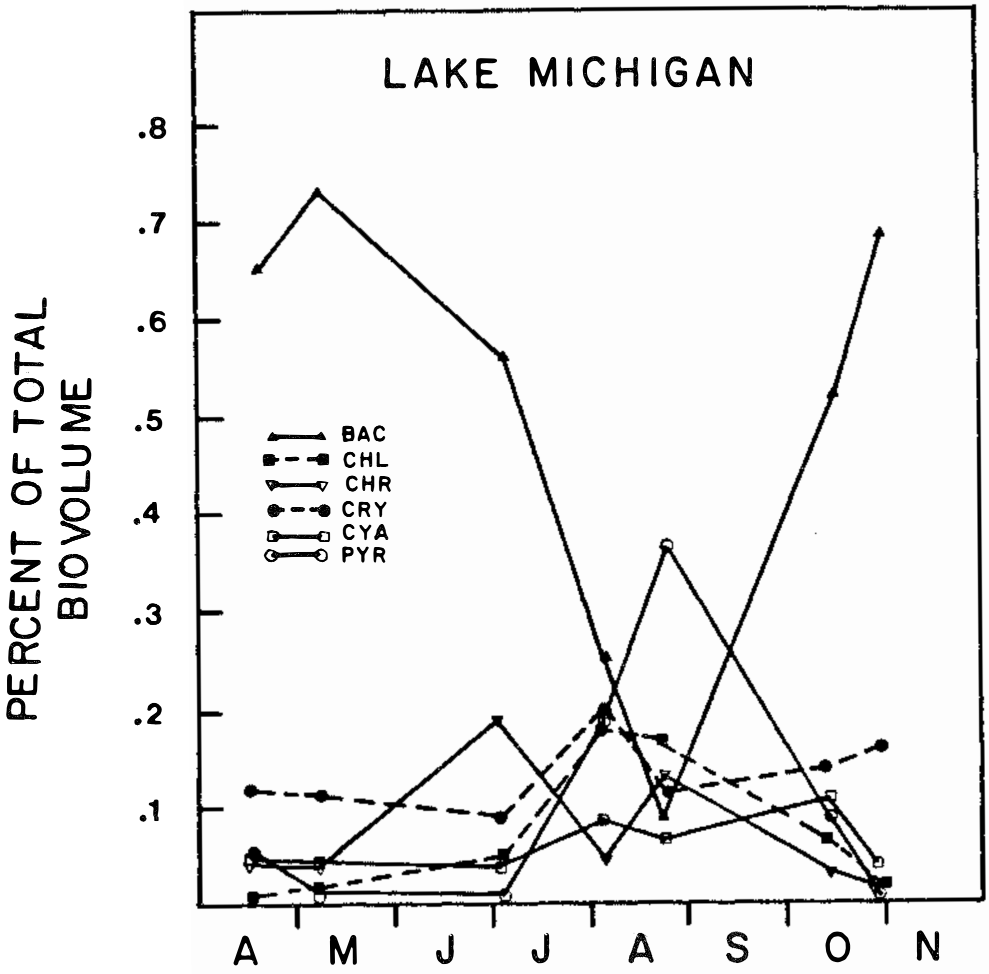


FIGURE 7 Seasonal distribution of algal divisions in Lake Michigan. BAC = Bacillariophyta, CHL = Chlorophyta, CHR = Chrysophyta, CRY = Cryptophyta, CYA = Cyanophyta, PYR = Pyrrhophyta.

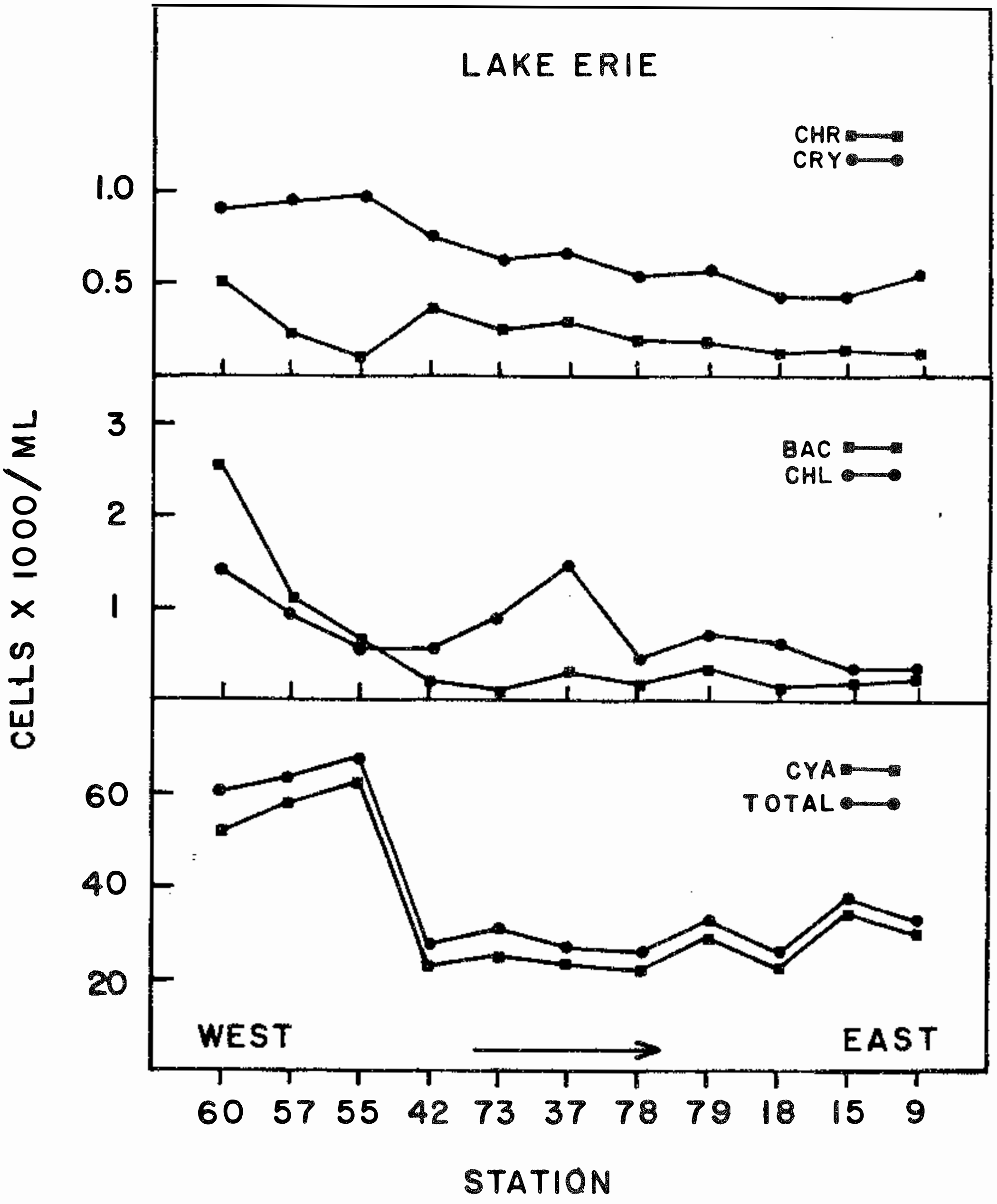


FIGURE 8 Annual geographical distribution of major divisions in Lake Erie. BAC = Bacillariophyta, CHL = Chlorophyta, CHR = Chrysophyta, CRY = Cryptophyta, CYA = Cyanophyta, PYR = Pyrrhophyta.

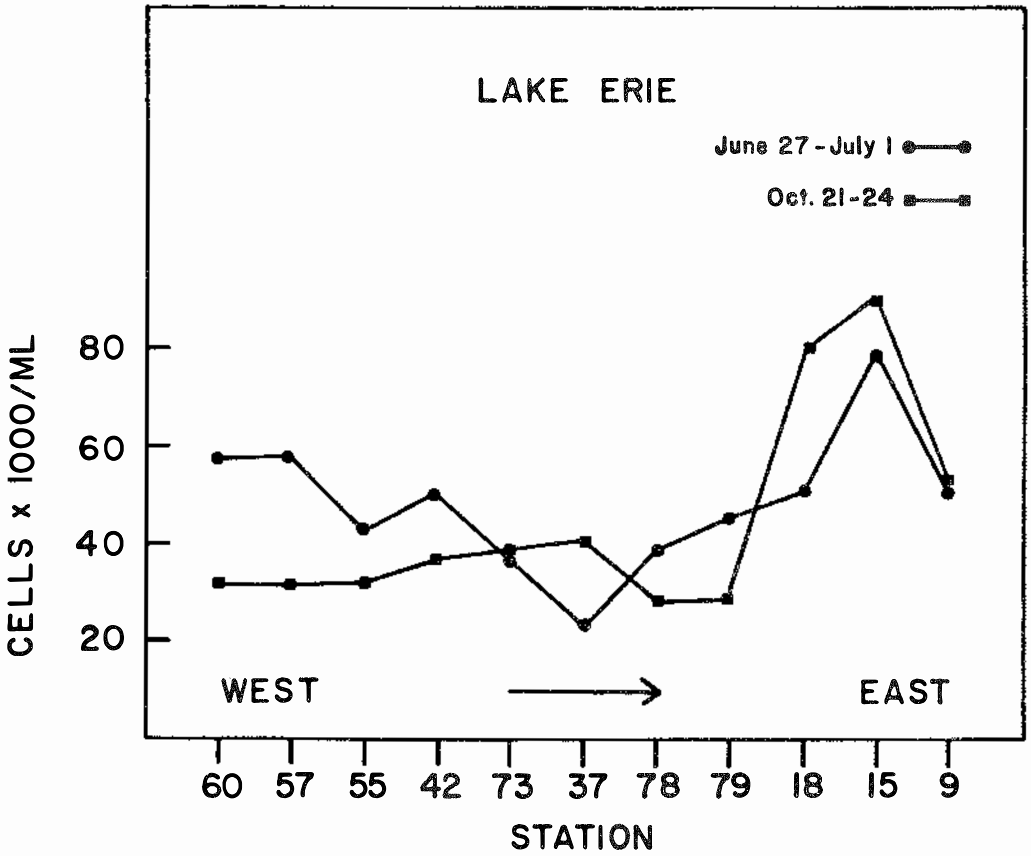


FIGURE 9 Geographical distribution of phytoplankton abundance on the June and October cruises, Lake Erie.

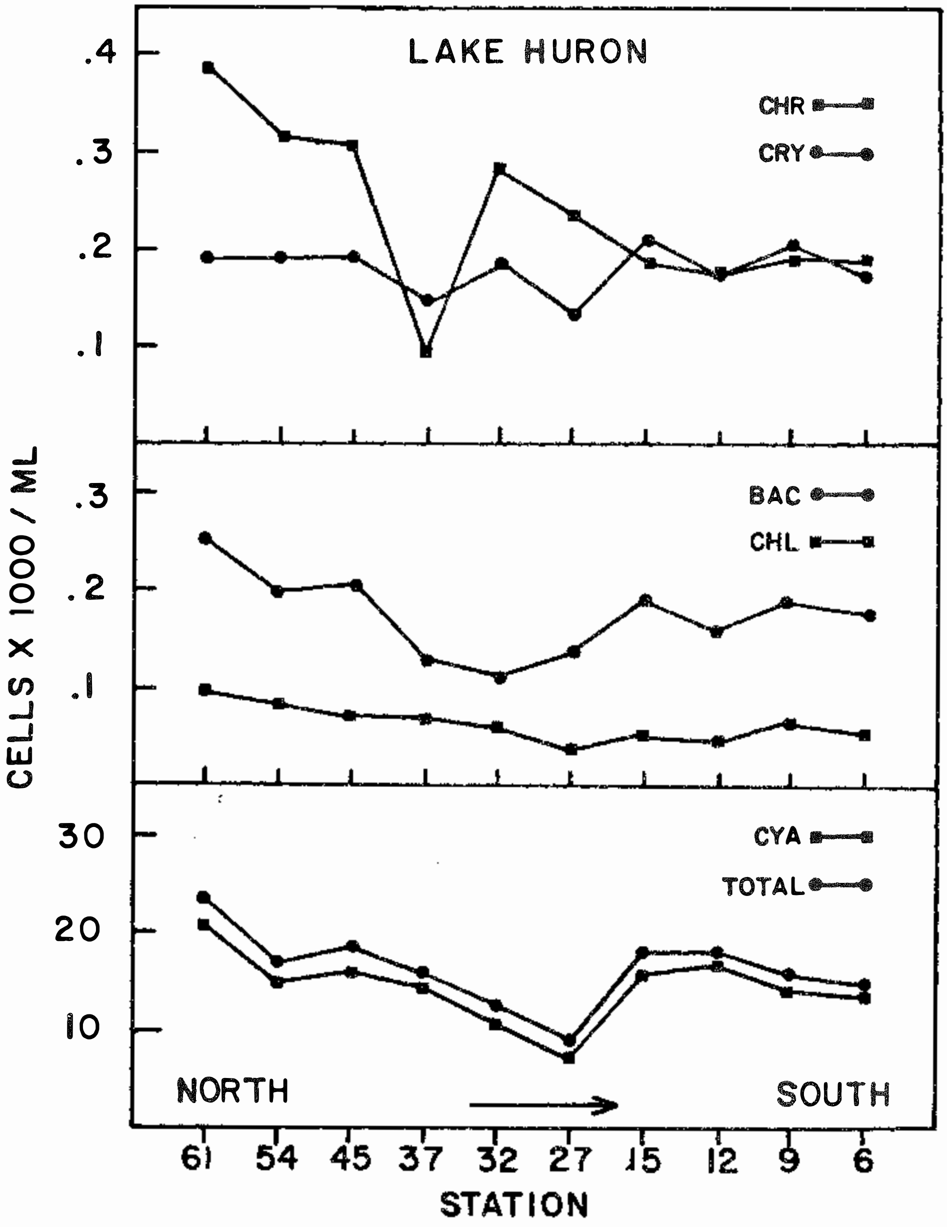


FIGURE 10 Annual geographical distribution of major algal divisions in Lake Huron. BAC = Bacillariophyta, CHL = Chlorophyta, CHR = Chrysophyta, CRY = Cryptophyta, CYA = Cyanophyta, PYR = Pyrrhophyta.

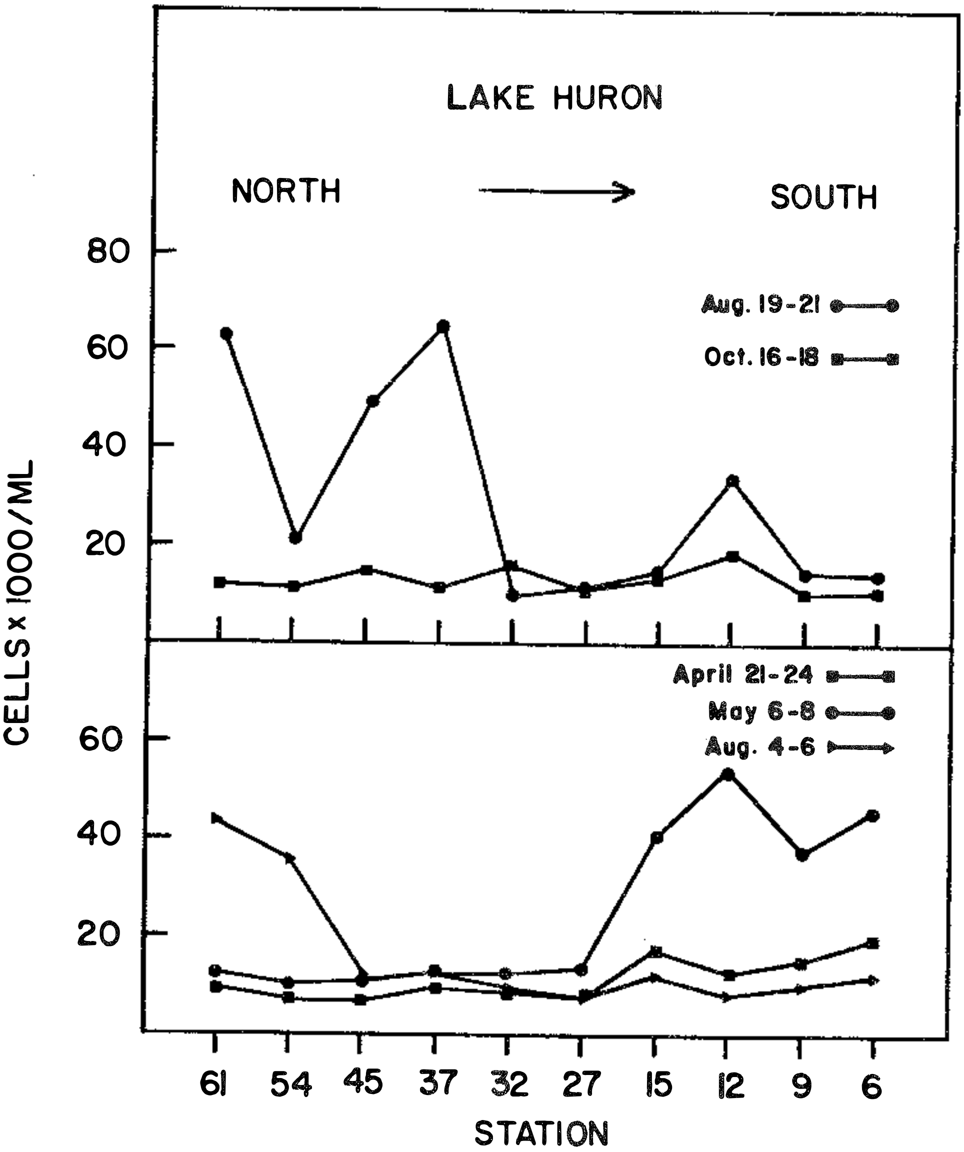


FIGURE 11 Geographical distribution of phytoplankton abundance on all cruises, Lake Huron.

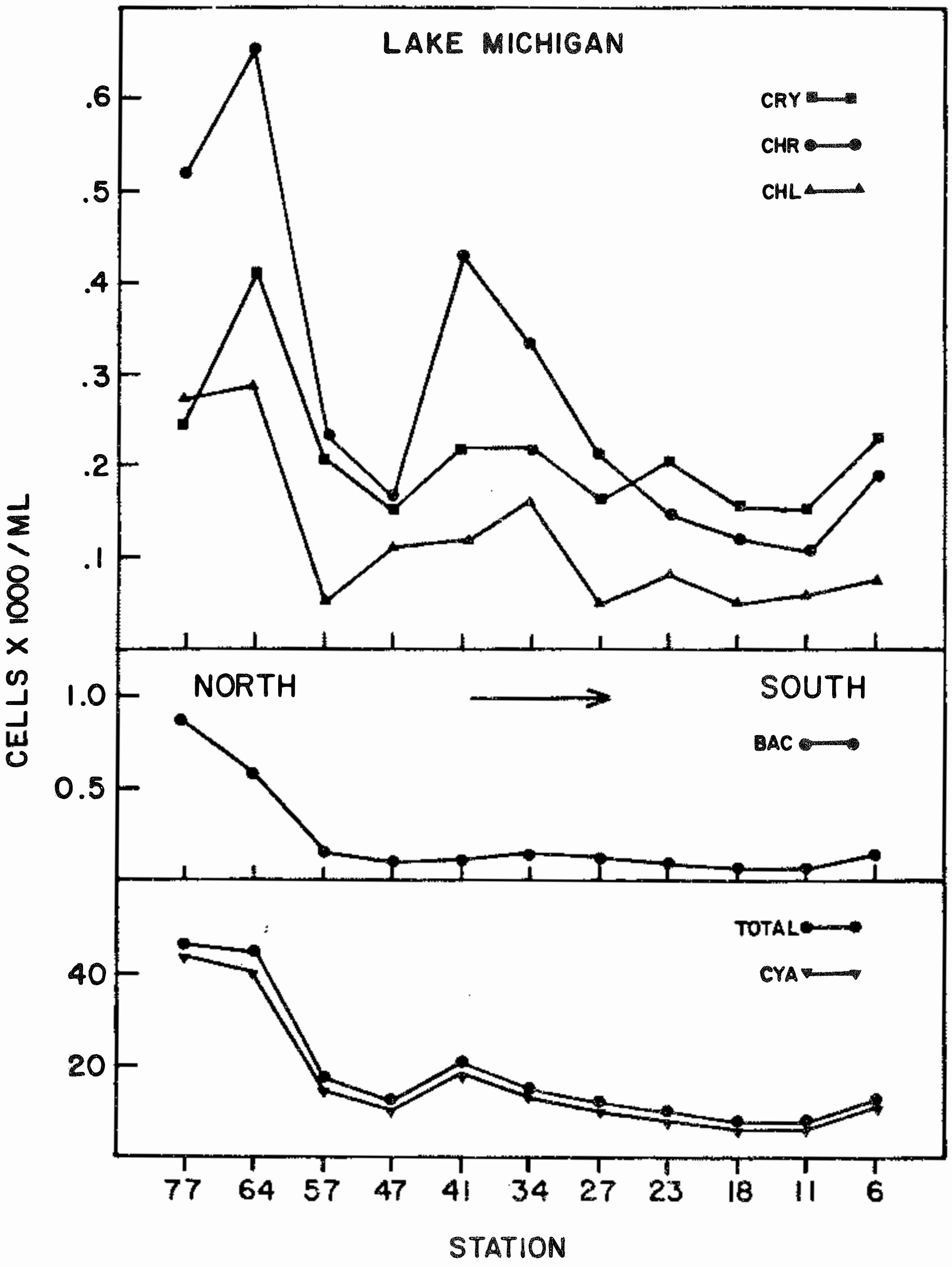


FIGURE 12 Annual geographical distribution of major algal divisions in Lake Michigan. BAC = Bacillariophyta, CHL = Chlorophyta, CHR = Chrysophyta, CRY = Cryptophyta, CYA = Cyanophyta, PYR = Pyrrhophyta.

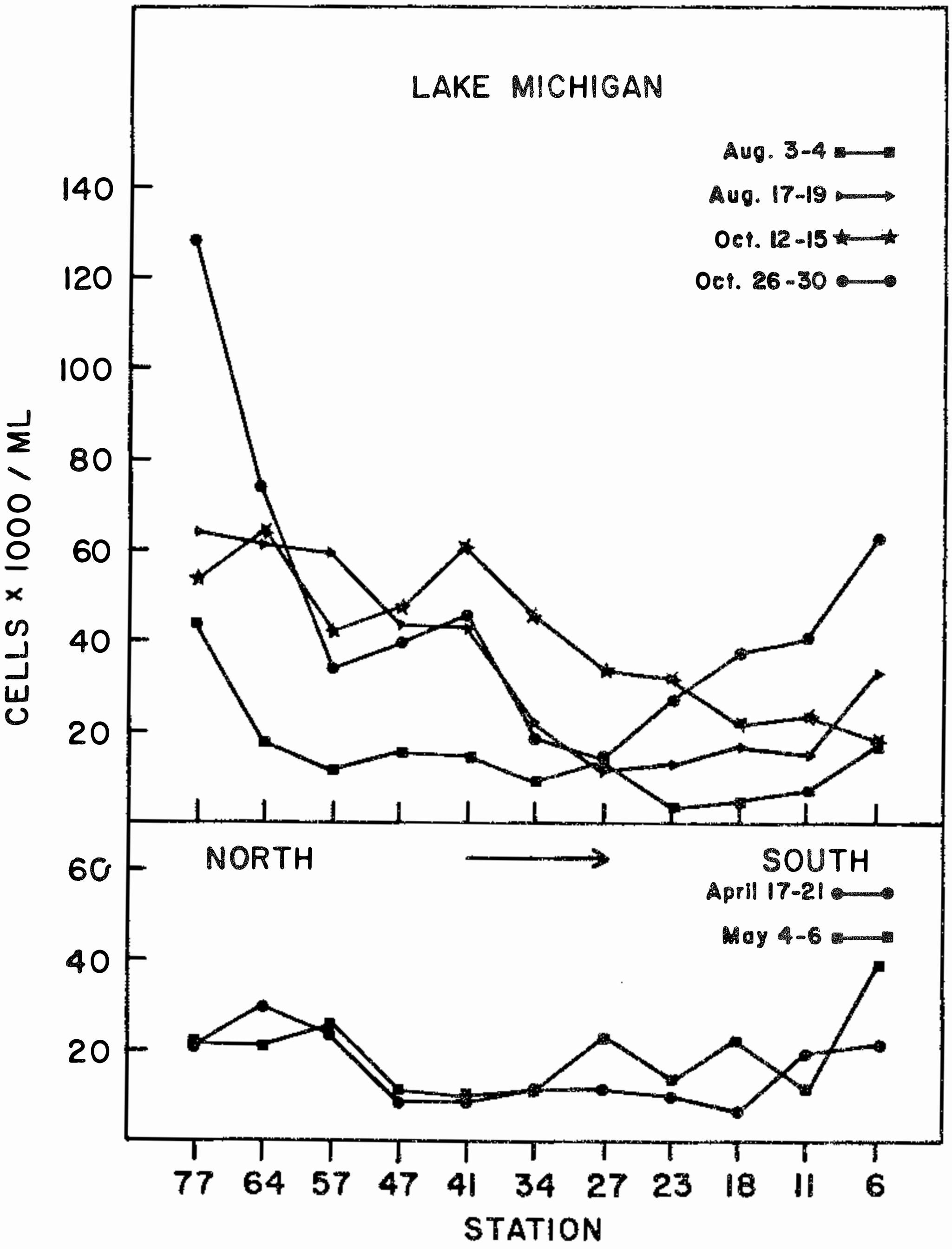


FIGURE 13 Geographical distribution of phytoplankton abundance on all cruises, Lake Michigan.

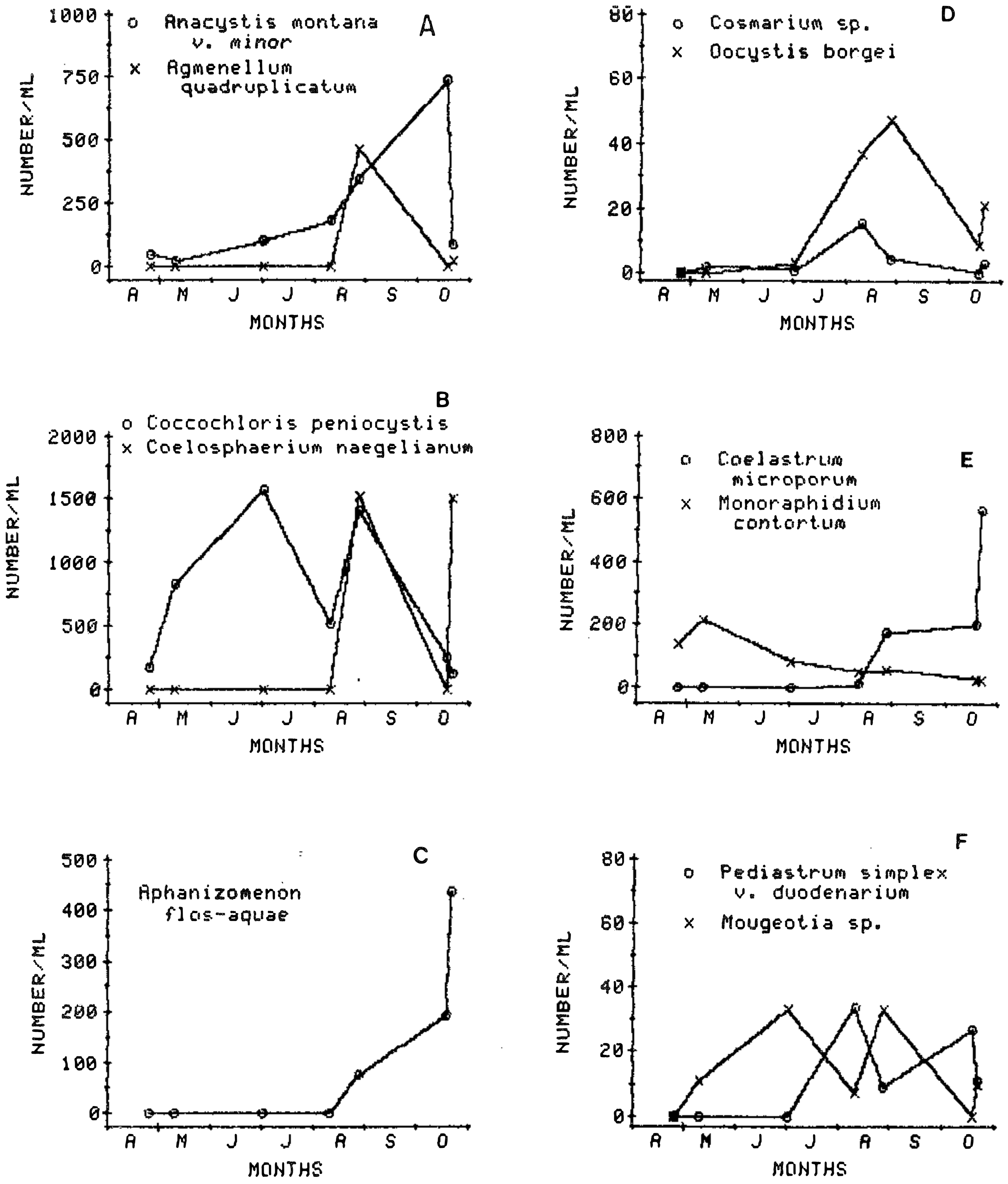


FIGURE 14 Mean seasonal distribution of a) Anacystis montana v. minor and Agmenellum quadruplicatum, b) Coccochloris peniocystis and Coelosphaerium naegelianum, c) Aphanizomenon flos-aquae, d) Cosmarium sp. and Oocystis borgei, e) Coelastrum microporum and Monoraphidium contortum, f) Pediastrum simplex v. duodenarium and Mougeotia sp., Lake Erie.

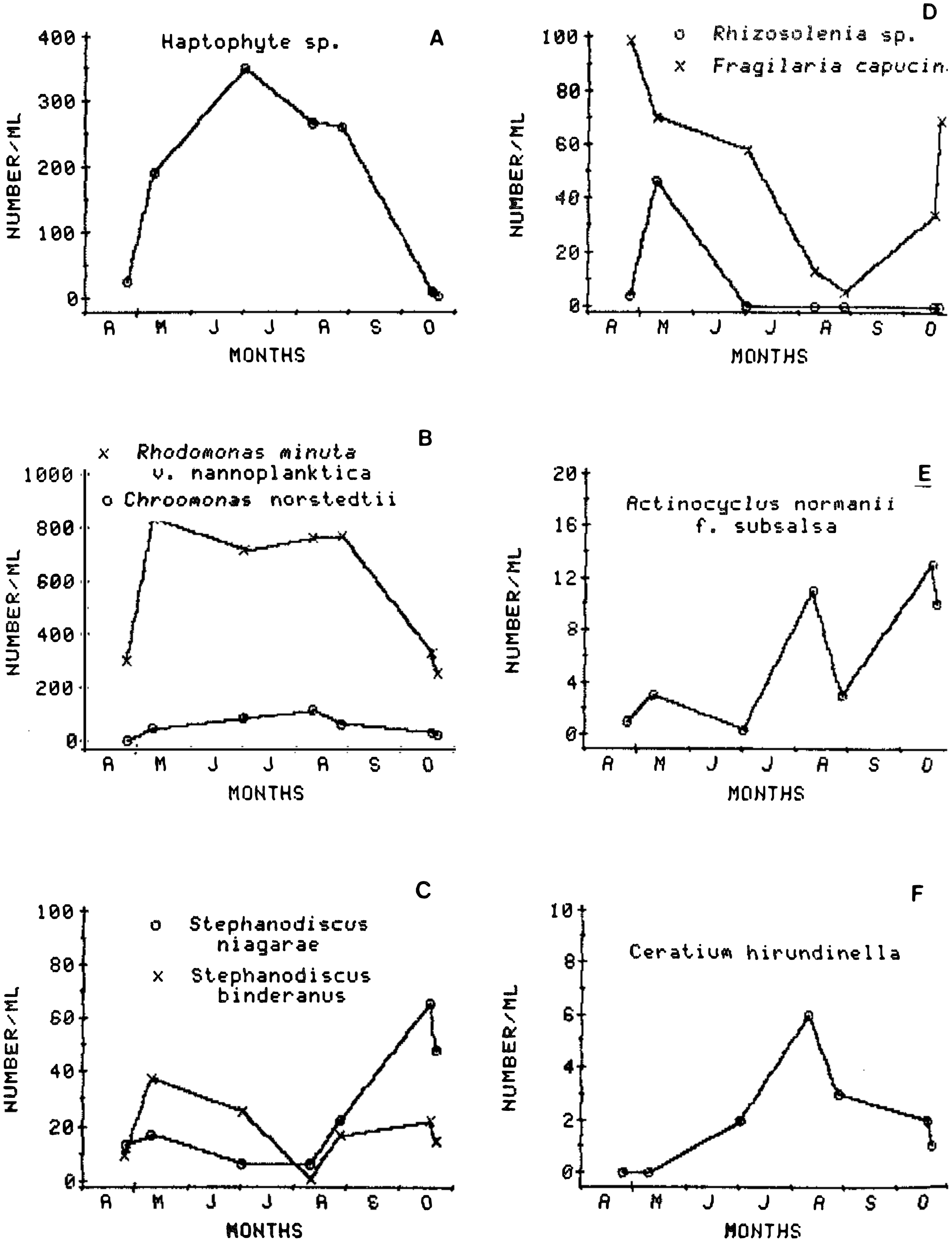


FIGURE 15 Mean seasonal distribution of a) *Haptophyte sp.*, b) *Rhodomonas minuta v. nannoplanktica* and *Chroomonas norstedtii*, c) *Stephanodiscus niagarae* and *Stephanodiscus binderanus*, d) *Rhizosolenia sp.* and *Fragilaria capucina*, e) *Actinocyclus normanii f. subsalsa*, f) *Ceratium hirundinella*, Lake Erie.

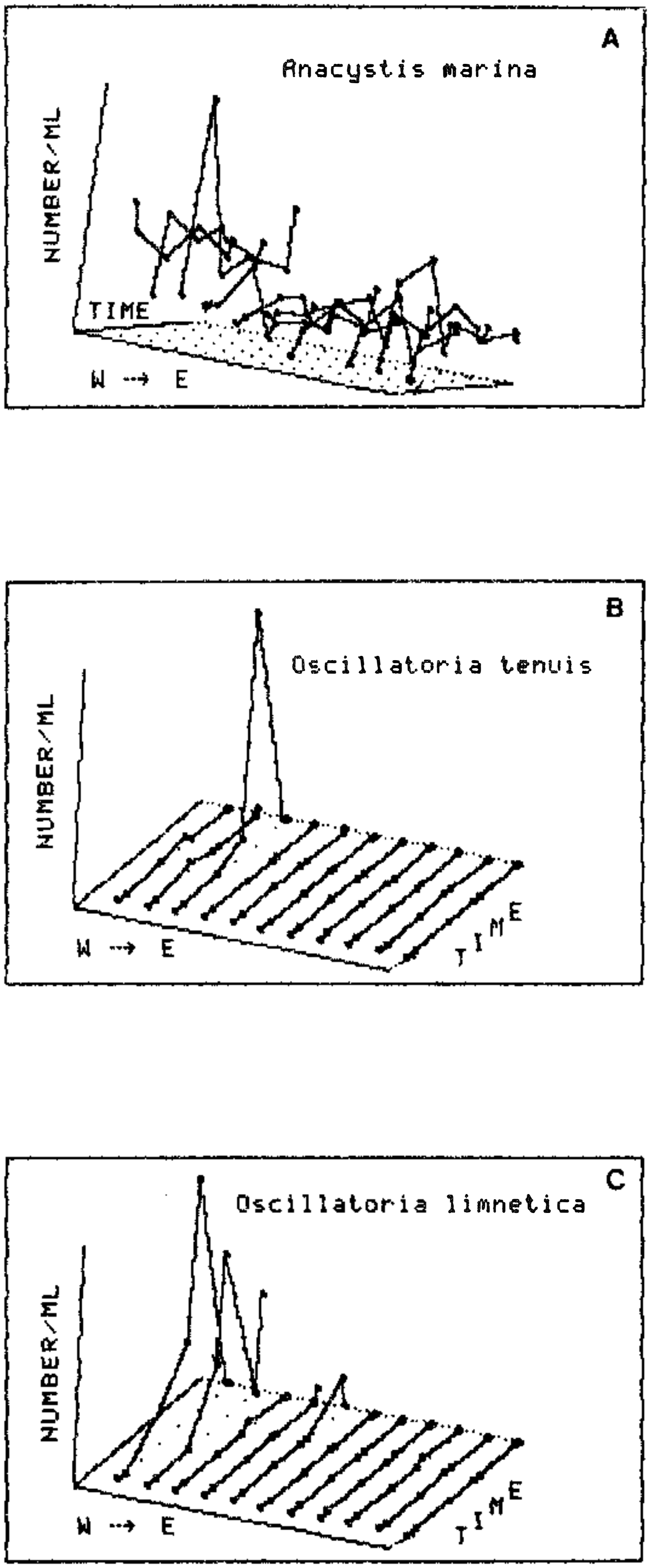


FIGURE 16 Seasonal and geographical distribution of a) *Anacystis marina*, b) *Oscillatoria tenuis*, c) *Oscillatoria limnetica*, Lake Erie.

