Preliminary Results of the 1978-1979 Lake Erie

Intensive Study - Phytoplankton

by

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Introduction

As part of the International Joint Commission's monitoring plan on the Great Lakes, intensive surveys of Lake Erie were undertaken in 1978 and 1979 by the U.S. Environmental Protection Agency. These surveys included monitoring of phytoplankton populations in the open waters on nine cruises in each year (Table 1) to detect changes in the quantity and quality of phytoplankton reflective of changing water quality and to provide data by which future changes may be measured. This report includes results of the 1978-79 study as well as a discussion of changes occurring between 1978 and 1979.

Methods

Phytoplankton samples were collected according to the following sampling regime. When the lake was thermally stratified, samples were collected from 1 meter, 1 meter above the metalimnion, at the thermocline, 1 meter above the hypolimnion, and 1 meter above the bottom. When thermal stratification was not evident samples were obtained at 1 meter, mid-depth, and 1 meter above the bottom. The exception to this was on the March 1979 cruise when samples were obtained at the 1 meter depth from a U.S. Coast Guard helicopter. Table 1 gives the cruise dates in 1978 and 1979. In 1978 phytoplankton samples were collected from all stations on all cruises (Figure 1). In 1979 a reduced station network was implemented (Figure 2).

Phytoplankton samples were obtained from the same opaque 8 liter Niskin bottles used for nutrient-analysis. Following removal of water for nutrient analysis a 500 ml aliquot of sample was drawn into an 540 ml polyethylene bottle and 10 ml of modified Lugols solution added. Samples were returned to Chicago where analysis and quality control were carried out by USEPA's Central Regional Laboratory

(CRL). In CRL the samples were shaken vigorously for several minutes and 10 ml poured into settling chambers and allowed to settle for 35 to 48 hours. Organisms greater than 10 µm were enumerated and identified at 250 with 2 perpendicular strips 13.6 mm long (10.93 mm^2) counted. Organisms less than 10 µm were enumerated and identified at 500 X with 2 perpendicular strips 13.6 mm long (5.55 mm^2) being counted. All analysis was performed using Lietz Ultralux inverted microscopes. All data was expressed as cell/ml.

Due to the large volume of samples generated and other commitments of Great Lakes National Program Office (GLNPO); resources were not available for exhaustive station by station measurements for the calculation of biovolumes. Instead the following regimen was used to generate approximate cell dimensions for calculating biovolume. Organisms or cells were measured in surface samples from stations 61, 84, 58, 50, 51, 86, 30, 79, 18, 80, and 5 on cruise numbers 4, 6, and 9 in 1978. At least 10 cells (usually many more) of each common species were measured. Less common species were measured as they occurred. These measurements were combined and mean dimensions calculated for each species. Geometric shapes were approximated and mean volumes calculated. When species not measured in this process or were measured infrequently (n <10), biovolumes supplied by the Center for Lake Erie Area Research at Ohio State University, State University of New York at Buffalo, or obtained from the literature were utilized. Biomass was calculated assuming a density of 1.

Results

Seasonal Variation 1978

In 1978 total phytoplankton biomass in the western basin ranged from 2.0 g/m^3 to 9.1 g/m^3. Total biomass (Figure 3) decreased from 2.0 g/m^3 to 1.1 g/m3 between May and June before increasing to the observed maximum of 9.1 g/m^3in August. Following the August peak, biomass declined to 1.25 g/m^3 in November. The population was dominated (Figure 4) in turn by Diatomeae (May), Cryptomonadinae (June), Dinophycinae (July), cyanophyta (August), Diatomeae (September-October), and Cyanophyta (October-November). The seasonal variations in biomass of major taxonomic groups are given in Figures 5 and 6.

Total phytoplankton biomass in the central basin in 1978 was less than that observed in the western basin, ranging from 1.0 $g/m^3$to 3.1 g/m^3 (Figure 7). Biomass decreased from 2.8 g/m^3 in May to 1.05 g/m^3 in June before reaching the maximum observed value of 3.0 g/m^3 in July. Following the July maximum, biomass decreased steadily to the low of 1.0 g/m^3 observed in November. The Diatomeae dominated the plankton from May through late June (Figure 8). In July the population was nearly equally dominated by the Chlorophyta (26%) and Dinophycinae (27%). The Chlorophyta continued to dominate the central basin phytoplankton throughout the rest of the 1978 study period. The seasonal variations in biomass of major taxonomic groups are given in Figures 9 and 10.

The lowest total phytoplankton biomass and least seasonal variation in 1978 occurred in the eastern basin (Figure 11) where biomass ranged from a low of 0.4 g/m^3 in November to a high of 2.2 g/m^3 in May. The major group composition (Figure 12) resembled that of the central basin with the Diatomeae dominating the plankton on the May and June cruises and the Chlorophyto dominating from July through early October. The summer dominance of the Chlorophyta was, however more pronounced in the eastern basin where it comprised over 88% of the total biomass. The seasonal variations in major taxonomic groups are given in Figures 13 and 14.

Seasonal Variation - 1979

Caution should be exercised when considering seasonal variations in 1979. Vessel breakdown and other technical difficulties resulted in data being available for seven cruises in the western basin, six in the central and five in the eastern basin.

The most complete data set in 1979 is for the western basin where total biomass ranged from a low of 2.0 g/m^3 in April to a high of 17.3 g/m^3 in November (Figure 15). Biomass remained relatively constant (2.0 g/m^3 to 2.35 g/m^3) on the April, May, and July cruises. By early August phytoplankton biomass had increased to 15.7 g/m^3 primarily as a result of large increases in Diatomeae (5.8 g/m^3) (Coscinodiscus rothii 3.1 g/m^3) and Cyanophyta (7.3 g/m^3) (Aphanizomenon flos-aquae 3.6 g/m^3) biomass. Following a decrease to 12.3 g/m^3 in September, total biomass again increased reaching 17.4 g/m^3 in November. The November peak resulted from very high 14.1 g/m^3 Diatomeae biomass (Melosira sp. 6.7g/m^3, Stephanodiscus binderana 2.8 g/m^3, S. Niagarea 2.5 g/m^3) as well as a high Cyanophyta biomass (2.1 g/m^3) (Aphanizomenon flos-aquae 1 g/m^3). As in 1978, the western basin phytoplankton was dominated by the Diatomeae on the early cruises while the Cyanophyta dominated the early to mid-summer cruises (Figure 16) with the Diatomeae again dominating in September through November. The seasonal variations in major taxonomic groups are given in Figures 17 and 18.

The central basin was similar to the western basin in that large diatom populations occurred on the October (2.2 g/m^3) and November (7.5 g/m^3) (Melosira sp 3.5 g/m^3, S. binderana 1.2 g/m^3, S. Niagarea 2.5 g/m^3) cruises. In 1979 total phytoplankton biomass in the central basin ranged from 1.5 g/m^3 to 8.4 g/m^3 (Figure 19). The spring (March and May) cruises were dominated by the Diatomeae, with the Chlorophyta dominating the plankton on the July cruise and the Diatomeae dominating on the September, October and November cruises (Figure 20). The seasonal variations of major taxonomic groups in the central basin in 1979 are given in Figure 17.

Total biomass in the eastern basin in 1979 ranged from a low of 0.65 g/m^3 in March to a high of 1.25 g/m^3 in October (Figure 23). As in the central basin the spring cruise (March) was dominated by Diatomeae, the summer (July through September) by Chlorophyta and the fall (October and November) by Diatomeae (Figure-24). (Figures 25 and 26) give the abundance of major taxonomic groups.

Species Composition

The relative abundance of common species in 1978 and 1979 are given in Tables 2 through 7. These tables also give the trophic preference of those species which have well defined trophic preference (Stoermer and Yang 1970, Tarapchak and Stoermer 1976, Munawar 1981).

The 1978 spring cruise (May 18-25) in the western basin was dominated by Melosira sp. with Tabellaria fenestrata and Closterium lunula as sub-dominants. The late spring (June 6-15 and June 23-July 2) cruises were dominated by Cryptomonas erosa and Covata with Mougeotia sp. and Ceratium hirundinella sub-dominants on the June 23-July 2 cruise. The three summer (July 19-September 6) cruises were dominated by Ceratium hirundinella, Aphanizomenon flos-aquae, and Coscino discus rothii.

Sub-dominants during this period included Cosmarium spp. and Melosira, spp. The fall cruises (October 3-November 16) were dominated by Oscillatroia sp. with Melosira sp. and Coscinodiscus rothii as sub-dominants.

In 1979 the early spring cruises (March 27-April 20) in the western basin were dominated by Fragillaria sp. and Melosira sp. with Diatoma tenue and Stephanodiscus binderanus sub-dominate in April. The summer period (July 11-August) was, as in 1978, dominated by Aphanizomenon flos-aquae with Ceratium hirundinella and Coscinodiscus rothii as sub-dominants. The fall (September 11-November 16) cruises were dominated by Melosira sp., and Stephanodiscus niagarae with Coscinodiscus rothii, Aphani zomenon flos-aquae, and Stephanodiscus binderanus as sub-dominants.

The 1978 spring (May 18-25) cruise in the central basin was dominated by Asterinonella formosa with Melosira sp. a sub-dominant. By late spring (June 6-July 2) an unidentified non-green flagcallate and Fragilaria crotonensis were the dominant phytoplankton organisms with Cryptomonas erosa and an unidentified pennate diatom important contributors to the total biomass. The summer (July 19September 6) cruises were dominated by eutropic forms, such as Ceratium hirundinella and Oocystis borgei with other eutrophic species such as Aphanizomenon flos-aquae, Stephanodiscus niagarae, and Scenedesmus bijuga common. The fall (October 3-November 16) cruises were dominated by Stephanodiscus niagarae, and Cryptomonas erosa. Oscillatoria sp. and Cryptomonas ovata were sub-dominates. Eutrophic indicators such as Aphanizomenon flos-aquae, Oocystis borgei; and Oscillatoria sp. were, common.

In 1979 the central basin spring (March 27-May 26) cruises were dominated by the Stephanodiscus niagarea with Stephanodiscus binderanus, Diatoma tenue var. elongatum, Fragilaria sp., Melosira sp., Tabellaria fenestrata, and Rhodomonus minuta common. The summer (July 11-August 4) cruises were dominated by Ceratium hirundinella with eutrophic indicators such as Coelastrum reticulatum, Staurastrum paradoxum, Oocystis borgei, Aphanizomenon flos-aquae, and Coscinodiscus rothii common. The fall cruises (September 11-November 16) were dominated by Stephanodiscus niagarea in September and October while Melosira sp. dominated the November cruise.

In the eastern basin the spring 1978 (May cruise was dominated by Stephanodiscus binderanus with Asterionella formosa a sub-dominate. By late spring (June 6-July 2) an unidentified pennate diatom and Cryptomonas erosa were the dominant and subdominant species. Diatoms such as Fragilaria crotonensis, and Tabellaria fenestrata were important.

The summer (July 19-September 6) cruises were dominated by eutrophic green and blue-green species such as Anabaena flos-aquae, Scenedesmus bijuga, and Oocystis borgei. Other typically eutrophic forms such as Ceratium hirundinella and Staurastrum paradoxum were common. By the fall (October - November) cruises diatoms were becoming relatively more important in the plankton with Tabellaria fenestrata and Stephanodiscus niagarea common. The fall 1978 cruises were dominated in turn by Oocystis borgei, Tabellaria fenestrata, and Cryptomonas erosa.

In 1979 only five phytoplankton cruises were completed in the eastern basin. Three of these were clustered in the September-November period. The Spring (March) cruise was dominated by Stephanodiscus niagarea which comprised over 78% of the total biomass. The summer and fall cruises for which data is available indicates a successional pattern similar to that observed in 1978.

Horizontal Variation

Figures 27 and 28 illustrate the horizontal distribution of total biomass in 1978 and 1979. In 1978 a growth pulse had apparently begun in the central and stern basins prior to our May cruise. A second pulse began in the western basin on the June 28 cruise which spread into the central and eastern basins in July. Throughout the 1978 study season total biomass tended to be higher near shore in all basins. The western basin, particularly west of the Detroit River and southwest of the Bass Islands exhibited the highest total biomass. Biomass concentrations in the central and eastern basins were surprisingly similar.

In 1979 total biomass at most stations in the western and central basins (from August through November) was substantially higher than that observed in 1978 while eastern basin concentrations were relatively unchanged from the previous year.

Discussion

In both years of the study there was a west to east decrease in total biomass and change in dominant groups. In 1978 mean total biomass ranged from 4.0 g/m^3 in the western basin to 1.8 g/m^3 in the central and 1.2 g/m^3 in the eastern basin. In 1979 the reduced station network and limited number of cruises yielded mean biomass of 9.4 g/m^3, 3.4 g/m^3, 0.9 g/m^3 in the western, central, and eastern basins respectively. Between May and November, both years, the Cyanophyta was most common in the western basin, the Diatomeae in the central and the Chlorophyta in the eastern basin. The large dominance of diatoms on the April cruise in 1979 resulted in the Diatomeae being the dominate form in the western basin that year. (Munawar and Munawar (1976) reported similar dominance of major groups in the three basins between April and December 1970.

The major observation of our study was the increase in phytoplankton biomass observed between 1978 and 1979 in the western and to a lesser extent in the central basin. This was particularly evident in the western basin where a nearly complete data base in 1979 and similar station locations in 1970, 1978, and 1979 allows a more direct comparison than can be made in the other basins. Figure 29 illustrates the cruise means for total phytoplankton biomass in 1970 (Munawar and Munawar 1976), 1978, and 1979 at stations 50, 51, 55, 58, and 61. The data indicates that western basin biomass between April and August in both 1978 and 1979 was substantially below that observed in 1970. However, in the latter portion of the 1979 season total biomass frequently equalled or exceeded that observed in 1970.

While the lack of May and June cruises in 1979 prevents direct comparison over the season, the data can be compared for the July through November period. This is given in Table 8 and shows the large biomass increase over 1978 levels that occurred in the later half of 1979. This increase is supported by field observations of visible blue-green algae blooms over large areas of the western basin in August, September, and October 1979. We also observed blooms associated with whitings (Schelski & Callender 1970) probably as a result of $CaCO_3$ precipitation, in August 1979.

Vollenweider (1968) has used maximum phytoplankton biomass as an indicator of trophic status. He classifies lakes with maximum biomass <1.0 g/m^3 as ultra-oligotrophic, 3 to 5 g/m^3 as mesotrophic and those >10 g/m^3 as highly eutrophic. Based on this system, the western basin of Lake Erie would be classified between mesotrophic and highly eutrophic (9.1 g/m^3) in 1978 and as highly eutrophic (17.3 g/m^3) in 1979. The central basin would be considered mesotrophic (3.1 g/m^3) in 1978 and between mesotrophic and highly eutrophic (8.4 g/m^3) in 1979. The eastern basins with maximum biomass of 2.2 g/m^3 and 1.25 g/m^3 would be considered mesotrophic both years.