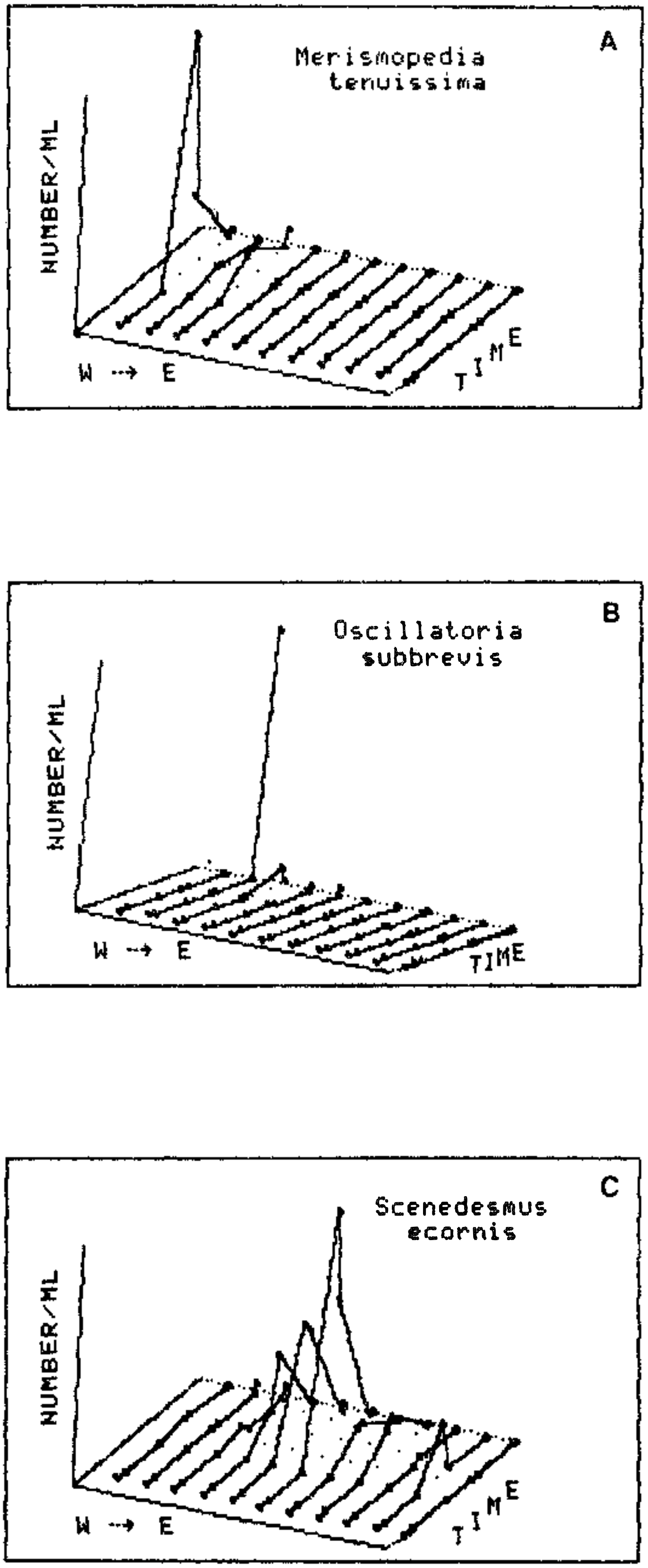


FIGURE 17 Seasonal and geographical distribution of a) *Merismopedia tenuissima*, b) *Oscillatoria subrevis*, c) *Scenedesmus ecornis*, Lake Erie.

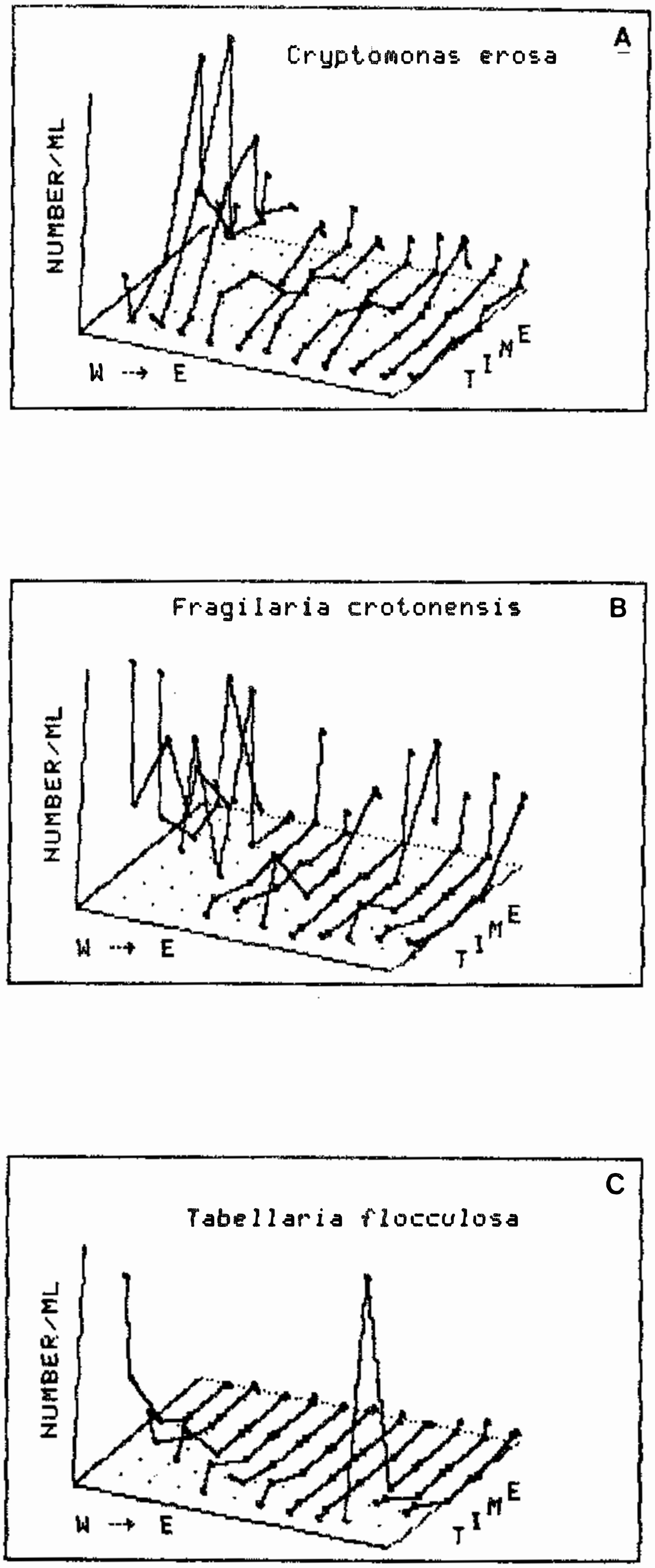


FIGURE 18 Seasonal and geographical distribution of a) *Cryptomonas erosa*, b) *Fragilaria crotonensis*, c) *Tabellaria flocculosa*, Lake Erie.

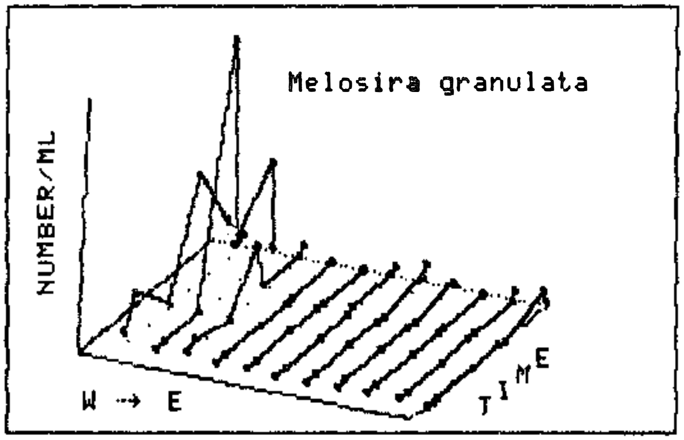


FIGURE 19 Seasonal and geographical distribution of *Melosira granulata*, Lake Erie.

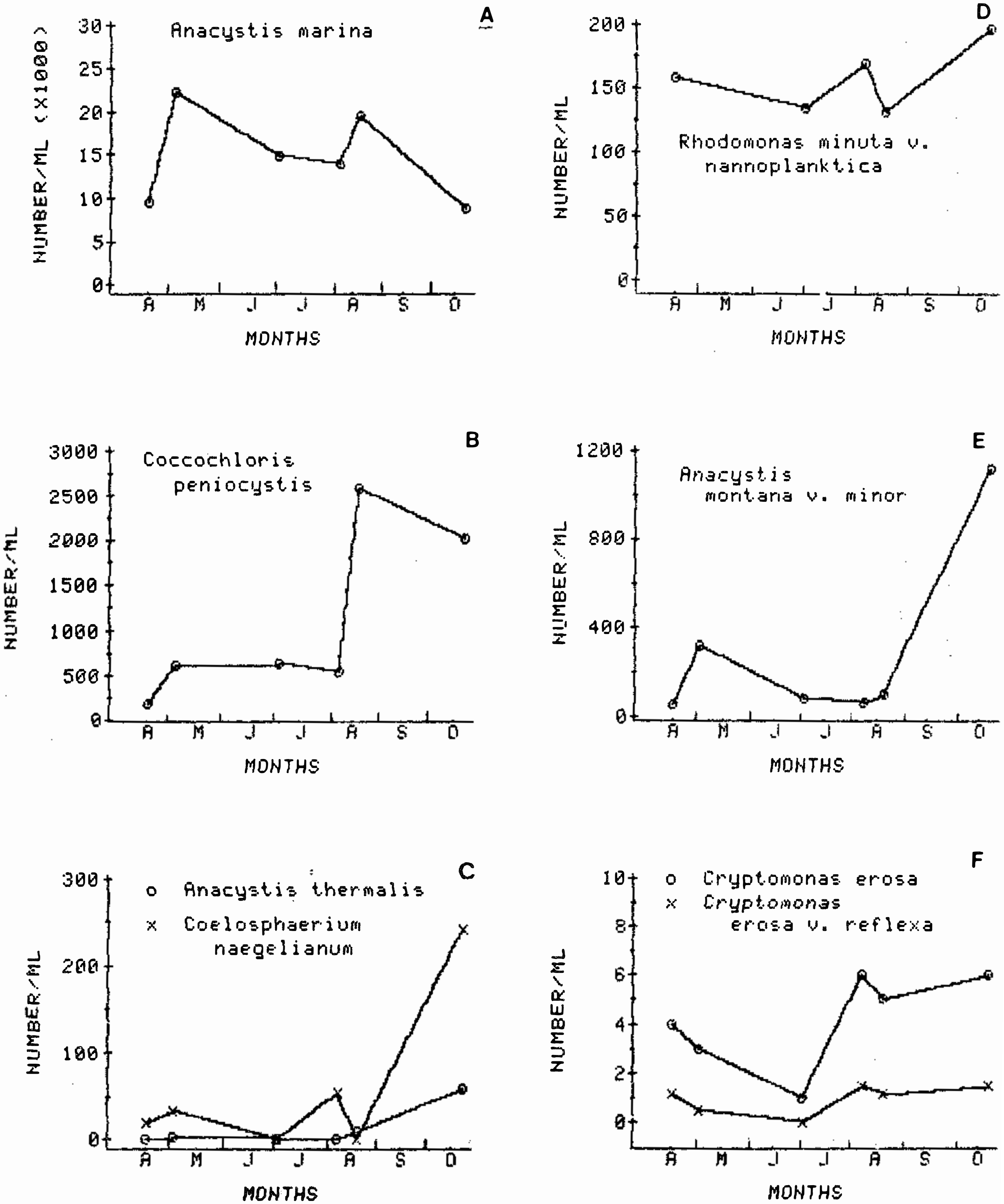


FIGURE 20 Mean seasonal distribution of a) *Anacystis marina*, b) *Coccochloris peniocystis*, c) *Anacystis thermalis* and *Coelosphaerium naegelianum*, d) *Rhodomonas minuta v. nannoplanktica*, e) *Anacystis montana v. minor*, f) *Cryptomonas erosa* and *Cryptomonas erosa v. reflexa*, Lake Huron.

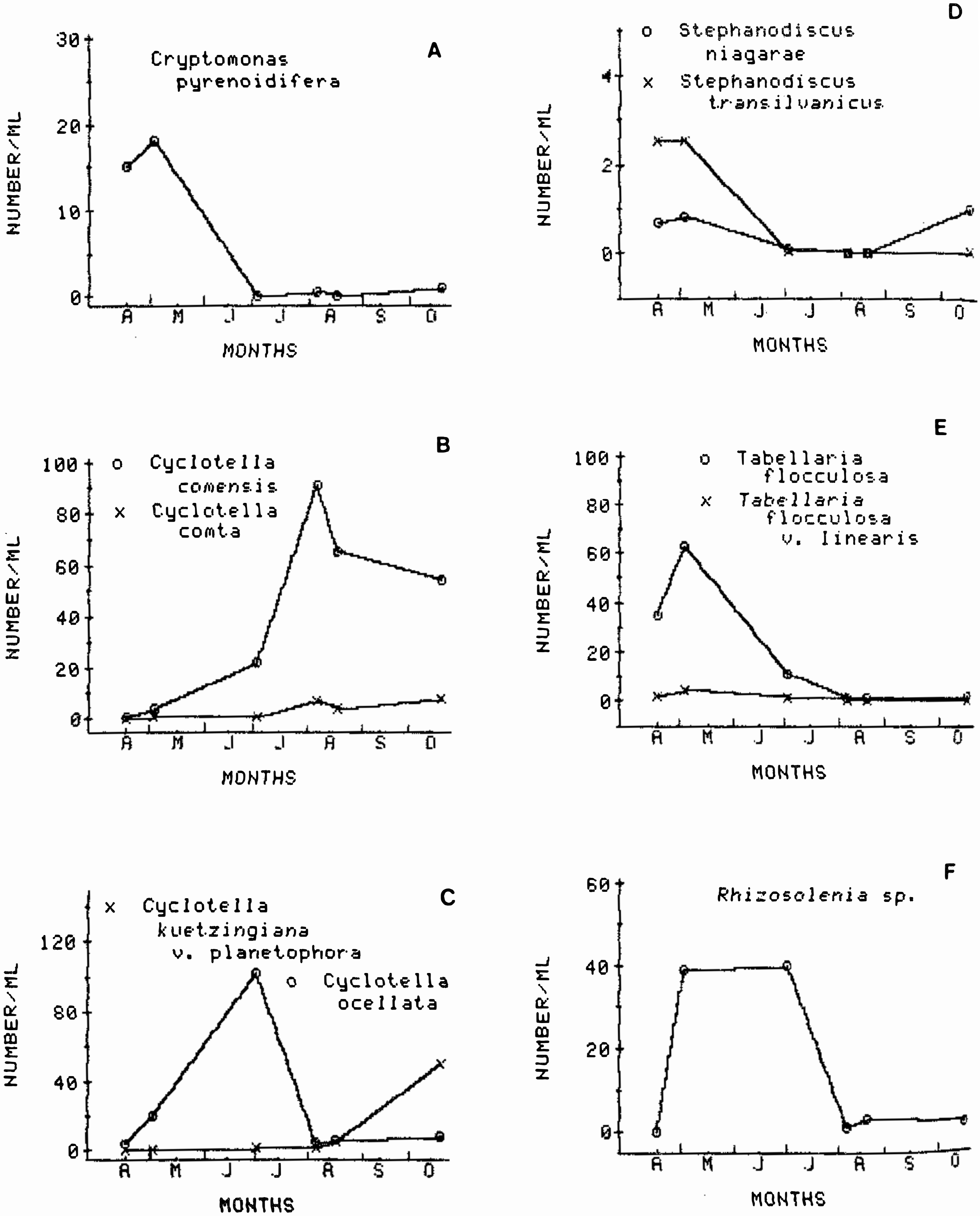


FIGURE 21 Mean seasonal distribution of a) *Cryptomonas pyrenoidifera*, b) *Cyclotella comensis* and *Cyclotella comta*, c) *Cyclotella kuetzingiana v. planetophora* and *Cyclotella ocellata*, d) *Stephanodiscus niagarae* and *Stephanodiscus transilvanicus*, e) *Tabellaria flocculosa* and *Tabellaria flocculosa v. linearis*, f) *Rhizosolenia sp.*, Lake Huron.

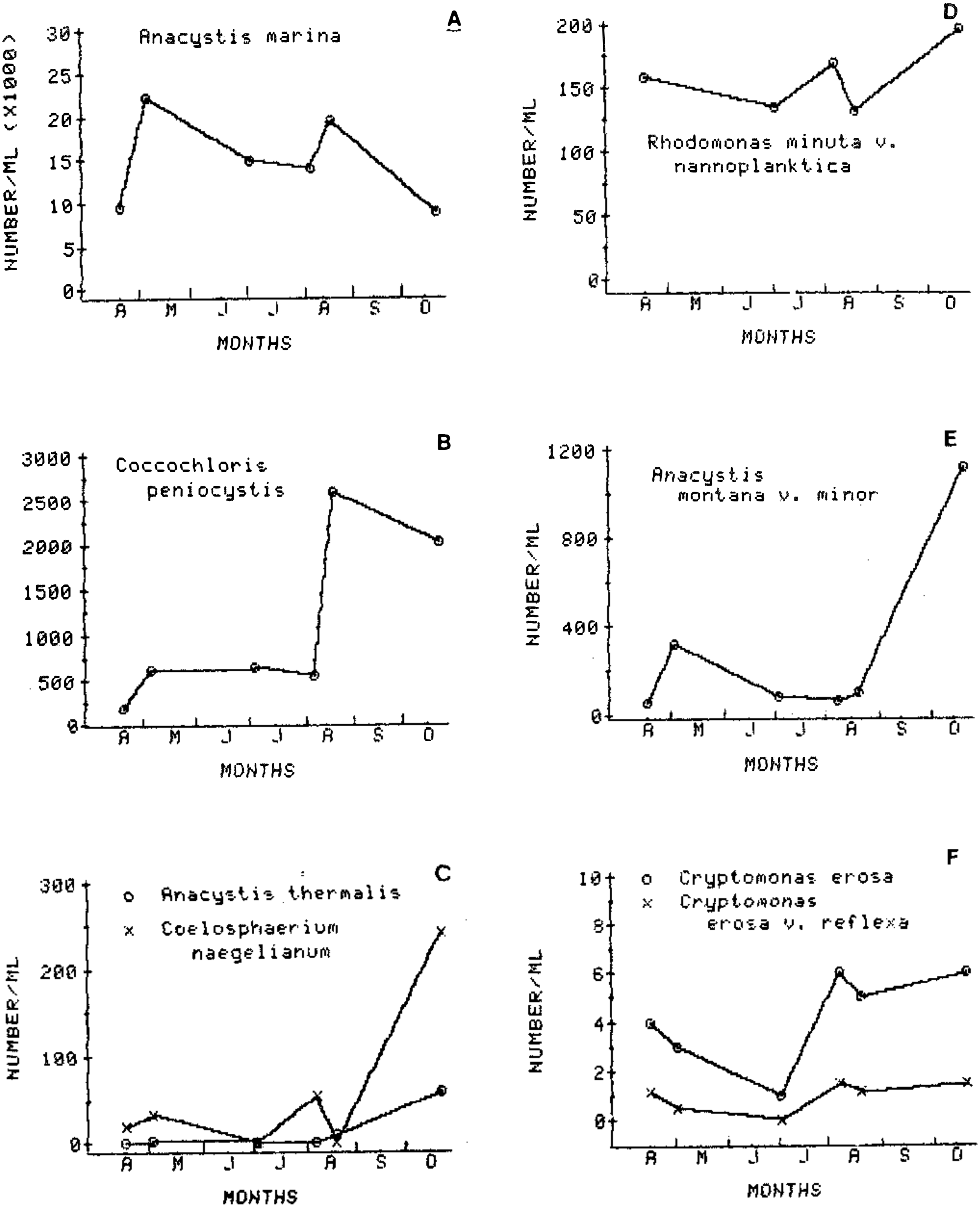


FIGURE 20 Mean seasonal distribution of a) *Anacystis marina*, b) *Coccochloris peniocystis*, c) *Anacystis thermalis* and *Coelosphaerium naegelianum*, d) *Rhodomonas minuta v. nannoplanktica*, e) *Anacystis montana v. minor*, f) *Cryptomonas erosa* and *Cryptomonas erosa v. reflexa*, Lake Huron.

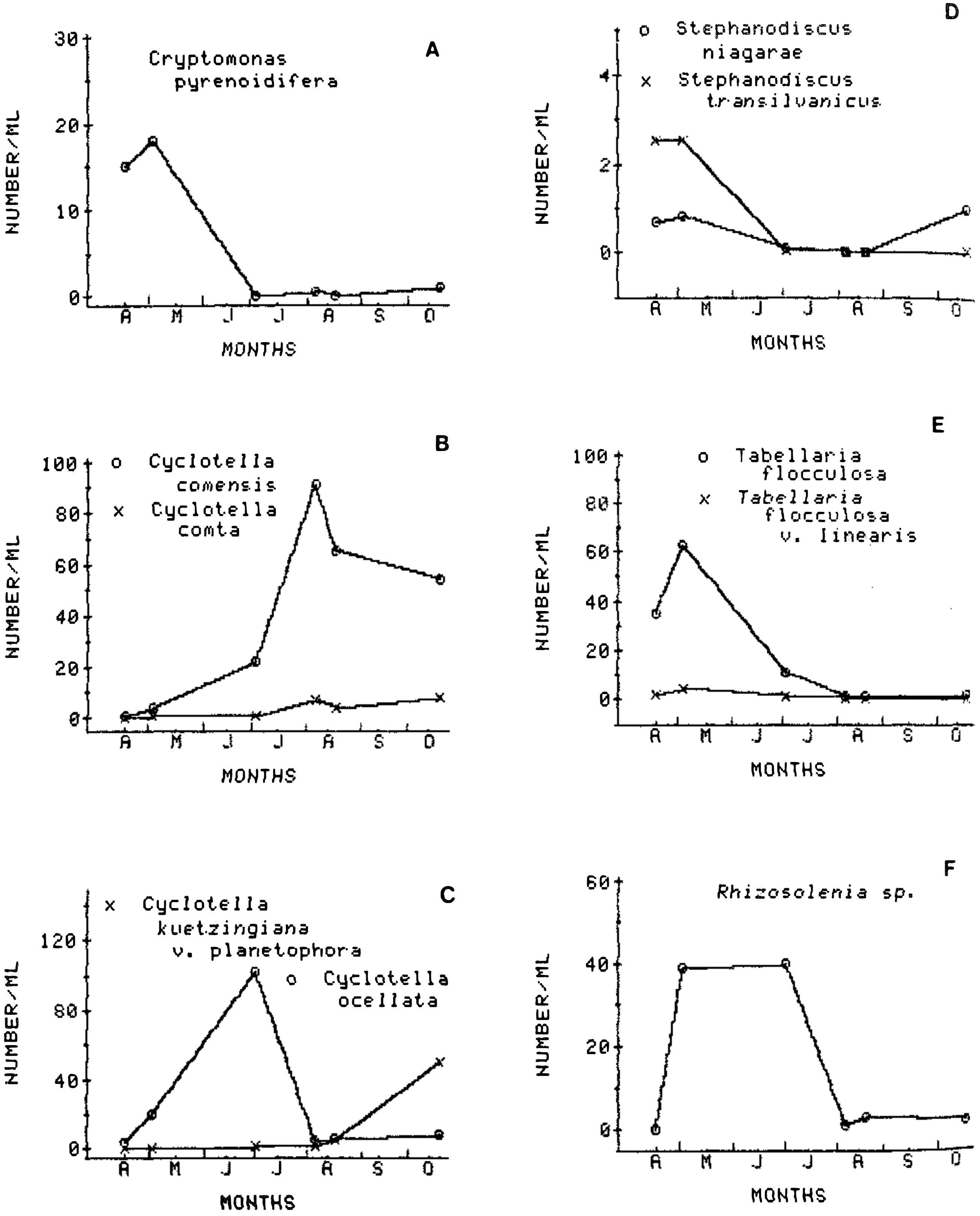


FIGURE 21 Mean seasonal distribution of a) <u>Cryptomonas pyrenoidifera</u>, b) <u>Cyclotella comensis</u> and <u>Cyclotella comta</u>, c) <u>Cyclotella kuetzingiana v. planetophora</u> and <u>Cyclotella ocellata</u>, d) <u>Stephanodiscus niagarae</u> and <u>Stephanodiscus transilvanicus</u>, e) <u>Tabellaria flocculosa</u> and <u>Tabellaria flocculosa v. linearis</u>, f) <u>Rhizosolenia sp.</u>, Lake Huron.

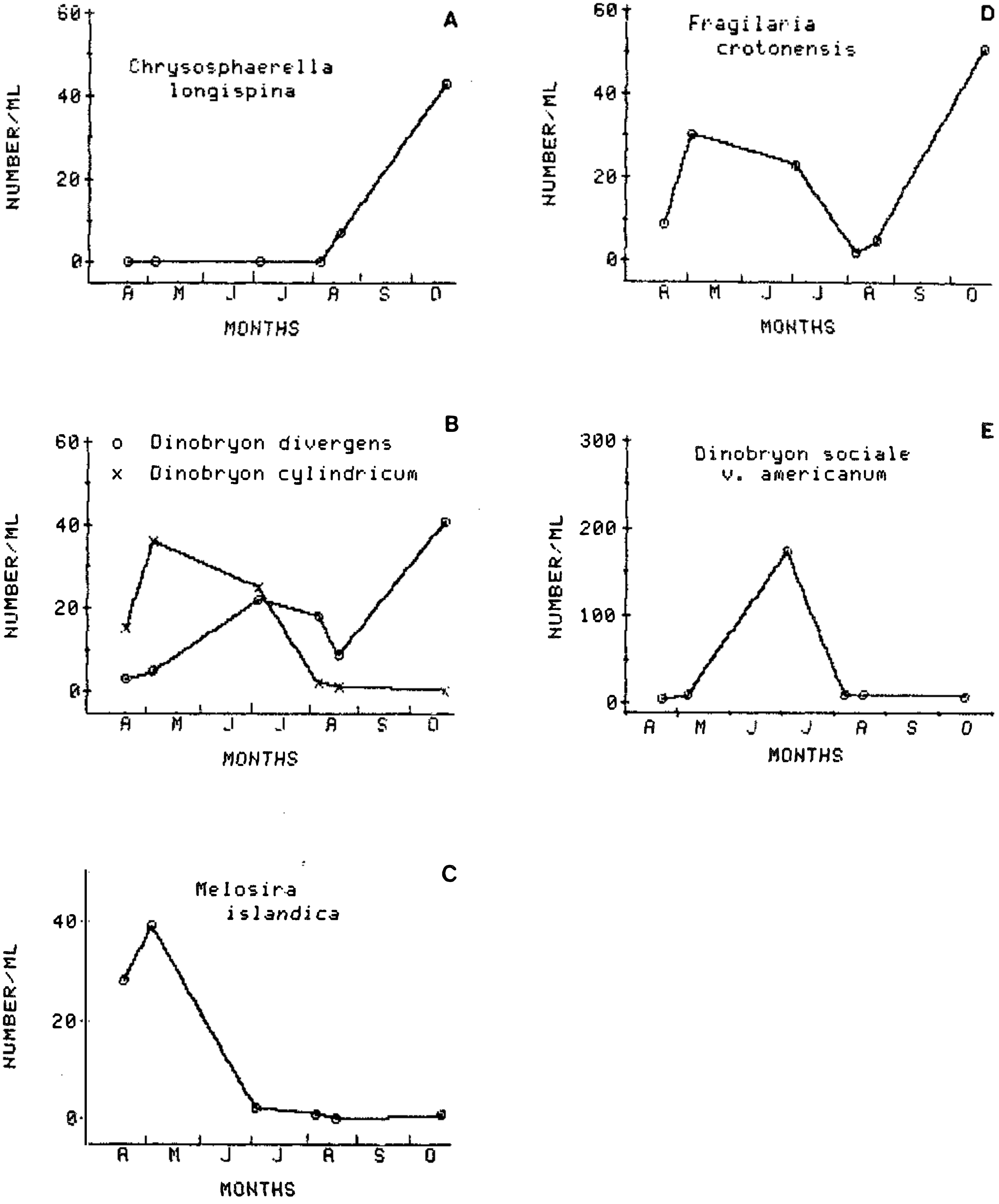


FIGURE 22 Mean seasonal distribution of a) _Chrysosphaerella longispina_, b) _Dinobryon divergens_ and _Dinobryon cylindricum_, c) _Melosira islandica_, d) _Fragilaria crotonensis_, Lake Huron.

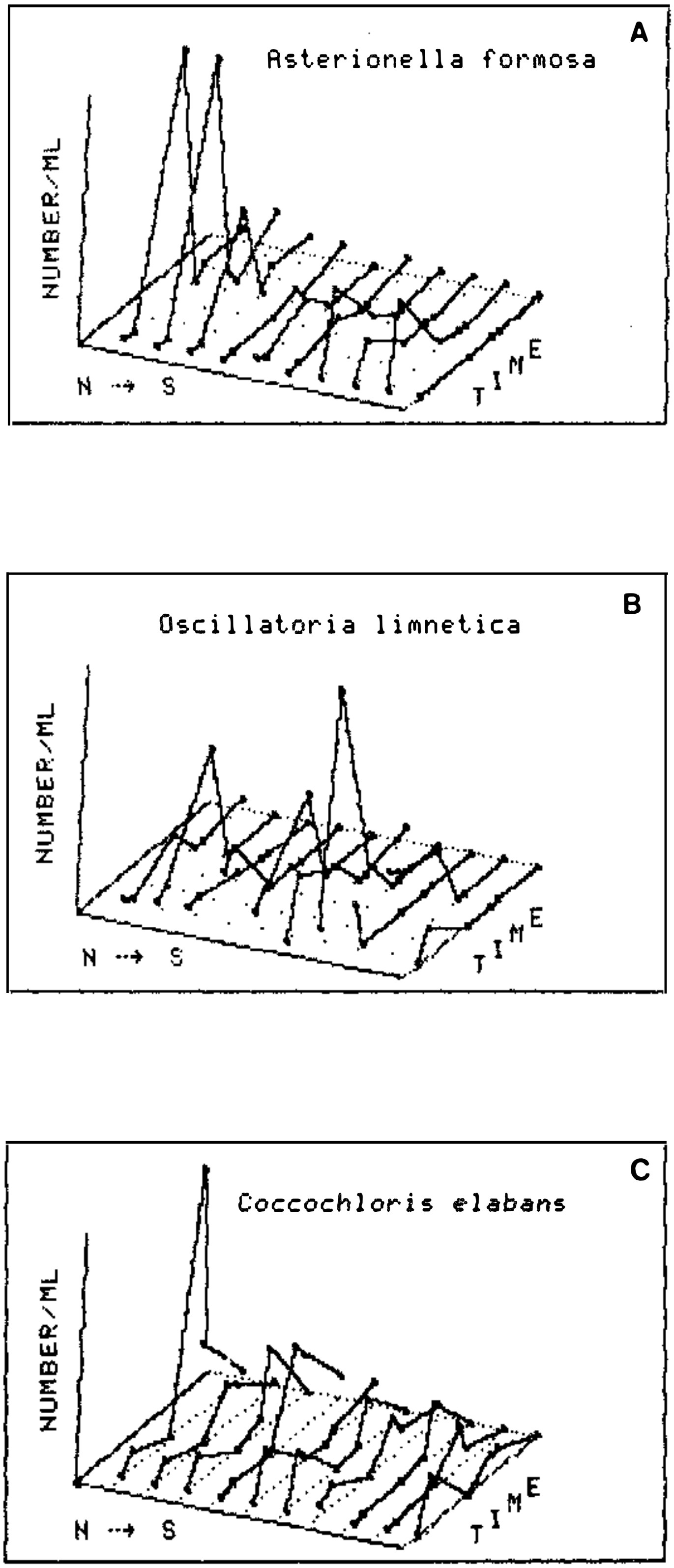
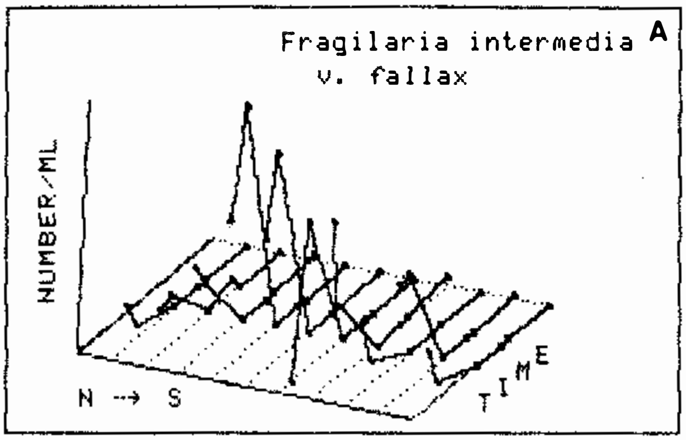


FIGURE 23 Seasonal and geographical distribution of a) *Asterionella formosa*, b) *Oscillatoria limnetica*, c) *Coccochloris elabans*, Lake Huron.



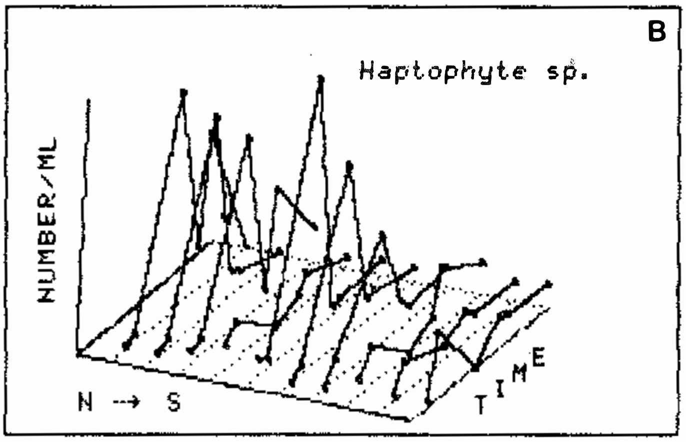


FIGURE 24 Seasonal and geographical distribution of a) *Fragilaria intermedia* v. *fallax*, b) *Haptophyte sp.*, Lake Huron.

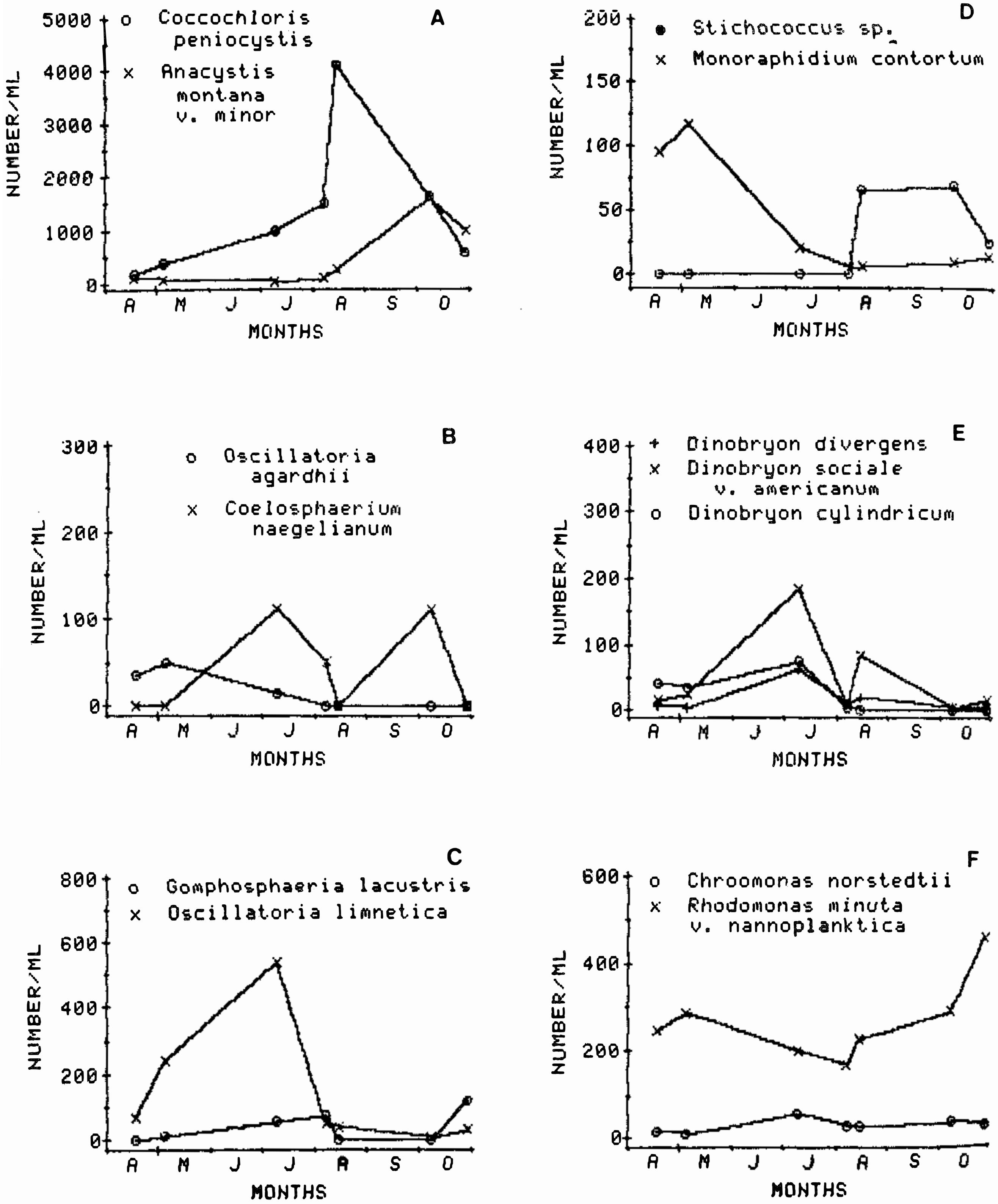


FIGURE 25 Mean seasonal distribution of a) *Coccochloris peniocystis* and *Anacystis montana* v. *minor*, b) *Coelosphaerium naegelianum* and *Oscillatoria agardhii*, c) *Gomphosphaeria lacustris* and *Oscillatoria limnetica*, d) *Stichococcus* sp. and *Monoraphidium contortum*, e) *Dinobryon divergens*, *Dinobryon sociale* v. *americanum* and *Dinobryon cylindricum*, f) *Chroomonas norstedtii* and *Rhodomonas minuta* v. *nannoplanktica*, Lake Michigan.

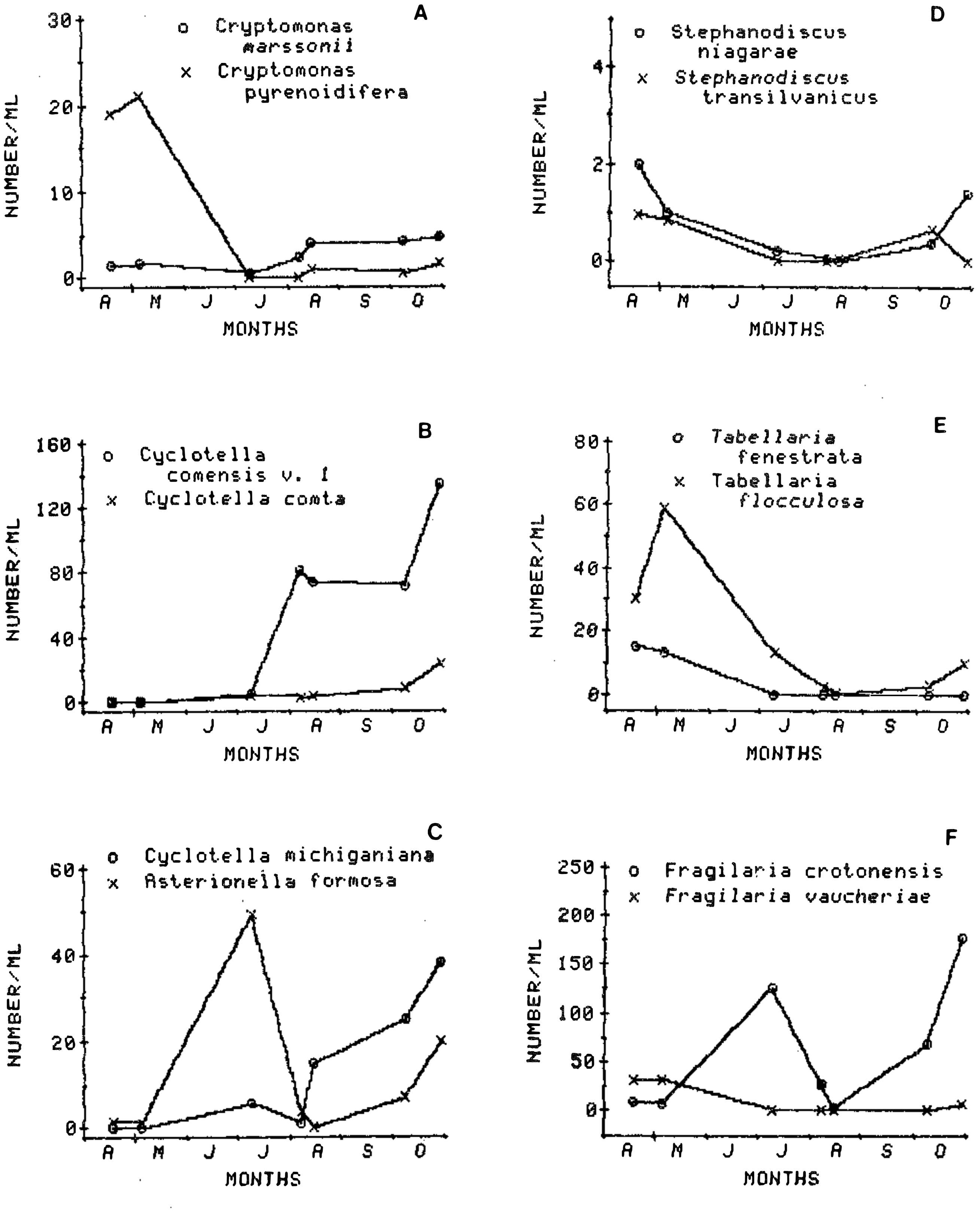


FIGURE 26 Mean seasonal distribution of a) Cryptomonas marssonii and Cryptomonas pyrenoidifera, b) Cyclotella comensis v. 1 and Cyclotella comta, c) Cyclotella michiganiana and Asterionella formosa, d) Stephanodiscus niagarae and Stephanodiscus transilvanicus, e) Tabellaria fenestrata and Tabellaria flocculosa, f) Fragilaria crotonensis and Fragilaria vaucheriae, Lake Michigan.

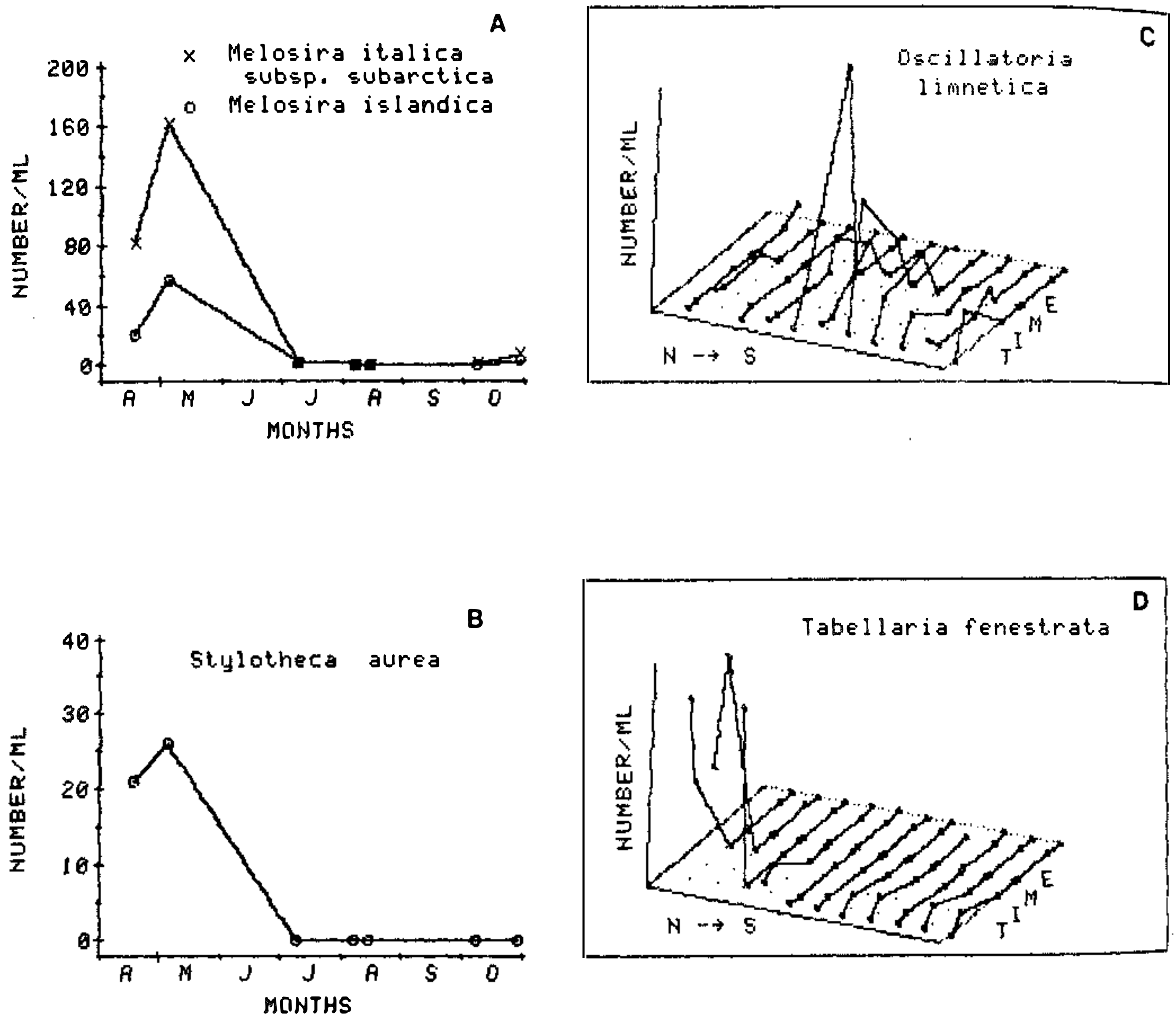


FIGURE 27 Mean seasonal distribution of a) *Melosira italica* subsp. *subarctica* and *Melosira islandica*, b) *Stylotheca aurea*, c) *Oscillatoria limnetica*, d) *Tabellaria fenestrata*. Lake Michigan

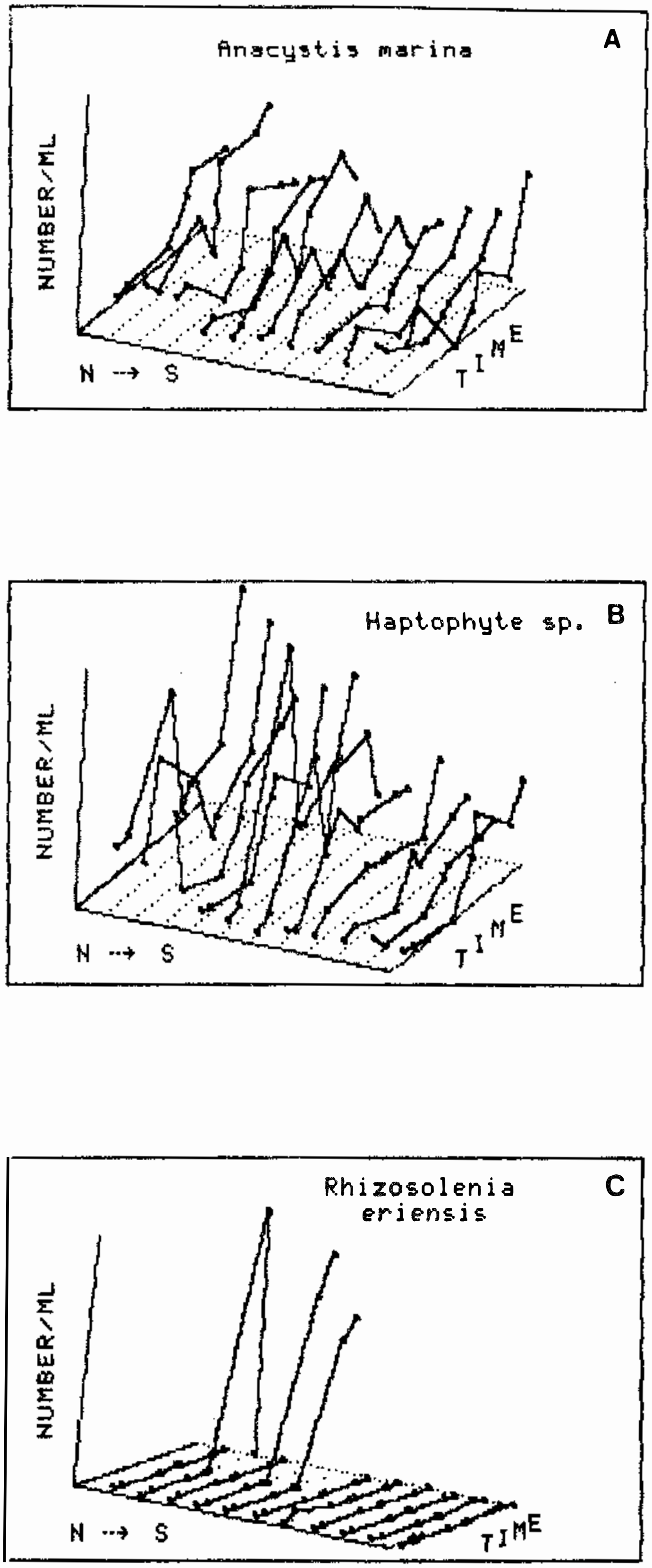


FIGURE 28 Seasonal and geographical distribution of a) *Anacystis marina*, b) *Haptophyte sp.*, c) *Rhizosolenia eriensis*, Lake Michigan.

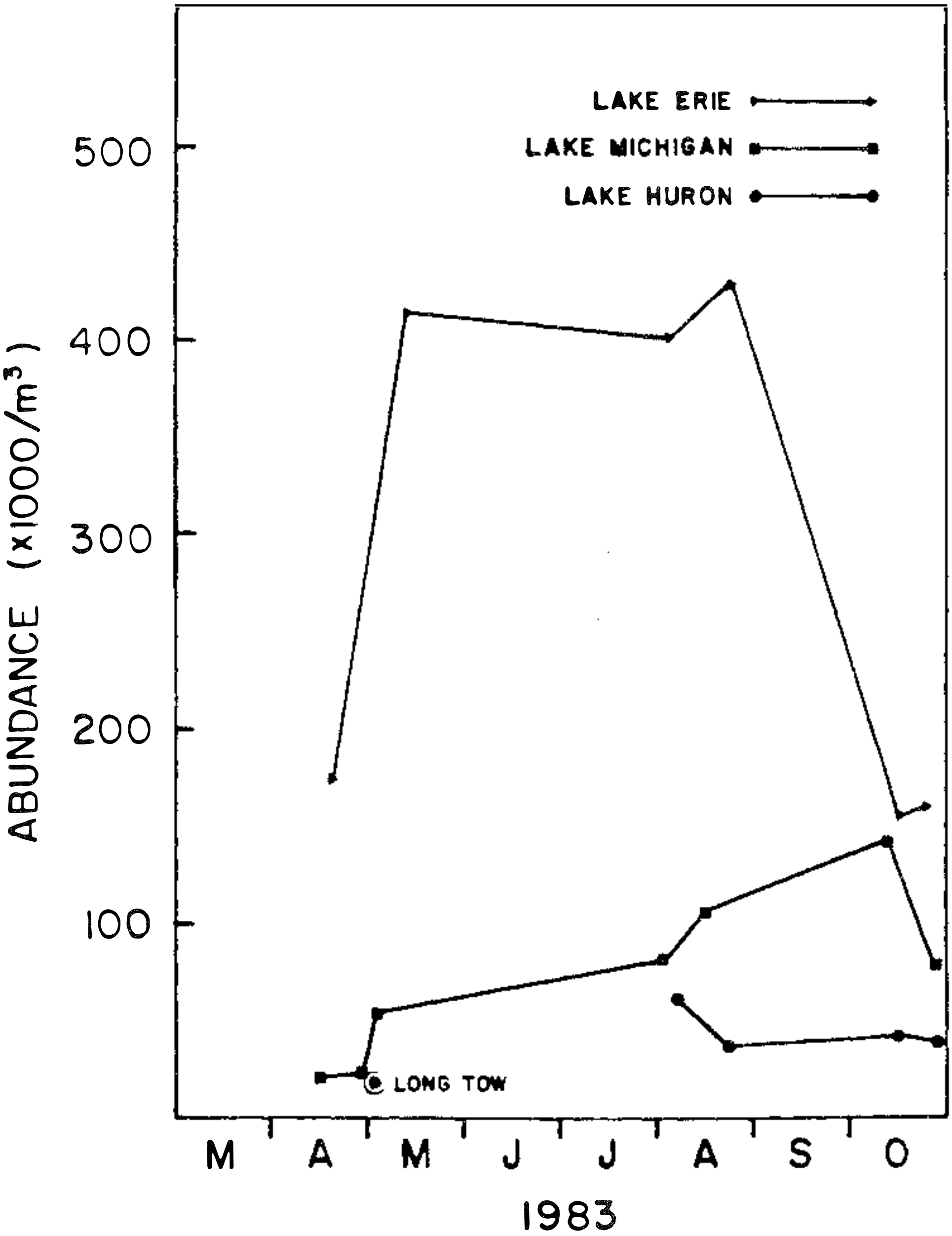


FIGURE 29 Seasonal zooplankton abundance in Lakes Erie, Huron and Michigan. Short hauls are plotted.

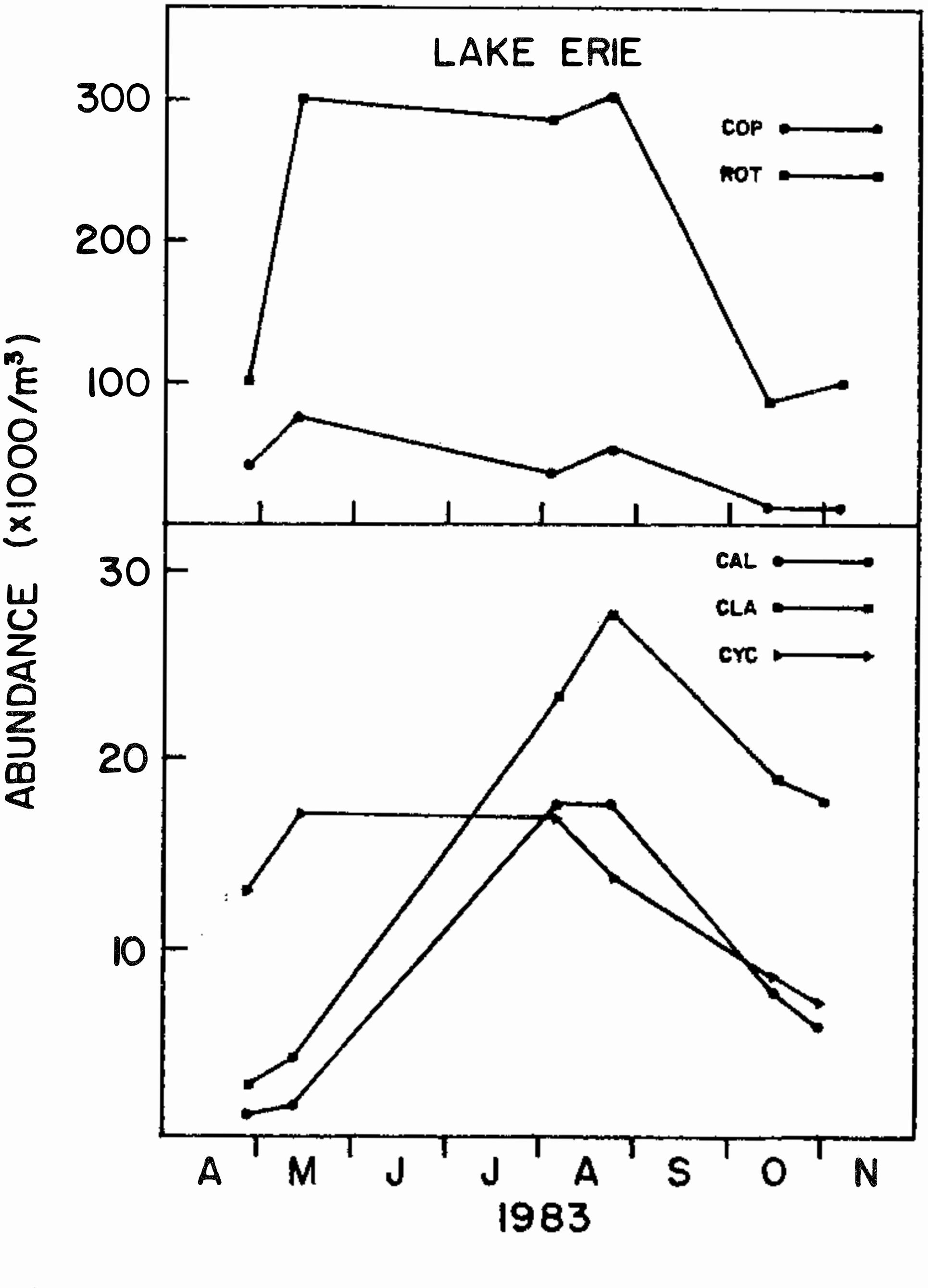


FIGURE 30 Seasonal distribution of zooplankton groups in Lake Erie. Short hauls are plotted. COP = Copepoda nauplii, ROT = Rotifera, CAL = Calanoida, CLA = Cladocera, CYC = Cyclopoida.

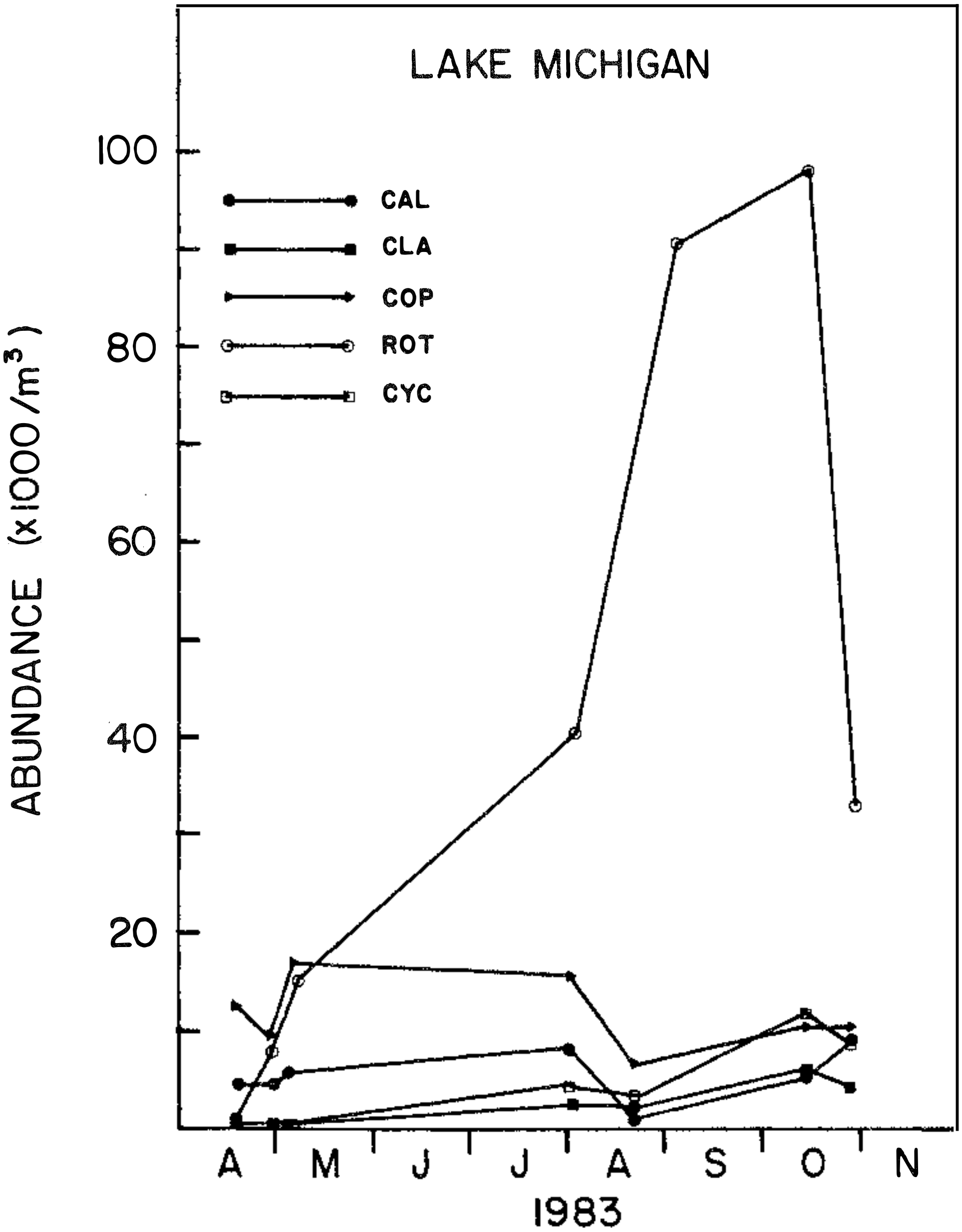


FIGURE 31 Seasonal distribution of zooplankton groups in Lake Michigan. Abundances from short hauls are plotted. COP = Copepoda nauplii, ROT = Rotifera, CAL = Calanoida, CLA = Cladocera, CYC = Cyclopoida.

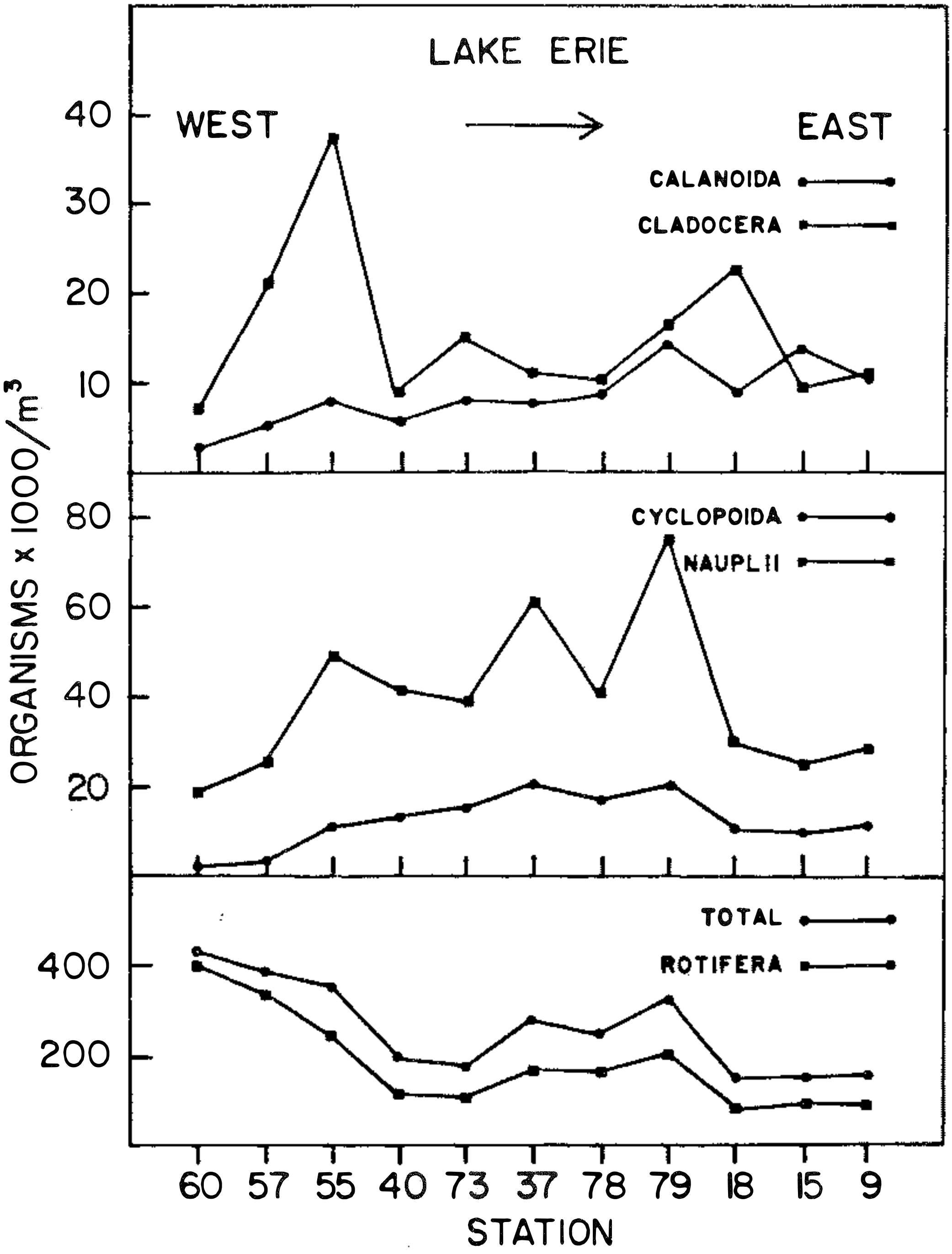


FIGURE 32 Geographical distribution of major zooplankton groups in Lake Erie.

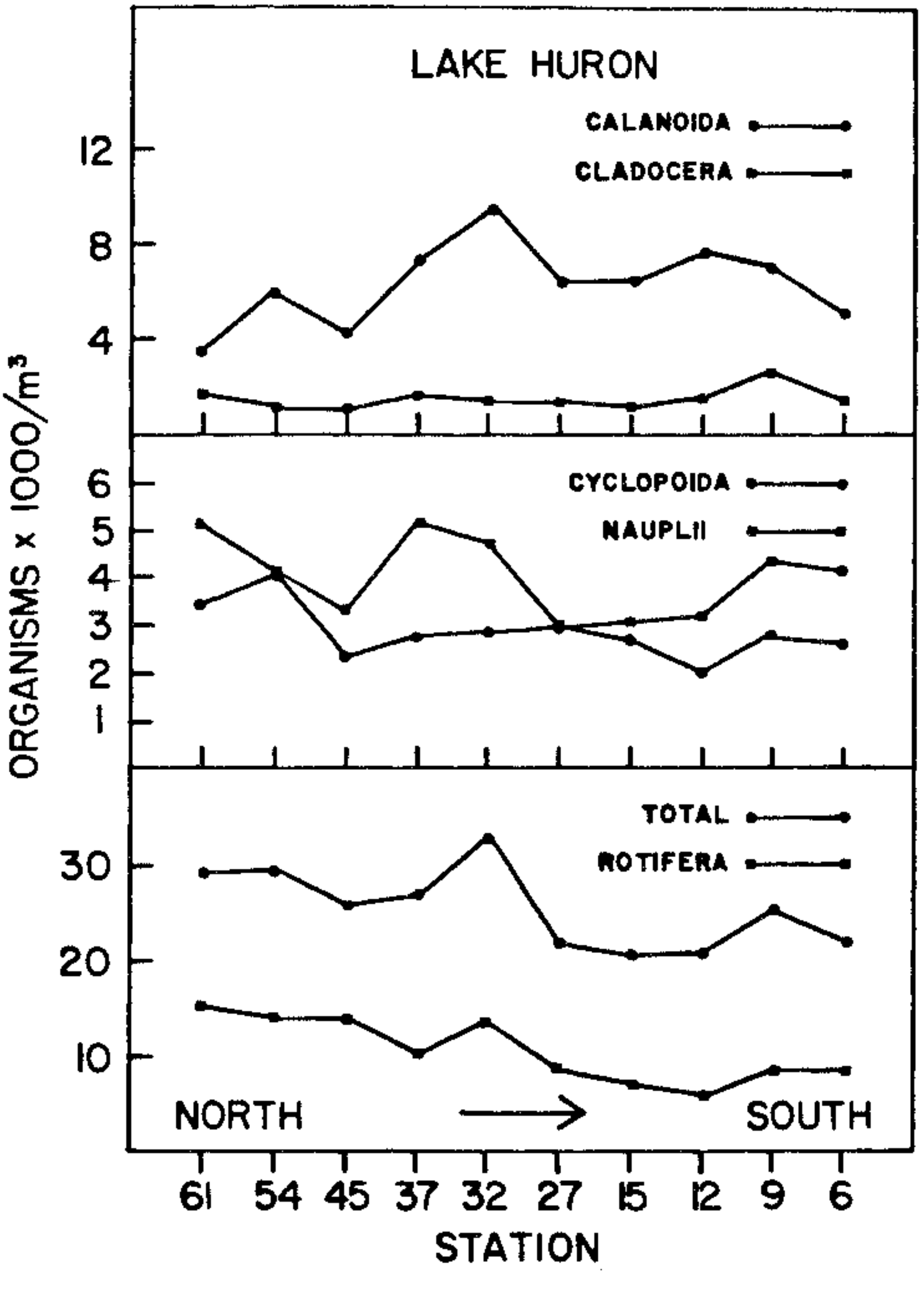


FIGURE 33 Geographical distribution of major zooplankton groups in Lake Huron.

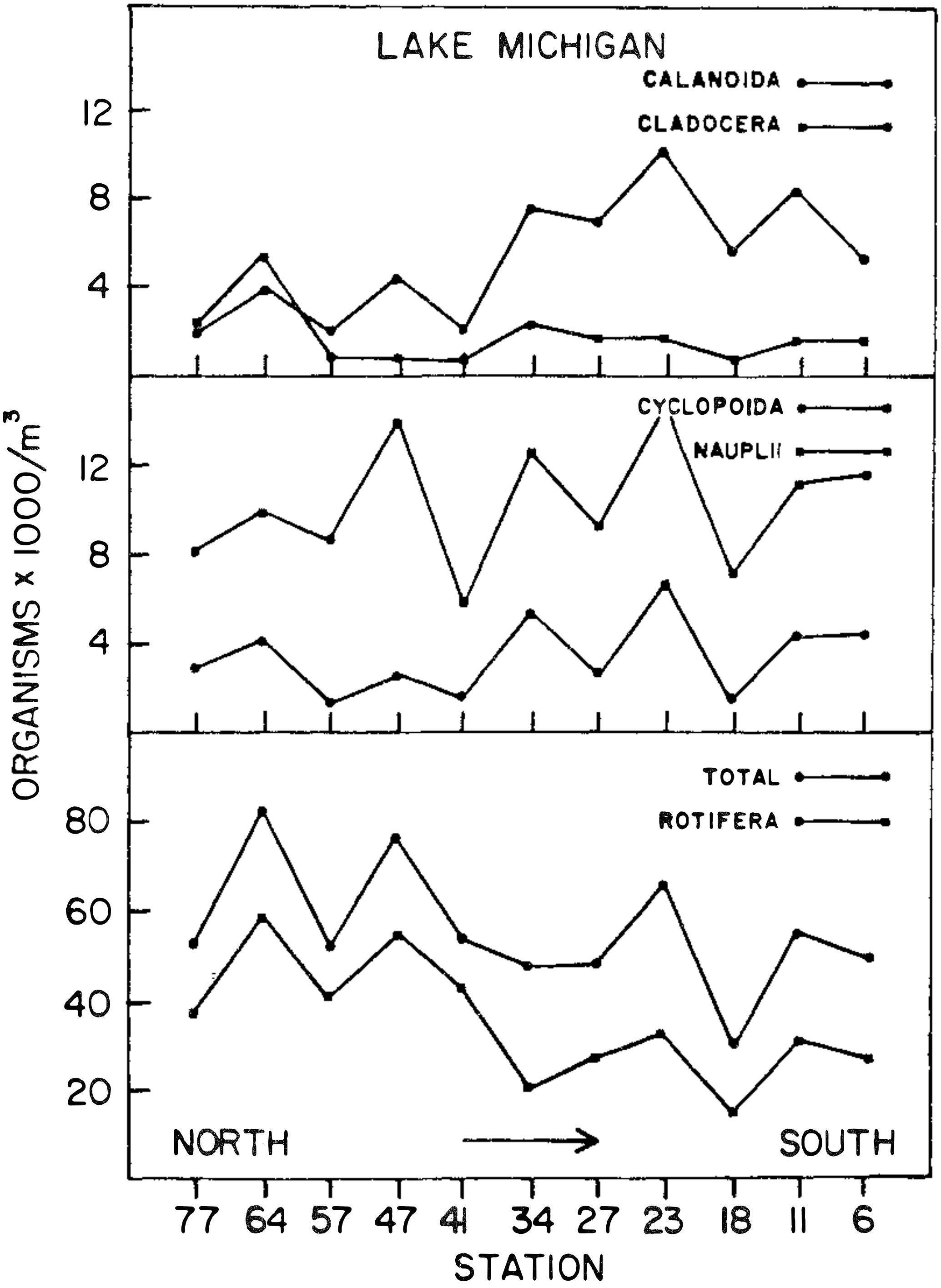


FIGURE 34 Geographical distribution of major zooplankton groups in Lake Michigan.