The above classification is consistent with the trophic preference of common species given in Tables 2 through 7. In the western basin; between 44% (in 1978) and 62% (in 1979) of those species comprising 5% or more of the total biomass have been classified by at least one author as eutrophic. In the central basin 41% and 55% fall in this category in 1978 and 1979. The percentage of eutrophic species in the eastern basin in 1979 may be influenced by the limited number (5) of cruises.

As the largest phosphorus loading and the most complete data bases are from the western basin, the reminder of this discussion will be directed at that basin.

Heterotrophic bacterial populations have been shown to be sensitive to minute changes in nutrient concentrations and are thus sensitive indicators of nutrient changes (Godlewska and Lippowa 1976, Rao and Jurkovic 1977). Heterotrophic bacterial populations in the western basin increased from an annual geometric mean of 478 organisms/100ml in 1978 to a geometric mean of 526 organism/100ml in 1979. The highest bacterial populations in both years were observed in the areas influenced by the Detroit River, River Raisin, and Maumee River (stations 60, 61, 75, and 84). In 1978 the annual geometric mean for the above stations was 1136 organisms/100ml with a maximum observed population of 21500 organisms/100ml at station 60 during the October-November cruise. In 1979 the annual geometric mean for these stations increased almost three times to 3150 organism/100ml with a maximum population of 115,000 organisms/100ml observed at station 60 during the May cruise (#2). There were three occurrences of populations >5000 organisms/100ml in 1978 and seven in 1979 in this area (USEPA - unpublished data). The increased bacterial activity observed in 1979 is in agreement with the larger phytoplankton biomass and is suggestive of increased nutrient concentrations.

Unfortunately total phosphorus data is not available for a large portion of the 1978 study period. However, during those periods for which data are available, western basin concentrations were higher in 1979. Total phosphorus concentrations from May through July averaged 18.8 ug/l and 19.0 ug/l in 1978 and 1979 respectively. This excludes the western basin mean of 98 ug/l which was observed in April 1979, following severe storms. In 1979, a mean total phosphorus concentration of 29.3 ug/l was observed in the August through October period. While data is not available for this period in 1978, comparison of the November cruises in each year suggests that total phosphorus concentrations in the later portion of the 1979 season were as much as 50 percent higher than that observed in 1978. The mean western basin total phosphorus concentration in November 1978 was 22.3 ug/l compared to 32.7 ug/l in 1979 (Fay and Herdendorf 1981). Total phosphorus concentrations also increased from 1978 to 1979 in the central and eastern basins. During the periods for which data is available (May-November) total phosphorus in the central basin averaged 8.4 ug/l in 1978 and 12.1 ug/l in 1978. In the eastern basin (May-August) total phosphorus averaged 9.5 ug/l in 1978 and 11.7 ug/l in 1979 (Fay and Herdendorf 1981). The increase in total phosphorus concentrations which occurred in 1979 supports, and probably contributed to, the increased phytoplankton biomass.

It must be noted, however, that total phosphorus loads to the western basin decreased by 1075 metric tons (Yaksich and Melfi 1982) from 1978 to 1979. A period during which biological and chemical data indicates that increased concentrations occurred, particularly in the western basin. Changes in lake levels may be responsible for part of the concentration change. Water levels were 30 to 122mm below 1978 levels the first half of 1979, and 30 to 122mm above 1978 levels during the last six months of 1979. As a result, the mean western basin volume for the two cruise seasons was relatively constant, averaging 24.41 Km^3 in 1978 and 24.79 Km^3 in 1979 (Fay and Herdendorf 1981). It is evident that while some of the increase in total phosphorus concentration may be the result of complicated interactions between loading and lake level, the majority must be explained by other mechanisms.

One possibility is that the increased loads of orthophosphorous (Table 9) in 1979 resulted in an increase biologically available phosphorus despite the decrease in total phosphorus loading. The bioavailability of the phosphorus from tributary loads ranges from 1 to 55 percent depending on the contributing source of the phosphorus. Cowen and Lee (1976) reported that available phosphorus comprised 5 percent or less of the total phosphorus in particulates in tributaries and from 1 to 24 percent of the total phosphorus in urban run off to the Genessee River. Algal available phosphorus ranged from 0 to 50 percent (mean 22.7%) of the total particulate phosphorus in several tributaries to Lakes Erie and Ontario (Maumee River, Sandusky-Honey Creek, Cuyahoga River, Cattaraugus Creek, Genessee River)

(Martin et al 1982). If biologically available phosphorus comprised 13 percent or less of the total tributary load to Lake Erie the 146 metric ton increase in the orthophosphorous load may have resulted in an increase in biologically available phosphorus despite the decreased total phosphorus load.

That this may have occurred is suggested by the timing of the biomass increase, precipitation events, and orthophosphate load in 1979 (Table 9). Precipitation was significantly above 1978 levels in July, August, and November 1979. While Table 9 indicates that annual total phosphorus loads were reduced in 1979, orthophosphorous loads were above 1978 levels from July through December 1979 with the exception of October. In addition, during August and November 1979, total phosphorus loads exceeded 1978 loads. Thus, probably not coincidently, total biomass increased dramatically from mid-July to early August and remained high throughout the remainder of the 1979 season.

The results of the 1978-79 intensive study indicate that severe deterioration in water quality occurred in the last half of the 1979 study. While chemical (phosphorus) data is lacking for a good portion of 1978, the consensus of the data overwhelmingly indicates that deterioration in water quality did occur. The increased phytoplankton biomass and bacterial activity in 1979 may have been a result of the increased loads of bioavailable phosphorus that occurred in spite of the decrease in total phosphorus loadings. Orthophosphorous loads to the western basin increased by 146 metric tons during the study, from 3742 metric tons in 1978 to 3888 metric tons in 1979. The Detroit River contributed 116 metric tons of this increase (Yaksich and Melfi 1982).

The increase in orthophosphorous loading may have resulted from combined sewer overflows and runoff due to the increased precipitation. Combined sewer, overflows from 25 major events contributed 160 mt TP in the Detroit area (Giffels, Black, and Veatchs 1981) in 1979 (Table 9). This load was estimated to be 50 mt above a normal rainfall year.

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Table 1

Lake Erie Cruise Dates 1978 - 1979

Cruise Number	1978	1979
1		March 27-29
2	May 18-25	April 17-20
3	June 6-15	May 15-26
4	June 23 - July 2	sediments only
5	July 19-29	July 11-19
6	August 8-16	July 31 - August 4
7	August 29- September 6	ship failure
8	October 3-12	September 11-21
9	October 24 - November 1	October 4-10
10	November 7-16	November 7-16

Table 2

Seasonal Relative Abundance of Common (>5%) Species in the Western Basin 1978

Cruise	Species	Percent of Total Biovolume
May 18-25	Melosira spp.	34.43
	Tabellaria fenestrata	16.28
	Closterium Lunula	15.11
	Unidentified pennate diatom	7.57
June 6-15	Cryptomonas erosa	32.74
	Cryptomonas ovata	12.63
	Tabellaria fenestrata	9.20
	Cosmarium spp.	7.16
	Unidentified non-green flagellate	6.11
	Rhodomonas minuta	5.41
June 23- July 2	Cryptomonas ovata	14.57
	Cryptomonas erosa	12.89
	Mougeotia spp.	12.84
	Ceratium hinrundinella •	10.03
	Aphanizomenon flos-aquae •	7.30
July 19.-20	Ceratium hinrundinella •	53.79
	Cosmarium sp.	11.99
	Aphanizomenon flos-aquae •	7.99
	Cryptomonas erosa	7.11
	Cryptomonas ovata	6.07
August 8-16	Aphanizomenon flos-aquae •	49.50
	Coscinodiscus rothii •	14.38
	Melosira spp.	11.88
August 29 - September 6	Coscinodiscus rothii •	28.62
	Aphanizomenon flos-aquae	14.13
	Melosira spp.	11.58
	Stephanodiscus niagarae	9.28
	Oscillatoria spp. •	6.58
	Anabaena spp. •	5.14

• eutrophic species

Table 2 (Continued)

Cruise	Species	Percent of Total Biovolume
October 3-12	Oscillatoria sp. •	18.60
	Melosira spp.	17.82
	Coscinodiscus rothii •	12.32
	Anabaena spp. •	6.85
	Stephanodiscus niagarae •	6.40
	Pediastrum simplex •	6.16
October 24 - November 1	Oscillatoria spp. •	31.04
	Melosira spp.	16.40
	Anabaena spp. •	8.32
	Mougeotia spp.	5.68
November 7-16	Oscillatoria spp. •	26.73
	Melosira spp.	15.04
	Coscinodiscus rothii •	6.42
	Mougeotia spp.	5.88
	Tabellaria fenestrata	5.73
	Dinobryon spp.	5.06

• eutrophic species

Table 3

Seasonal Relative Abundance of Common (>5%)
Species in the Western Basin -1979

Cruise	Species	Percent of Total Biovolume
March 27-29	Fragilaria spp.	17.02
	Tabellaria fenestrata	9.71
	Stephanodiscus niagarae •	9.59
	Melosira spp.	8.51
	Stephanodiscus binderana	7.92
	Unidentified Centric Diatom	7.54
	Unidentified non-green flagellate	6.90
	Diatoma tenue var. elongatum •	6.00
	Asterionella formosa	5.77
	Fragilaria crotonensis	5.01
April 17-20	Melosira spp.	29.54
	Diatoma tenue var. elonatum •	15.49
	Stephanodiscus binderana •	14.18
	Tabellaria fenestrata	7.49
	Stephanodiscus niagarae •	6.24
May 15-26	No data	
July 11-19	Aphanizomenon flos-aquae •	18.43
	Ceratium hirundinella •	16.82
	Cryptomonas erosa	11.57
	Coscinodiscus rothii •	6.70
	Cryptomonas ovata	6.14
July 31 - August 4	Aphanizomenon flos-aquae •	23.10
	Coscinodiscus rothii •	19.48
	Anabaena spp. •	9.95
	Melosira spp. •	8.18
	Anabaena spiroides •	7.49

• eutrophic species

Table 3 (Continued)

Cruise	Species	Percent of Total Biovolume
September 11-21	Melosira spp.	16.71
	Stephanodiscus niagarae •	12.54
	Coscinodiscus rothii •	12.21
	Aphanizomenon flos-aquae •	10.93
	Anabaena spiroides •	7.66
	Anabaena spp. •	6.38
September 4-10	Stephanodiscus niagarae •	22.73
	Melosira spp.	12.93
	Aphanizomenon flos-aquae •	11.96
	Gyrosigma spp.	8.10
	Pediastrum simplex •	5.32
	Stephanodiscus binderana •	5.13
October 7-16	Melosira spp.	38.45
	Stephanodiscus binderana •	17.82
	Stephanodiscus niagarae •	14.59
	Aphanizomenon flos-aquae •	6.01
	Diatoma tenue var. elongatum •	5.07

• eutrophic species

Table 4

Seasonal Relative Abundance of Common (>5%) Species in the Central Basin 1978

Cruise	**Species**	**Percent of Total Biovolume**
May 18-25	Asterionella formosa	31.92
	Melosira spp.	18.08
	Fragilaria crotonensis	6.44
	Stephanodiscus niagarae •	6.40
	Stephanodiscus binderana •	6.39
June 6-15	Unidentified non-green flagellate	27.95
	Unidentified pennate diatom	13.06
	Rhodomonas minuta	9.48
	Tabellaria fenestrata	8.70
	Cryptomonas erosa	8.54
	Fragilaria crotonensis	7.25
June 23 - July 2	Fragilaria crotonensis	15.72
	Cryptomonas erosa	11.42
	Unidentified non-green flagellate	12.21
	Stephanodiscus niagarae •	9.64
	Rhodomonas minuta	8.32
	Cryptomonas ovata	7.32
	Tabellaria fenestrata	6.77
July 19-29	Ceratium hirundinella •	29.34
	Aphanizomenon flos-aquae •	8.00
	Stephanodiscus niagarae •	7.59
	Cosmarium spp.	5.10
August 8-16	Ceratium hirundinella •	21.93
	Aphanizomenon flos-aquae •	13.30
	Oedogonium spp.	9.61
	Unidentified coccoid green	5.49
	Scenedesmus bijuga •	5.13

• eutrophic species

Table 4 (Continued)

Cruise	Species	Percent of Total Biovolume
August 29 - September 6	Oocystis borgei •	17.68
	Aphanizomenon flos-aquae •	11.53
	Unidentified coccoid green	8.79
	Scenedesmus bijuga •	8.79
	Oocystis spp.	7.60
	Oocystis pusilla	5.75
October 3-12	Stephanodiscus niagarae •	12.53
	Cryptomonas erosa	6.56
	Aphanizomenon flos-aquae •	5.81
	Unidentified pennate diatom	5.71
	Oocystsi borgei •	5.60
	Oocystis spp.	5.22
October 24 - November 1	Cryptomonas erosa	13.85
	Oscillatoria sp. •	11.44
	Cryptomonas ovata	9.74
	Oocystis borgei •	7.80
	Stephandiscus niagarae •	6.55
	Unidentified coccoid green	5.53
November 7-16	Cryptomonas erosa	17.10
	Cryptomona ovata	12.21
	Oscillatoria spp. •	11.79
	Stephanodiscus niagarae •	6.22

• eutrophic species

Table 5

Seasonal Relative Abundance of Common (>5%) Species in the Central Basin 1979

Cruise	Species	Percent of Total Biovolume
March 27-29	Stephanodiscus niagarae •	36.03
	Fragilaria spp.	10.81
	Stephanodiscus binderana •	8.89
	Unidentified centric diatom	7.59
	Gyrosigma spp.	7.32
April 17-20	No data	
May 15-26	Stephanodiscus niagarae •	15.55
	Melosira spp.	12.29
	Tabellaria Fenestrata	11.26
	Diatoma tenue var. elongatum •	10.65
	Rhodomonas minuta	10.47
	Unidentified non-green flagellate	7.09
	Fragilaria crotonensis	5.99
July 11-19	Ceratium hirundinella •	28.53
	Coelastrum reticulatum	14.67
	Staurastrum paradoxum •	7.21
	Cryptomonas erosa	5.81
	Rhodomonas minuta	5.53
	Oocystis borgei •	5.08
July 31 - August 4	Represents only the western portion of the basin	
	Ceratium hirundinella •	25.30
	Aphanizomenon flos-aquae •	22.98
	Fragilaria crotonensis	19.28
	Coscinodiscus rothii •	8.19
September 11-21	Stephanodiscus niagarae •	28.05
	Aphanizomenon flos-aquae •	8.36
	Pediastrum simplex •	7.39
	Ceratium hirundinella •	7.28