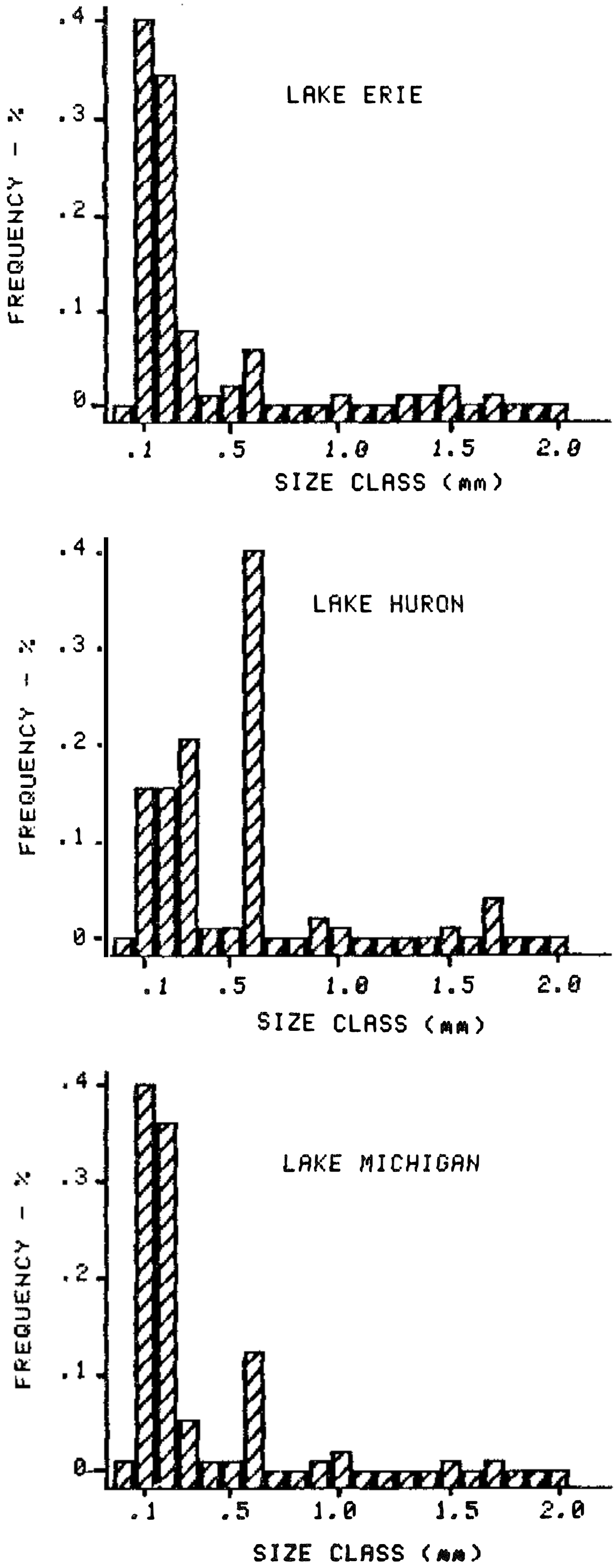


FIGURE 35 Size-frequency distribution of zooplankton in Lakes Erie, Huron and Michigan. Short hauls are plotted. The 0.1 size class refers to the 0.1 to .199 size range.

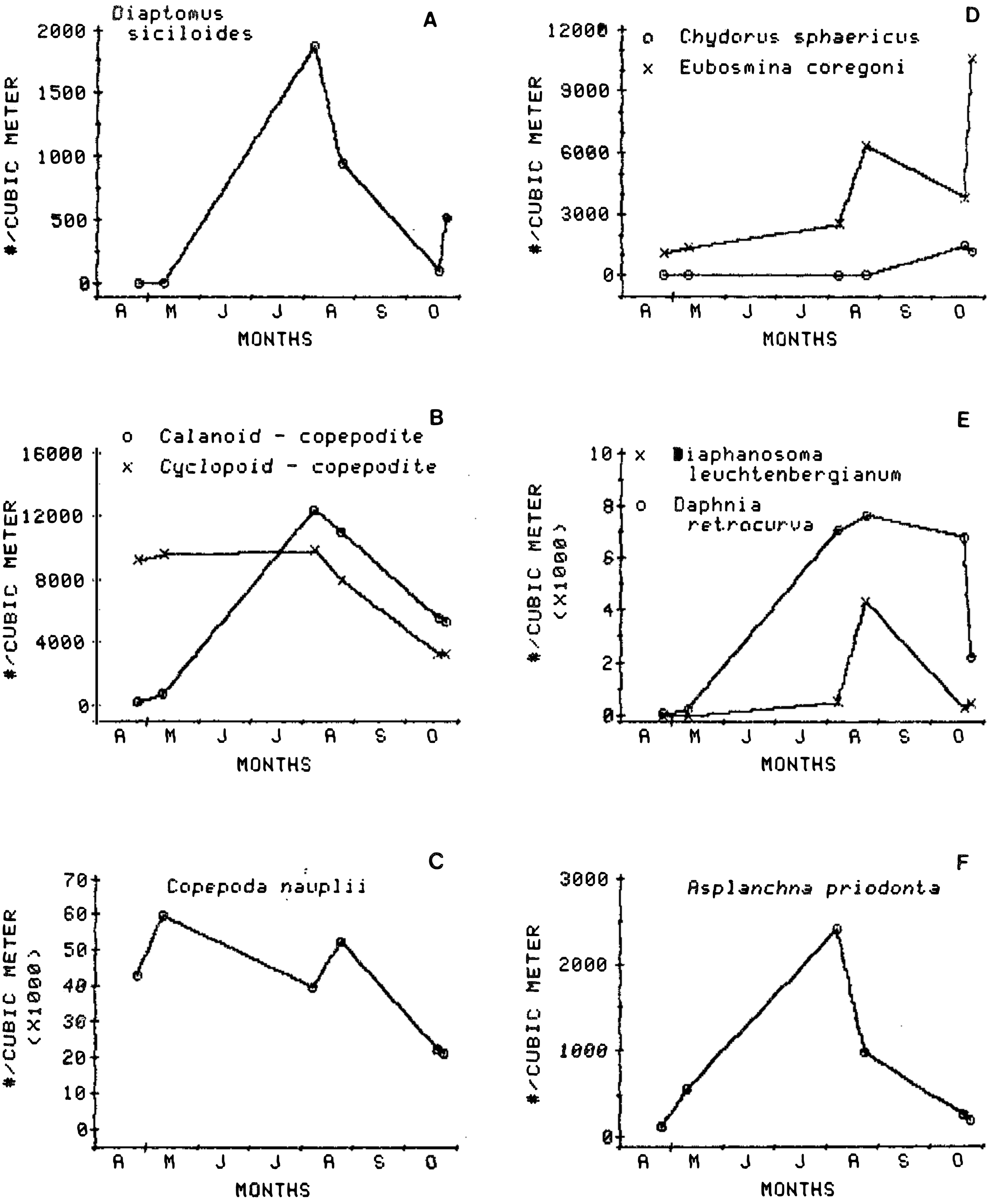


FIGURE 36 Mean seasonal distribution of a) *Diaptomus siciloides*, b) Calanoid - copepodite and Cyclopoid - copepodite, c) Copepoda nauplii, d) *Chydorus sphaericus* and *Eubosmina coregoni*, e) *Diaphanosoma leuchtenbergianum* and *Daphnia retrocurva*, f) *Asplanchna priodonta*, Lake Erie.

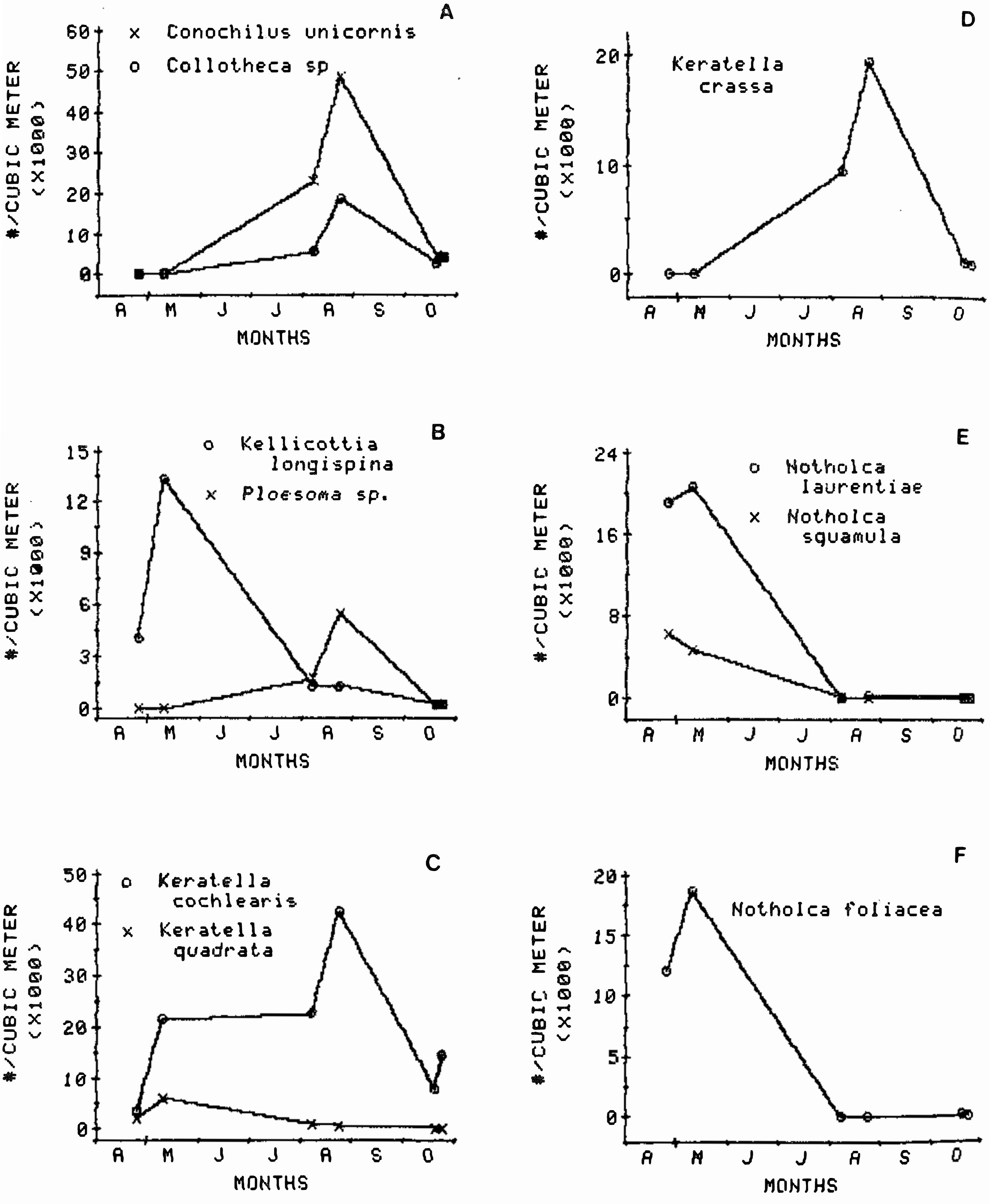


FIGURE 37 Mean seasonal distribution of a) Conochilus unicornis and Collotheca sp., b) Kellicottia longispina and Ploesoma sp., c) Keratella cochlearis and Keratella quadrata, d) Keratella crassa, e) Notholca laurentiae and Notholca squamula, f) Notholca foliacea, Lake Erie.

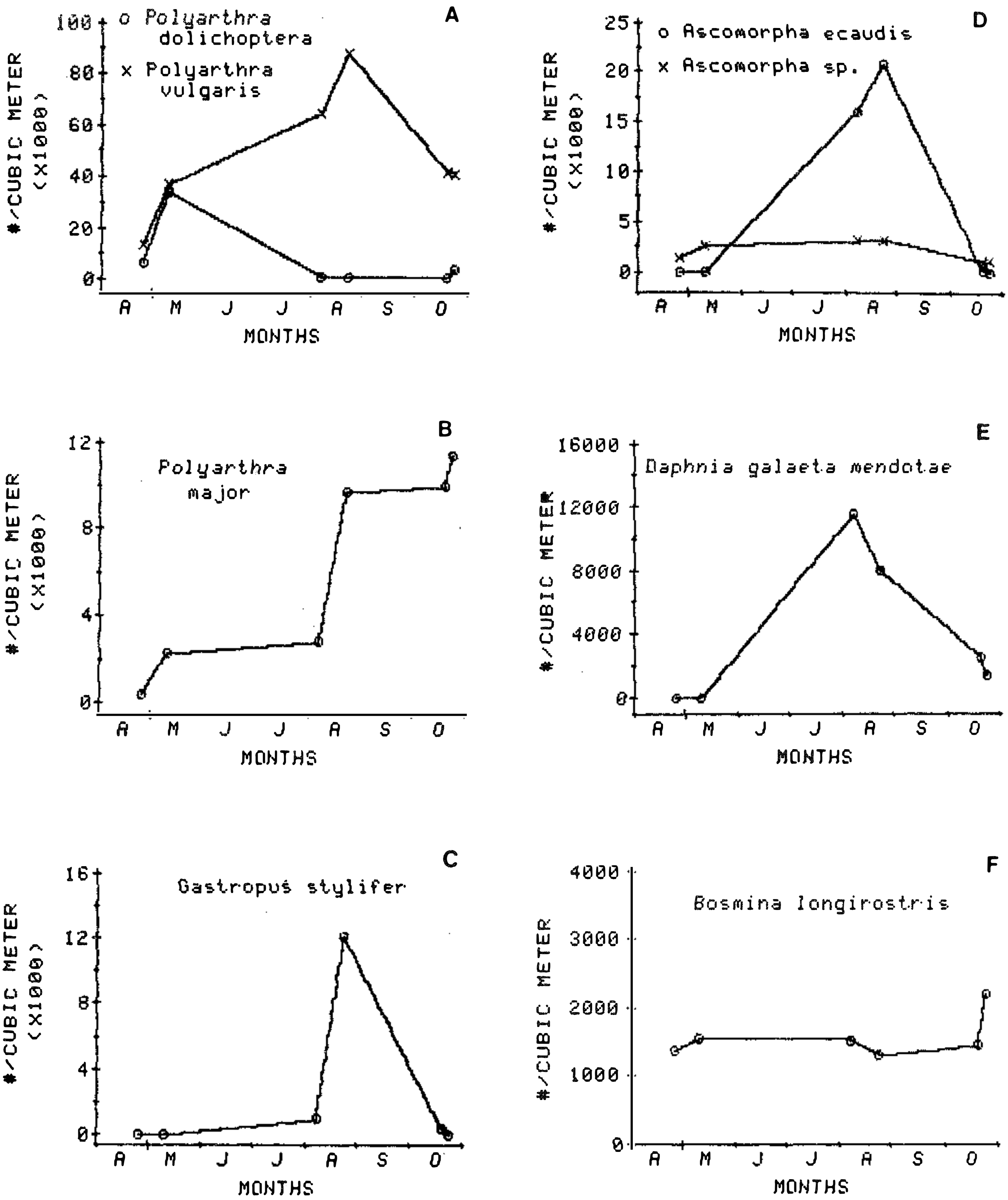


FIGURE 38 Mean seasonal distribution of a) Polyarthra dolichoptera and Polyarthra vulgaris, b) Polyarthra major, c) Gastropus stylifer, d) Ascomorpha ecaudis and Ascomorpha sp., e) Daphnia galeata mendotae, f) Bosmina longirostris, Lake Erie.

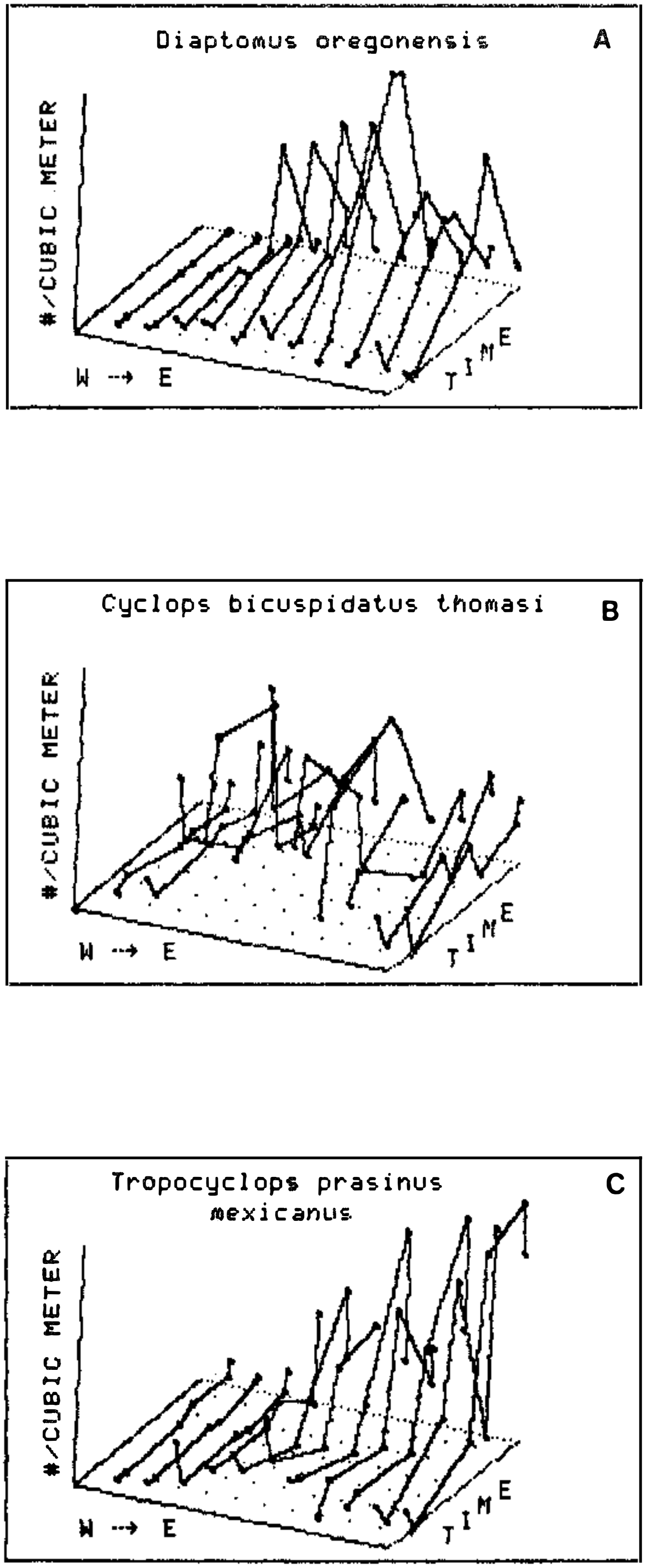


FIGURE 39 Seasonal and geographical distribution of a) *Diaptomus oregonensis*, b) *Cyclops bicuspidatus thomasi*, c) *Tropocyclops prasinus mexicanus*, Lake Erie.

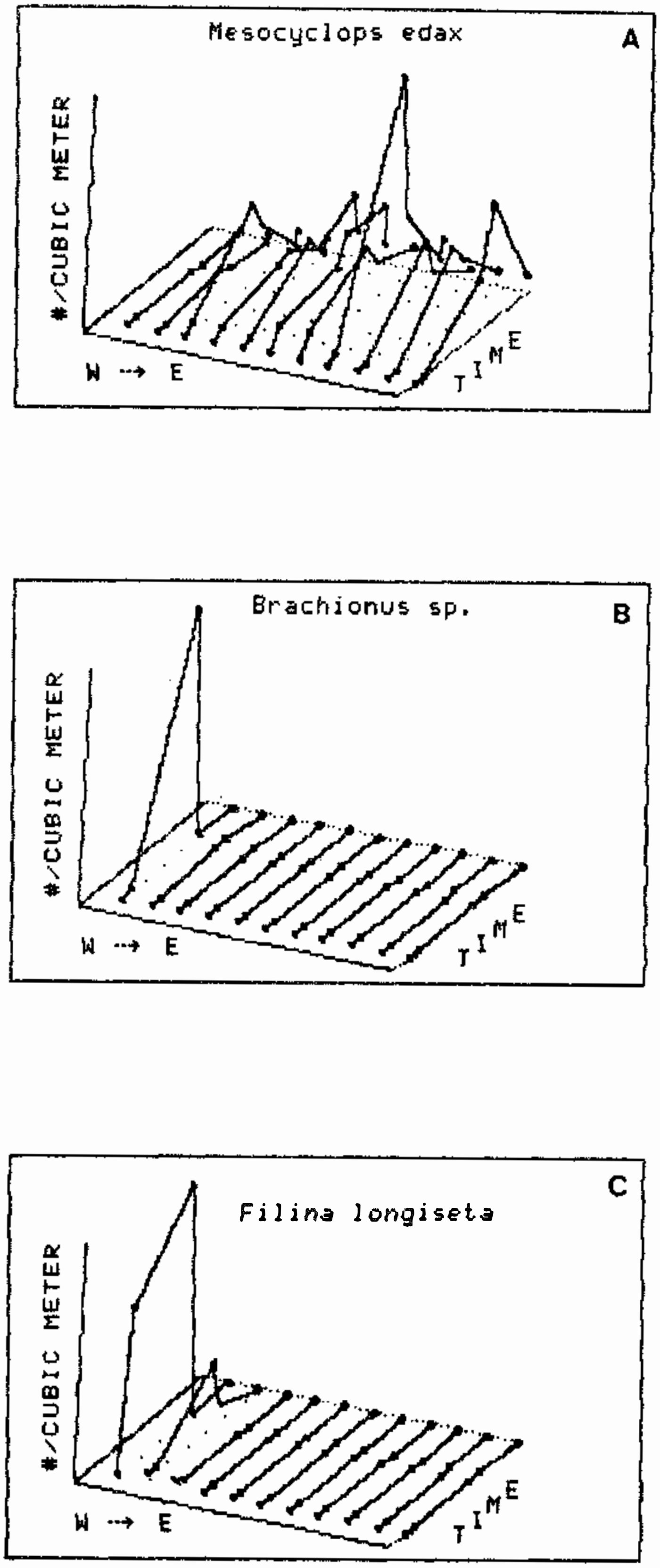


FIGURE 40 Seasonal and geographical distribution of a) *Mesocyclops edax*, b) *Brachionus sp.*, c) *Filina longiseta*. Lake Erie.

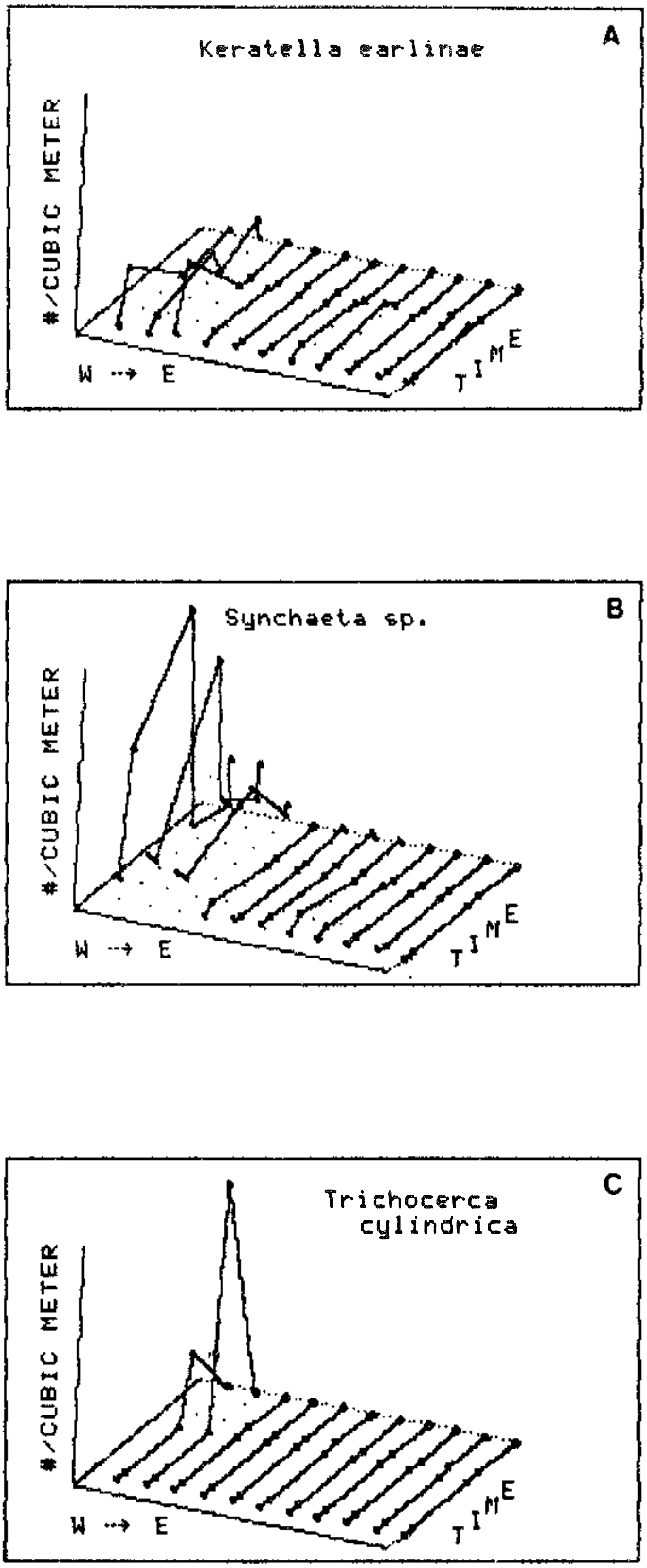


FIGURE 41 Seasonal and geographical distribution of a) *Keratella earlinae*, b) *Synchaeta sp.*, c) *Trichocerca cylindrica*, Lake Erie.

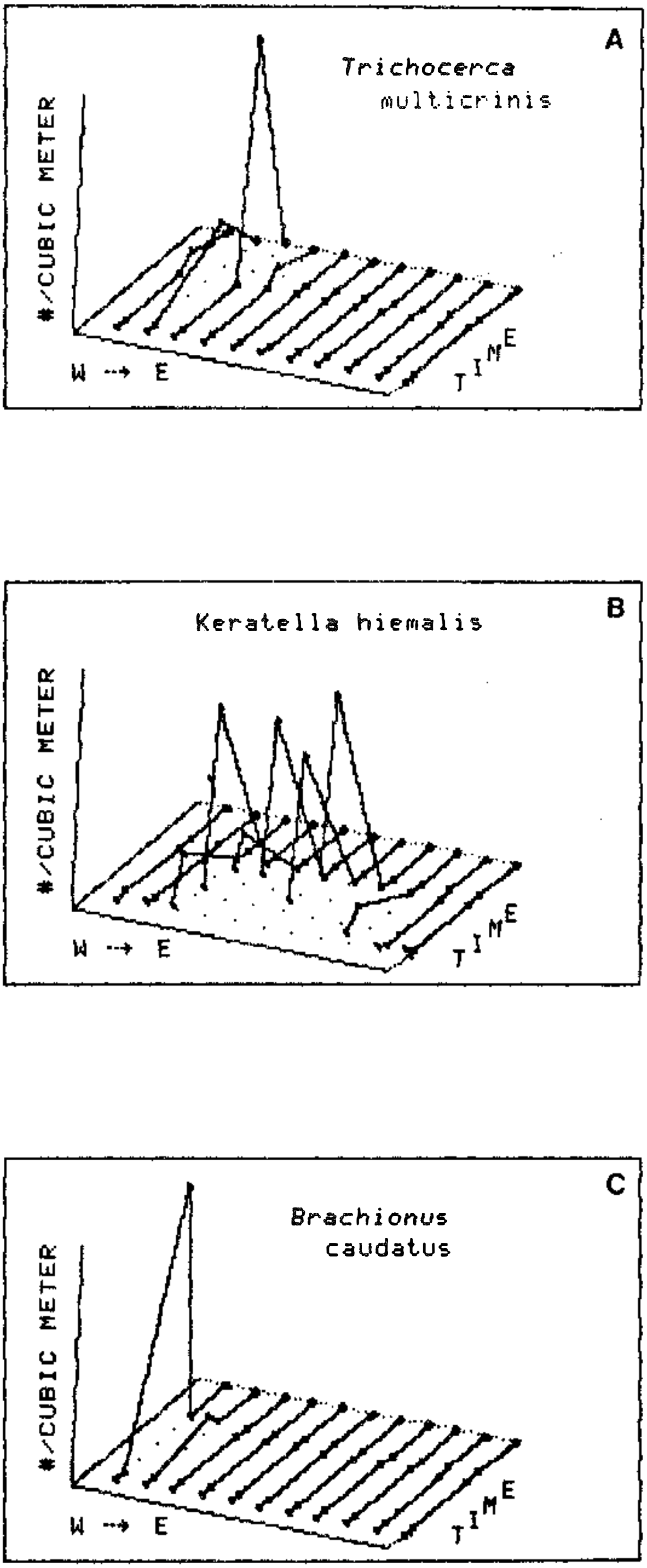


FIGURE 42 Seasonal and geographical distribution of a) *Trichocerca multricinis*, b) *Keratella hiemalis*, c) *Brachionus caudatus*, Lake Erie.

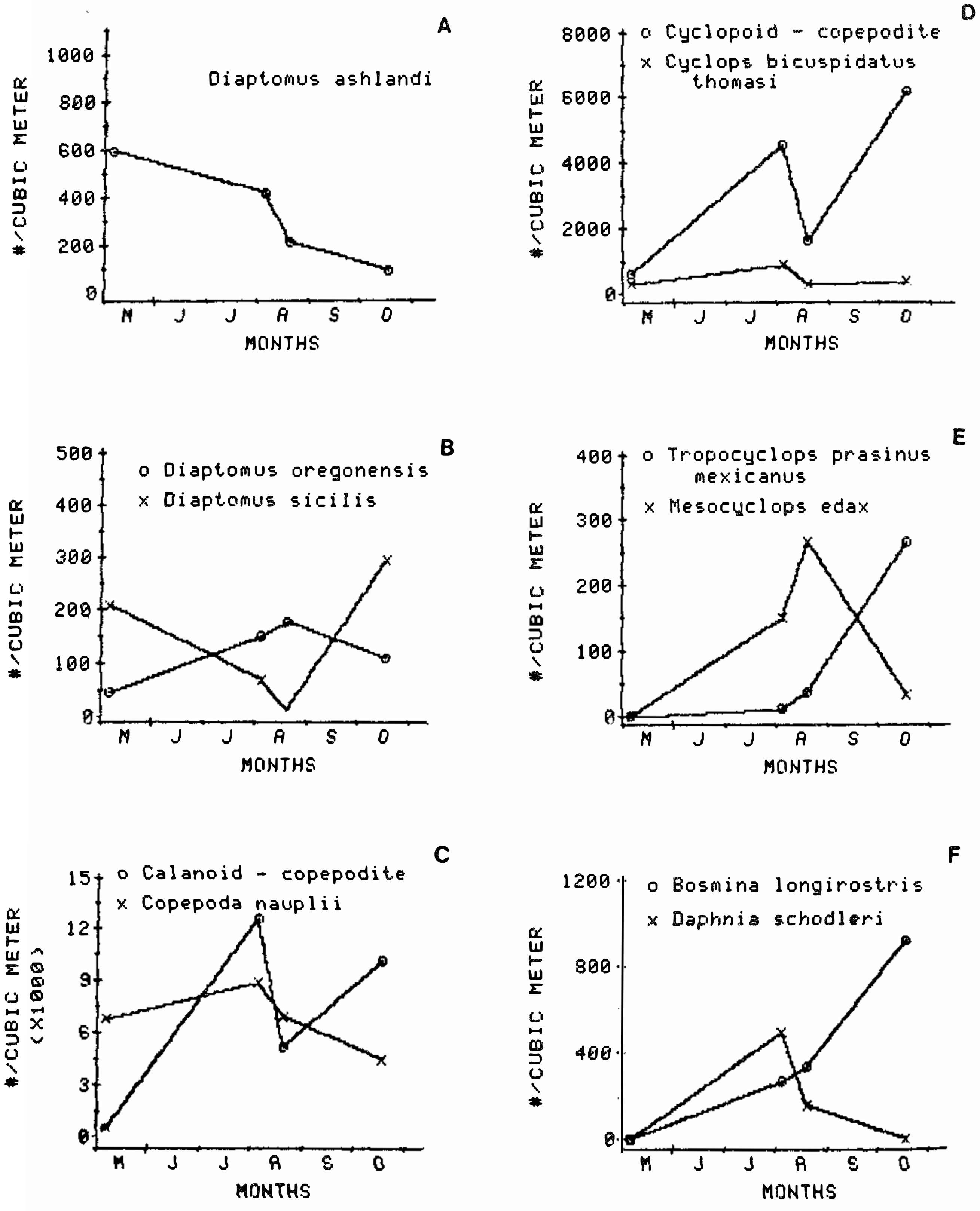


FIGURE 43 Mean seasonal distribution of a) *Diaptomus ashlandi*, b) *Diaptomus oregonensis* and *Diaptomus sicilis*, c) Calanoid - copepodite and Copepoda nauplii, d) Cyclopoid - copepodite and *Cyclops bicuspidatus thomasi*, e) *Tropocyclops prasinus mexicanus* and *Mesocyclops edax*, f) *Bosmina longirostris* and *Daphnia schodleri*, Lake Huron.

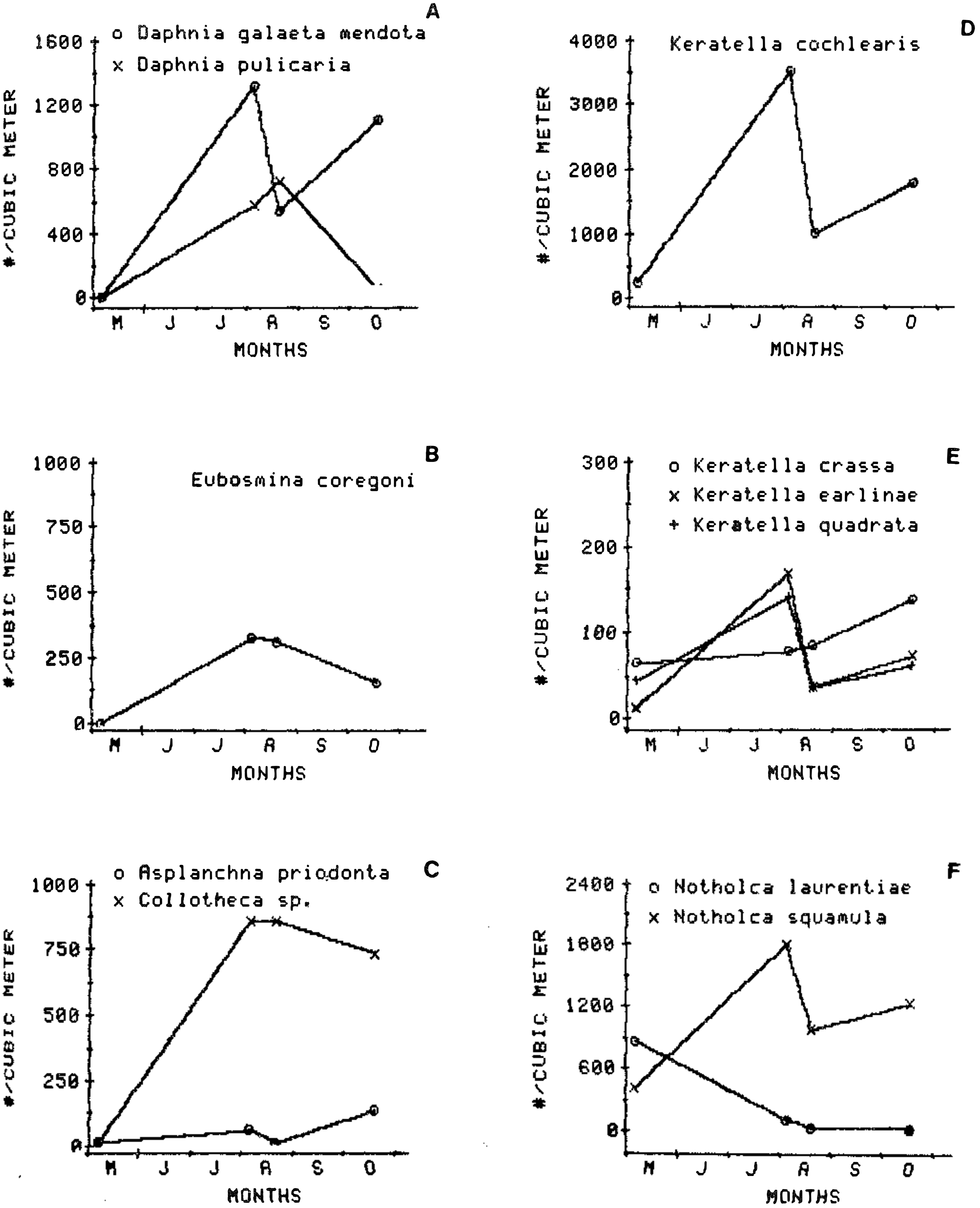


FIGURE 44 Mean seasonal distribution of a) _Daphnia galaeta mendota_ and _Daphnia pulicaria_, b) _Eubosmina coregoni_, c) _Asplanchna priodonta_ and _Collotheca sp._, d) _Keratella cochlearis_, e) _Keratella crassa_, _Keratella earlinae_ and _Keratella quadrata_, f) _Notholca laurentiae_ and _Notholca squamula_, Lake Huron.

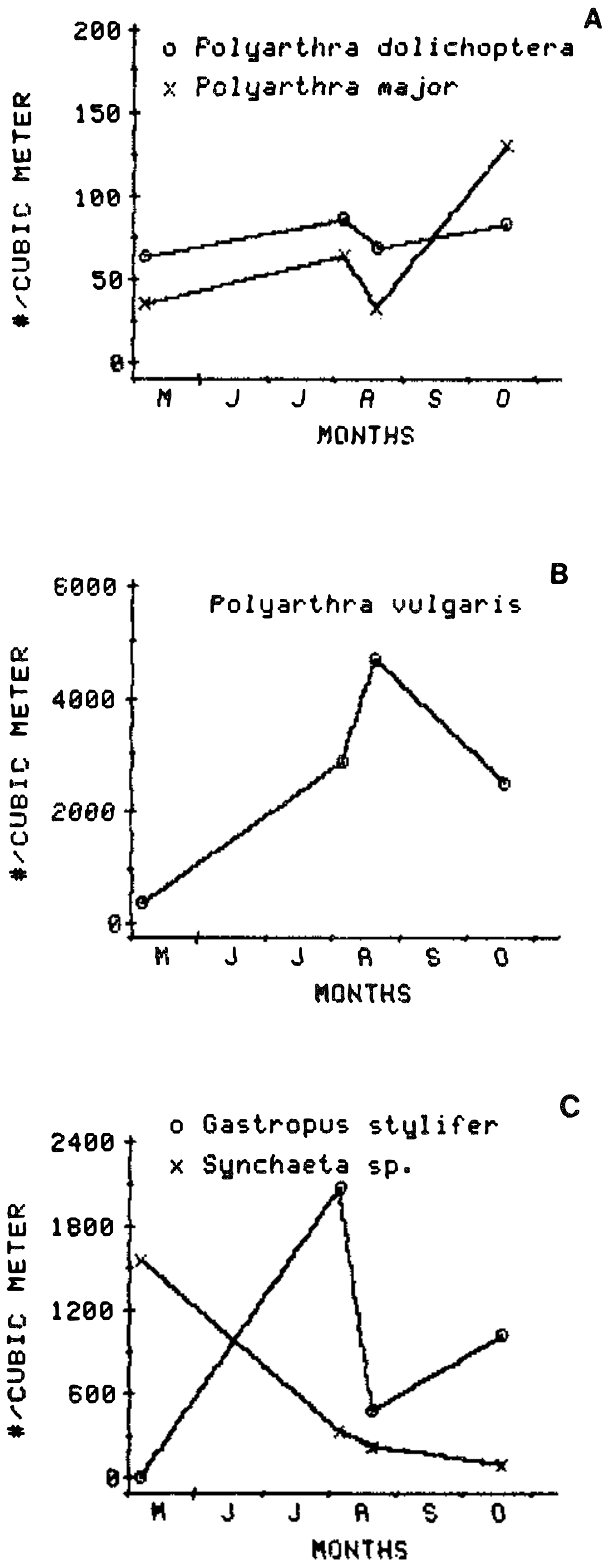
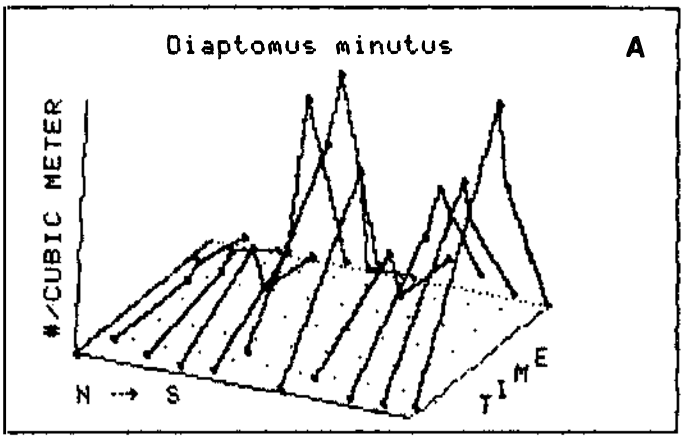


FIGURE 45 Mean seasonal distribution of a) *Polyarthra dolichoptera* and *Polyarthra major*, b) *Polyarthra vulgaris*, c) *Gastropus stylifer* and *Synchaeta sp.*, Lake Huron.



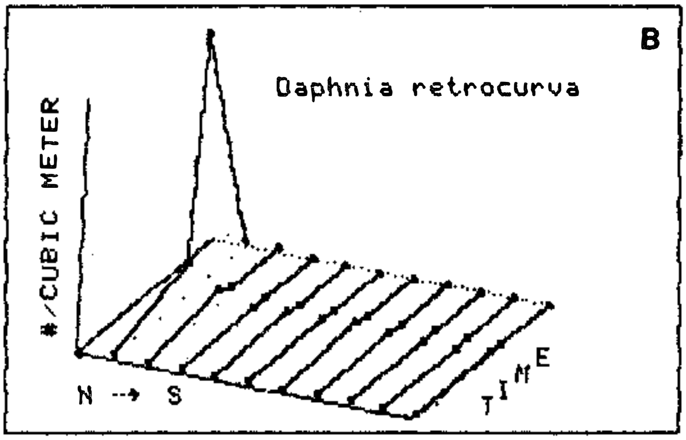
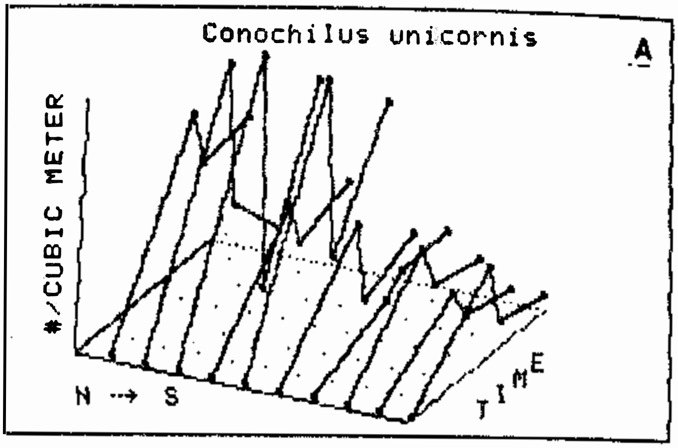


FIGURE 46 Seasonal and geographical distribution of a) _Diaptomus minutus_, b) _Daphnia retrocurva_, Lake Huron.



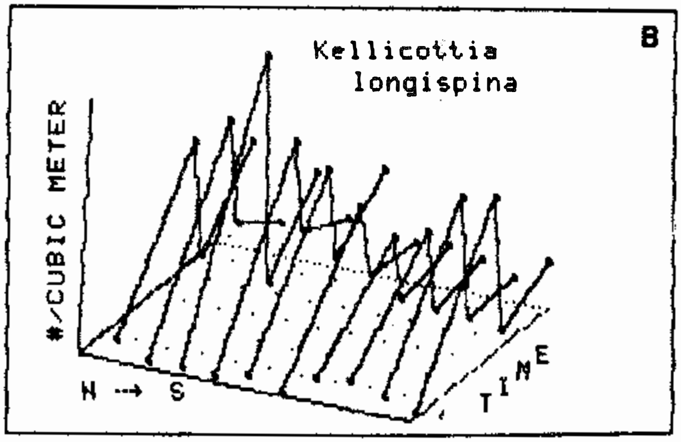


FIGURE 47 Seasonal and geographical distribution of a) Conochilus unicornis, b) Kellicottia longispina. Lake Huron.

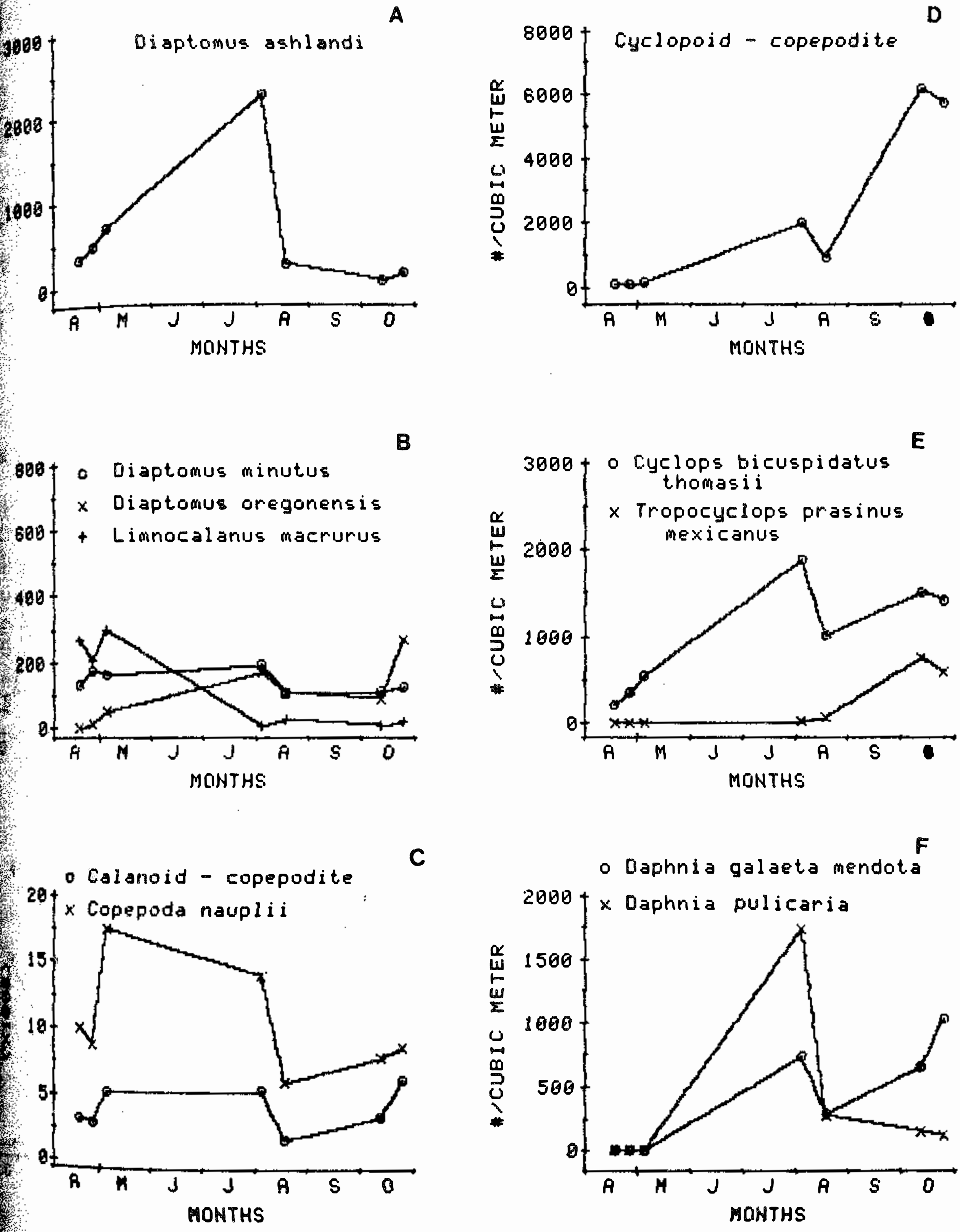


FIGURE 48 Mean seasonal distribution of a) *Diaptomus ashlandi*, b) *Diaptomus minutus*, *Diaptomus oregonensis* and *Limnocalanus macrurus*, c) Calanoid - copepodite and Copepoda nauplii, d) Cyclopoid - copepodite, e) *Cyclops bicuspidatus thomassi* and *Tropocyclops prasinus mexicanus*, f) *Daphnia galaeta mendota* and *Daphnia pulicaria*, Lake Michigan.

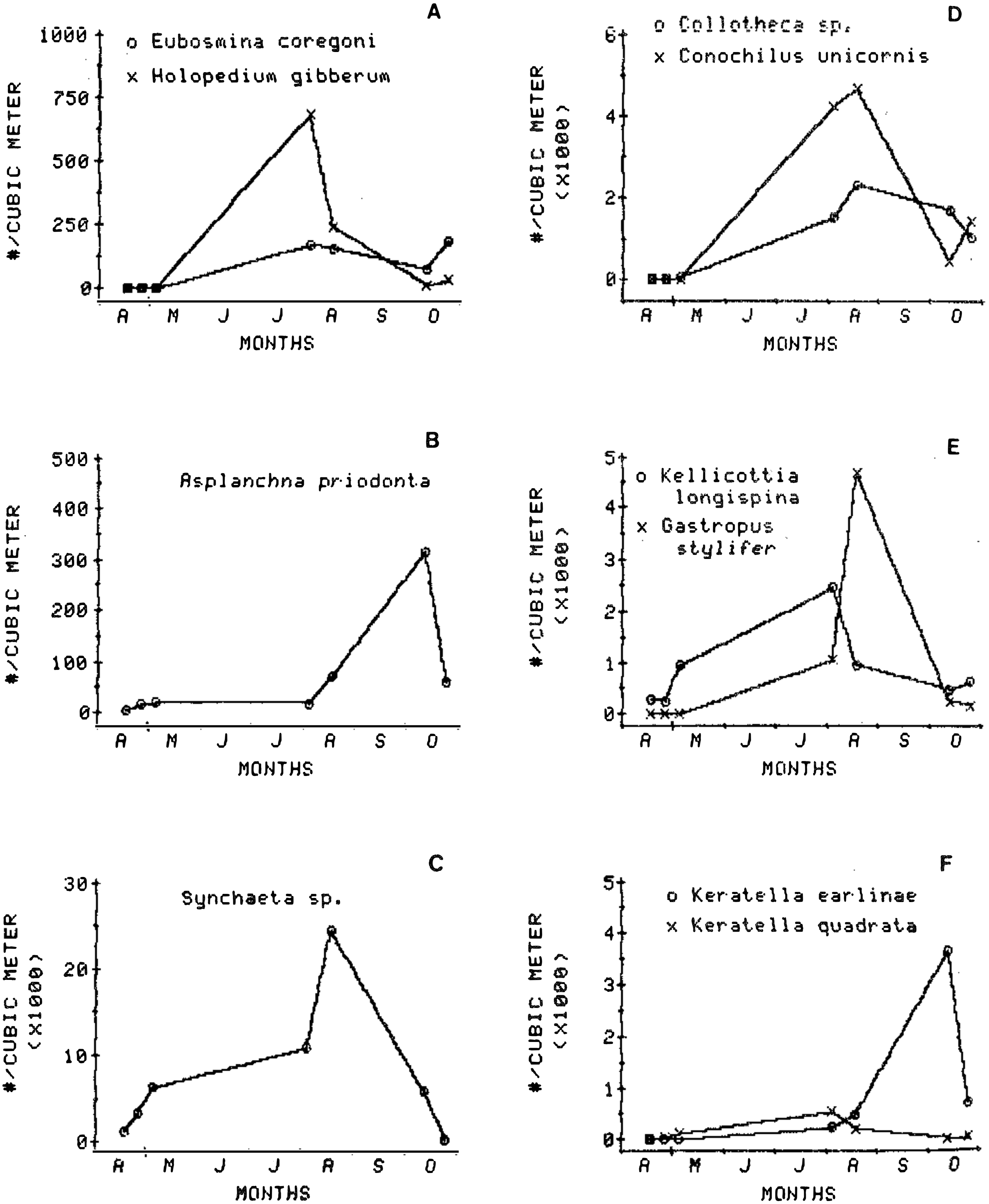


FIGURE 49 Mean seasonal distribution of a) Eubosmina coregoni and Holopedium gibberum, b) Asplanchna priodonta, c) Synchaeta sp., d) Collotheca sp. and Conochilus unicornis, e) Kellicottia longispina and Gastropus stylifer, f) Keratella earlinae and Keratella quadrata, Lake Michigan.

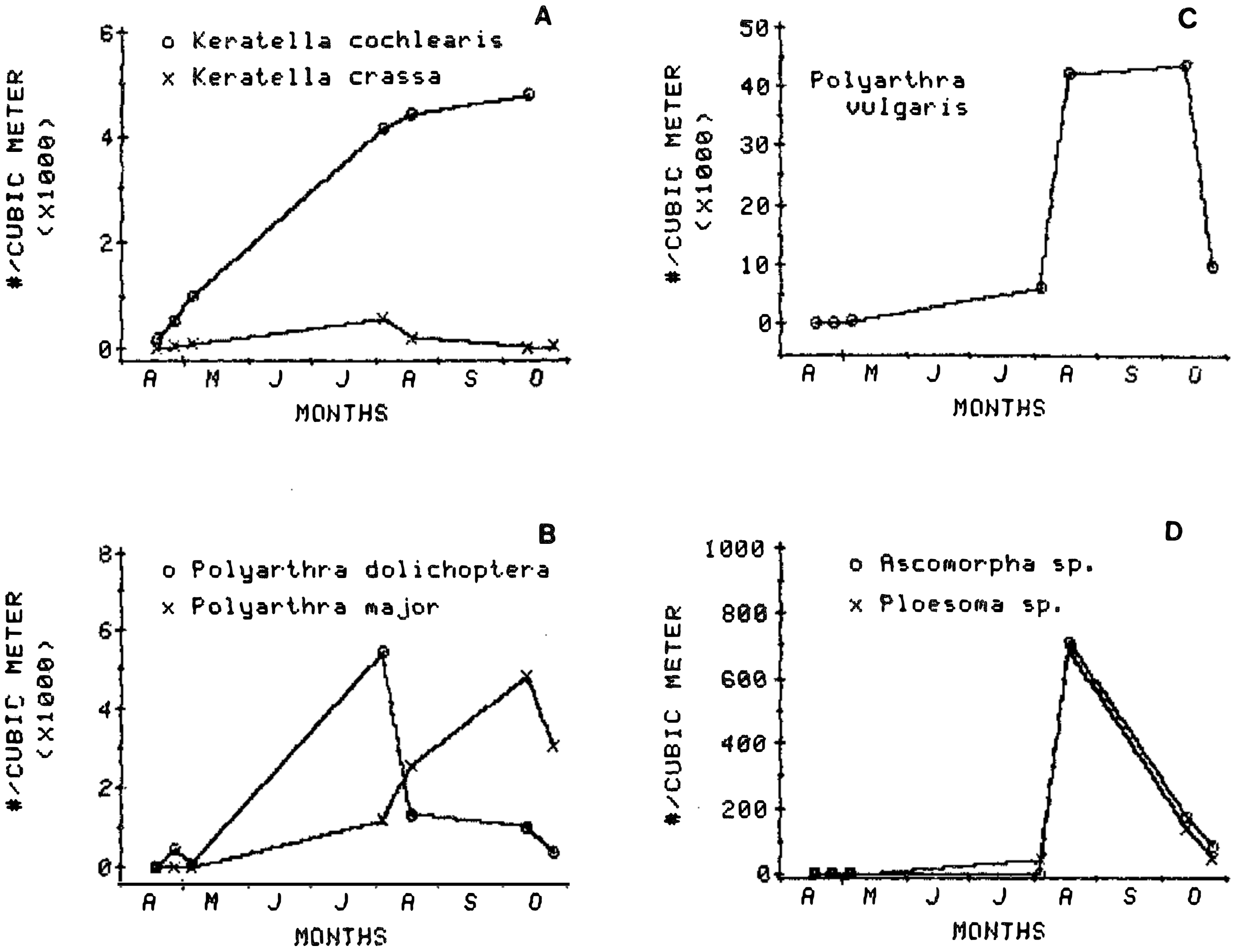


FIGURE 50 Mean seasonal distribution of a) *Keratella cochlearis* and *Keratella crassa*, b) *Polyarthra dolichoptera* and *Polyarthra major*, c) *Polyarthra vulgaris*, d) *Ascomorpha sp.* and *Ploesoma sp.*, Lake Michigan.

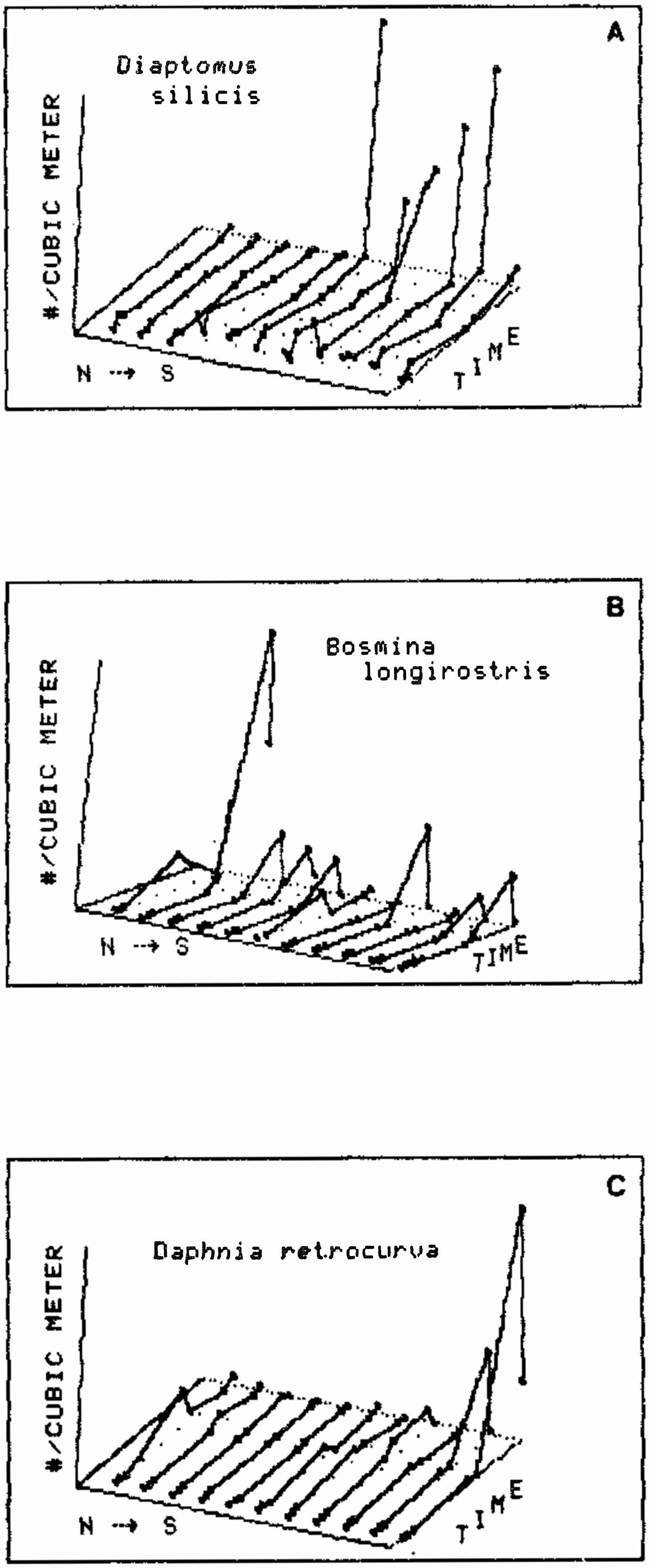


FIGURE 51 Seasonal and geographical distribution of a) *Diaptomus silicis*, b) *Bosmina longirostris*, c) *Daphnia retrocurva*, Lake Michigan.

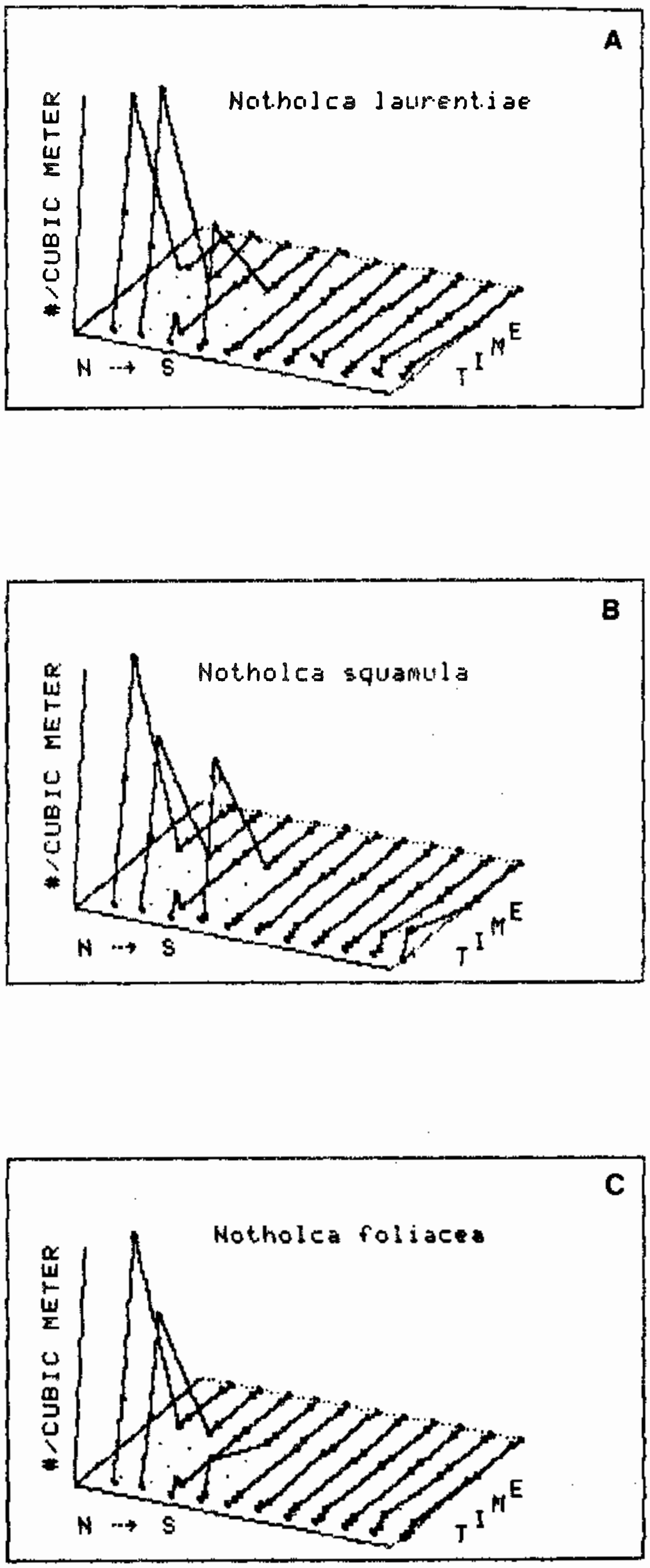


FIGURE 52 Seasonal and geographical distribution of a) *Notholca laurentiae*, b) *Notholca squamula*, c) *Notholca foliacea*, Lake Michigan.

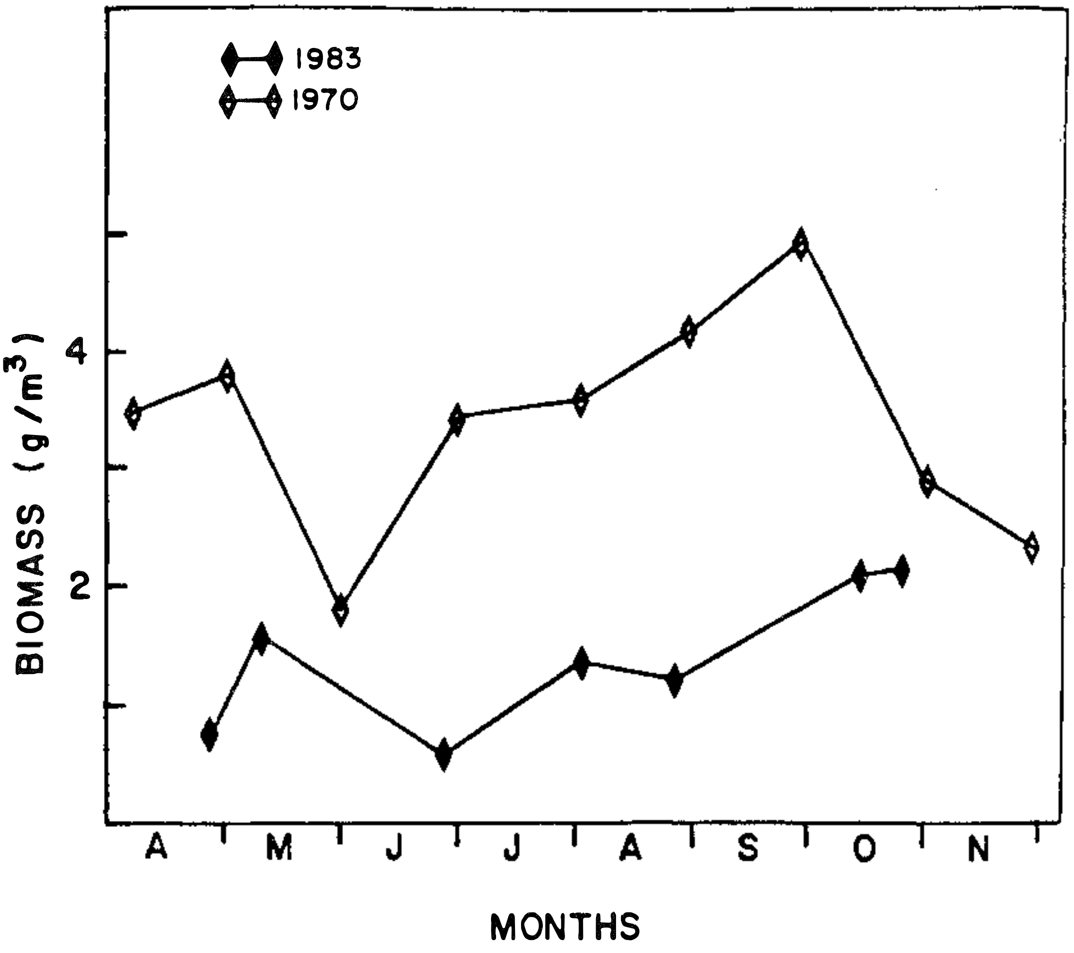


FIGURE 53 Seasonal fluctuation of weighted mean phytoplankton biomass in 1970 and 1983, Lake Erie. 1970 data modified from Munawar and Munawar (1976). Values are corrected by using the weighting factors of 15.6%, 59.6% and 24.6% for the western, central and eastern basins (after Munawar and Munawar 1976).

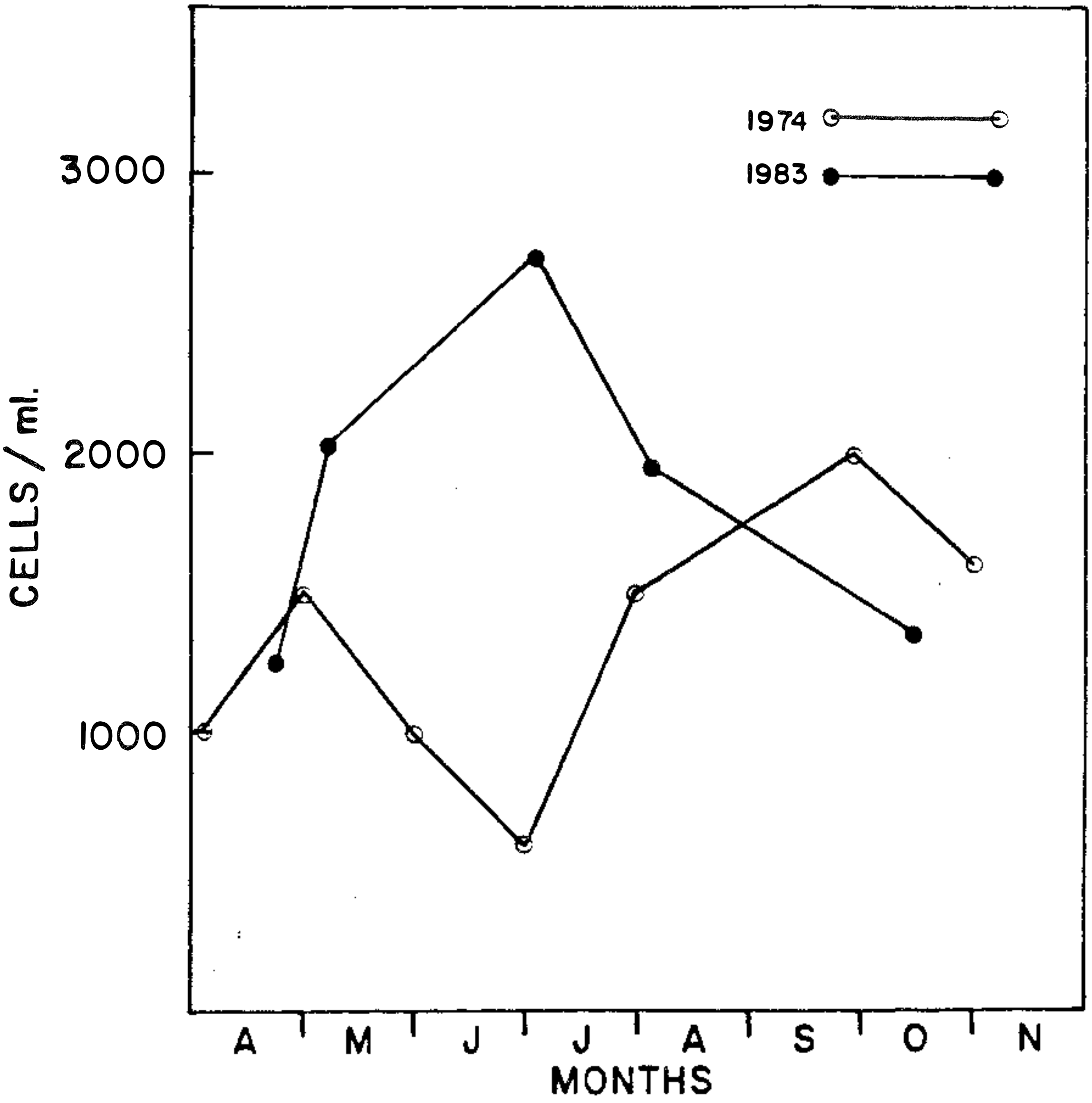


FIGURE 54 Seasonal abundance of phytoplankton in southern Lake Huron. Data from 1974 (Section 8) are modified from Stoermer and Kreis (1980). The 1983 seasonal abundance data from this study have had the density of *Anacystis marina* and *Coccochloris peniocystis* subtracted. 1983 data from southern Lake Huron only (Stations 27, 15, 12, 9, and 6).

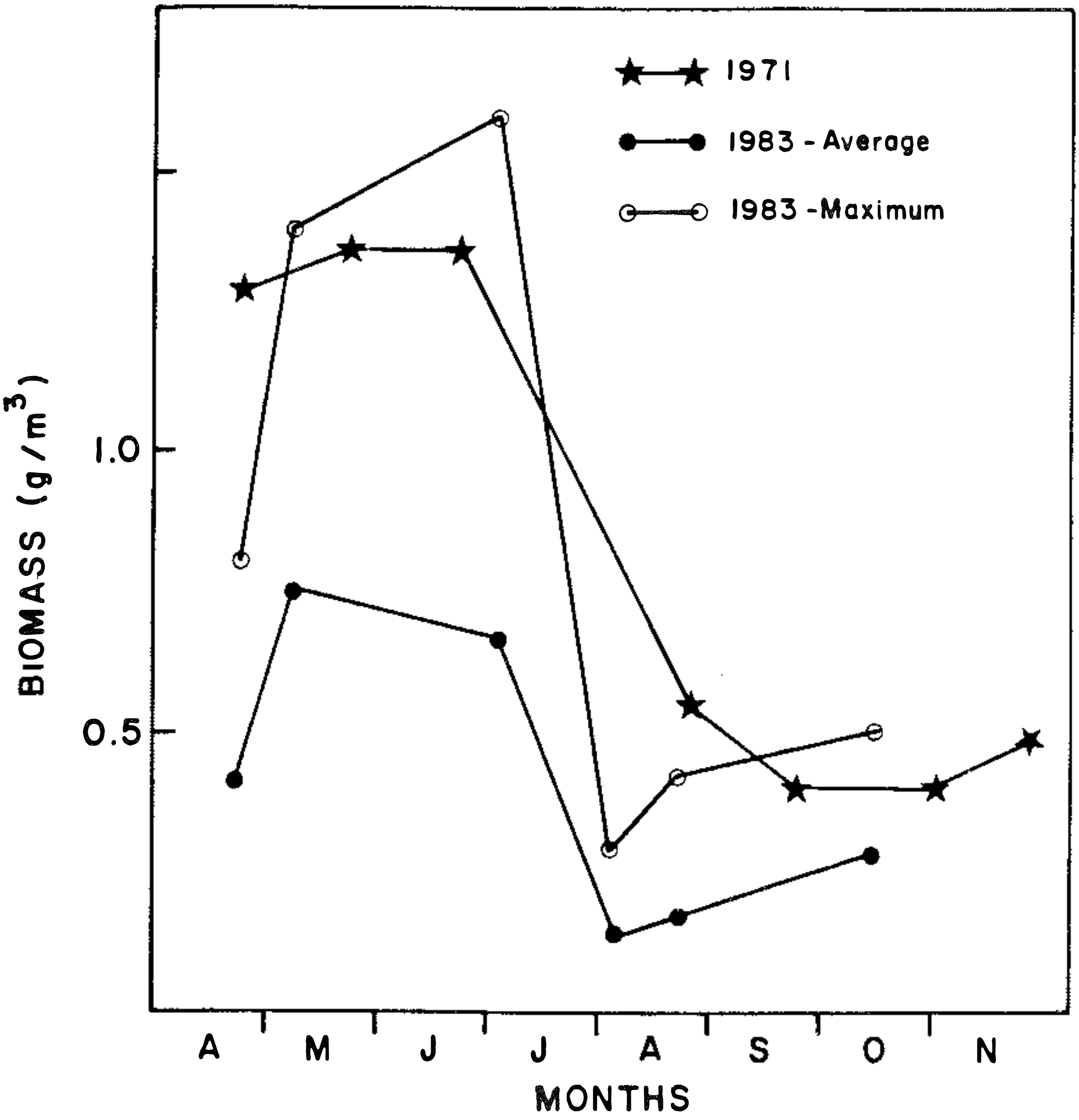


FIGURE 55 Seasonal abundance of phytoplankton in Lake Huron in 1971 and 1983. Data are modified from Munawar and Munawar (1982) and this study. Maximum represents the upper limit of the range of seasonal biomass for ten stations in 1983.