• eutrophic species

Table 5 (Continued)

Cruise	Species	Percent of Total Biovolume
October 4-10	Stephanodiscus niagarae •	30.63
	Melosira spp.	18.40
	Aphanizomenon flos-aquae •	8.23
November 7-16	Melosira spp.	41.76
	Stephanodiscus niagarae •	29.97
	Stephanodiscus binderana •	14.69

• eutrophic species

Table 6

Seasonal Relative Abundance of Common (>5%) Species in the Eastern Basin - 1978

Cruise	Species	Percent of Total Biovolume
May 18-25	Stephanodiscus binderana •	20.45
	Asterionella Formosa	17.8
	Melosira spp.	9.6
	Stephanodiscus niagarae •	9.6
	Fragilaria crotonensis	9.2
June 6-15	Unidentified pennate	15.7
	Cryptomonas erosa	14.0
	Tabellaria fenestrata	11.5
	Closterium lunula	5.3
June 23 - July 2	Cryptomonas erosa	16.4
	Fragilaria crotonensis	14.4
	Rhodomonus minuta	11.7
	Unidentified flagellate	11.2
	Asterionella formosa	9.8
	Tabellaria fenestrata	6.6
July 19-29	Anabaena flos-aquae •	18.7
	Oocystsi borgei •	17.0
	Ceratium hirundinella •	13.0
	Staurastrum paradoxum •	7.4
	Cryptomonas ovata	5.1
August 8-16	Scenedesmus bijuga •	28.4
	Oocystis borgei •	15.1
	Ceratium hirundinella •	8.3
	Unidentified coccoid green	5.5
August 29 - September 6	Oocystis borgei •	24.9
	Oocystis sp. •	16.7
	Scenedesmus bijuga •	11.1
	Unidentified coccoid green	8.0

• eutrophic species

Table 6 (Continued)

Cruise	Species	Percent of Total Biovolume
October 3-12	Oocystis borgei •	13.9
	Oocystis sp.	11.1
	Tabellaria fenestrata	10.4
	Staurastrum paradoxum •	8.6
	Unidentified coccoid green	6.3
	Unidentified pennate	5.8
October 24 - November 1	Tabellaria fenestrata	21.9
	Stephanodiscus niagarae •	14.7
	Cryptomonas erosa	13.3
	Oocystis borgei •	7.2
	Cryptomonas ovata	7.0
	Staurastrum paradoxum •	5.1
November 7 - 16	Cryptomonas erosa	18.1
	Tabellaria fenestrata	15.2
	Staurastrum paradoxum •	12.8
	Cryptomonas ovata	10.6
	Cosmarium sp.	5.2

• eutrophic species

Table 7

Seasonal Relative Abundance of Common (>5%) Species in the Eastern Basin - 1979

Cruise	Species	Percent of Total Biovolume
March 27-29	Stephanodiscus niagarae •	78.33
	Unidentified Centric Diatom	8.17
April 17-20	No Data	
May 15-26	No Data	
July 11-19	Oocystis borgei •	19.31
	Ceratium hinrundinella •	17.49
	Rhodomonas minuta	11.06
	Fragilaria crotonensis	7.30
	Cryptomona erosa	5.70
July 31 - August 4	No Data	
September 11-12	Ceratium hirundinella •	27.78
	Staurastrum paradoxum •	10.02
	Oocystsi spp.	8.72
	Cosmarium spp.	7.50
	Coelastrum microporum •	6.78
October 4-10	Stephanodiscus niagarae •	35.73
	Ceratium hirundinella •	10.54
	Microcystis aeruginosa	10.49
	Staurastrum paradoxum •	5.02
November 7-16	Stephanodiscus niagarae •	66.87
	Cryptomonas erosa	5.24

• eutrophic species

Table 8

Mean Epilimnetic Biomass in the Western Basin[1] of Lake Erie (mg/1)

July - November 1970,[2] 1978, 1979

1970	5.18
1978	2.48
1979	7.70 (4.91)[3]

1) 1978 and 1979 mean for stations 50, 51, 55, 58 and 61 which correspond to those surveyed in 1970.

2) 1970 data from Munawar and Munawar 1976.

3) Mean biomass not including the large bloom observed on the November 11, 1979 cruise.

Table 9

Mean Monthly Precipitation at Toledo, Ohio and Tributary Phosphorus Load to the Western Basin

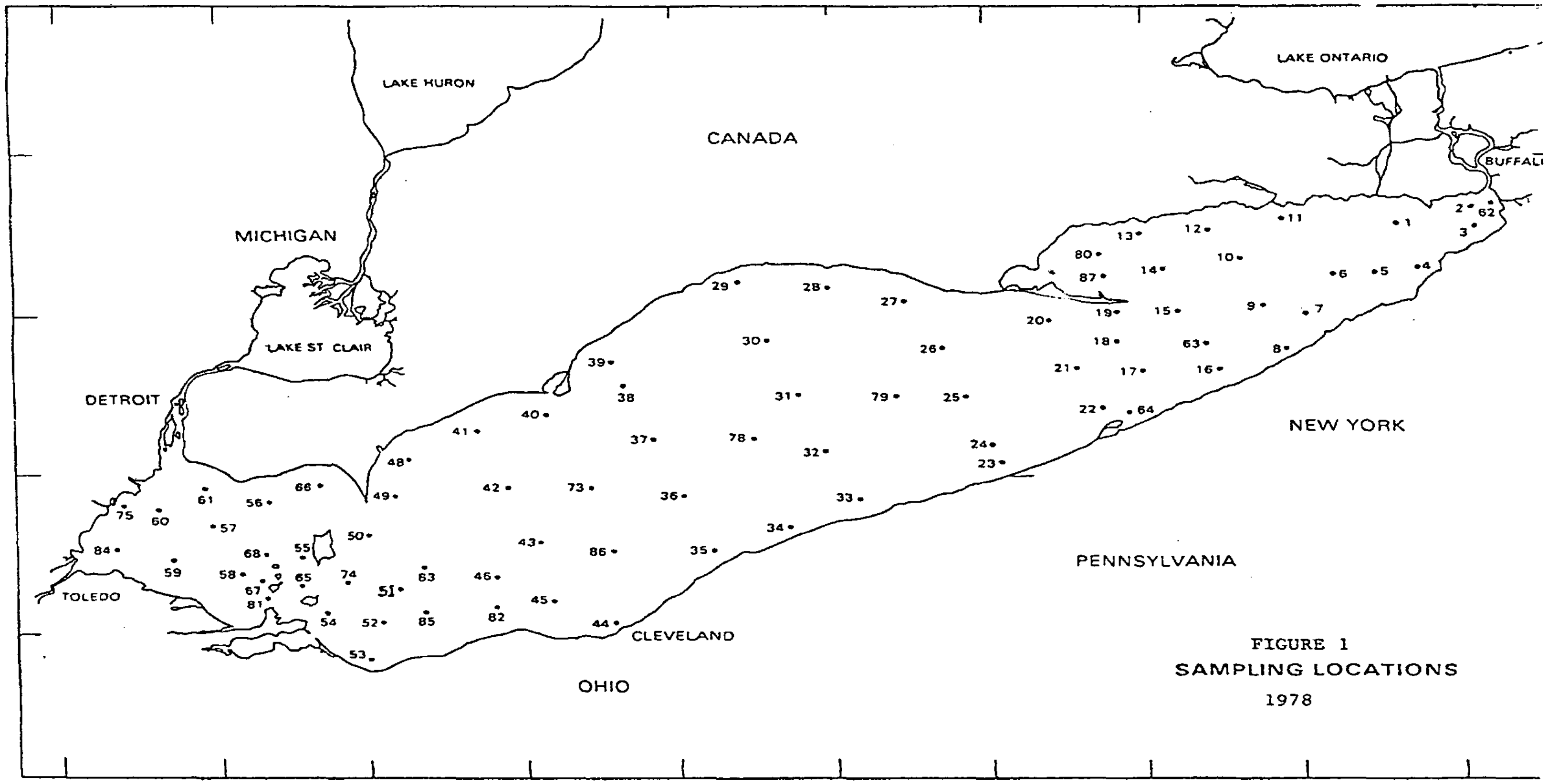
Precipitation (inches)

		Difference	30 year	
Month	**1978**	**1979**	**(1979-1978**	**Normal**
January	3.14	1.24	-1.90	2.08
February	0.54	0.70	0.16	1.75
March	2.34	2.55	0.21	2.52
April	3.74	4.03	0.29	2.95
May	2.48	3.15	0.67	3.33
June	5.34	4.23	-1.11	3.38
July	1.86	3.96	2.10	3.23
August	1.67	4.71	3.04	3.07
September	3.19	2.90	-0.29	2.40
October	1.65	2.02	0.37	2.24
November	2.48	4.25	1.77	2.32
December	3.31	2.46	-0.85	2.24

Tributary Phosphorus Loads (Metric Tons) to the Western Basin

	Total Phosphorus		Orthophosphorous	
Month	**1978**	**1979**	**1978**	**1979**
January	562	496	255	259
February	474	411	210	225
March	2099	1245	676	522
April	1605	1279	580	539
May	679	642	315	315
June	573	468	254	251
July	588	530	266	284
August	517	584	231	304
September	506	438	228	234
October	527	434	239	235
November	514	626	233	301
December	506	982	255	414

Figure 1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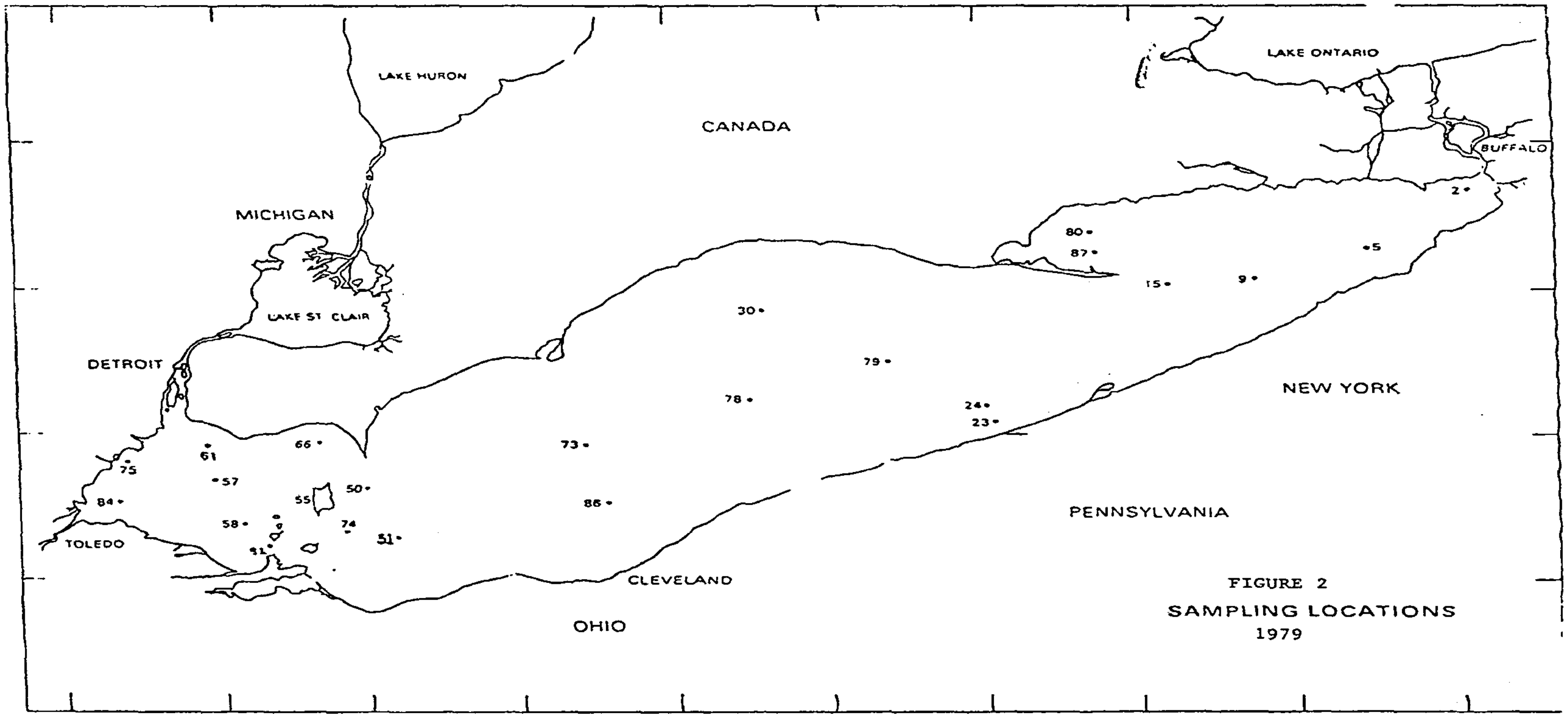
LAKE ONTARIO
CANADA
MICHIGAN
LAKE ST CLAIR
DETROIT
TOLEDO
BUFFALO
NEW YORK
PENNSYLVANIA
OHIO
CLEVELAND
FIGURE 1
SAMPLING LOCATIONS
1978

Figure 2


LAKE HURON
CANADA
LAKE ONTARIO
BUFFALO
MICHIGAN
LAKE ST CLAIR
DETROIT
TOLEDO
CLEVELAND
OHIO
NEW YORK
PENNSYLVANIA
80
87
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24
23
73
86
66
61
75
57
84
55
50
58
74
51
FIGURE 2
SAMPLING LOCATIONS
1979

Figure 3

Seasonal Fluctuation in Total Phytoplankton Biomass in the Western Basin of Lake Erie in - 1978