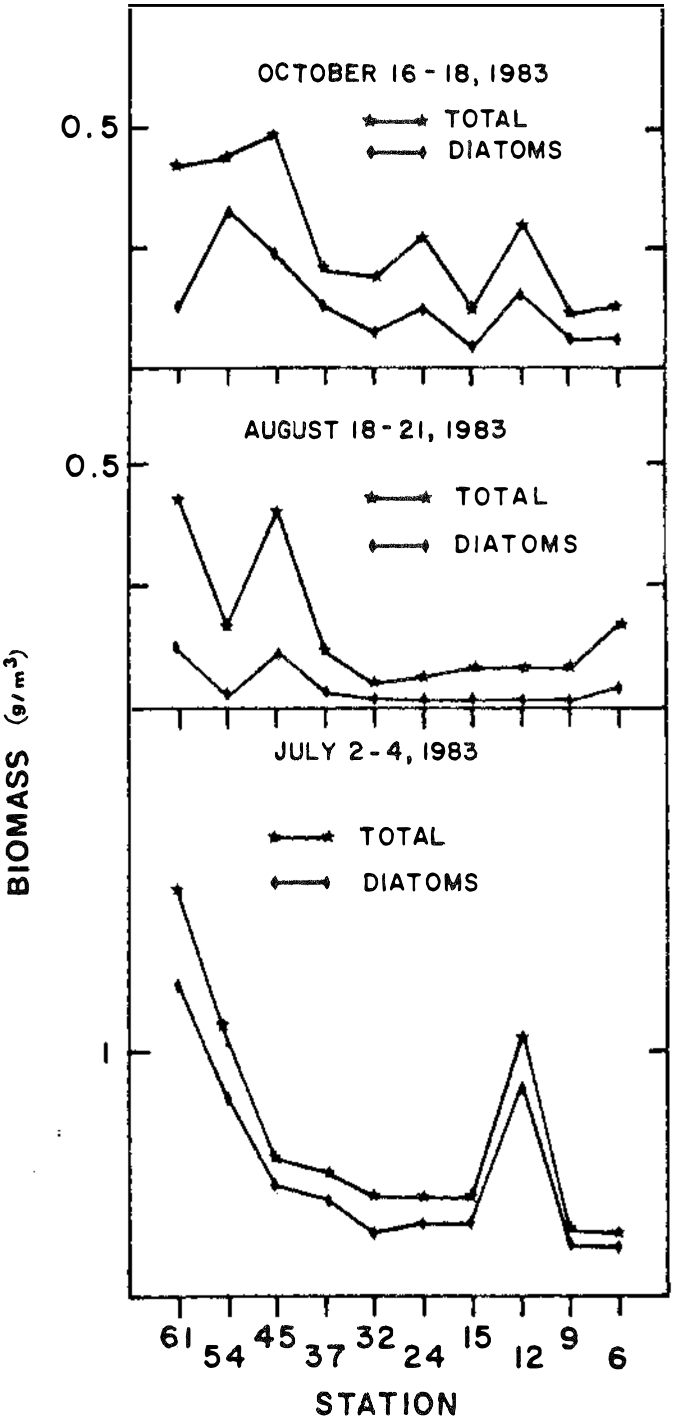


FIGURE 56 Mean seasonal distribution of total algal and diatom biomass on selected dates, Lake Huron, 1983.

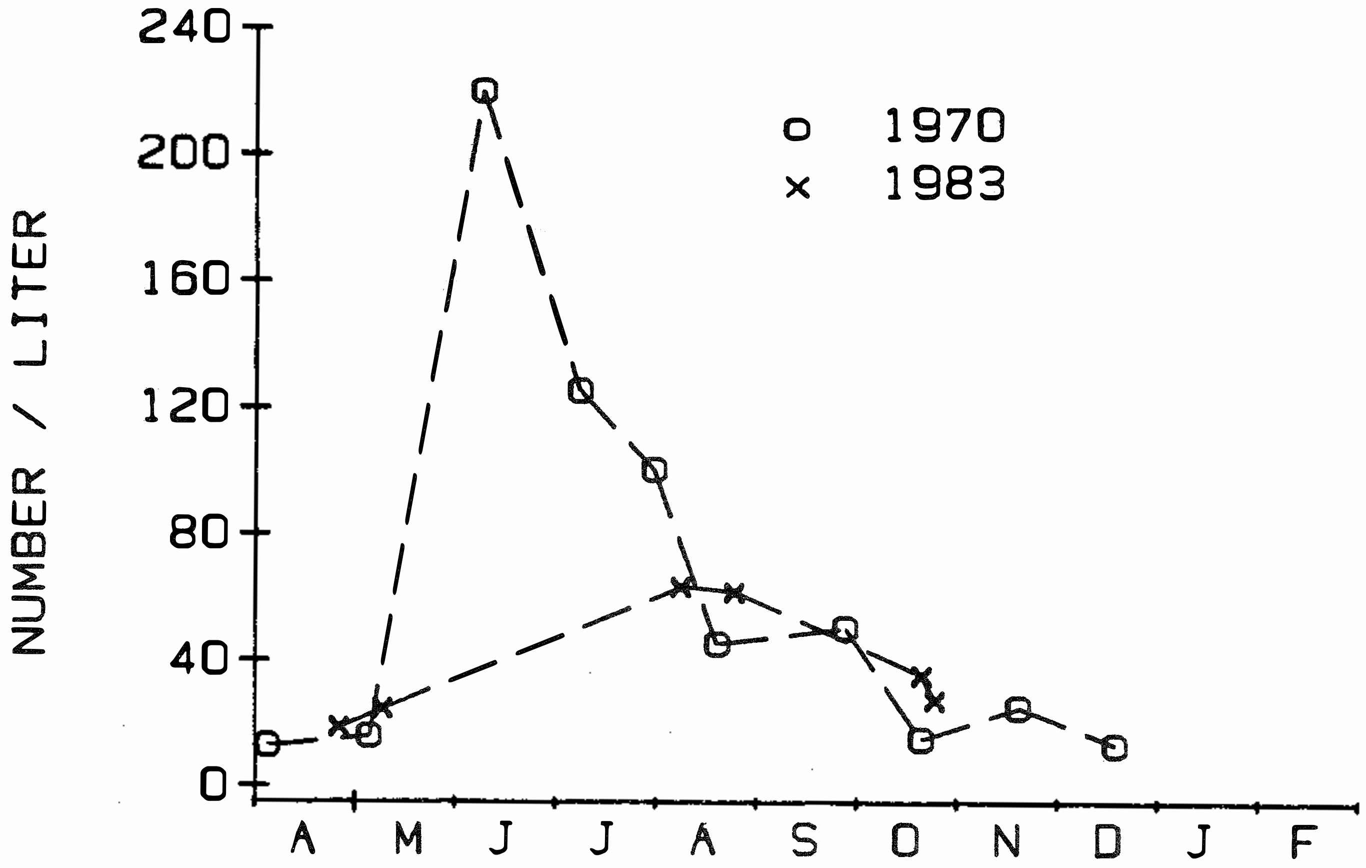


Figure 57 Mean abundance of crustaceans in Lake Erie in 1970 and 1983. 1970 data are modified from Watson and Carpenter (1974).

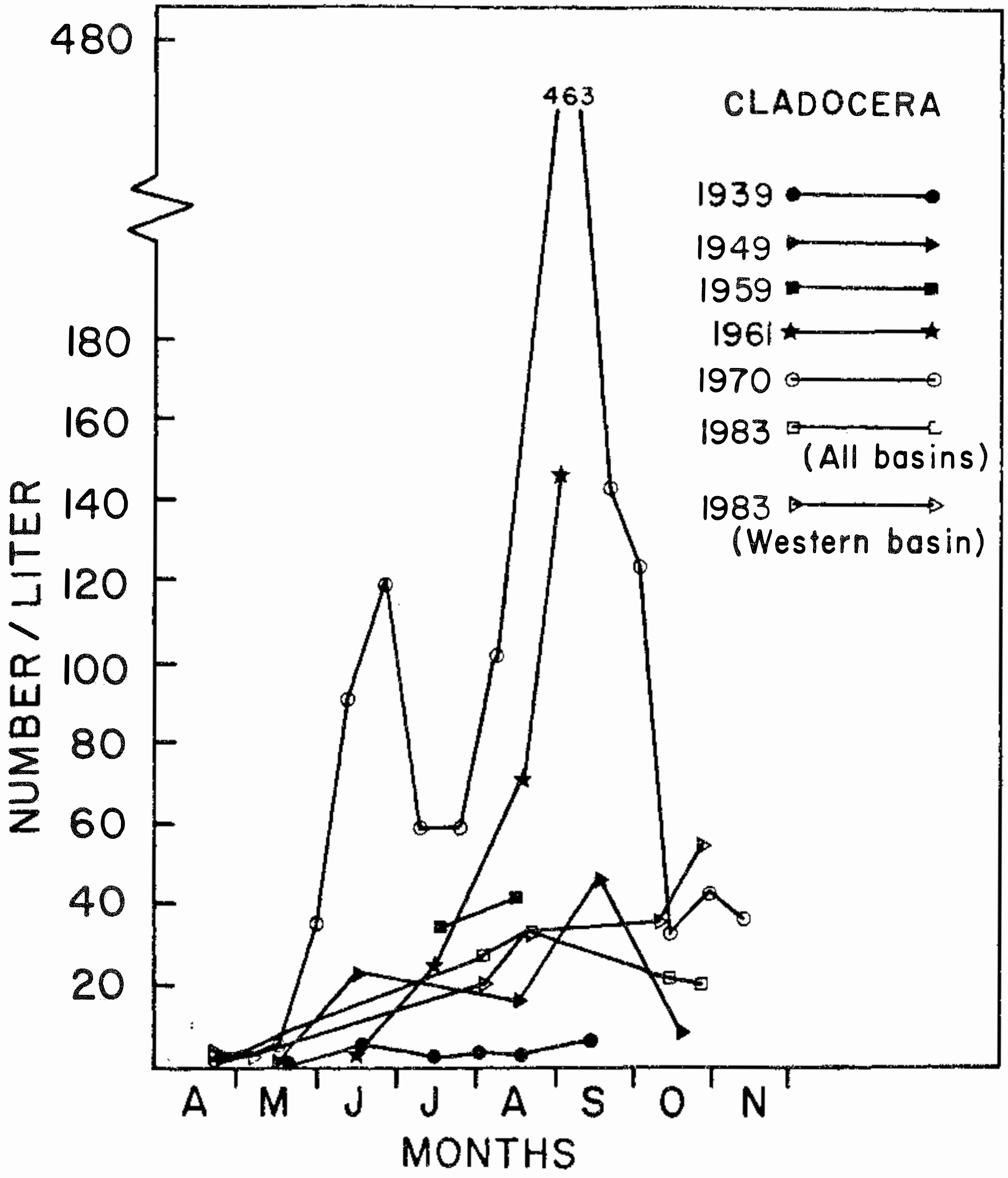


Figure 58 Mean number of cladocerans in Western Lake Erie from 1939 to 1983. Sources: 1939-Chandler (1940); 1949-Bradshaw (1964); 1959-Hubschman (1960); 1961-Britt et al. (1973); 1970-Nalepa (1972). Modified after Nalepa (1972) and Gannon 1981.

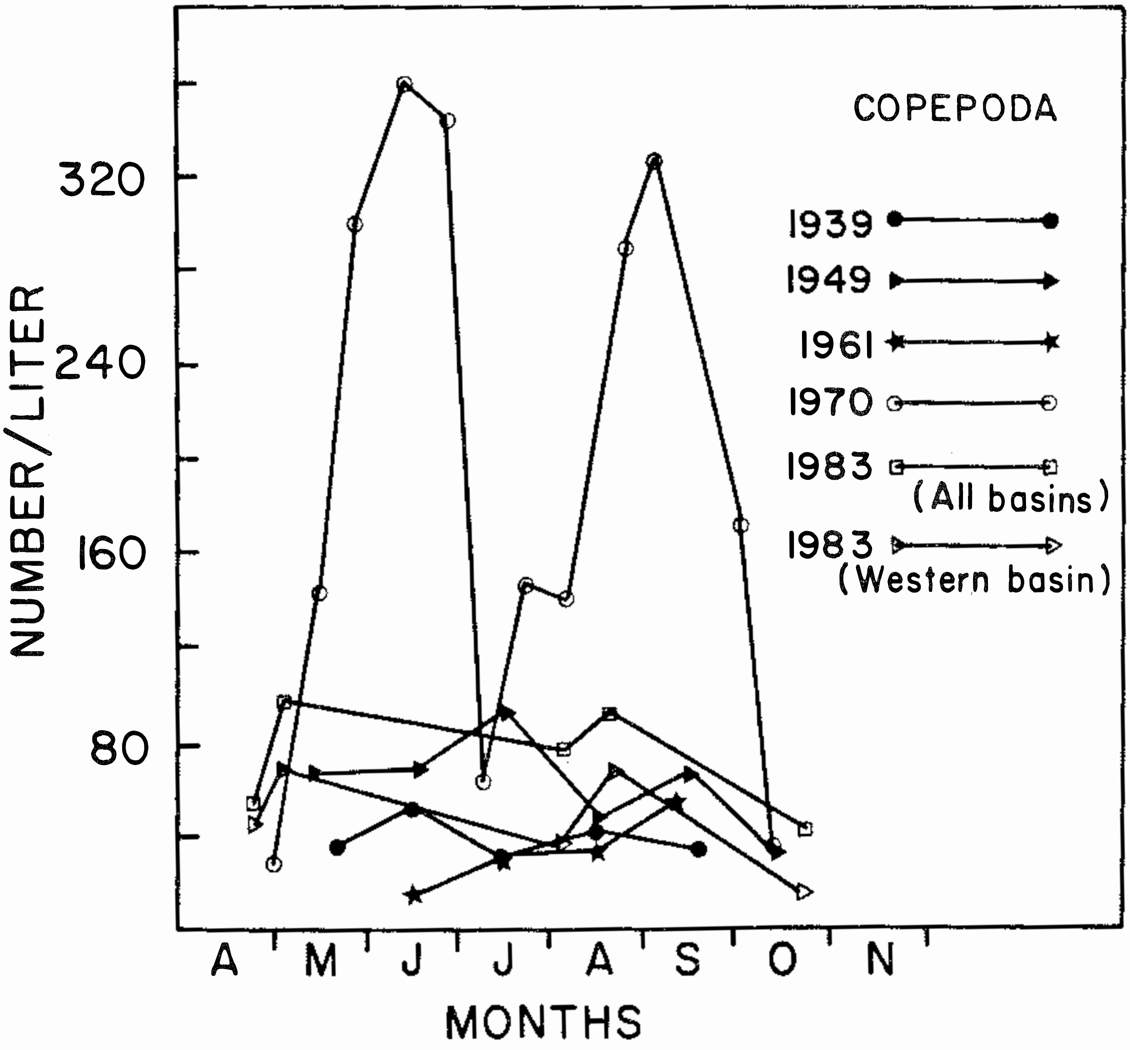


Figure 59 Mean number of copepods in Western Lake Erie from 1939 to 1983. Sources: 1939-Chandler (1940); 1949-Bradshaw (1964); 1959-Hubschman (1960); 1961-Britt et al. (1973); 1970-Nalepa (1972). Modified after Nalepa (1972) and Gannon (1981).

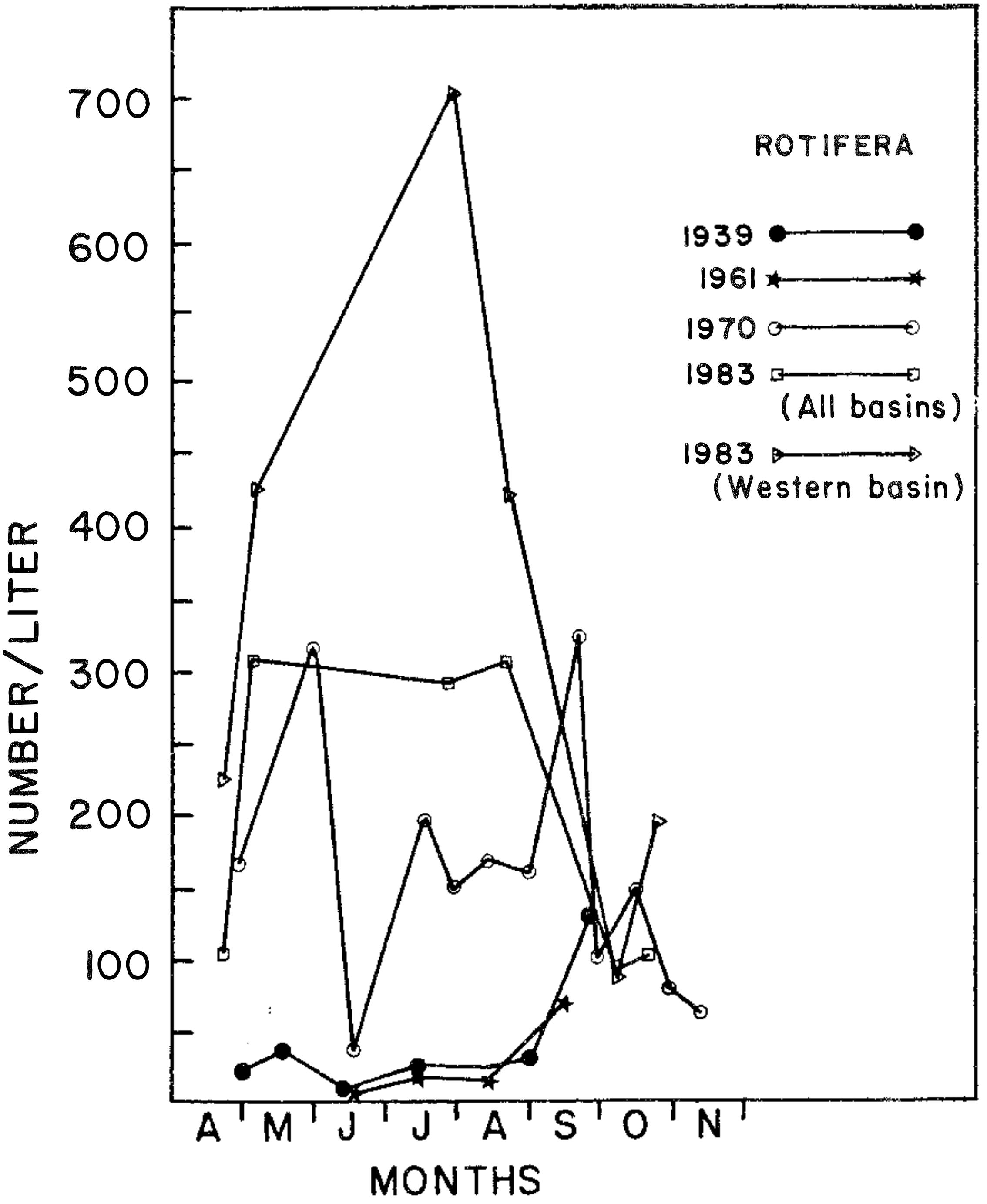


Figure 60 Mean number of rotifers in Western Lake Erie from 1939-1983. Sources: 1939-Chandler (1940); 1961-Britt et al. (1973); 1970-Nalepa (1972). Modified after Nalepa (1972) and Gannon (1981).

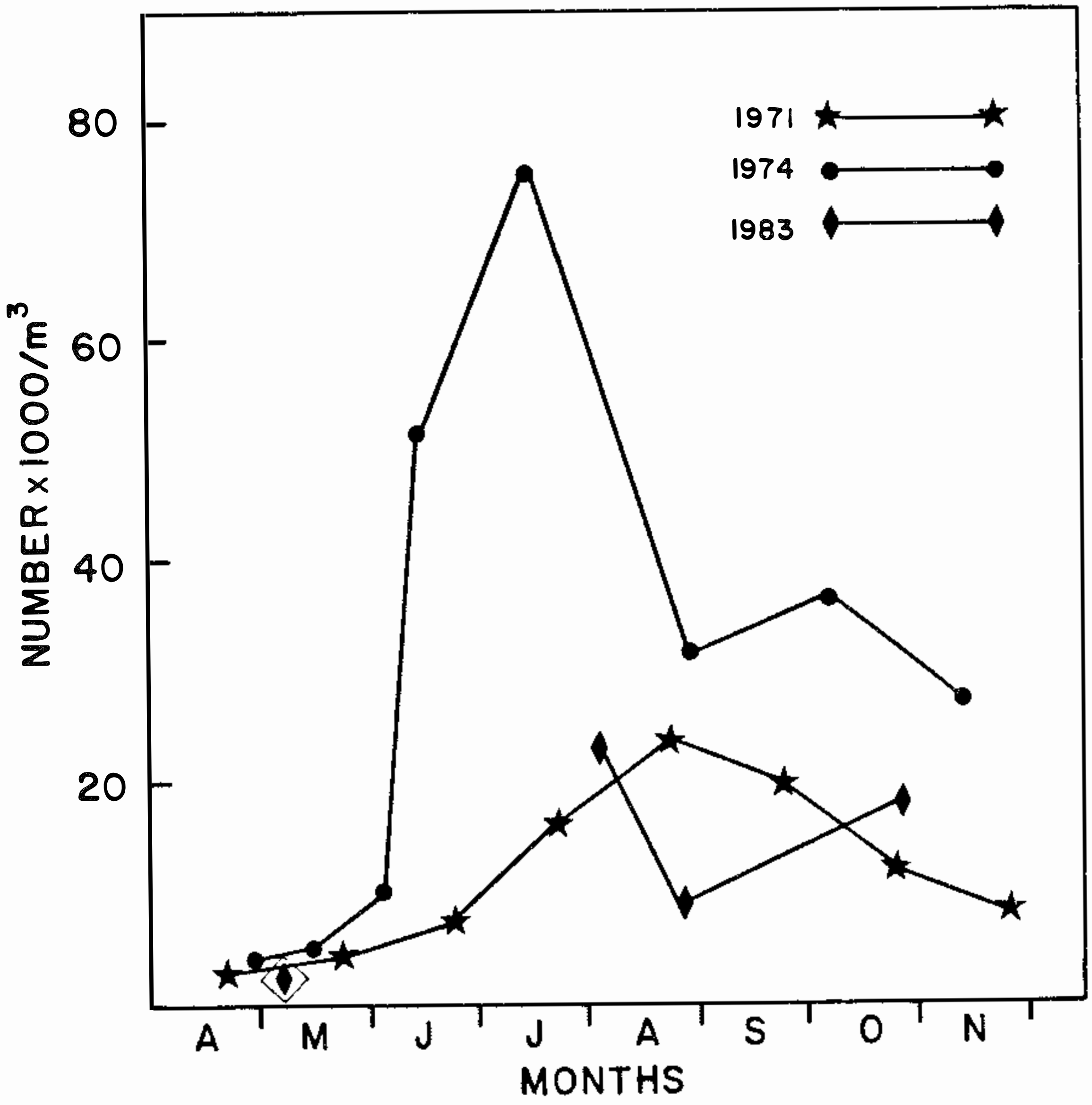


Figure 61 Mean number of crustaceans (exclusive of copepod nauplii) in Lake Huron in 1971, 1974 and 1983. Data are modified from Watson (1974), McNaught et al. (1980) and this study.

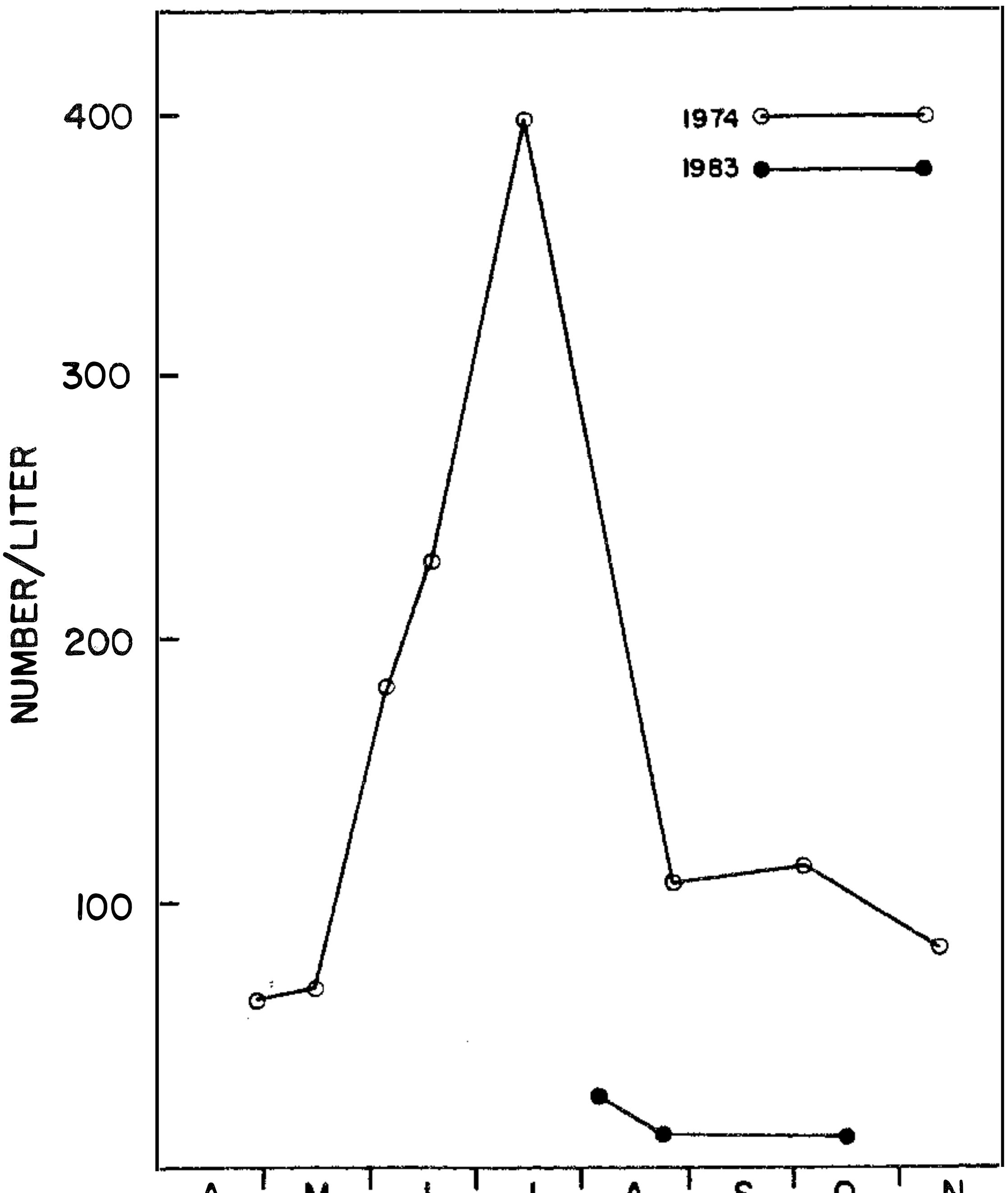


Figure 62 Mean number of rotifers in Lake Huron in 1974 and 1983. 1974 data was modified from Stemberger el al. (1979).

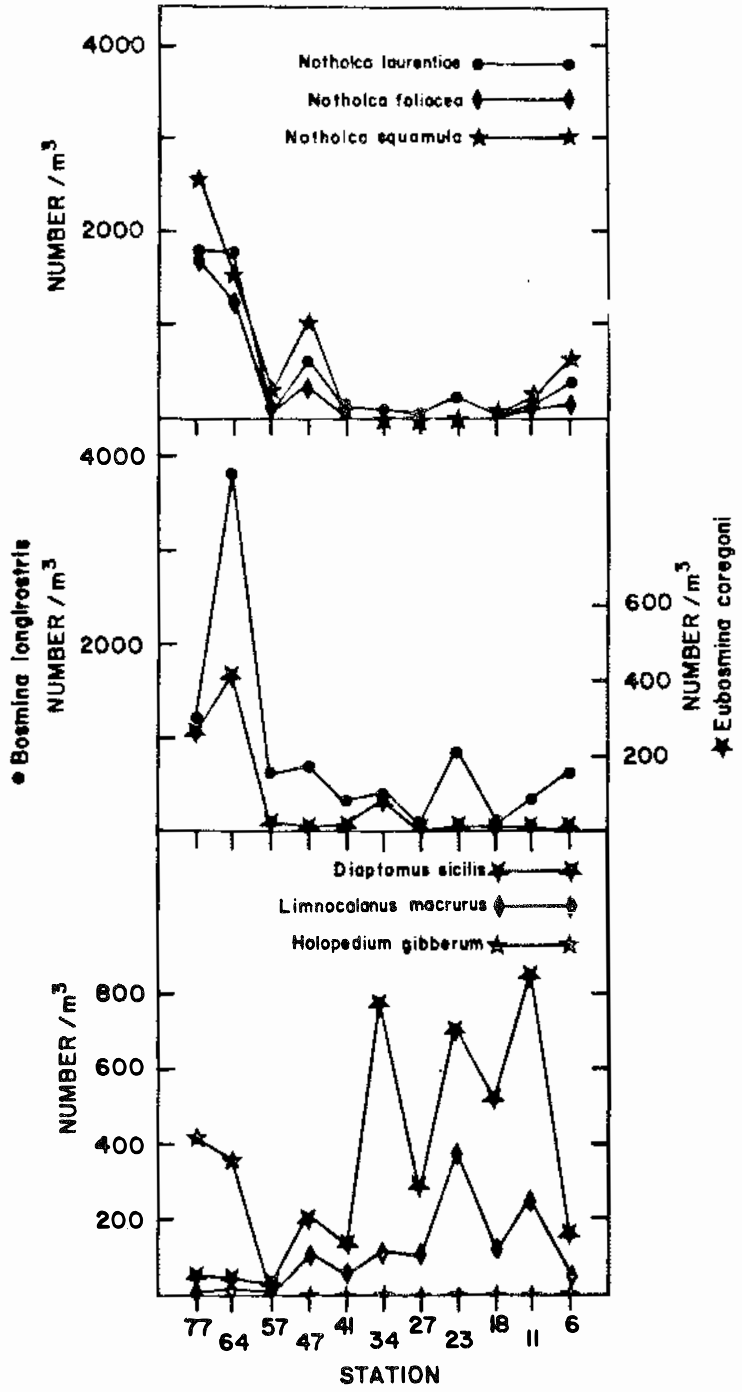


Figure 63 Geographical distribution of *Limnocalanus macrurus*, *Diaptomus sicilis*, *Holopedium gibberum*, *Bosmina longirostris*, *Eubosmina coregoni*, *Notholca laurentiae*, *N. squamula* and *N. foliacea*, Lake Michigan.

## SPECIES LIST - LAKE ERIE PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Achnanthes biasolettiana | (Kutz.) Grun. |
| | Achnanthes bioreti | Germ. |
| | Achnanthes clevei | Grun. |
| | Achnanthes clevei v. rostrata | Hust. |
| | Achnanthes conspicua | A. Mayer |
| | Achnanthes exigua | Grun. |
| | Achnanthes hauckiana | Grun. |
| | Achnanthes lanceolata v. dubia | Grun. |
| | Achnanthes lemmermanni | Hust. |
| | Achnanthes linearis | (W. Sm.) Grun. |
| | Achnanthes linearis fo. curta | H.L. Sm. |
| | Achnanthes microcephala | (Kutz.) Grun. |
| | Achnanthes minutissima | Kutz. |
| | Achnanthes sp. | |
| | Achnanthes sp.? | |
| | Achnanthes sublaevis | Hust. |
| | Actinocyclus normanii f. subsalsa | (Juhl.-Dannf.) Hust. |
| | Actinocyclus sp. | |
| | Amphora ovalis v. affins | (Kutz.) V.H. ex DeT. |
| | Amphora ovalis v. pediculius | (Kutz.) V.H. ex DeT. |
| | Amphora perpusilla | (Grun.) Grun. |
| | Amphora sp. | |
| | Amphora tenuistriata | Mang. in Bourr. & Mang. |
| | Anomoeoneis vitrea | (Grun.) Patr. & Reim. |
| | Asterionella formosa | Hass. |
| | Caloneis bacillaris v. thermalis? | |
| | Caloneis bacillum | (Grun.) Cl. |
| | Caloneis hyalina | Hust. |
| | Caloneis ventricosa v. minuta | (Grun.) Mills |
| | Cocconeis diminuta | Pant. |
| | Cocconeis pediculus | Ehr. |
| | Cocconeis placentula | Ehr. |
| | Cocconeis placentula v. euglypta | (Ehr.) Cl. |
| | Cocconeis placentula v. lineata | (Ehr.) Cl. |
| | Cocconeis sp. | |
| | Coscinodiscus lacustris | Grun. |
| | Cyclotella antiqua? | W. Sm. |
| | Cyclotella atomus | Pant. |
| | Cyclotella atomus? | Pant. |
| | Cyclotella comensis | Grun. |
| | Cyclotella comensis v. 1 | |
| | Cyclotella comensis v. 2 | |
| | Cyclotella comta | (Ehr.) Kutz. |
| | Cyclotella comta v. oligactis | (Ehr.) Grun. |
| | Cyclotella cryptica | Reim. et al. |
| | Cyclotella gamma | Sov. |
| | Cyclotella kuetzingiana | Thw. |
| | Cyclotella kuetzingiana v. planetophora | Fricke |
| | Cyclotella kuetzingiana v. planetophora? | Fricke |
| | Cyclotella meneghiniana | Kutz. |
| | Cyclotella michiganiana | Skv. |
| | Cyclotella ocellata | Pant. |

## SPECIES LIST - LAKE ERIE PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Cyclotella operculata | (Ag.) Kutz. |
| | Cyclotella pseudostelligera | Hust. |
| | Cyclotella sp. | |
| | Cyclotella sp. #1 | |
| | Cyclotella stelligera | (Cl. & Grun.) V.H. |
| | Cyclotella woltereckí | Hust. |
| | Cymatopleura solea | (Breb. & Godey) W. Sm. |
| | Cymatopleura solea v. apiculata | (W. Sm.) Ralfs |
| | Cymbella affinis | Kutz. |
| | Cymbella microcephala | Grun. |
| | Cymbella minuta | Hilse |
| | Cymbella minuta v. silesiaca | (Bleisch) Reim. |
| | Cymbella prostrata v. auerswaldii | (Rabh.) Reim. |
| | Cymbella pusilla | Grun. |
| | Cymbella sp. | |
| | Denticula tenuis v. crassula | (Nag.) W. & G.S. West. |
| | Diatoma anceps | (Ehr.) Kirchn. |
| | Diatoma tenue v. elongatum | Lyngb. |
| | Diatoma vulgare | Bory |
| | Diploneis oculata | (Breb.) Cl. |
| | Entomoneis ornata | (J.W. Bail.) Reim. |
| | Fragilaria brevistriata | Grun. |
| | Fragilaria brevistriata v. inflata | (Pant.) Hust. |
| | Fragilaria capucina | Desm. |
| | Fragilaria construens | (Ehr.) Grun. |
| | Fragilaria construens v. minuta | Temp. & Per. |
| | Fragilaria construens v. pumila | Grun. |
| | Fragilaria construens v. venter | (Ehr.) Grun. |
| | Fragilaria crotonensis | Kitton |
| | Fragilaria intermedia v. fallax | (Grun.) Stoerm. & Yang |
| | Fragilaria leptostauron | (Ehr.) Hust. |
| | Fragilaria leptostauron v. dubia | (Grun.) Hust. |
| | Fragilaria nitzschicides | Grun. |
| | Fragilaria pinnata | Ehr. |
| | Fragilaria pinnata v. lancettula | (Schum.) Hust. |
| | Fragilaria pinnata v. pinnata | |
| | Fragilaria sp. | |
| | Fragilaria vaucheriae | (Kutz.) Peters. |
| | Gomphonema clevei | Fricke |
| | Gomphonema dichotomum | Kutz. |
| | Gomphonema parvulum | Kutz. |
| | Gomphonema sp. | |
| | Gomphonema tergestinum | (Grun.) Fricke |
| | Gyrosigma attenuatum | (Kutz.) Rabh. |
| | Gyrosigma scictense | (Sulliv. & Wormley) Cl. |
| | Melosira agassizii v. malayensis | Ostenf. |
| | Melosira distans | (Ehr.) Kutz. |
| | Melosira distans v. limnetica | O. Mull. |
| | Melosira granulata | (Ehr.) Ralfs |
| | Melosira granulata v. angustissima | O. Mull. |
| | Melosira granulata? | (Ehr.) Ralfs |
| | Melosira islandica | O. Mull. |