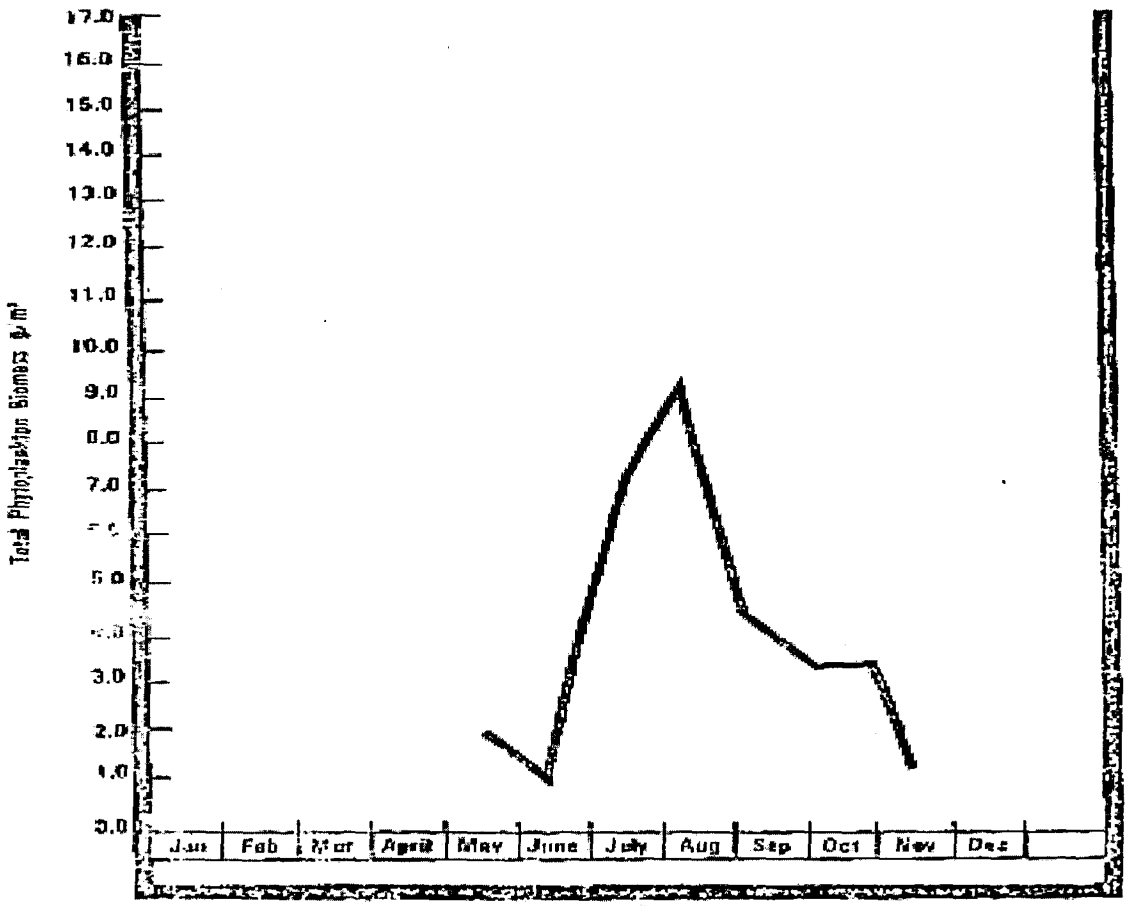

Figure 4

Seasonal Fluctuation in the Major Group Composition of the Phytoplankton in the Western Basin in 1978

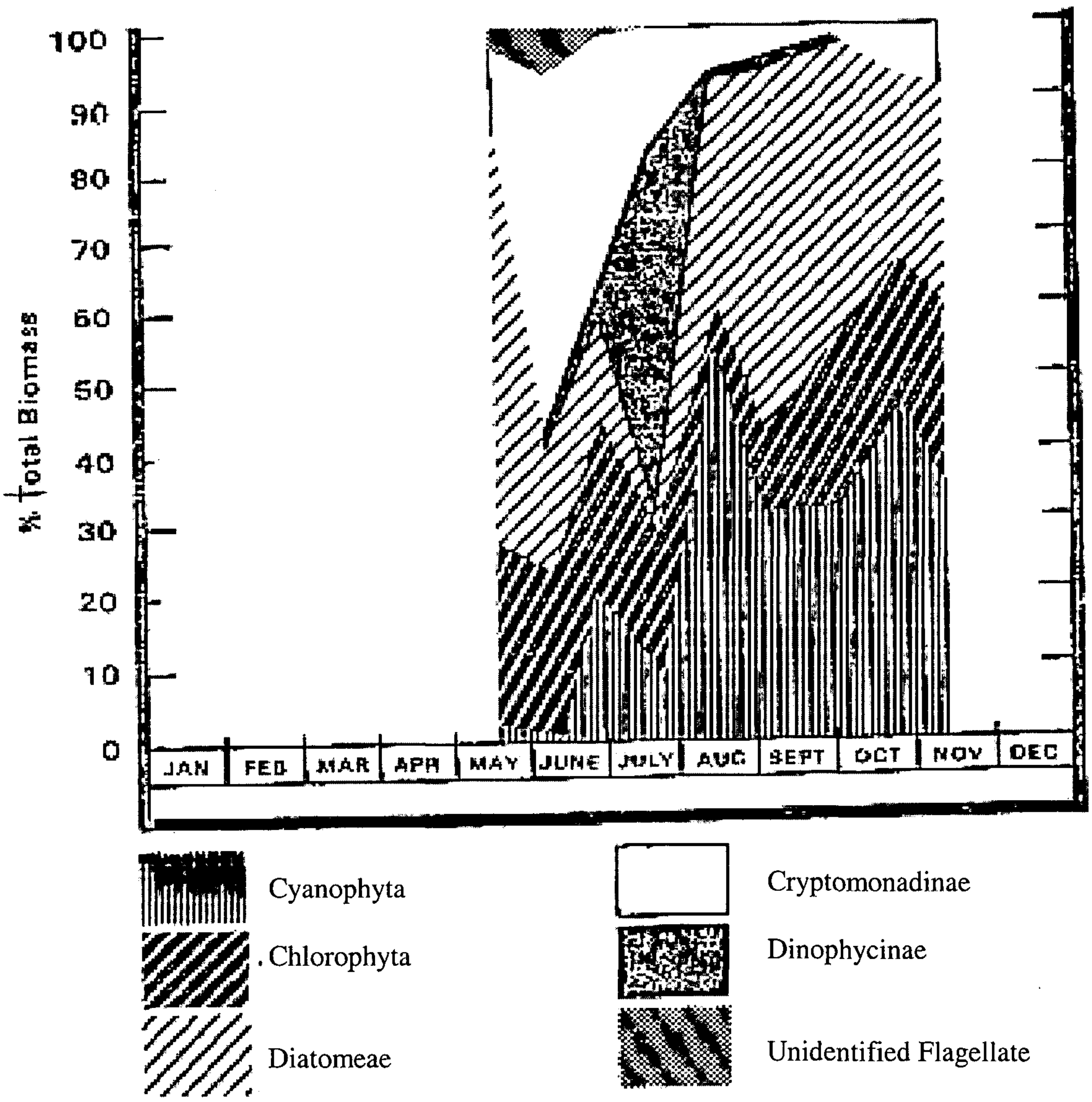

Figure 5

Seasonal Variation in the Diatomeae, Chlorophyta, and Cyanophyta in the Western Basin - 1978

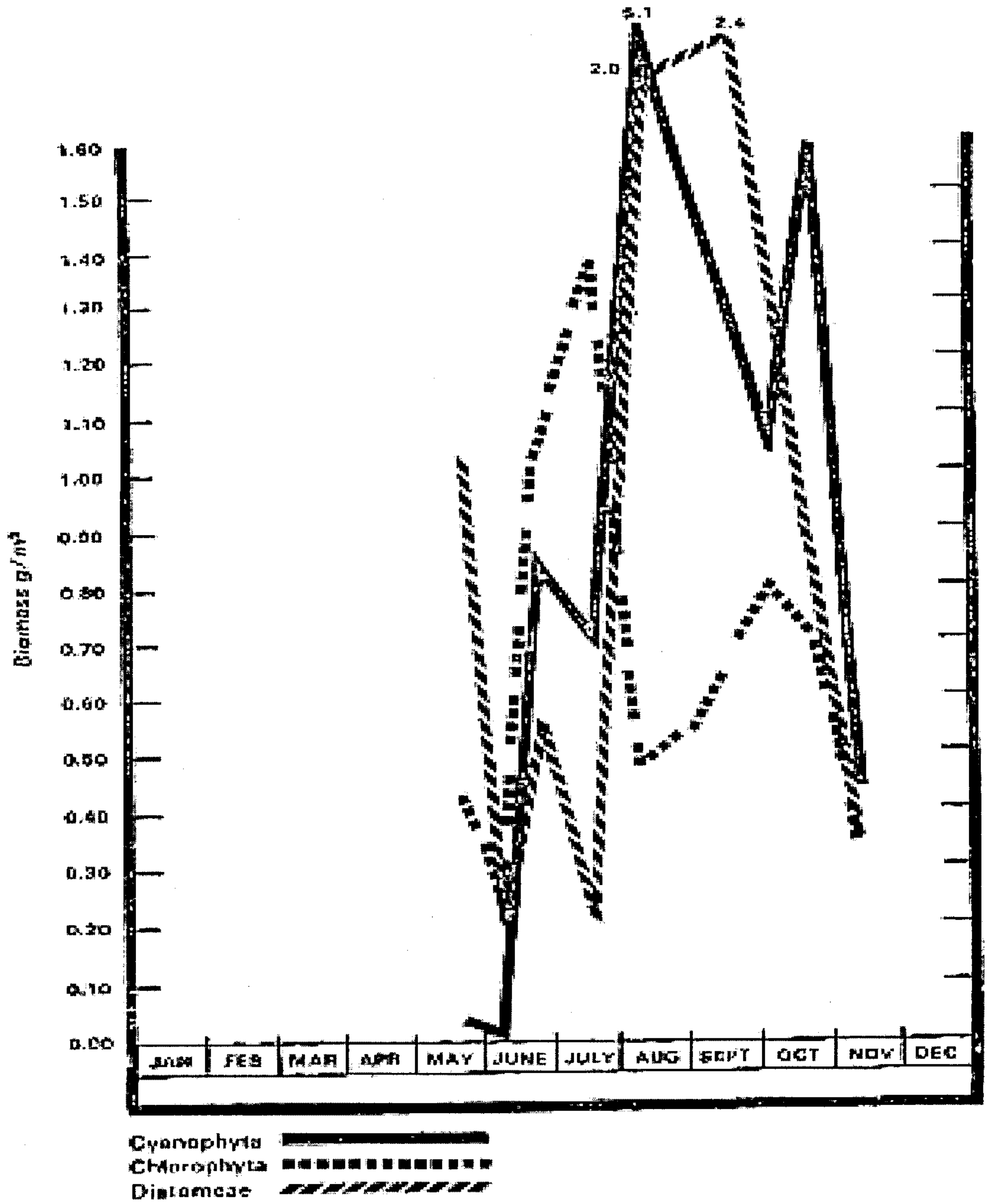

Figure 6

Seasonal Variation in the Dinophycinae, Chrysomonadinae, and Cryptomonadinae in the Western Basin - 1978

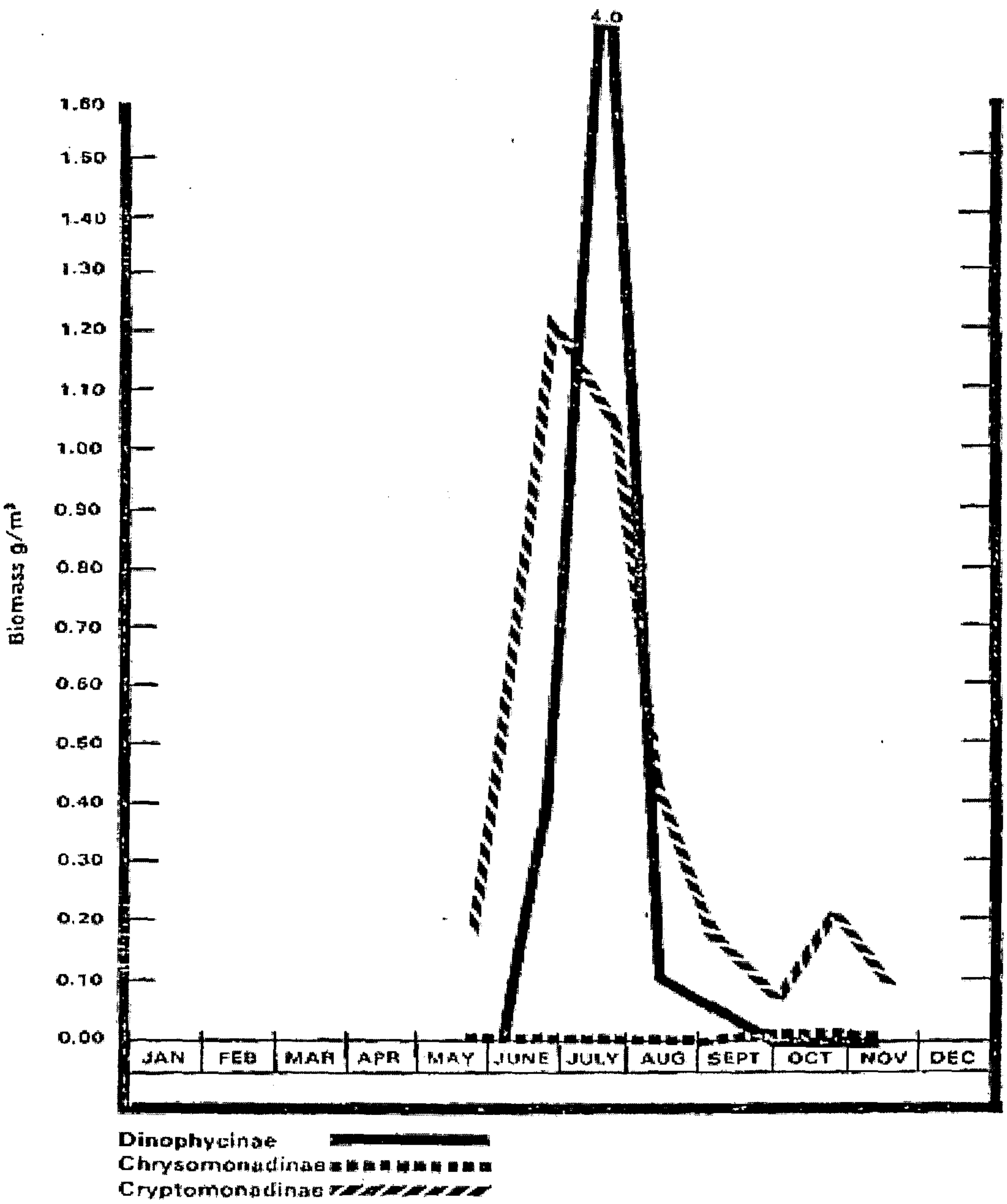

Figure 7

Seâsonal Fluctuation in the Total Phytoplankton Biomass in the Central Basin of Lake Erie in - 1978

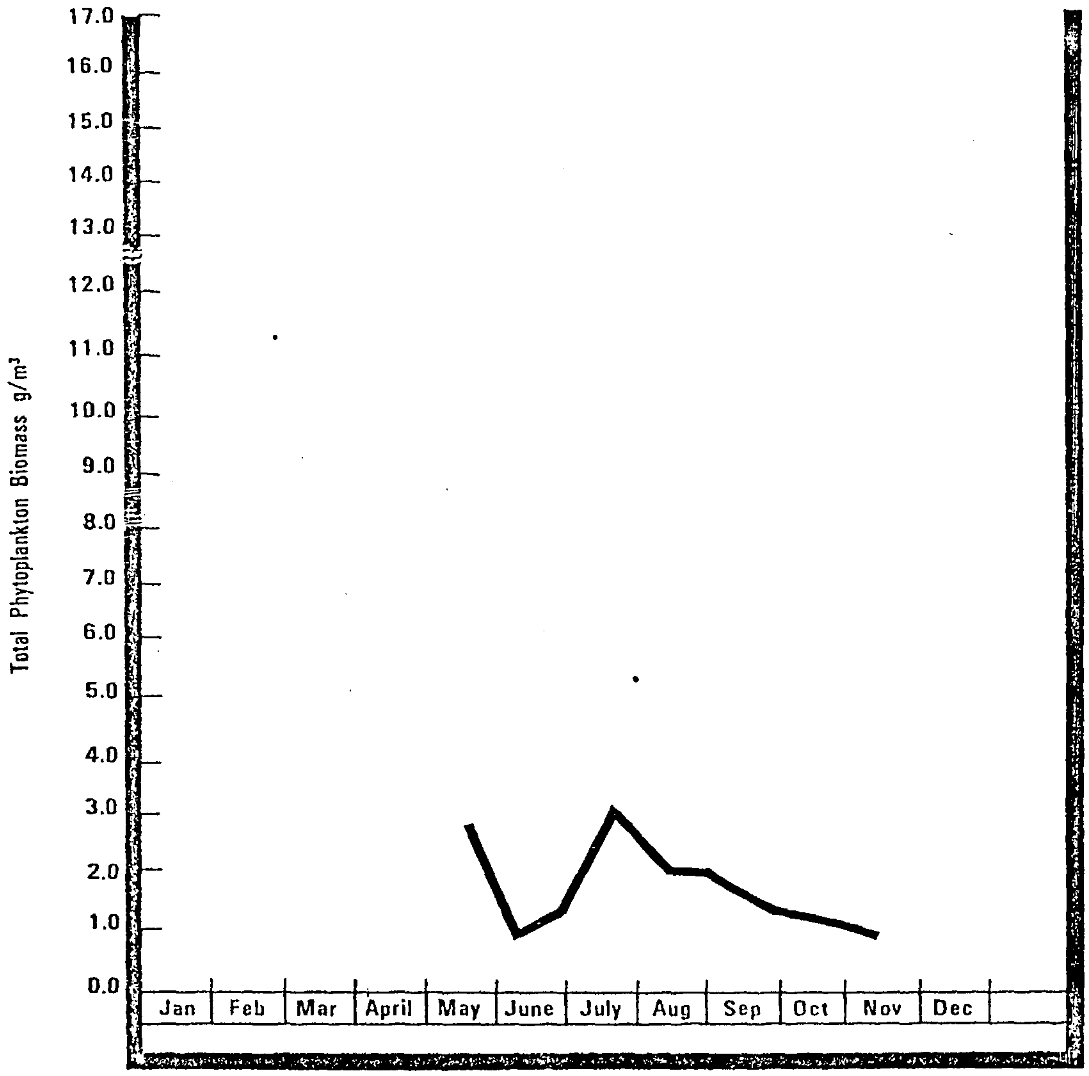

Figure 8

Seasonal Fluctuation in the Major Group Composition of the Phytoplankton in the Central Basin in 1978

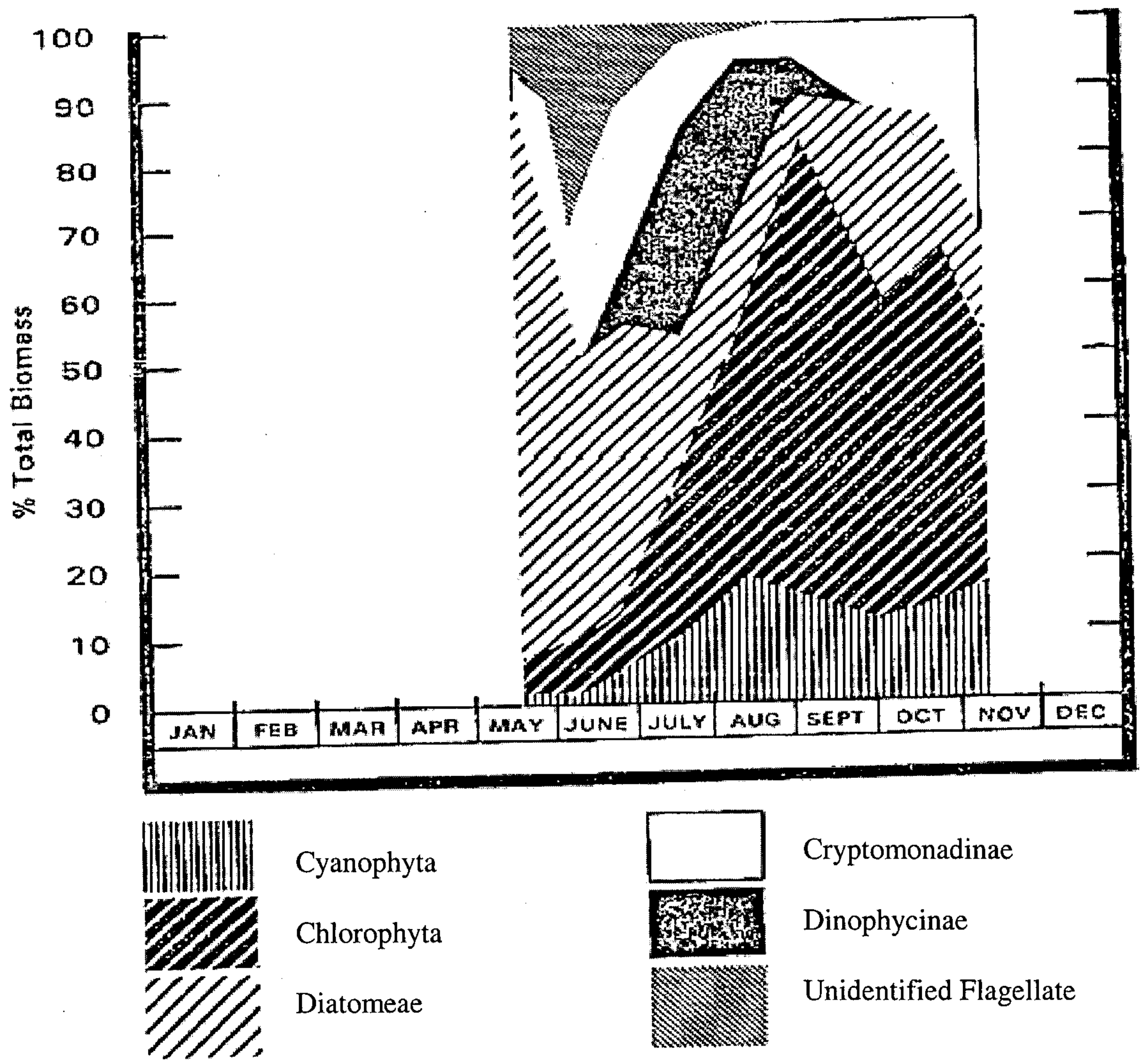

Figure 9

Seasonal Variation in the Diatomeae, Chlorophyta, and Cyanophyta in the Central Basin - 1978

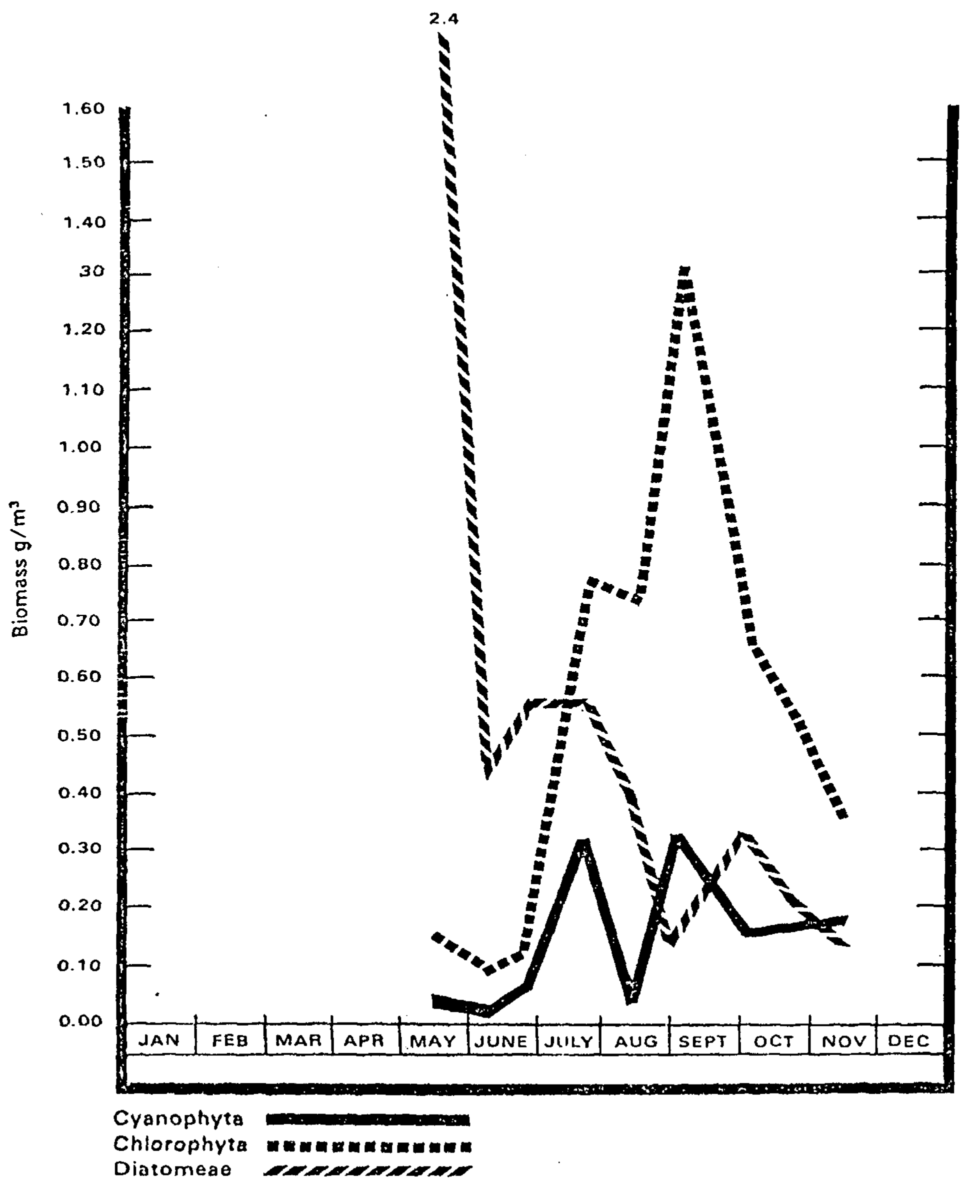

Figure 10

Seasonal Variation in the Dinophycinae, Chrysomonadinae, and Cryptomonadinae in the Central Basin - 1978

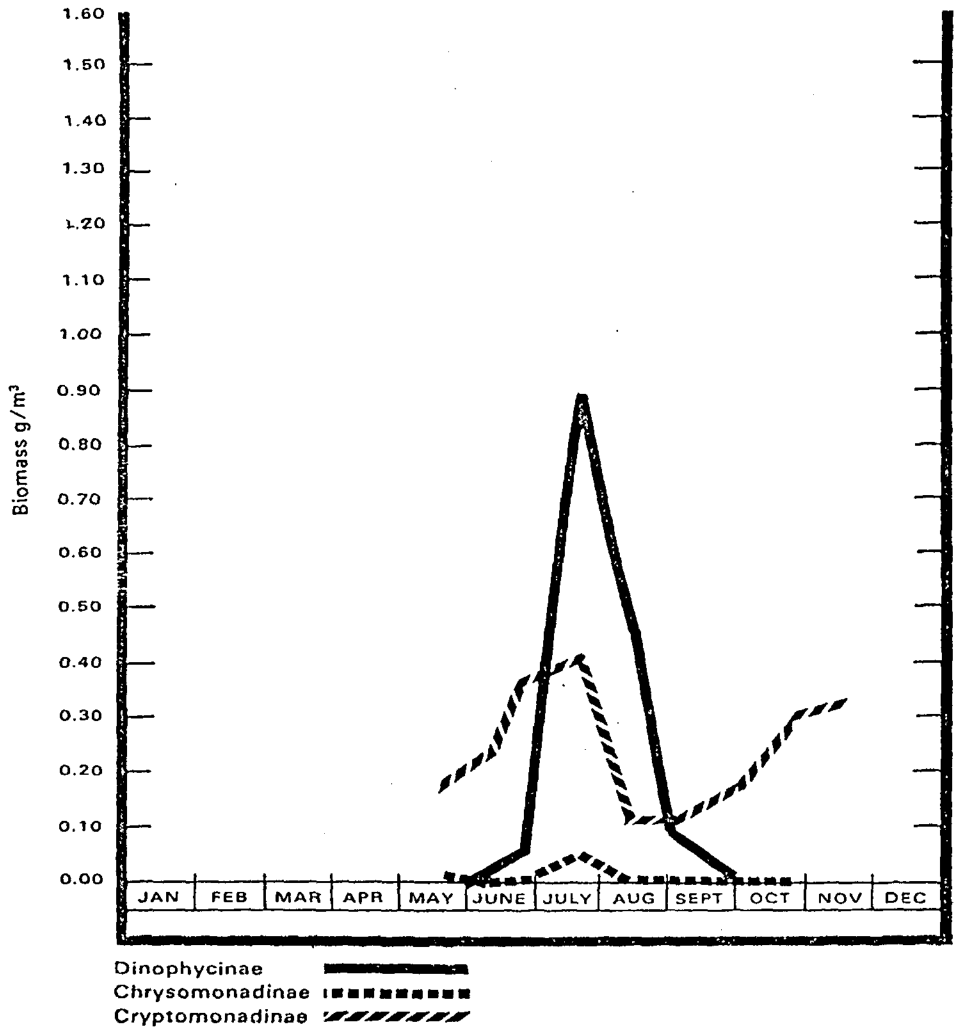

Figure 11

Seasonal Fluctuation in the Total Phytoplankton Biomass in the Eastern Basin of Lake Erie in 1978