## SPECIES LIST - LAKE ERIE PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Melosira italica subsp. subarctica | O. Mull. |
| | Melosira sp. | |
| | Navicula acceptata | Hust. |
| | Navicula anglica | Ralfs |
| | Navicula capitata | Ehr. |
| | Navicula capitata v. hurgarica | (Grun.) Ross |
| | Navicula capitata v. luneburgensis | (Grun.) Patr. |
| | Navicula cincta | (Ehr.) Ralfs |
| | Navicula cocconeiformis | Greg. |
| | Navicula cryptocephala | Kutz. |
| | Navicula cryptocephala v. veneta | (Kutz.) Rabh. |
| | Navicula exigua | Greg. ex Grun. |
| | Navicula exigua v. capitata | Patr. |
| | Navicula lanceolata | (Ag.) Kutz. |
| | Navicula menisculus | Schum. |
| | Navicula menisculus v. upsaliensis | (Grun.) Grun. |
| | Navicula minima | Grun. |
| | Navicula pseudoscutiformis | Hust. |
| | Navicula pupula | Kutz. |
| | Navicula radiosa v. tenella | (Breb.) Cl. & Moll. |
| | Navicula salinarum v. intermedia | (Grun.) Cl. |
| | Navicula seminulcides | Hust. |
| | Navicula seminulum | Grun. |
| | Navicula sp. | |
| | Navicula stroemii | Hust. |
| | Navicula terminata | Hust. |
| | Navicula tripunctata | (O.F.Mull.) Bory |
| | Navicula viridula v. rostellata | (Kutz.) Cl. |
| | Navicula vitabunda | Hust. |
| | Navicula zanoni | Hust. |
| | Neidium affine | Pfitz. |
| | Nitzschia acicularioides | Arch. non Hust. |
| | Nitzschia acicularis | (Kutz.) W. Sm. |
| | Nitzschia acicularis? | (Kutz.) W. Sm. |
| | Nitzschia acula | Hantz. ex Cl. & Grun. |
| | Nitzschia amphibia | Grun. |
| | Nitzschia angustata | (W. Sm.) Grun. |
| | Nitzschia angustata v. acuta | Grun. |
| | Nitzschia apiculata | (Greb.) Grun. |
| | Nitzschia archbaldii | L.-B. |
| | Nitzschia closterium | (Ehr.) W. Sm. |
| | Nitzschia confinis | Hust. |
| | Nitzschia dissipata | (Kutz.) Grun. |
| | Nitzschia dissipata v. media | (Hantz.) Grun. |
| | Nitzschia fonticola | Grun. |
| | Nitzschia frustulum | (Kutz.) Grun. |
| | Nitzschia gancersheimiensis | Krasske |
| | Nitzschia gracilis | Hantz. |
| | Nitzschia hantzschiana | Rabh. |
| | Nitzschia inconspicua | Grun. |
| | Nitzschia intermedia | Hantz. |
| | Nitzschia kuetzingiana | Hilse |

# SPECIES LIST - LAKE ERIE PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Nitzschia kuetzingioides? | |
| | Nitzschia lauerburgiana | Hust. |
| | Nitzschia linearis | W. Sm. |
| | Nitzschia palea | (Kutz.) W. Sm. |
| | Nitzschia palea v. debilis | (Kutz.) Grun. |
| | Nitzschia palea v. tenuirostris | Grun. |
| | Nitzschia paleacea | Grun. |
| | Nitzschia pumila | Hust. |
| | Nitzschia pura | Hust. |
| | Nitzschia pusilla | (Kutz.) Grun. em. L.-B. |
| | Nitzschia recta | Hantz. |
| | Nitzschia romana | Grun. |
| | Nitzschia rostellata | Hust. |
| | Nitzschia sociabilis | Hust. |
| | Nitzschia sp. | |
| | Nitzschia spiculoides | Hust. |
| | Nitzschia subacicularis | Hust. |
| | Nitzschia sublinearis | Hust. |
| | Nitzschia tenuis | W. Sm. |
| | Nitzschia tropica | Hust. |
| | Nitzschia tryblionella | |
| | Nitzschia tryblionella v. debilis | (Arnott) A. Mayer |
| | Nitzschia tryblionella v. victoriae | Grun. |
| | Nitzschia tryblionella v. victoriae? | Grun. |
| | Rhizosolenia eriensis | H.L. Sm. |
| | Rhizosolenia longiseta | Zach. |
| | Rhizosolenia sp. | |
| | Skeletonema potamos | (Weber) Hasle & Evens. |
| | Stauroneis kriegeri | Patr. |
| | Stephanodiscus alpinus | Hust. |
| | Stephanodiscus alpinus - auxospore | |
| | Stephanodiscus alpinus? | Hust. |
| | Stephanodiscus binderanus | (Kutz.) Krieg. |
| | Stephanodiscus hantzschii | Grun. |
| | Stephanodiscus minutus | Grun. |
| | Stephanodiscus minutus - auxospore | |
| | Stephanodiscus niagarae | Ehr. |
| | Stephanodiscus niagarae - auxospore | |
| | Stephanodiscus niagarae v. magnifica | Fricke |
| | Stephanodiscus sp. | |
| | Stephanodiscus sp. #03 | |
| | Stephanodiscus sp. #04 | |
| | Stephanodiscus sp. #07 | |
| | Stephanodiscus sp. -auxospore | |
| | Stephanodiscus tenuis | Hust. |
| | Stephanodiscus tenuis v. #01 | |
| | Stephanodiscus tenuis v. #02 | |
| | Stephanodiscus tenuis? | Hust. |
| | Surirella birostrata | Hust. |
| | Surirella ovata | Kutz. |
| | Surirella ovata v. pinnata | (W. Sm.) Hust. |
| | Surirella ovata v. salina | (W. Sm.) Hust. |

## SPECIES LIST - LAKE ERIE PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Surirella sp. | |
| | Surirella turgida | W. Sm. |
| | Synedra acus? | Kutz. |
| | Synedra amphicephala v. austrica | (Grun.) Hust. |
| | Synedra delicatissima | W. Sm. |
| | Synedra delicatissima v. angustissima | Grun. |
| | Synedra filiformis | Grun. |
| | Synedra filiformis v. exilis | A. Cl. |
| | Synedra miniscula | Grun. |
| | Synedra parasitica | W. Sm. |
| | Synedra ulna v. longissima | (W. Sm.) Brun. |
| | Tabellaria fenestrata | Kutz. |
| | Tabellaria fenestrata v. geniculata | A. Cl. |
| | Tabellaria flocculosa | (Roth) Kutz. |
| | Tabellaria flocculosa v. linearis | Koppen |
| | Tabellaria sp. | |
| | Thalassiosira fluviatilis | Hust. |
| CAT | Vacuolaria sp. | |
| CHL | Actinastrum gracilimum | G.M. Smith |
| | Ankistrodesmus sp. #02 | |
| | Ankyra judayi | (G.M. Sm.) Fott |
| | Carteria sp. | |
| | Carteria sp. -cvoid | |
| | Carteria sp. -sphere | |
| | Chlamydocapsa planktonica | (W. & G.S. West) Fott |
| | Chlamydocapsa sp. | |
| | Chlamydomonas sp. | |
| | Chlamydomonas sp. - ovoid | |
| | Chlamydomonas sp. - sphere | |
| | Chlorogonium minimum | Playf. |
| | Chlorogonium sp. | |
| | Closterium aciculare | T. West |
| | Closterium parvulum | Nag. |
| | Closterium sp. | |
| | Coelastrum cambricum | Arch. |
| | Coelastrum microporum | Nag. in A. Braun |
| | Coelastrum sp. | |
| | Cosmarium sp. | |
| | Crucigenia irregularis | Wille |
| | Crucigenia quadrata | Morren |
| | Crucigenia rectangularis | A. Braun |
| | Crucigenia tetrapedia | (Kirch.) W. & G.S. West |
| | Dictyosphaerium ehrenbergianum | Nag. |
| | Dictyosphaerium pulchellum | Wood. |
| | Elakatothrix gelatinosa | Wille |
| | Elakatothrix viridis | (Snow) Printz |
| | Eudorina elegars | Ehr. |
| | Franceia ovalis | (France) Lemm. |
| | Golenkinia radiata | (Chod.) Wille |
| | Green Filament | |

# SPECIES LIST - LAKE ERIE PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| CHL | Green coccoid #04 | |
| | Green coccoid - acicular | |
| | Green coccoid - bacilliform | |
| | Green coccoid - bicells | |
| | Green coccoid - fusiform bicells | |
| | Green coccoid - oval | |
| | Green coccoid - ovoid | |
| | Green coccoid - sphere | |
| | Green flagellate - sphere | |
| | Kirchneriella contorta | (Schmid.) Bohlm |
| | Kirchneriella obesa | (W. West) Schmidle |
| | Lagerheimia balatonica | (Scherff. in Kol) Hind. |
| | Lagerheimia ciliata | (Lagerh.) Chod. |
| | Lagerheimia genevensis | (Chod.) Chod. |
| | Lagerheimia longiseta v. major | G.M. Sm. |
| | Lagerheimia quadriseta | (Lemm.) G.M. Sm. |
| | Lagerheimia sp. | |
| | Lagerheimia subsalsa | Lemm. |
| | Lobomonas sp.? | |
| | Micractinium pusillum | Fresenius |
| | Monoraphidium contortum | (Thur.) Kom.-Legn. |
| | Monoraphidium griffithii | (Berkel.) Kom.-Legn. |
| | Monoraphidium irregulare | (G.M. Sm.) Kom.-Legn. |
| | Monoraphidium minutum | (Nag.) Kom.-Legn. |
| | Mougeotia sp. | |
| | Nephrocytium Agardhianum | Nag. |
| | Nephrocytium limneticum | (G.M. Sm.) G.M. Sm. |
| | Nephrocytium limneticum? | (G.M. Sm.) G.M. Sm. |
| | Oedogonium sp. | |
| | Oocystis sp. | |
| | Oocystis sp. #1 | |
| | Oocystis sp.? | |
| | Oocystis borgei | Snow |
| | Oocystis crassa | Wittr. in Wittr. & Nord. |
| | Oocystis elliptica v. minor | W. West |
| | Oocystis lacustris | Chod. |
| | Oocystis marsonii | Lemm. |
| | Oocystis parva | West & West |
| | Oocystis pusilla | Hansg. |
| | Oocystis solitaria | Wittr. in Wittr. & Nord. |
| | Oocystis submarina | Lagerh. |
| | Pandorina morum? | (Muell.) Bory |
| | Paradoxia multiseta | Swir. |
| | Pediastrum boryanum | (Turp.) Menegh. |
| | Pediastrum duplex v. clathratum | (A. Braun) Lagerh. |
| | Pediastrum duplex v. reticulatum | Lagerh. |
| | Pediastrum simplex | (Meyen) Lemm. |
| | Pediastrum simplex v. duodenarium | (Bail.) Rabh. |
| | Pediastrum sp. | |
| | Scenedesmus abundans | (Kirch.) Chod. |
| | Scenedesmus acuminatus | (Lagerh.) Chod. |
| | Scenedesmus arcuatus | Lemm. |

## SPECIES LIST - LAKE ERIE PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| CHL | Scenedesmus armatus | (Chod.) G.M. Sm. |
| | Scenedesmus bicaudatus | (Hansg.) Chod. |
| | Scenedesmus carinatus | (Lemm.) Chod. |
| | Scenedesmus denticulatus | Lagerh. |
| | Scenedesmus ecornis | (Ralfs) Chod. |
| | Scenedesmus intermedius | Chod. |
| | Scenedesmus intermedius v. bicaudatus | Hortob. |
| | Scenedesmus quadricauda | (Turp.) Breb. |
| | Scenedesmus securiformis | Playf. |
| | Scenedesmus sp. | |
| | Scenedesmus spinosus | Chod. |
| | Scenedesmus spinosus? | Chod. |
| | Schroederia setigera | (Schroed.) Lemm. |
| | Sphaerellocystis lateralis | Fott & Novak. |
| | Sphaerellopsis sp. | |
| | Sphaerocystis schroeteri | Chod. |
| | Staurastrum paradoxum | Meyen |
| | Staurastrum sp. | |
| | Stichococcus sp. | |
| | Tetraedron caudatum | (Corda) Hansg. |
| | Tetraedron minimum | (A. Braun) Hansg. |
| | Tetraedron muticum | (A. Braun) Hansg. |
| | Tetraedron regulare v. incus | Teilung |
| | Tetraspora lacustris | Lemm. |
| | Tetrastrum heteracanthum | (Nordst.) Chod. |
| | Tetrastrum staurogeniaeforme | (Schroed.) Lemm. |
| | Treubaria planktonica | (G.M. Sm.) Korch. |
| | Treubaria setigera | (Arch.) G.M. Sm. |
| | Treubaria sp. | |
| CHR | Bitrichia chodatii | (Rev.) Chod. |
| | Chrysolykos planktonicus | Mack. |
| | Chrysolykos skujae | (Nauw.) Bourr. |
| | Chrysosphaerella longispina | Laut. em. Nich. |
| | Dinobryon acuminatum | Rutt. |
| | Dinobryon bavaricum | Imhof |
| | Dinobryon cylindricum | Imhof |
| | Dinobryon divergens | Imhof |
| | Dinobryon sertularia | Ehr. |
| | Dinobryon sociale v. americanum | (Brunnth.) Bachm. |
| | Dinobryon sp. | |
| | Dinobryon stokesii v. epiplanktonicum | Skuja |
| | Dinobryon utriculus v. tabellariae | Lemm. |
| | Haptophyte sp. | |
| | Kephyrion cupuliformae | Conr. |
| | Kephyrion sp. #1 -Pseudokephyrion entzii | |
| | Kephyrion sp. #2 | |
| | Kephyrion sp. #3 | |
| | Mallomonas sp. | |
| | Ochromonas sp. | |
| | Ochromonas sp. - ovoid | |
| | Paraphysomonas sp.? | |

# SPECIES LIST - LAKE ERIE PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| CHR | Pseudokephyrion millerense | Nich. |
| | Pseudokephyrion sp. #1 | |
| | Pseudotetraedron neglectum | Pasch. |
| | Unidentified coccoids | |
| | Unidentified flagellate | |
| | Unidentified loricate - ovoid | |
| | Unidentified loricate - sphere | |
| COL | Bicoeca campanulata | (Lack.) Bourr. em. Skuja |
| | Bicoeca crystallina | Skuja |
| | Bicoeca sp. | |
| | Bicoeca sp. #01 | |
| | Bicoeca sp. #04 | |
| | Bicoeca sp. #05 | |
| | Bicoeca tubiformis | Skuja |
| | Codonosiga sp. | |
| | Colorless flagellates | |
| | Colorless flagellates - colonial | |
| | Monosiga ovata | Kent |
| | Salpingoeca amphorae | Kent |
| | Salpingoeca gracilis | Clark |
| | Stelexmonas dichotoma | Lack. |
| | Stylotheca aurea | (Bachm.) Boloch. |
| CRY | Chroomonas acuta | Uterm. |
| | Chroomonas norstedtii | Hansg. |
| | Cryptomonas - cyst | |
| | Cryptomonas caudata | Schill. |
| | Cryptomonas curvata | Ehr. |
| | Cryptomonas curvata? | Ehr. |
| | Cryptomonas erosa | Ehr. |
| | Cryptomonas erosa v. reflexa | Marss. |
| | Cryptomonas marssonii | Skuja |
| | Cryptomonas marssonii v.? | Skuja |
| | Cryptomonas ovata | Ehr. |
| | Cryptomonas phaseolus | Skuja |
| | Cryptomonas pyrenoidifera | Geitl. |
| | Cryptomonas reflexa | Skuja |
| | Cryptomonas rostratiformis | Skuja |
| | Cryptomonas rostratiformis? | Skuja |
| | Cryptomonas sp. | |
| | Rhodomonas lens | Pasch. & Rutt. |
| | Rhodomonas minuta | Skuja |
| | Rhodomonas minuta v. nannoplanktica | Skuja |
| CYA | Agmenellum quadruplicatum | (Menegh.) Breb. |
| | Anabaena sp. | |
| | Anabaena spiroides | Kleb. |
| | Anacystis marina | (Hansg.) Dr. & Daily |
| | Anacystis montana v. minor | Dr. & Daily |
| | Anacystis thermalis | (Menegh.) Dr. & Daily |
| | Anacystis thermalis f. major | (Lagerh.) Dr. & Daily |

# SPECIES LIST - LAKE ERIE PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| CYA | Aphanizomenon flos-aquae | |
| | Coccochloris elabans | (L.) Ralfs |
| | Coccochloris peniocystis | Dr. & Daily |
| | Coelosphaerium dubium | (Kutz.) Dr. & Daily |
| | Coelosphaerium naegelianum | Grun. in Rabh. |
| | Gomphosphaeria lacustris | Unger |
| | Merismopedia tenuissima | Chod. |
| | Oscillatoria limnetica | Lemm. |
| | Oscillatoria subbrevis | Lemm. |
| | Oscillatoria tenuis | Schmid. |
| | Oscillatoria tenuis? | C.A. Ag. |
| | | C.A. Ag. |
| EUG | Euglena sp. | |
| | Trachelomonas sp. | |
| PYR | Amphidinium sp. | |
| | Ceratium hirundinella | |
| | Ceratium hirundinella - cyst | (O.F.Mull.) Schrank |
| | Gymnodinium sp. | (O.F.Mull.) Schrank |
| | Gymnodinium sp. #2 | |
| | Gymnodinium sp. #3 | |
| | Peridinium aciculiferum | |
| | Peridinium aciculiferum? | Lemm. |
| | Peridinium inconspicuum | Lemm. |
| | Peridinium sp. | Lemm. |
| UNI | Unidentified flagellate #01 | |
| | Unidentified flagellate - ovoid | |
| | Unidentified flagellate - spherical | |

## SPECIES LIST - LAKE HURON PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Achnanthes affinis | Grun. |
| | Achnanthes biasolettiana | (Kutz.) Grun. |
| | Achnanthes brevipes v. intermedia | (Kutz.) Cl. |
| | Achnanthes clevei | Grun. |
| | Achnanthes clevei v. rostrata | Hust. |
| | Achnanthes conspicua? | A. Mayer |
| | Achnanthes detha | Hohn & Hellerm. |
| | Achnanthes exigua | Grun. |
| | Achnanthes exigua v. heterovalva | Krasske |
| | Achnanthes flexella | (Kutz.) Brun. |
| | Achnanthes hauckiana | Grun. |
| | Achnanthes lanceolata | (Breb.) Greg. |
| | Achnanthes lanceolata v. dubia | Grun. |
| | Achnanthes lapponica v. ninckei | (Guerm. & Mang.) Reim. |
| | Achnanthes laterostrata | Hust. |
| | Achnanthes linearis | (W. Sm.) Grun. |
| | Achnanthes linearis fo. curta | H.L. Sm. |
| | Achnanthes marginulata | Grun. |
| | Achnanthes microcephala | (Kutz.) Grun. |
| | Achnanthes minutissima | Kutz. |
| | Achnanthes sp. | |
| | Amphipleura pellucida | (Kutz.) Kutz. |
| | Amphora coffeiformis | (Ag.) Kutz. |
| | Amphora inariensis | Kram. |
| | Amphora ovalis | (Kutz.) Kutz. |
| | Amphora ovalis v. pediculius | (Kutz.) V.H. ex DeT. |
| | Amphora perpusilla | (Grun.) Grun. |
| | Amphora sp. | |
| | Anomoeoneis vitrea | (Grun.) Patr. & Reim. |
| | Asterionella formosa | Hass. |
| | Asterionella formosa v. gracillima | (Hantz.) Grun |
| | Caloneis bacillum | (Grun.) Cl. |
| | Cocconeis diminuta | Pant. |
| | Cocconeis disculus | (Schum.) Cl. |
| | Cocconeis placentula v. euglypta | (Ehr.) Cl. |
| | Cocconeis placentula v. lineata | (Ehr.) Cl. |
| | Cyclostephanos dubius | (Fricke) Round |
| | Cyclotella antiqua? | W. Sm. |
| | Cyclotella catenata | Brun. |
| | Cyclotella comensis | Grun. |
| | Cyclotella comensis - auxospore | |
| | Cyclotella comensis v. 1 | |
| | Cyclotella comensis v. 2 | |
| | Cyclotella comta | (Ehr.) Kutz. |
| | Cyclotella comta - auxospore | |
| | Cyclotella comta v. #2 | |
| | Cyclotella comta v. oligactis | (Ehr.) Grun. |
| | Cyclotella cryptica | Reim. et al. |
| | Cyclotella kuetzingiana | Thw. |
| | Cyclotella kuetzingiana v. planetophora | Fricke |
| | Cyclotella kuetzingiana v. planetophora? | Fricke |
| | Cyclotella kuetzingiana v. radiosa | Fricke |

## SPECIES LIST - LAKE HURON PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Cyclotella meneghiniana | Kutz. |
| | Cyclotella michiganiana | Skv. |
| | Cyclotella ocellata | Pant. |
| | Cyclotella operculata | (Ag.) Kutz. |
| | Cyclotella pseudostelligera | Hust. |
| | Cyclotella sp. | |
| | Cyclotella sp. #1 | |
| | Cyclotella sp. #2 | |
| | Cyclotella sp. - auxospore | |
| | Cyclotella stelligera | (Cl. & Grun.) V.H. |
| | Cymatopleura solea v. apiculata | (W. Sm.) Ralfs |
| | Cymbella angustata | (W. Sm.) Cl. |
| | Cymbella laevis | Naeg. ex Kutz. |
| | Cymbella microcephala | Grun. |
| | Cymbella minuta | Hilse |
| | Cymbella minuta v. silesiaca | (Bleisch) Reim. |
| | Cymbella naviculiformis | Auersw. |
| | Cymbella sp. | |
| | Cymbella triangulum | (Ehr.) Cl. |
| | Denticula sp. | |
| | Denticula tenuis v. crassula | (Nag.) W. & G.S. West. |
| | Diatoma tenue | Ag. |
| | Diatoma tenue v. elongatum | Lyngb. |
| | Diploneis elliptica | (Kutz.) Cl. |
| | Diploneis oblongella | (Naeg.ex Kutz.) Ross |
| | Diploneis oculata | (Breb.) Cl. |
| | Entomoneis ornata | (J.W. Bail.) Reim. |
| | Eunotia praerupta | Ehr. |
| | Fragilaria brevistriata | Grun. |
| | Fragilaria brevistriata v. subcapitata | Grun. |
| | Fragilaria capucina | Desm. |
| | Fragilaria capucina v. mesolepta | (Rabh.) Grun. |
| | Fragilaria construens | (Ehr.) Grun. |
| | Fragilaria construens v. minuta | Temp. & Per. |
| | Fragilaria construens v. pumila | Grun. |
| | Fragilaria construens v. subsalina | Hust. |
| | Fragilaria construens v. venter | (Ehr.) Grun. |
| | Fragilaria crotonensis | Kitton |
| | Fragilaria intermedia v. fallax | (Grun.) Stoerm. & Yang |
| | Fragilaria leptostauron | (Ehr.) Hust. |
| | Fragilaria leptostauron v. dubia | (Grun.) Hust. |
| | Fragilaria pinnata | Ehr. |
| | Fragilaria pinnata v. intercedens | (Grun.) Hust. |
| | Fragilaria pinnata v. lancettula | (Schum.) Hust. |
| | Fragilaria sp. | |
| | Fragilaria vaucheriae | (Kutz.) Peters. |
| | Gomphonema angustatum | (Kutz.) Rabh. |
| | Gomphonema dichotomum | Kutz. |
| | Gomphonema gracile | Ehr. em. V.H. |
| | Gomphonema olivaceum | (Lyngb.) Kutz. |
| | Gomphonema parvulum | Kutz. |
| | Gomphonema sp. | |

# SPECIES LIST - LAKE HURON PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Hantzschia amphioxys | (Ehr.) Grun. |
| | Melosira distans | (Ehr.) Kutz. |
| | Melosira distans? | (Ehr.) Kutz. |
| | Melosira granulata | (Ehr.) Ralfs |
| | Melosira granulata v. angustissima | O. Mull. |
| | Melosira islandica | O. Mull. |
| | Melosira italica subsp. subarctica | O. Mull. |
| | Melosira sp. | |
| | Navicula acceptata | Hust. |
| | Navicula atomus | (Kutz.) Grun. |
| | Navicula capitata v. luneburgensis | (Grun.) Patr. |
| | Navicula cincta | (Ehr.) Ralfs |
| | Navicula confervacea | Kutz. |
| | Navicula contenta v. biceps | (Arn.) V.H. |
| | Navicula cryptocephala v. veneta | (Kutz.) Rabh. |
| | Navicula gottlandica | Grun. |
| | Navicula mediocris | Krasske |
| | Navicula minima | Grun. |
| | Navicula muralis | Grun. |
| | Navicula muralis? | Grun. |
| | Navicula mutica | Kutz. |
| | Navicula perpusilla | (Kutz.) Grun. |
| | Navicula radiosa | Kutz. |
| | Navicula radiosa v. parva | Wallace |
| | Navicula radiosa v. tenella | (Breb.) Cl. & Moll. |
| | Navicula seminulum | Grun. |
| | Navicula similis? | Krasske |
| | Navicula sp. | |
| | Navicula sp. #16 | |
| | Navicula sp. #18 | |
| | Navicula submuralis | Hust. |
| | Navicula subtilissima | Cl. |
| | Navicula tantula | Hust. |
| | Navicula viridula v. avenacea | (Breb.) V.H. |
| | Navicula viridula v. rostellata? | (Kutz.) Cl. |
| | Nitzschia acicularioides | Arch. non Hust. |
| | Nitzschia acicularis | (Kutz.) W. Sm. |
| | Nitzschia acula | Hantz. ex Cl. & Grun. |
| | Nitzschia amphibia | Grun. |
| | Nitzschia angustata | (W. Sm.) Grun. |
| | Nitzschia angustata v. acuta | Grun. |
| | Nitzschia confinis | Hust. |
| | Nitzschia dissipata | (Kutz.) Grun. |
| | Nitzschia fonticola | Grun. |
| | Nitzschia frustulum | (Kutz.) Grun. |
| | Nitzschia frustulum v. perpusilla | (Rabh.) Grun. |
| | Nitzschia gracilis | Hantz. |
| | Nitzschia kuetzingiana | Hilse |
| | Nitzschia lauenburgiana | Hust. |
| | Nitzschia palea | (Kutz.) W. Sm. |
| | Nitzschia paleacea | Grun. |
| | Nitzschia pura | Hust. |

## SPECIES LIST - LAKE HURON PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Nitzschia pusilla | (Kutz.) Grun. em. L.-B. |
| | Nitzschia recta | Hantz. |
| | Nitzschia romana | Grun. |
| | Nitzschia rostellata | Hust. |
| | Nitzschia sp. | |
| | Nitzschia sublinearis | Hust. |
| | Nitzschia subrostrata | Hust. |
| | Nitzschia tenuis | W. Sm. |
| | Opephora martyi | Herib. |
| | Pinnularia microstauron | (Ehr.) Cl. |
| | Rhizosolenia eriensis | H.L. Sm. |
| | Rhizosolenia sp. | |
| | Stephanodiscus alpinus | Hust. |
| | Stephanodiscus alpinus - auxospore | |
| | Stephanodiscus alpinus? | Hust. |
| | Stephanodiscus binderanus | (Kutz.) Krieg. |
| | Stephanodiscus binderanus? | (Kutz.) Krieg. |
| | Stephanodiscus hantzschii | Grun. |
| | Stephanodiscus minutus | Grun. |
| | Stephanodiscus niagarae | Ehr. |
| | Stephanodiscus niagarae - auxospore | |
| | Stephanodiscus sp. | |
| | Stephanodiscus sp. #03 | |
| | Stephanodiscus sp. #05 | |
| | Stephanodiscus sp. -auxospore | |
| | Stephanodiscus tenuis | Hust. |
| | Stephanodiscus tenuis v. #01 | |
| | Stephanodiscus tenuis v. #02 | |
| | Stephanodiscus tenuis? | Hust. |
| | Stephanodiscus transilvanicus | Pant. |
| | Surirella ovata | Kutz. |
| | Surirella ovata v. salina | (W. Sm.) Hust. |
| | Synedra amphicephala v. austrica | (Grun.) Hust. |
| | Synedra cyclopum | Brutschy |
| | Synedra delicatissima | W. Sm. |
| | Synedra delicatissima v. angustissima | Grun. |
| | Synedra fameilica? | Kutz. |
| | Synedra filiformis | Grun. |
| | Synedra filiformis v. exilis | A. Cl. |
| | Synedra miniscula | Grun. |
| | Synedra nana | Meister |
| | Synedra parasitica | W. Sm. |
| | Synedra radians | Kutz. |
| | Synedra rumpens | Kutz. |
| | Synedra rumpens v. fragilarioides | Grun. |
| | Synedra sp. | |
| | Synedra ulna v. chaseana | Thomas |
| | Synedra ulna v. danica | (Kutz.) V.H. |
| | Synedra ulna v. longissima | (W. Sm.) Brun. |
| | Tabellaria ferestrata | Kutz. |
| | Tabellaria fenestrata v. geniculata | A. Cl. |
| | Tabellaria flocculosa | (Roth) Kutz. |

## SPECIES LIST - LAKE HURON PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Tabellaria flocculosa v. linearis | Koppen |
| | Tabellaria sp. | |
| | Thalassirosira sp. | |
| CAT | Vacuolaria sp. | |
| | Vacuolaria sp.? | |
| CHL | Ankistrodesmus falcatus | (Corda) Ralfs |
| | Ankistrodesmus falcatus v. mirabilis | (West & West) G.S. West |
| | Ankistrodesmus gelifactum | (Chod.) Bourr. |
| | Ankistrodesmus sp. #01 | |
| | Ankistrodesmus sp. #02 | |
| | Ankistrodesmus spiralis | (Turner) Lemm. |
| | Ankistrodesmus stipitatus? | (Chod.) Kom.-Legn. |
| | Botryococcus Braunii | Kutz. |
| | Chlamydocapsa bacillus | (Teil.) Fott |
| | Chlamydocapsa planktonica | (W. & G.S. West) Fott |
| | Chlamydocapsa sp. | |
| | Chlamydocapsa sp.? | |
| | Chlamydomonas sp. | |
| | Chlamydomonas sp. - ovoid | |
| | Chlamydomonas sp. - sphere | |
| | Coelastrum microporum | Nag. in A. Braun |
| | Cosmarium sp. | |
| | Cosmarium sp. #1 | |
| | Crucigenia irregularis | Wille |
| | Crucigenia quadrata | Morren |
| | Crucigenia rectangularis | A. Braun |
| | Dictyosphaerium pulchellum | Wood. |
| | Echinosphaerella limnetica | G.M. Sm. |
| | Elakatothrix gelatinosa | Wille |
| | Elakatothrix viridis | (Snow) Printz |
| | Eudorina elegans | Ehr. |
| | Franceia ovalis | (France) Lemm. |
| | Gloeocystis sp. #3 | |
| | Golenkinia radiata | (Chod.) Wille |
| | Green coccoid #02 | |
| | Green coccoid #03 | |
| | Green coccoid #04 | |
| | Green coccoid - acicular | |
| | Green coccoid - bacilliform | |
| | Green coccoid - bicells | |
| | Green coccoid - fusiform | |
| | Green coccoid - oval | |
| | Green coccoid - sphere | |
| | Kirchneriella contorta | (Schmid.) Bohlm |
| | Lagerheimia ciliata | (Lagerh.) Chod. |
| | Micractinium pusillum | Fresenius |
| | Monoraphidium contortum | (Thur.) Kom.-Legn. |
| | Monoraphidium convolutum | (Corda) Kom.-Legn. |
| | Monoraphidium minutum | (Nag.) Kom.-Legn. |
| | Monoraphidium saxatile | Kom.-Legn. |

# SPECIES LIST - LAKE HURON PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| CHL | Monoraphidium setiformae | (Nyg.) Kom.-Legn. |
| | Mougeotia sp. | |
| | Oocystis sp. | |
| | Oocystis sp. #1 | |
| | Oocystis Borgei | Snow |
| | Oocystis crassa | Wittr. in Wittr. & Nord. |
| | Oocystis lacustris | Chod. |
| | Oocystis marscnii | Lemm. |
| | Oocystis parva | West & West |
| | Oocystis pusilla | Hansg. |
| | Oocystis solitaria | Wittr. in Wittr. & Nord. |
| | Pyramidomonas sp. | |
| | Scenedesmus abundans | (Kirch.) Chod. |
| | Scenedesmus denticulatus | Lagerh. |
| | Scenedesmus ecornis | (Ralfs) Chod. |
| | Scenedesmus securiformis | Playf. |
| | Scenedesmus securiformis? | Playf. |
| | Scenedesmus serratus | (Corda) Bohlm |
| | Scenedesmus sp. | |
| | Scenedesmus subspicatus | Chod. |
| | Scenedesmus velitaris | Kom. |
| | Sphaerellocystis lateralis | Fott & Novak. |
| | Sphaerocystis schroeteri | Chod. |
| | Stichococcus sp. | |
| | Synechococcus sp. | |
| | Tetrachlorella alternans | (G.M. Smith) Kors. |
| | Tetraedron minimum | (A. Braun) Hansg. |
| | Treubaria planktonica | (G.M. Sm.) Korch. |
| | Treubaria planktonica? | (G.M. Sm.) Korch. |
| | Treubaria setigera | (Arch.) G.M. Sm. |
| CHR | Bitrichia chodatii | (Rev.) Chod. |
| | Chrysolykos planktonicus | Mack. |
| | Chrysolykos skujae | (Nauw.) Bourr. |
| | Chrysolykos sp. | |
| | Chrysosphaerella longispina | Laut. em. Nich. |
| | Dinobryon - statospore | |
| | Dinobryon acuminatum | Rutt. |
| | Dinobryon bavaricum | Imhof |
| | Dinobryon borgei | Lemm. |
| | Dinobryon cylindricum | Imhof |
| | Dinobryon cylindricum v. alpinum | (Imhof) Bachm. |
| | Dinobryon divergens | Imhof |
| | Dinobryon divergens - statospores | |
| | Dinobryon eurystoma | (Stokes) Lemm. |
| | Dinobryon sertularia | Ehr. |
| | Dinobryon sertularia v. protuberans | (Lemm.) Krieg. |
| | Dinobryon sociale | Ehr. |
| | Dinobryon sociale v. americanum | (Brunnth.) Bachm. |
| | Dinobryon stokesii v. epiplanktonicum | Skuja |
| | Dinobryon utriculus v. tabellariae | Lemm. |
| | Haptophyte sp. | |

## SPECIES LIST - LAKE HURON PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| CHR | Kephyrion cupuliformae | Conr. |
| | Kephyrion sp. #1 -Pseudokephyrion entzii | |
| | Kephyrion sp. #2 | |
| | Kephyrion sp. #3 | |
| | Kephyrion spirale | (Lack.) Conr. |
| | Mallomonas sp. | |
| | Mallomonas sp. #1 | |
| | Mallomonas sp. #3 | |
| | Ochromonas sp. | |
| | Ochromonas sp. - ovoid | |
| | Ochromonas sp. - sphere | |
| | Paraphysomonas sp. | |
| | Paraphysomonas sp.? | |
| | Pseudokephryion entzii | Conr. |
| | Pseudokephyrion conicum | (Schill.) Schum. |
| | Pseudokephyrion latum | (Schill.) Schum. |
| | Pseudokephyrion millerense | Nich. |
| | Pseudokephyrion sp. #1 | |
| | Unidentified coccoids | |
| | Unidentified loricate - ovoid | |
| | Unidentified loricate - sphere | |
| COL | Bicoeca campanulata | (Lack.) Bourr. em. Skuja |
| | Bicoeca crystallina | Skuja |
| | Bicoeca mitra v. suecica | Skuja |
| | Bicoeca socialis | Lauterb. |
| | Bicoeca sp. | |
| | Bicoeca sp. #04 | |
| | Bicoeca tubiformis | Skuja |
| | Colorless flagellates | |
| | Monosiga ovata | Kent |
| | Monosigna ovalis | Kent |
| | Salpingoeca amphorae | Kent |
| | Salpingoeca gracilis | Clark |
| | Stylotheca aurea | (Bachm.) Boloch. |
| CRY | Chroomonas acuta | Uterm. |
| | Chroomonas caudata | Geit. |
| | Chroomonas norstedtii | Hansg. |
| | Cryptomonas - cyst | |
| | Cryptomonas brevis | Schill. |
| | Cryptomonas caudata | Schill. |
| | Cryptomonas ercsa | Ehr. |
| | Cryptomonas ercsa v. reflexa | Marss. |
| | Cryptomonas marssonii | Skuja |
| | Cryptomonas obovata? | Skuja |
| | Cryptomonas ovata | Ehr. |
| | Cryptomonas parapyrenoidifera | Skuja |
| | Cryptomonas phaseolus | Skuja |
| | Cryptomonas phaseolus? | Skuja |
| | Cryptomonas pusilla | Bachm. |
| | Cryptomonas pyrenoicifera | Geitl. |