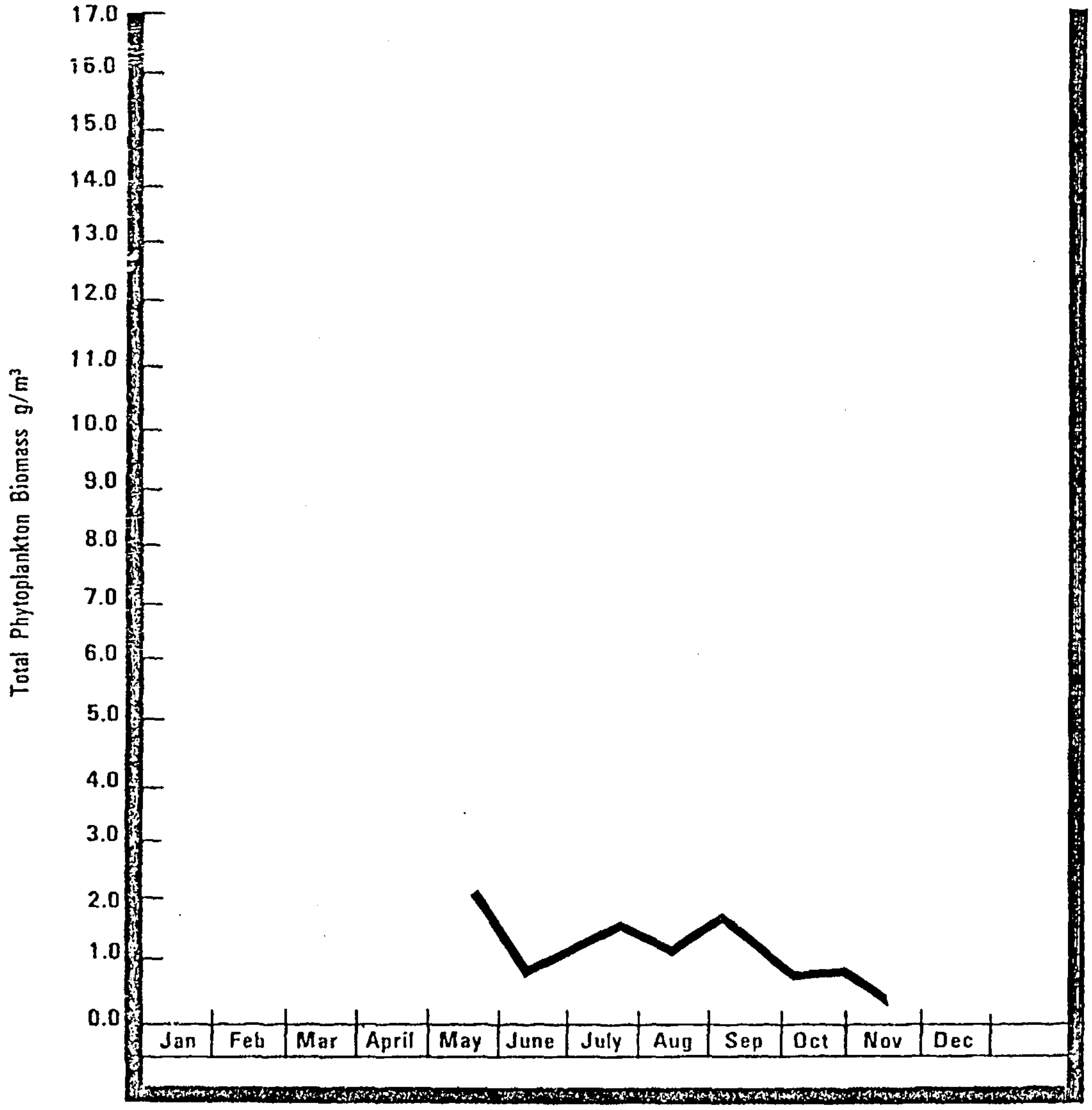

Figure 12

Seasonal Fluctuation in the Major Group Composition of the Phytoplankton in the Eastern Basin in - 1978

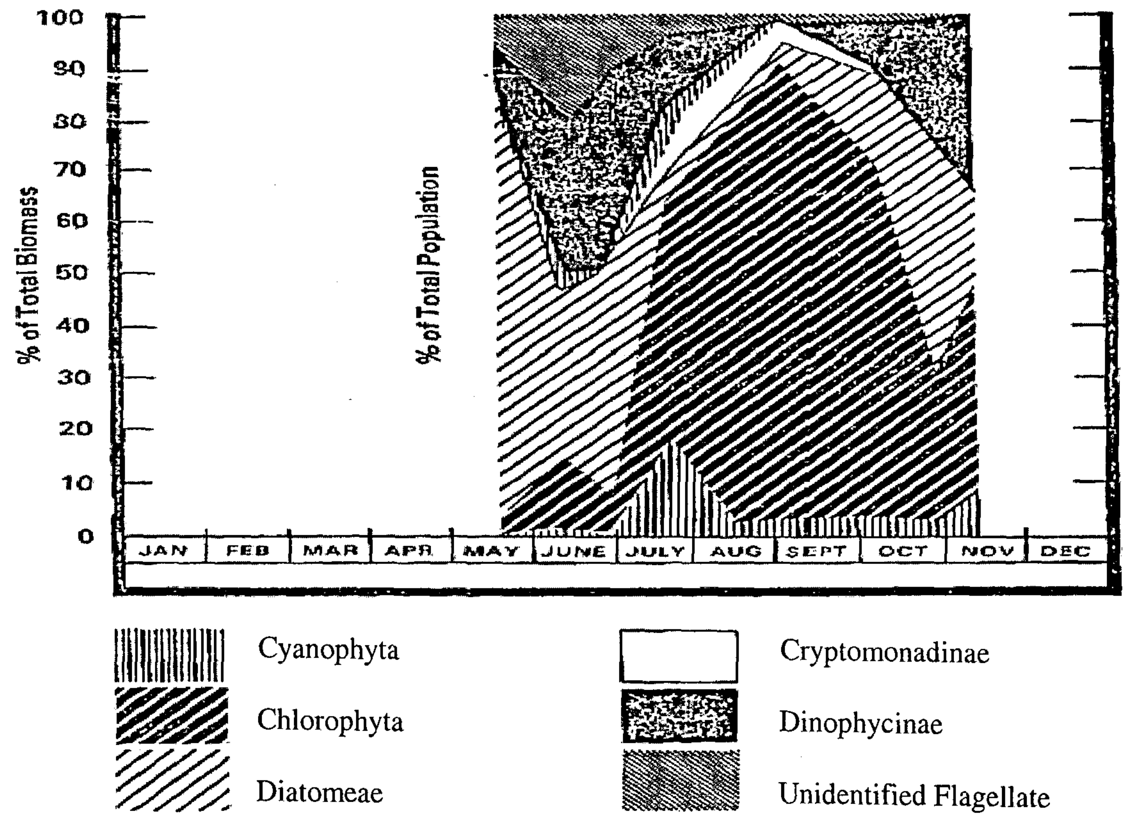

Figure 13

Seasonal Variation in the Diatomeae, Chlorophyta, and Cyanophyta in the Eastern Basin - 1978

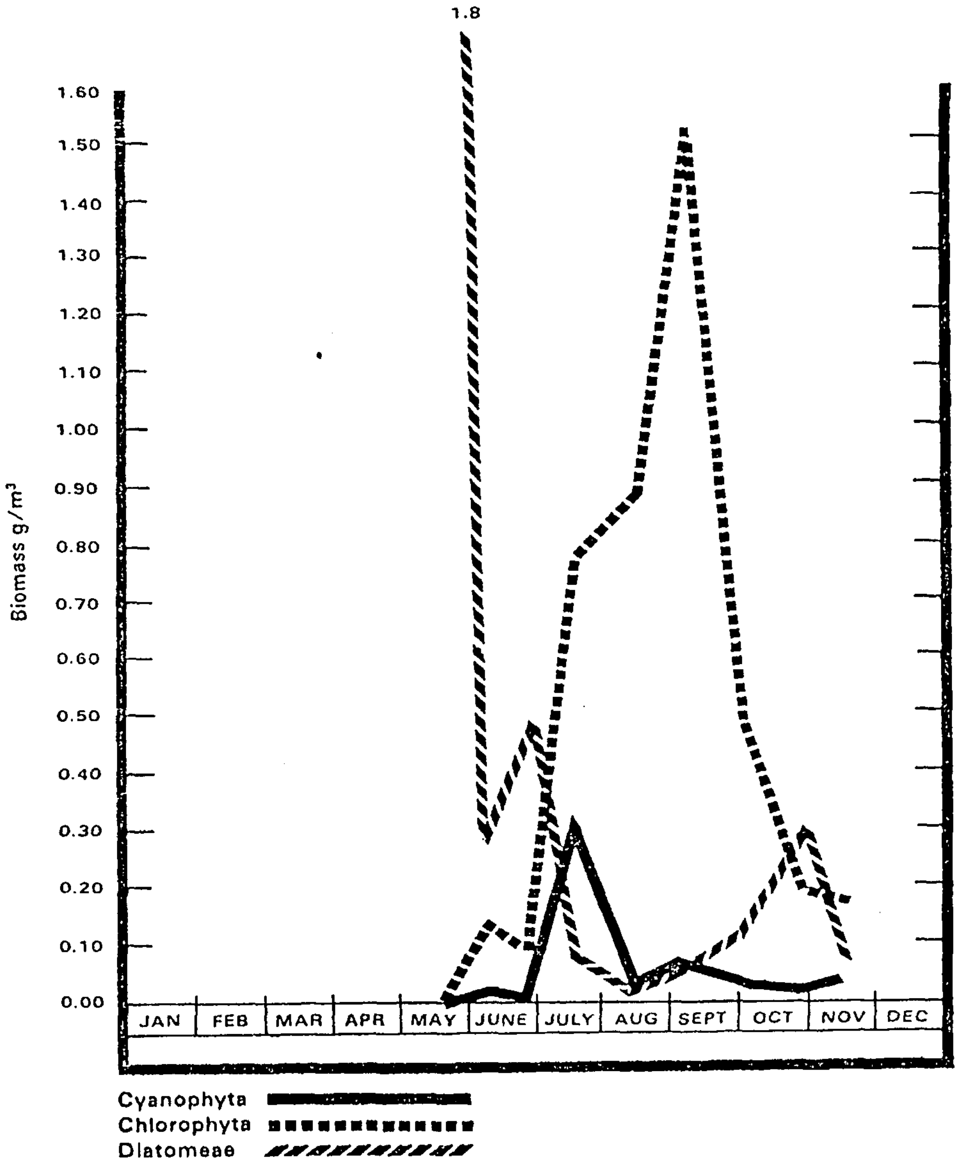

Figure 14

Seasonal Variation in the Dinophycinae, Chrysomonadinae, and Cryptomonadinae in the Eastern Basin - 1978

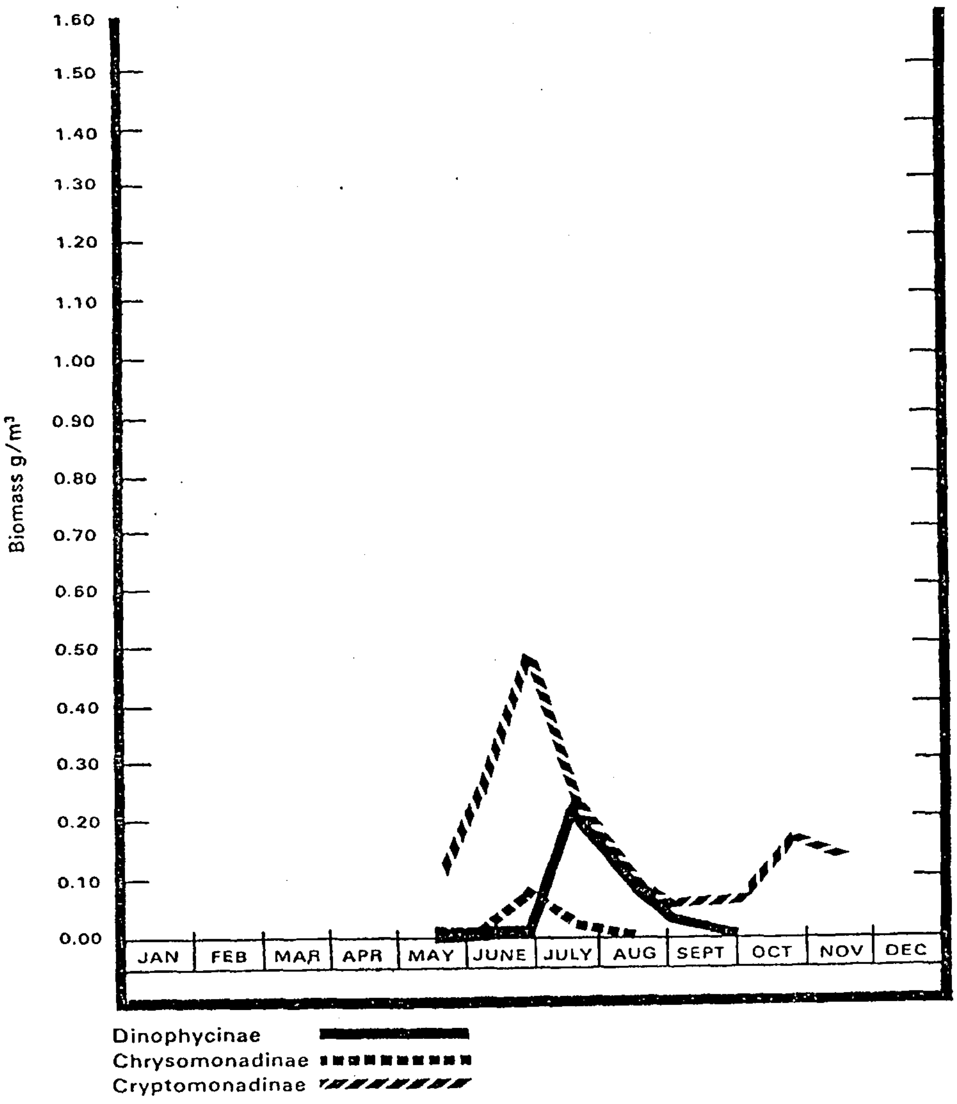

Figure 15

Seasonal Fluctuation in the Total Phytoplankton Biomass' in the Western Basin of Lake Erie in - 1979

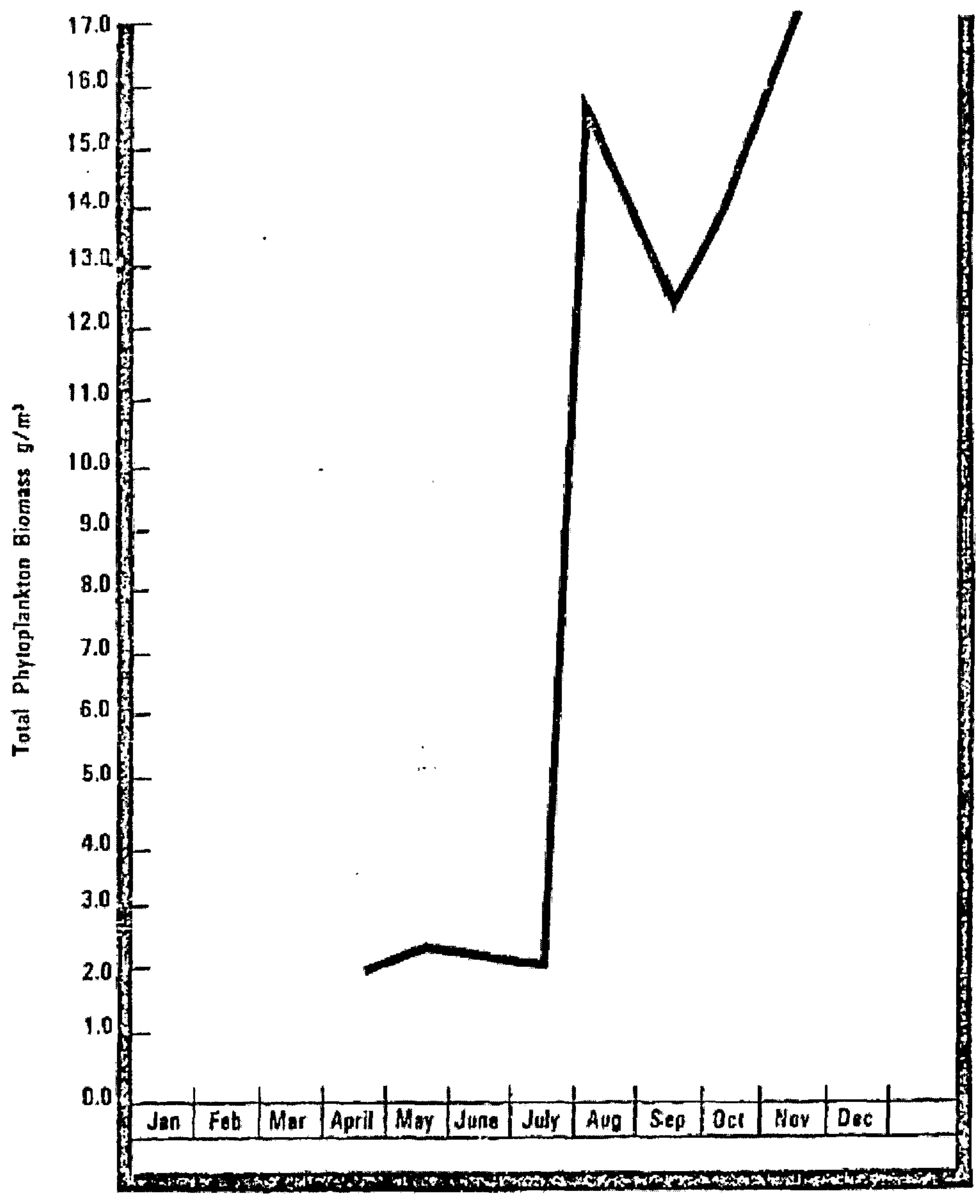

Figure 16

Seasonal Fluctuation in the Major Group Composition of the Phytoplankton in the Western Basin in - 1979

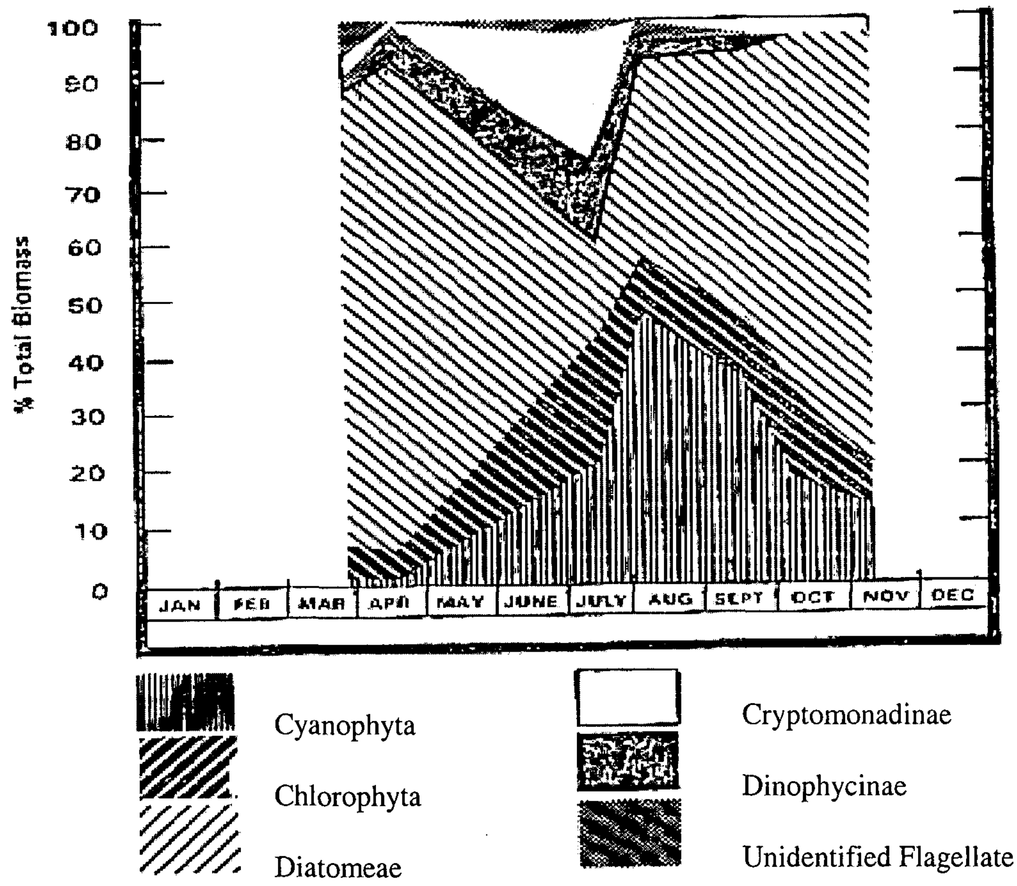

Figure 17

Seasonal Fluctuation in the Diatomeae, Chlorophyta, and Cyanophyta in the Western Basin - 1979

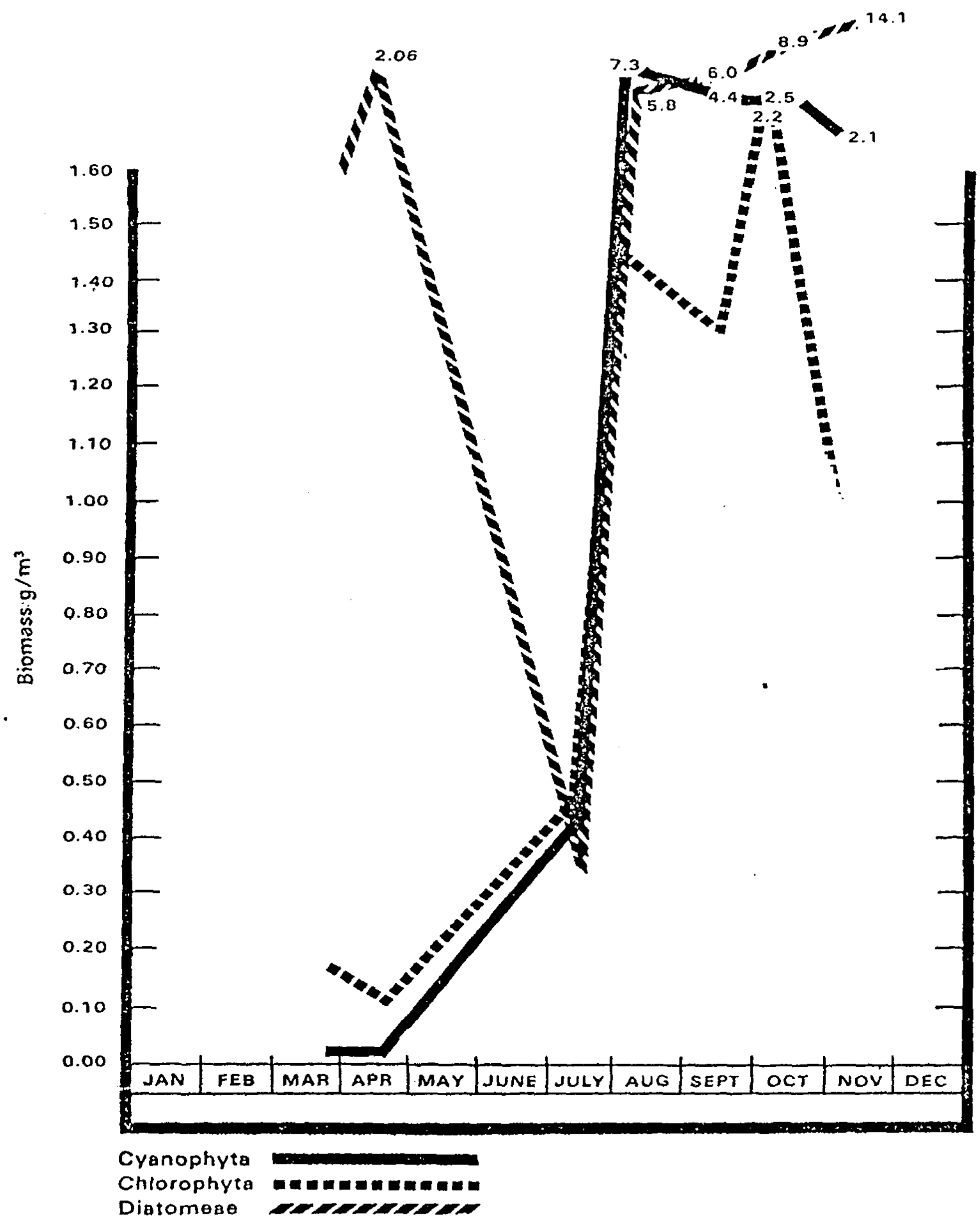

Figure 18

Seasonal Variation in the Dinophycinae, Chrysomonadinae, and Cryptomonadinae in the Western Basin - 1979

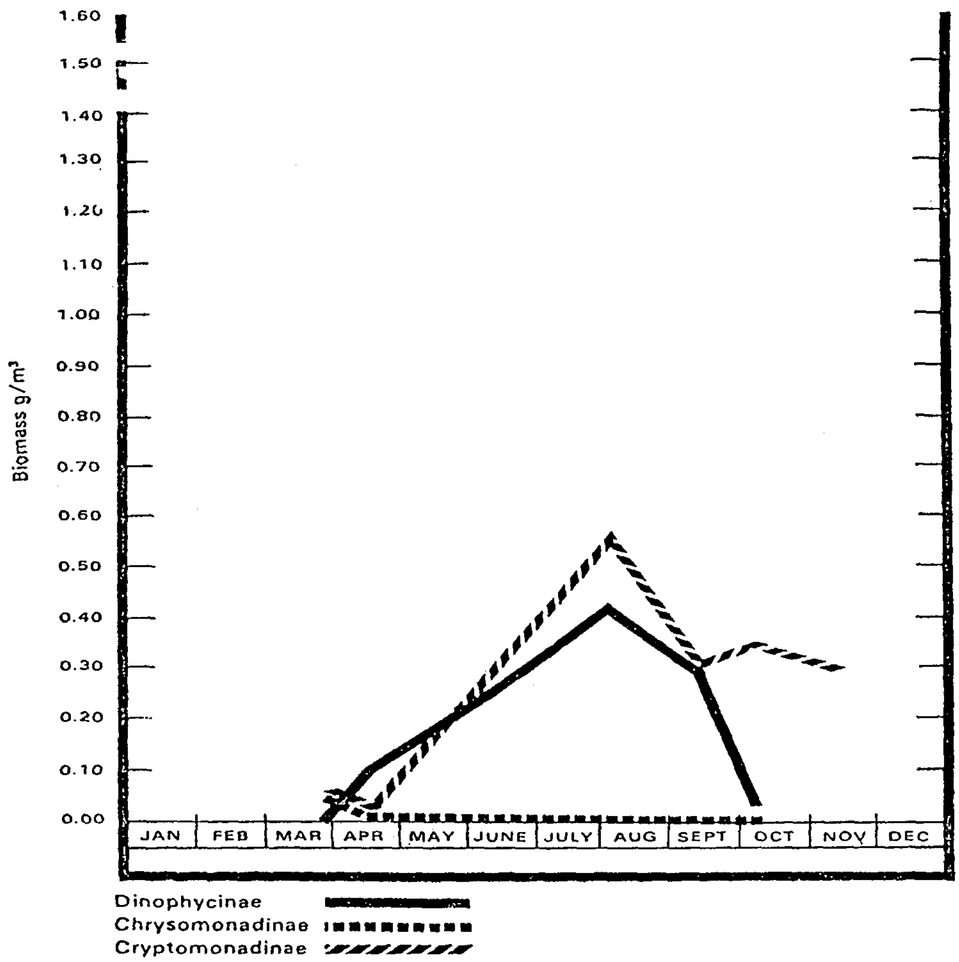

Figure 19

Seasonal Fluctuation in the Total Phytoplankton Biomass in the Central Basin of Lake Erie in - 1979