# SPECIES LIST - LAKE HURON PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| CRY | Cryptomonas reflexa | Skuja |
| | Cryptomonas rostratiformis | Skuja |
| | Cryptomonas sp. | |
| | Cryptomonas tenuis | Pasch. |
| | Cryptomonas tetrapyrenoidiosa? | Skuja |
| | Rhodomonas lacustris | Pasch. & Rutt. |
| | Rhodomonas lens | Pasch. & Rutt. |
| | Rhodomonas minuta | Skuja |
| | Rhodomonas minuta v. nannoplanktica | Skuja |
| | Unidentified coccoid | |
| CYA | Anabaena circinalis | Rabenhorst |
| | Anabaena sp. | |
| | Anacystis marina | (Hansg.) Dr. & Daily |
| | Anacystis montana v. minor | Dr. & Daily |
| | Anacystis thermalis | (Menegh.) Dr. & Daily |
| | Coccochloris elabans | Dr. & Daily |
| | Coccochloris peniocystis | (Kutz.) Dr. & Daily |
| | Coelosphaerium Naegelianum | Unger |
| | Gomphosphaeria lacustris | Chod. |
| | Oscillatoria limnetica | Lemm. |
| | Oscillatoria minima | Gicklh. |
| | Oscillatoria subbrevis | Schmid. |
| | Oscillatoria tenuis | C.A. Ag. |
| EUG | Euglena sp. | |
| | Phacus sp. | |
| | Trachelomonas hispida | (Perty) Stein em. Defl. |
| | Trachelomonas sp. | |
| PYR | Amphidinium sp. | |
| | Ceratium hirundinella | (O.F.Mull.) Schrank |
| | Gymnodinium sp. | |
| | Gymnodinium sp. #1 | |
| | Gymnodinium sp. #2 | |
| | Gymnodinium sp. #3 | |
| | Gymnodinium sp. #5 | |
| | Peridinium inconspicuum | Lemm. |
| | Peridinium sp. | |
| | Peridinium sp. #02 | |
| UNI | Unidentified flagellate #01 | |
| | Unidentified flagellate - ovoid | |
| | Unidentified flagellate - spherical | |

# SPECIES LIST - LAKE MICHIGAN PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Achnanthes affinis | Grun. |
| | Achnanthes biasolettiana | (Kutz.) Grun. |
| | Achnanthes clevei | Grun. |
| | Achnanthes clevei v. rostrata | Hust. |
| | Achnanthes conspicua | A. Mayer |
| | Achnanthes deflexa | Reim. in Patr. & Reim. |
| | Achnanthes exigua | Grun. |
| | Achnanthes exigua v. constricta | (Grun.) Hust. |
| | Achnanthes flexella | (Kutz.) Brun. |
| | Achnanthes hauckiana | Grun. |
| | Achnanthes lanceolata | (Breb.) Greg. |
| | Achnanthes lanceolata v. dubia | Grun. |
| | Achnanthes lapponica v. ninckei | (Guerm. & Mang.) Reim. |
| | Achnanthes lapponica v. ninckei? | (Guerm. & Mang.) Reim. |
| | Achnanthes linearis | (W. Sm.) Grun. |
| | Achnanthes linearis fo. curta | H.L. Sm. |
| | Achnanthes minutissima | Kutz. |
| | Achnanthes oestrupii v.lanceolata | Hust. |
| | Achnanthes sp. | |
| | Achnanthes suchlandtii | Hust. |
| | Actinocyclus normanii f. subsalsa | (Juhl.-Dannf.) Hust. |
| | Amphipleura pellucida | (Kutz.) Kutz. |
| | Amphora ovalis | (Kutz.) Kutz. |
| | Amphora ovalis v. affins | (Kutz.) V.H. ex DeT. |
| | Amphora ovalis v. pediculius | (Kutz.) V.H. ex DeT. |
| | Amphora perpusilla | (Grun.) Grun. |
| | Amphora sp. | |
| | Amphora thumensus | (Mayer) A. Cl. |
| | Anomoeoneis vitrea | (Grun.) Patr. & Reim. |
| | Asterionella formosa | Hass. |
| | Caloneis sp. | |
| | Cocconeis diminuta | Pant. |
| | Cocconeis disculus | (Schum.) Cl. |
| | Cocconeis placentula v. euglypta | (Ehr.) Cl. |
| | Cocconeis placentula v. lineata | (Ehr.) Cl. |
| | Cocconeis thumensis | A. Mayer |
| | Cyclotella antiqua | W. Sm. |
| | Cyclotella antiqua? | W. Sm. |
| | Cyclotella atomus | Pant. |
| | Cyclotella comensis | Grun. |
| | Cyclotella comensis - auxospore | |
| | Cyclotella comensis v. 1 | |
| | Cyclotella comensis v. 2 | |
| | Cyclotella comta | (Ehr.) Kutz. |
| | Cyclotella comta - auxospore | |
| | Cyclotella comta v. oligactis | (Ehr.) Grun. |
| | Cyclotella cryptica | Reim. et al. |
| | Cyclotella kuetzingiana | Thw. |
| | Cyclotella meneghiniana | Kutz. |
| | Cyclotella michiganiana | Skv. |
| | Cyclotella michiganiana - auxospore | |
| | Cyclotella ocellata | Pant. |

# SPECIES LIST - LAKE MICHIGAN PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Cyclotella operculata | (Ag.) Kutz. |
| | Cyclotella operculata unipunctata | Hust. |
| | Cyclotella pseudostelligera | Hust. |
| | Cyclotella sp. | |
| | Cyclotella sp. #1 | |
| | Cyclotella sp. - auxospore | |
| | Cyclotella stelligera | (Cl. & Grun.) V.H. |
| | Cymatopleura elliptica | (Breb.) W.Sm. |
| | Cymatopleura solea | (Breb. & Godey) W. Sm. |
| | Cymbella cesatii | (Rabh.) Grun. ex A.S. |
| | Cymbella cistula v. gibbosa | Brun. |
| | Cymbella delicatula | Kutz. |
| | Cymbella microcephala | Grun. |
| | Cymbella minuta | Hilse |
| | Cymbella minuta v. silesiaca | (Bleisch) Reim. |
| | Cymbella norvegica | Grun. |
| | Cymbella prostrata v. auerswaldii | (Rabh.) Reim. |
| | Cymbella sinuata | Greg. |
| | Cymbella sp. | |
| | Cymbella triangulum | (Ehr.) Cl. |
| | Denticula tenuis v. crassula | (Nag.) W. & G.S. West. |
| | Diatoma tenue | Ag. |
| | Diatoma tenue v. elongatum | Lyngb. |
| | Diploneis elliptica | (Kutz.) Cl. |
| | Diploneis oculata | (Breb.) Cl. |
| | Diploneis parma | Cl. |
| | Diploneis sp. | |
| | Entomoneis ornata | (J.W. Bail.) Reim. |
| | Eunotia incisa | W. Sm. |
| | Fragilaria brevistriata | Grun. |
| | Fragilaria brevistriata v. inflata | (Pant.) Hust. |
| | Fragilaria brevistriata v. subcapitata | Grun. |
| | Fragilaria capucina | Desm. |
| | Fragilaria capucina v. mesolepta | (Rabh.) Grun. |
| | Fragilaria construens | (Ehr.) Grun. |
| | Fragilaria construens v. binodis | (Ehr.) Grun. |
| | Fragilaria construens v. minuta | Temp. & Per. |
| | Fragilaria construens v. subsalina | Hust. |
| | Fragilaria construens v. venter | (Ehr.) Grun. |
| | Fragilaria crotonensis | Kitton |
| | Fragilaria leptostauron | (Ehr.) Hust. |
| | Fragilaria pinnata | Ehr. |
| | Fragilaria pinnata v. intercedens | (Grun.) Hust. |
| | Fragilaria pinnata v. lancettula | (Schum.) Hust. |
| | Fragilaria sp. | |
| | Fragilaria vaucheriae | (Kutz.) Peters. |
| | Fragilaria vaucheriae v. capitellata | (Grun.) Patr. |
| | Gomphonema affine | Kutz. |
| | Gomphonema dichotomum | Kutz. |
| | Gomphonema gracile | Ehr. em. V.H. |
| | Gomphonema parvulum | Kutz. |
| | Gomphonema sp. | |

# SPECIES LIST - LAKE MICHIGAN PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Gyrosigma scictense | (Sulliv. & Wormley) Cl. |
| | Melosira ambiqua | (Grun.) O. Mull. |
| | Melosira distans | (Ehr.) Kutz. |
| | Melosira granulata | (Ehr.) Ralfs |
| | Melosira granulata v. angustissima | O. Mull. |
| | Melosira islandica | O. Mull. |
| | Melosira italica | (Ehr.) Kutz. |
| | Melosira italica subsp. subarctica | O. Mull. |
| | Melosira sp. | |
| | Meridion circulare | (Greg.) Ag. |
| | Navicula anglica v. signata | Hust. |
| | Navicula anglica v. subsalsa | (Grun.) Cl. |
| | Navicula capitata | Ehr. |
| | Navicula capitata v. hurgarica | (Grun.) Ross |
| | Navicula cincta | (Ehr.) Ralfs |
| | Navicula cryptocephala | Kutz. |
| | Navicula cryptocephala v. veneta | (Kutz.) Rabh. |
| | Navicula exigua v. capitata | Patr. |
| | Navicula graciloides | A. Mayer |
| | Navicula gregaria | Donk. |
| | Navicula integra | (W. Sm.) Ralfs |
| | Navicula jaernefeldtii | Hust. |
| | Navicula lacustris | Greg. |
| | Navicula lanceolata | (Ag.) Kutz. |
| | Navicula menisculus v. upsaliensis | (Grun.) Grun. |
| | Navicula minima | Grun. |
| | Navicula pseudoreinhardtii? | Patr. |
| | Navicula pupula | Kutz. |
| | Navicula radiosa | Kutz. |
| | Navicula radiosa v. tenella | (Breb.) Cl. & Moll. |
| | Navicula reinhardtii | (Grun.) Grun. |
| | Navicula seminuloides | Hust. |
| | Navicula seminulum | Grun. |
| | Navicula sp. | |
| | Navicula tripunctata | (O.F.Mull.) Bory |
| | Navicula tripunctata v. schizonemoides | (Breb. ex Grun.) V.H. |
| | Navicula tuscula | Ehr. |
| | Navicula viridula | (Kutz.) Ehr. |
| | Neiduim sp. #1 | |
| | Nitzschia acicularioides | Arch. non Hust. |
| | Nitzschia acicularis | (Kutz.) W. Sm. |
| | Nitzschia acula | Hantz. ex Cl. & Grun. |
| | Nitzschia acuta | Hantz. |
| | Nitzschia amphibia | Grun. |
| | Nitzschia angustata | (W. Sm.) Grun. |
| | Nitzschia angustata v. acuta | Grun. |
| | Nitzschia bacata | Hust. |
| | Nitzschia capitellata | Hust. |
| | Nitzschia confinis | Hust. |
| | Nitzschia confinis? | Hust. |
| | Nitzschia dissipata | (Kutz.) Grun. |
| | Nitzschia fonticola | Grun. |

## SPECIES LIST - LAKE MICHIGAN PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Nitzschia frustulum | (Kutz.) Grun. |
| | Nitzschia frustulum v. minutula | |
| | Nitzschia gandersheimiensis | Krasske |
| | Nitzschia gracilis | Hantz. |
| | Nitzschia impressa | Hust. |
| | Nitzschia kuetzingiana | Hilse |
| | Nitzschia lauerburgiana | Hust. |
| | Nitzschia linearis | W. Sm. |
| | Nitzschia palea | (Kutz.) W. Sm. |
| | Nitzschia palea v. debilis | (Kutz.) Grun. |
| | Nitzschia paleacea | Grun. |
| | Nitzschia pura? | Hust. |
| | Nitzschia recta | Hantz. |
| | Nitzschia romana | Grun. |
| | Nitzschia sociabilis | Hust. |
| | Nitzschia sp. | |
| | Nitzschia spiculum | Hust. |
| | Nitzschia subacicularis | Hust. |
| | Nitzschia sublinearis | Hust. |
| | Nitzschia sublinearis? | Hust. |
| | Nitzschia subrostrata | Hust. |
| | Nitzschia tenuis | W. Sm. |
| | Nitzschia valdestrita | Aleem & Hust. |
| | Opephora martyi | Herib. |
| | Rhizosolenia eriensis | H.L. Sm. |
| | Rhizosolenia longiseta | Zach. |
| | Rhizosolenia sp. | |
| | Rhoiocosphenia curvata | (Kutz.) Grun. |
| | Skeletonema potamos | (Weber) Hasle & Evens. |
| | Stauroneis smithii v. minuta | Haw. |
| | Stephanodiscus alpinus | Hust. |
| | Stephanodiscus alpinus? | Hust. |
| | Stephanodiscus binderanus | (Kutz.) Krieg. |
| | Stephanodiscus binderanus? | (Kutz.) Krieg. |
| | Stephanodiscus hantzschii | Grun. |
| | Stephanodiscus minutus | Grun. |
| | Stephanodiscus niagarae | Ehr. |
| | Stephanodiscus sp. | |
| | Stephanodiscus sp. #03 | |
| | Stephanodiscus sp. -auxospore | |
| | Stephanodiscus subtilis | (Van Goor) A. Cl. |
| | Stephanodiscus tenuis | Hust. |
| | Stephanodiscus tenuis v. #01 | |
| | Stephanodiscus tenuis v. #02 | |
| | Stephanodiscus tenuis? | Hust. |
| | Stephanodiscus transilvanicus | Pant. |
| | Surirella angusta | Kutz. |
| | Synedra amphicephala v. austrica | (Grun.) Hust. |
| | Synedra cyclopum | Brutschy |
| | Synedra delicatissima v. angustissima | Grun. |
| | Synedra fameilica | Kutz. |
| | Synedra filiformis | Grun. |

# SPECIES LIST - LAKE MICHIGAN PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| BAC | Synedra filiformis v. exilis | A. Cl. |
| | Synedra miniscula | Grun. |
| | Synedra parasitica | W. Sm. |
| | Synedra radians | Kutz. |
| | Synedra sp. | |
| | Synedra ulna | (Nitz.) Ehr. |
| | Synedra ulna v. chaseana | Thomas |
| | Synedra ulna v. danica | (Kutz.) V.H. |
| | Synedra ulna v. longissima | (W. Sm.) Brun. |
| | Tabellaria ferestrata | Kutz. |
| | Tabellaria ferestrata v. geniculata | A. Cl. |
| | Tabellaria flocculosa | (Roth) Kutz. |
| | Tabellaria flocculosa v. linearis | Koppen |
| CAT | Vacuolaria sp. | |
| CHL | Ankistrodesmus falcatus | (Corda) Ralfs |
| | Ankistrodesmus gelifactum | (Chod.) Bourr. |
| | Ankistrodesmus sp. #01 | |
| | Ankistrodesmus sp.? | |
| | Arthrodesmus bifidus | Breb. |
| | Botryococcus Braunii | Kutz. |
| | Carteria sp. | |
| | Chlamydocapsa planktonica | (W. & G.S. West) Fott |
| | Chlamydocapsa sp. | |
| | Chlamydomonas sp. | |
| | Chlamydomonas sp. - ovoid | |
| | Chlamydomonas sp. - sphere | |
| | Closteriopsis sp. | |
| | Closterium aciculare | T. West |
| | Closterium gracile | Breb. |
| | Coelastrum cambricum | Arch. |
| | Coelastrum microporum | Nag. in A. Braun |
| | Coelastrum sp. | |
| | Coenocystis sp. | |
| | Cosmarium sp. | |
| | Crucigenia irregularis | Wille |
| | Crucigenia quadrata | Morren |
| | Crucigenia rectangularis | A. Braun |
| | Dictyosphaerium ehrenbergianum | Nag. |
| | Dictyosphaerium pulchellum | Wood. |
| | Elakatothrix gelatinosa | Wille |
| | Elakatothrix viridis | (Snow) Printz |
| | Elakatothrix viridis? | (Snow) Printz |
| | Gloedactinium limneticum | G.M. Sm. |
| | Golenkinipsis sp. | |
| | Green coccoid | |
| | Green coccoid #04 | |
| | Green coccoid - acicular | |
| | Green coccoid - bacilliform | |
| | Green coccoid - bicells | |
| | Green coccoid - fusiform | |

## SPECIES LIST - LAKE MICHIGAN PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| CHL | Green coccoid - fusiform bicells | |
| | Green coccoid - oocystis-like bicell | |
| | Green coccoid - oval | |
| | Green coccoid - reniform | |
| | Green coccoid - sphere | |
| | Green coccoid - sphere (large) | |
| | Kirchneriella contorta | (Schmid.) Bohlm |
| | Monoraphidium contortum | (Thur.) Kom.-Legn. |
| | Monoraphidium irregulare | (G.M. Sm.) Kom.-Legn. |
| | Monoraphidium minutum | (Nag.) Kom.-Legn. |
| | Monoraphidium saxatile | Kom.-Legn. |
| | Monoraphidium setiformae | (Nyg.) Kom.-Legn. |
| | Monoraphidium tortile | (W. & W.) Kom.-Legn. |
| | Nephrocytium Agardhianum | Nag. |
| | Nephrocytium limneticum | (G.M. Sm.) G.M. Sm. |
| | Oedogonium sp. | |
| | Oocystis sp. | |
| | Oocystis sp. #1 | |
| | Oocystis borgei | Snow |
| | Oocystis crassa | Wittr. in Wittr. & Nord. |
| | Oocystis lacustris | Chod. |
| | Oocystis marsonii | Lemm. |
| | Oocystis parva | West & West |
| | Oocystis pusilla | Hansg. |
| | Oocystis solitaria | Wittr. in Wittr. & Nord. |
| | Oocystis submarina | Lagerh. |
| | Pediastrum sp.? | |
| | Phacotus minuscula | Bourr. |
| | Phacotus sp. | |
| | Planktonema lauterbornii | Schmidle |
| | Planktonema sp. | |
| | Pteromonas sp. | |
| | Pyramidomonas sp. | |
| | Scenedesmus acuminatus | (Lagerh.) Chod. |
| | Scenedesmus ecornis | (Ralfs) Chod. |
| | Scenedesmus quadricauda | (Turp.) Breb. |
| | Scenedesmus quadricauda v. longspina | (Chod.) G.M. Sm. |
| | Scenedesmus securiformis | Playf. |
| | Scenedesmus serratus | (Corda) Bohlm |
| | Scenedesmus sp. | |
| | Scenedesmus spinosus | Chod. |
| | Schroederia setigera | (Schroed.) Lemm. |
| | Sphaerellocystis lacustris | Skuja |
| | Sphaerellocystis lateralis | Fott & Novak. |
| | Sphaerocystis schroeteri | Chod. |
| | Stichococcus sp. | |
| | Tetraedron caudatum | (Corda) Hansg. |
| | Tetraedron minimum | (A. Braun) Hansg. |
| | Tetraspora lacustris | Lemm. |
| | Tetrastrum glabrum | |
| | Treubaria planktonica | (G.M. Sm.) Korch. |
| | Treubaria setigera | (Arch.) G.M. Sm. |

## SPECIES LIST - LAKE MICHIGAN PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| CHR | Bitrichia chodatii | (Rev.) Chod. |
| | Bitrichia ohridiana | (Fott) Nich. |
| | Chromulina sp. | |
| | Chrysococcus sp.? | |
| | Chrysolykos angulatus | (Willen) Nauw. |
| | Chrysolykos planktonicus | Mack. |
| | Chrysolykos skujae | (Nauw.) Bourr. |
| | Chrysolykos sp. | |
| | Chrysosphaerella longispina | Laut. em. Nich. |
| | Dinobryon - cyst | |
| | Dinobryon acuminatum | Rutt. |
| | Dinobryon bavaricum | Imhof |
| | Dinobryon borgei | Lemm. |
| | Dinobryon cylindricum | Imhof |
| | Dinobryon divergens | Imhof |
| | Dinobryon eurystoma? | (Stokes) Lemm. |
| | Dinobryon sertularia | Ehr. |
| | Dinobryon sociale | Ehr. |
| | Dinobryon sociale v. americanum | (Brunnth.) Bachm. |
| | Dinobryon sociale v. stiptatum | (Stein) Lemm. |
| | Dinobryon sp. | |
| | Dinobryon stokesii v. epiplanktonicum | Skuja |
| | Dinobryon tubaeformae | Nyg. |
| | Dinobryon utriculus v. tabellariae | Lemm. |
| | Halobryon sp.? | |
| | Haptophyte sp. | |
| | Kephyrion cupuliformae | Conr. |
| | Kephyrion doliolum | Conr. |
| | Kephyrion rubi-calustri | Conr. |
| | Kephyrion sp. | |
| | Kephyrion sp. #1 -Pseudokephyrion entzii | |
| | Kephyrion sp. #2 | |
| | Kephyrion sp. #3 | |
| | Kephyrion spirale | (Lack.) Conr. |
| | Mallomonas majorensis | Skuja |
| | Mallomonas sp. | |
| | Mallomonas sp. #3 | |
| | Ochromonas sp. | |
| | Ochromonas sp. - oval | |
| | Ochromonas sp. - ovoid | |
| | Ochromonas sp. - sphere | |
| | Paraphysomonas sp. | |
| | Paraphysomonas sp.? | |
| | Pseudokephyrion conicum | (Schill.) Schum. |
| | Pseudokephyrion latum | (Schill.) Schum. |
| | Pseudokephyrion millerense | Nich. |
| | Pseudokephyrion sp. #1 | |
| | Pseudokephyrion undulatissimum | Scherff. |
| | Unidentified coccoid - ovoid | |
| | Unidentified coccoid - sphere | |
| | Unidentified coccoids | |
| | Unidentified loricate - sphere | |

# SPECIES LIST - LAKE MICHIGAN PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| CHR | Unidentified loricate-flagellate sphere | |
| COL | Bicoeca campanulata | (Lack.) Bourr. em. Skuja |
| | Bicoeca lacustris? | J. Clark |
| | Bicoeca mitra v.? | |
| | Bicoeca sp. | |
| | Bicoeca sp. #C4 | |
| | Bicoeca tubiformis | Skuja |
| | Codonosiga sp. | |
| | Colorless flagellate - ovoid | |
| | Colorless flagellate - sphere | |
| | Colorless flagellates | |
| | Mastigella sp. | |
| | Monosiga ovata | Kent |
| | Salpingoeca amphorae | Kent |
| | Salpingoeca gracilis | Clark |
| | Salpingoeca sp. | |
| | Stylotheca aurea | (Bachm.) Boloch. |
| CRY | Chroomonas acuta | Uterm. |
| | Chroomonas caudata | Geit. |
| | Chroomonas norstedtii | Hansg. |
| | Chroomonas pochmanni | Huber-Pest. |
| | Cryptomonas - cyst | |
| | Cryptomonas brevis | Schill. |
| | Cryptomonas brevis? | Schill. |
| | Cryptomonas caudata | Schill. |
| | Cryptomonas erosa | Ehr. |
| | Cryptomonas erosa v. reflexa | Marss. |
| | Cryptomonas lobata | Korsch. |
| | Cryptomonas marssonii | Skuja |
| | Cryptomonas marssonii v.? | Skuja |
| | Cryptomonas ovata | Ehr. |
| | Cryptomonas parapyrenoidifera | Skuja |
| | Cryptomonas phaseolus | Skuja |
| | Cryptomonas pusilla | Bachm. |
| | Cryptomonas pyrenoidifera | Geitl. |
| | Cryptomonas reflexa v. erosa | |
| | Cryptomonas rostratiformis | Skuja |
| | Cryptomonas sp. | |
| | Cryptomonas tenuis | Pasch. |
| | Cryptomonas tetrapyreniodiosa | Skuja |
| | Rhodomonas lacustris | Pasch. & Rutt. |
| | Rhodomonas lens | Pasch. & Rutt. |
| | Rhodomonas minuta | Skuja |
| | Rhodomonas minuta v. nannoplanktica | Skuja |
| | Sennia parvula | Skuja |
| | Sennia parvula? | Skuja |
| CYA | Anabaena flos-aquae | (Lyngb.) Breb. |
| | Anabaena sp. | |
| | Anacystis marina | (Hansg.) Dr. & Daily |

## SPECIES LIST - LAKE MICHIGAN PHYTOPLANKTON (1983)

| DIV | TAXON | AUTHORITY |
|---|---|---|
| CYA | Anacystis montana | Dr. & Daily |
| | Anacystis montana v. minor | Dr. & Daily |
| | Anacystis thermalis | (Menegh.) Dr. & Daily |
| | Aphanothece gelatinosa | (Henn.) Lemm. |
| | Coccochloris elabans | Dr. & Daily |
| | Coccochloris peniocystis | (Kutz.) Dr. & Daily |
| | Coelosphaerium naegelianum | Unger |
| | Dactylococcopsis Smithii | Chod. & Chod. |
| | Dactylococcopsis sp. | |
| | Gloeothece ruprestris | (Lyngb.) Born. |
| | Gomphosphaeria lacustris | Chod. |
| | Lyngbya limneticum | Lemm. |
| | Oscillatoria agardhii | Gom. |
| | Oscillatoria limnetica | Lemm. |
| | Oscillatoria limnetica? | Lemm. |
| | Oscillatoria minima | Gicklh. |
| | Oscillatoria sp. | |
| | Oscillatoria subbrevis | Schmid. |
| | Oscillatoria tenuis | C.A. Ag. |
| | Oscillatoria tenuis v. natans | Gom. |
| | Oscillatoria tenuis v. tergistina | (Kutz.) Rabh. |
| | Unidentified blue-greens | |
| EUG | Euglena sp. | |
| PYR | Amphidinium sp. | |
| | Ceratium hirundinella | (O.F.Mull.) Schrank |
| | Dinoflagellate cyst | |
| | Gymnodinium sp. | |
| | Gymnodinium sp. #1 | |
| | Gymnodinium sp. #2 | |
| | Gymnodinium sp. #3 | |
| | Peridinium cinctum | (Mull.) Ehr. |
| | Peridinium inconspicuum | Lemm. |
| | Peridinium sp. | |
| UNI | Unidentified coccoid flagellates | |
| | Unidentified flagellate #01 | |
| | Unidentified flagellate #03 | |
| | Unidentified flagellate - ovoid | |
| | Unidentified flagellate - spherical | |

# GREAT LAKES ZOOPLANKTON SPECIES LIST
LAKE ERIE
(1983)

| DIVISION | TAXON |
|---|---|
| Calanoida | Calanoid - copepodite |
| | Diaptomus ashlandi |
| | Diaptomus minutus |
| | Diaptomus oregonensis |
| | Diaptomus sicilis |
| | Diaptomus siciloides |
| | Epischura lacustris |
| | Eurytemora affinis |
| | Limnocalanus macrurus |
| | Senecella calanoides |
| Cladocera | Bosmina longirostris |
| | Ceriodaphnia lacustris |
| | Ceriodaphnia reticulata |
| | Ceriodaphnia sp. |
| | Chydorus sphaericus |
| | Daphnia catawba |
| | Daphnia galaeta mendota |
| | Daphnia retrocurva |
| | Daphnia schodleri |
| | Daphnia sp. |
| | Diaphanosoma ecaudis |
| | Diaphanosoma leuchtenbergianum |
| | Eubosmina coregoni |
| | Eurycercus lamellatus |
| | Holopedium gibberum |
| | Ilyocryptus spinifer |
| | Leptodora kindtii |
| | Sida crystallina |
| Copepoda | Copepoda Nauplii |
| Cyclopoida | Cyclopoid - copepodite |
| | Cyclops bicuspidatus thomasi |
| | Eucyclops edax |
| | Eucyclops prionophorus |
| | Mesocyclops edax |
| | Tropocyclops prasinus mexicanus |
| Harpacticoida | Harpacticoida |
| Rotifera | Alona quadranqularis |
| | Ascomorpha ecaudis |
| | Ascomorpha sp. |
| | Asplanchna priodonta |
| | Bdelloid Rotifera |
| | Brachionus bidentata |
| | Brachionus caudatus |
| | Brachionus sp. |
| | Collotheca sp. |

# GREAT LAKES ZOOPLANKTON SPECIES LIST
## LAKE ERIE
## (1983)

| DIVISION | TAXON |
|---|---|
| Rotifera | Conochiloides sp. |
| | Conochilus unicornis |
| | Euchlanis sp. |
| | Filina longiseta |
| | Gastropus sp. |
| | Gastropus stylifer |
| | Kellicottia longispina |
| | Keratella cochlearis |
| | Keratella crassa |
| | Keratella earlinae |
| | Keratella hiemalis |
| | Keratella quadrata |
| | Lepadella sp. |
| | Notholca foliacea |
| | Notholca laurentiae |
| | Notholca squamula |
| | Ploesoma sp. |
| | Polyarthra dolichoptera |
| | Polyarthra major |
| | Polyarthra remata |
| | Polyarthra vulgaris |
| | Synchaeta sp. |
| | Trichocerca cylindrica |
| | Trichocerca multicrinis |
| | Trichocerca similis |
| | Trichocerca sp. |

# GREAT LAKES ZOOPLANKTON SPECIES LIST
## LAKE HURON
## (1983)

| DIVISION | TAXON |
|---|---|
| Calanoida | Calanoid - copepodite |
| | Diaptomus ashlandi |
| | Diaptomus minutus |
| | Diaptomus oregonensis |
| | Diaptomus sicilis |
| | Diaptomus siciloides |
| | Epischura lacustris |
| | Limnocalanus macrurus |
| | Senecella calanoides |
| Cladocera | Bosmina longirostris |
| | Daphnia catawba |
| | Daphnia dubia |
| | Daphnia galaeta mendota |
| | Daphnia pulicaria |
| | Daphnia retrocurva |
| | Daphnia schodleri |
| | Daphnia sp. |
| | Diaphanosoma leuchtenbergianum |
| | Diaphanosoma sp. |
| | Eubosmina coregoni |
| | Holopedium gibberum |
| | Leptodora kindtii |
| | Polyphemus pediculus |
| | Sida crystallina |
| Copepoda | Copepoda Nauplii |
| Cyclopoida | Cyclopoid - copepodite |
| | Cyclops bicuspidatus thomasi |
| | Cyclops vernalis |
| | Mesocyclops edax |
| | Tropocyclops prasinus mexicanus |
| Mysidacea | Mysis relicta |
| Rotifera | Ascomorpha sp. |
| | Asplanchna priodonta |
| | Cephalodella sp. |
| | Collotheca sp. |
| | Conochilus unicornis |
| | Euchlanis sp. |
| | Filina longiseta |
| | Gastropus sp. |
| | Gastropus stylifer |
| | Kellicottia longispina |
| | Keratella cochlearis |
| | Keratella cochlearis hispida |
| | Keratella crassa |
| | Keratella earlinae |

# GREAT LAKES ZOOPLANKTON SPECIES LIST
## LAKE HURON
## (1983)

| DIVISION | TAXON |
|---|---|
| Rotifera | Keratella hiemalis |
| | Keratella quadrata |
| | Monostyla lunaris |
| | Notholca foliacea |
| | Notholca laurentiae |
| | Notholca squamula |
| | Ploesoma sp. |
| | Polyarthra dolichoptera |
| | Polyarthra major |
| | Polyarthra remata |
| | Polyarthra vulgaris |
| | Rotifer - soft body |
| | Synchaeta sp. |
| | Trichocerca cylindrica |
| | Trichocerca multicrinis |
| | Trichocerca sp. |
| | Trichotria pocillum |

# GREAT LAKES ZOOPLANKTON SPECIES LIST
# LAKE MICHIGAN
# (1983)

| DIVISION | TAXON |
|---|---|
| Calanoida | Calanoid - copepodite |
| | Diaptomus ashlandi |
| | Diaptomus minutus |
| | Diaptomus oregonensis |
| | Diaptomus sicilis |
| | Diaptomus siciloides |
| | Epischura lacustris |
| | Eurytemora affinis |
| | Limnocalanus macrurus |
| | Senecella calanoides |
| Cladocera | Alona affinis |
| | Bosmina longirostris |
| | Camptocercus rectirostris |
| | Ceriodaphnia lacustris |
| | Chydoridae |
| | Chydorus sphaericus |
| | Daphnia catawba |
| | Daphnia dubia |
| | Daphnia galaeta mendota |
| | Daphnia immatures |
| | Daphnia longiremis |
| | Daphnia middendorffiana |
| | Daphnia pulicaria |
| | Daphnia retrocurva |
| | Daphnia schodleri |
| | Daphnia sp. |
| | Diaphanosoma leuchtenbergianum |
| | Eubosmina coregoni |
| | Eurycercus lamellatus |
| | Holopedium gibberum |
| | Ilyocryptus spinifer |
| | Leptodora kindtii |
| | Polyphemus pediculus |
| Copepoda | Copepoda Nauplii |
| Cyclopoida | Cyclopoid - copepodite |
| | Cyclops bicuspidatus thomasi |
| | Eucyclops prionophorus |
| | Mesocyclops edax |
| | Tropocyclops prasinus mexicanus |
| Harpacticoida | Harpacticoida |
| Mysidacea | Mysis relicta |
| Rotifera | Ascomorpha sp. |
| | Asplanchna priodonta |
| | Brachionus quadridentatus |

# GREAT LAKES ZOOPLANKTON SPECIES LIST
# LAKE MICHIGAN
# (1983)

| DIVISION | TAXON |
|---|---|
| Rotifera | Cephalodella sp. |
| | Collotheca sp. |
| | Conochilcides sp. |
| | Conochilus unicornis |
| | Encentrum sp. |
| | Euchlanis sp. |
| | Filina longiseta |
| | Gastropus stylifer |
| | Kellicottia longispina |
| | Keratella cochlearis |
| | Keratella crassa |
| | Keratella earlinae |
| | Keratella hiemalis |
| | Keratella quadrata |
| | Lecane tenuiseta |
| | Monostyla sp. |
| | Notholca acuminata |
| | Notholca foliacea |
| | Notholca laurentiae |
| | Notholca squamula |
| | Notholca striata |
| | Ploesoma sp. |
| | Polyarthra dolichoptera |
| | Polyarthra major |
| | Polyarthra remata |
| | Polyarthra vulgaris |
| | Synchaeta sp. |
| | Trichocerca cylindrica |
| | Trichocerca multicrinis |
| | Trichocerca sp. |

## TECHNICAL REPORT DATA

*(Please read Instructions on the reverse before completing)*

| | | |
|---|---|---|
| 1. REPORT NO.<br>EPA-905/2-87-002 | 2. | 3. RECIPIENT'S ACCESSION NO. |
| 4. TITLE AND SUBTITLE<br>Phytoplankton and Zooplankton Composition, Abundance and Distribution: Lake Erie, Lake Huron and Lake Michigan-1983 | | 5. REPORT DATE<br>April 1987<br>6. PERFORMING ORGANIZATION CODE<br>5GL |
| 7. AUTHOR(S)<br>Joseph C. Makarewicz | | 8. PERFORMING ORGANIZATION REPORT NO.<br>GLNPO Report No. 87-06 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>State University of New York at Brockport<br>Department of Biological Sciences<br>Brockport, New York 14450<br>for the Research Foundation of State University of New York | | 10. PROGRAM ELEMENT NO.<br>11. CONTRACT/GRANT NO.<br>R005772-01 |
| 12. SPONSORING AGENCY NAME AND ADDRESS<br>U.S. Environmental Protection Agency<br>Great Lakes National Program Office<br>230 South Dearborn Street<br>Chicago, Illinois 60604 | | 13. TYPE OF REPORT AND PERIOD COVERED<br>FINAL<br>14. SPONSORING AGENCY CODE<br>Great Lakes National Program Office-USEPA, Region V |

15. SUPPLEMENTARY NOTES

Paul Bertram
Project Officer

16. ABSTRACT

An in-depth comparison of phytoplankton and zooplankton from Lakes Erie, Huron and Michigan is presented based on extensive lake-wide surveys during spring, summer and autumn of 1983. This comparison was achieved by the application of standard and consistent identification, enumeration and data-processing techniques of plankton along north-south transects in Lakes Huron and Michigan and east-west transects in Lake Erie.

For Lakes Erie, Huron and Michigan respectively, 436, 411 and 452 algal taxa and 71, 61 and 73 zooplankton taxa were identified. Based on indicator species and species associations, the plankton assemblage was consistent with a mesotrophic-eutrophic designation for Lake Erie, oligotrophic designation for Lake Huron, and mesotrophic-oligotrophic designation for Lake Michigan.

Species lists for each are provided. Original source data for each station visit are provided in the attached microfiche.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Lake, Michigan, Huron, Erie<br>Phytoplankton<br>Zooplankton<br>Picoplankton | | |

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|---|---|---|
| 18. DISTRIBUTION STATEMENT<br>Document is available through the National Technical Information Service(NTIS)<br>Springfield, VA 22161 | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES<br>280 |
| | 20. SECURITY CLASS *(This page)* | 22. PRICE |

EPA Form 2220-1 (9-73)

★ U.S. GOVERNMENT PRINTING OFFICE: 1987 744-960