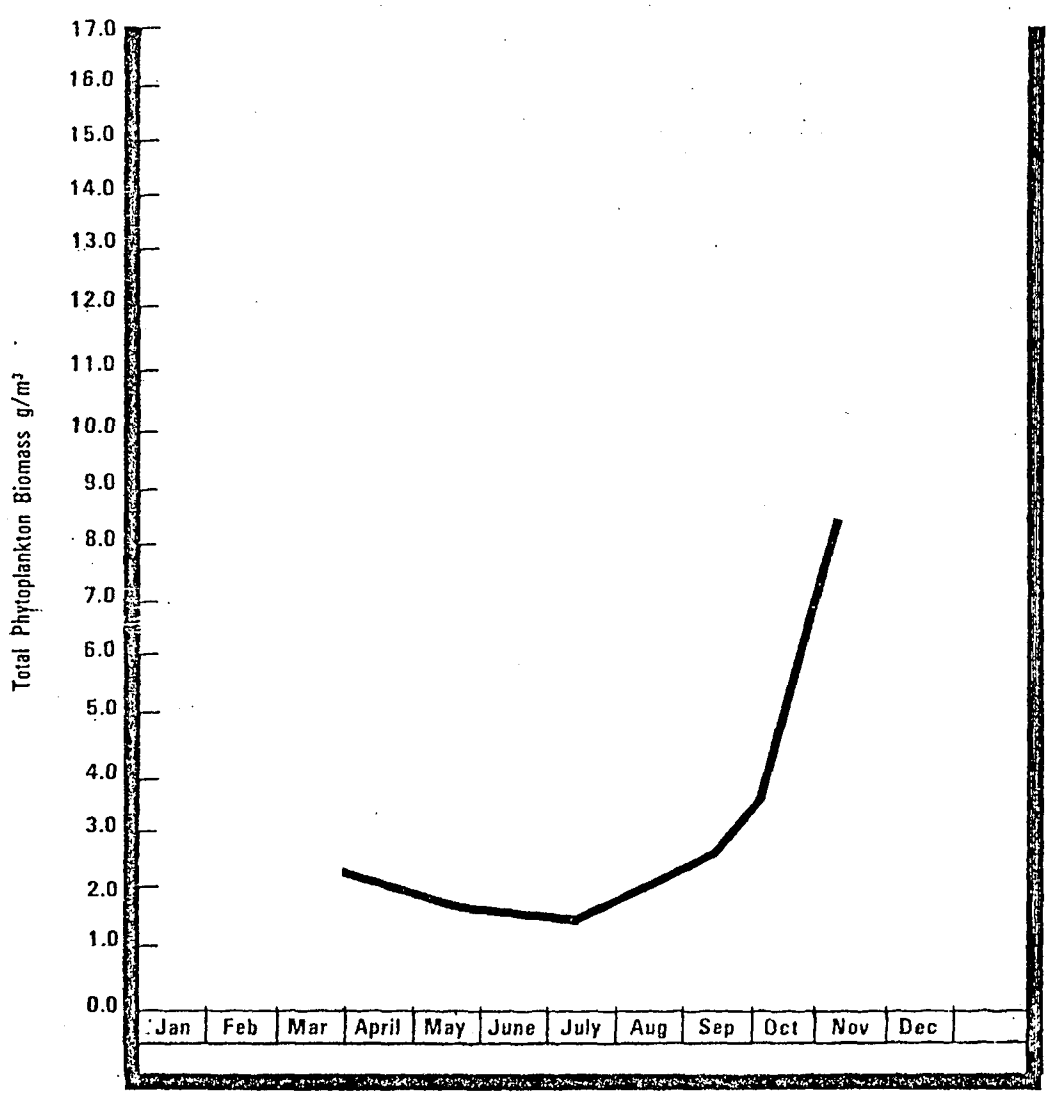

Figure 20

Seasonal Fluctuation in the Major Group Composition of the Phytoplankton in the Central Basin in - 1979

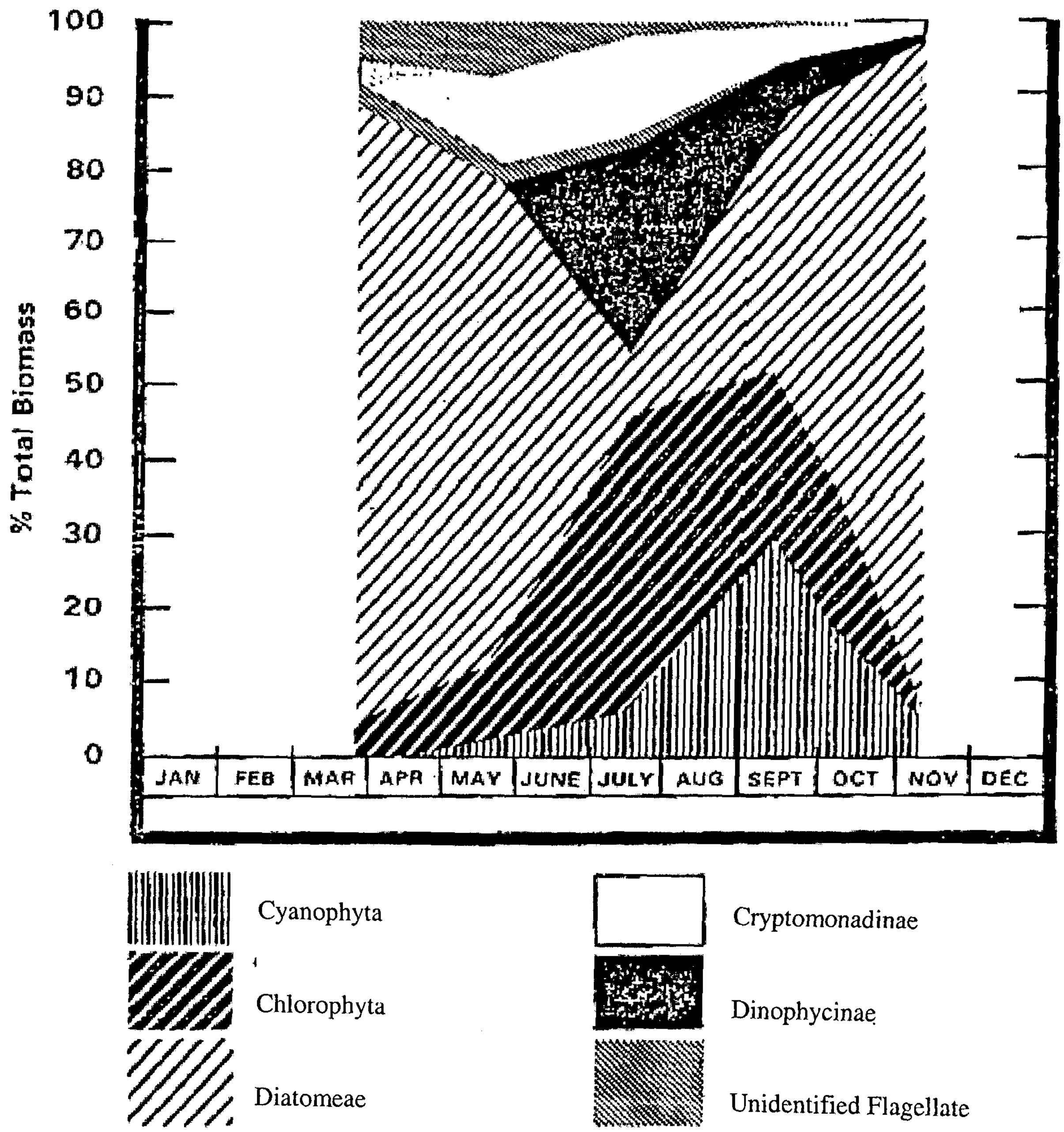

Figure 21

Seasonal Variation in the Diatomeae, Chlorophyta, and Cyanophyta in the Central Basin - 1979

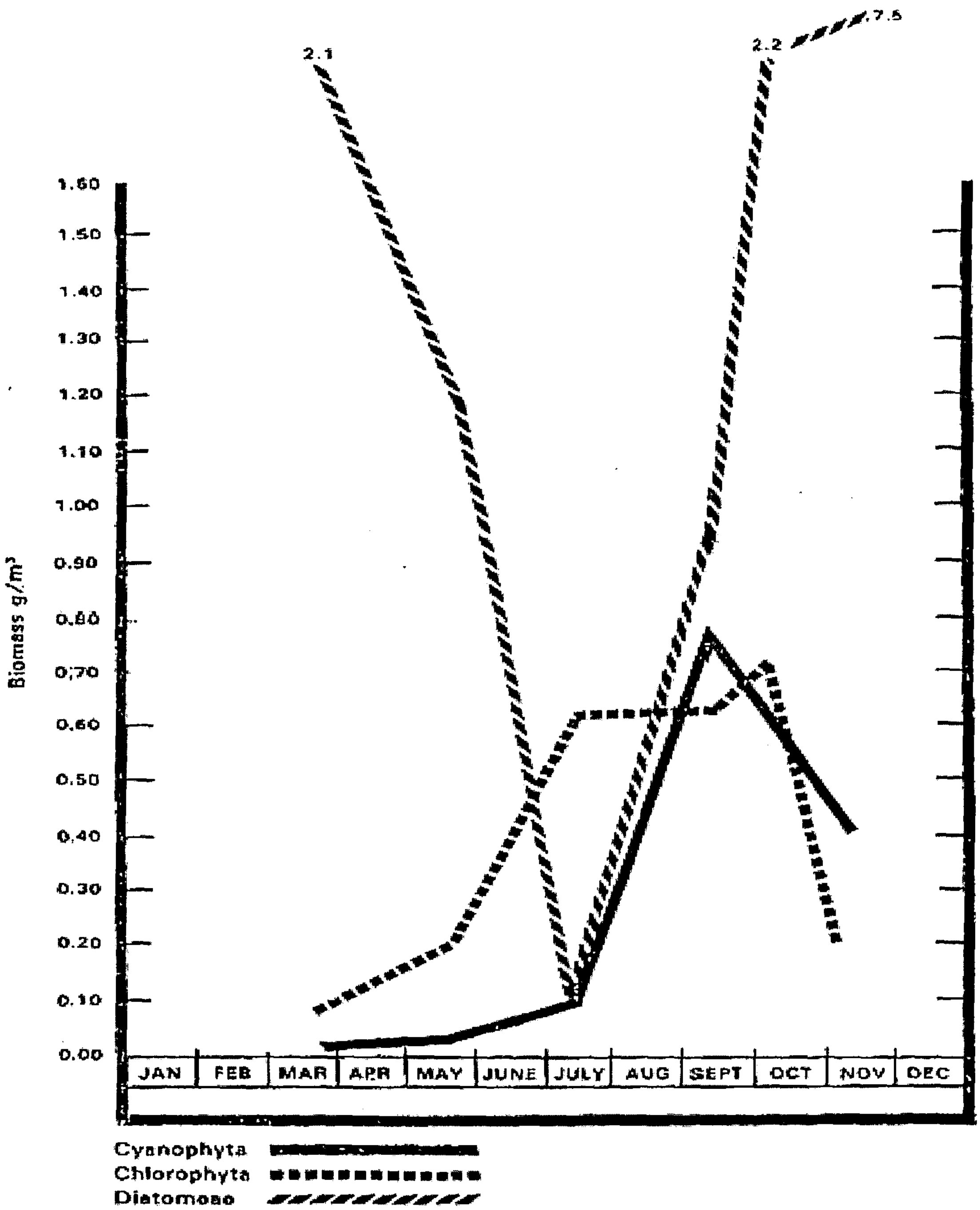

Figure 22

Seasonal Variation in the Dinophycinae, Chrysomonadinae, and Cryptomonadinae in the Central Basin - 1979

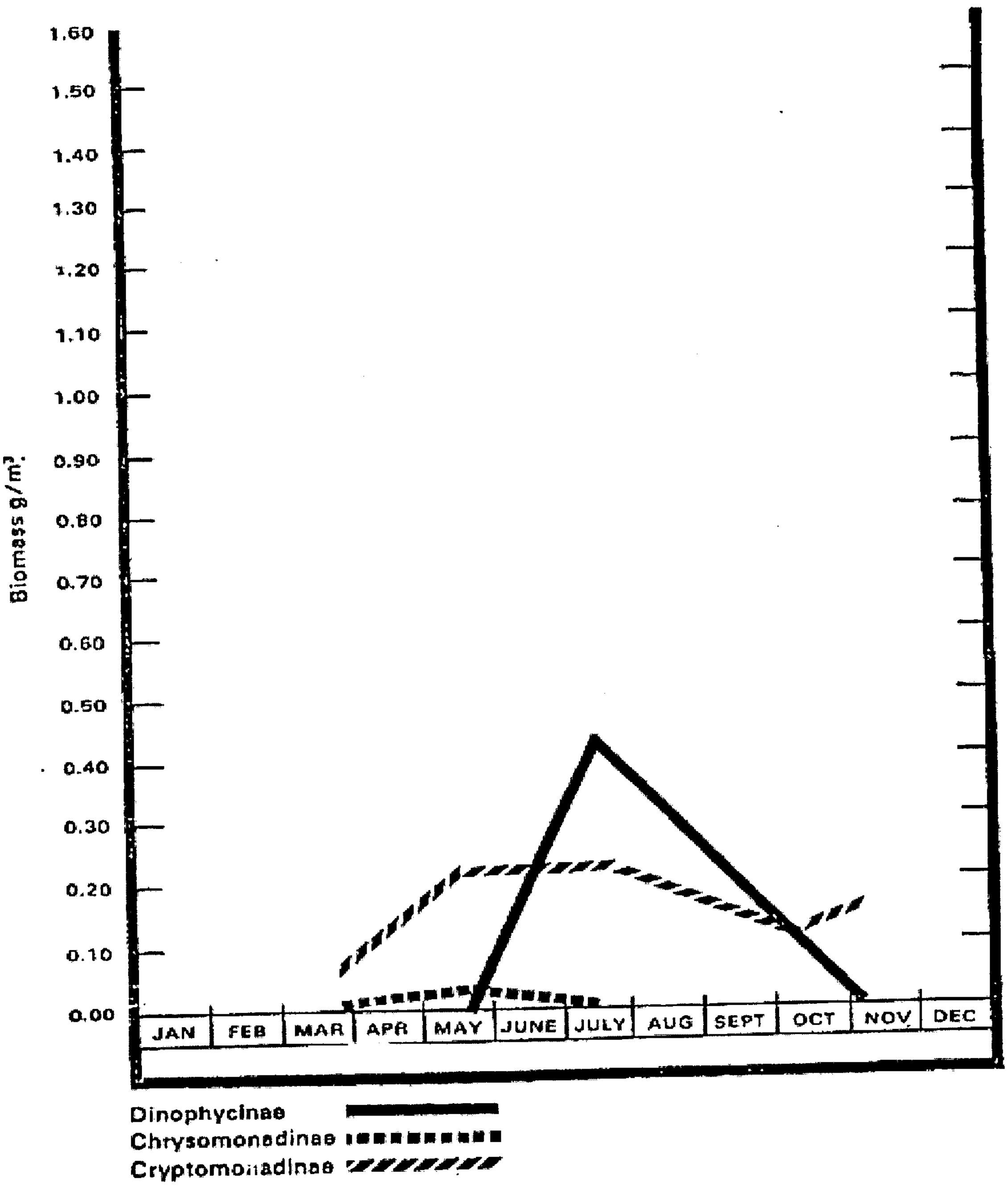

Figure 23

Seasonal Fluctuation in the total Phytoplankton Biomass in the Eastern Basin of Lake Erie in - 1979

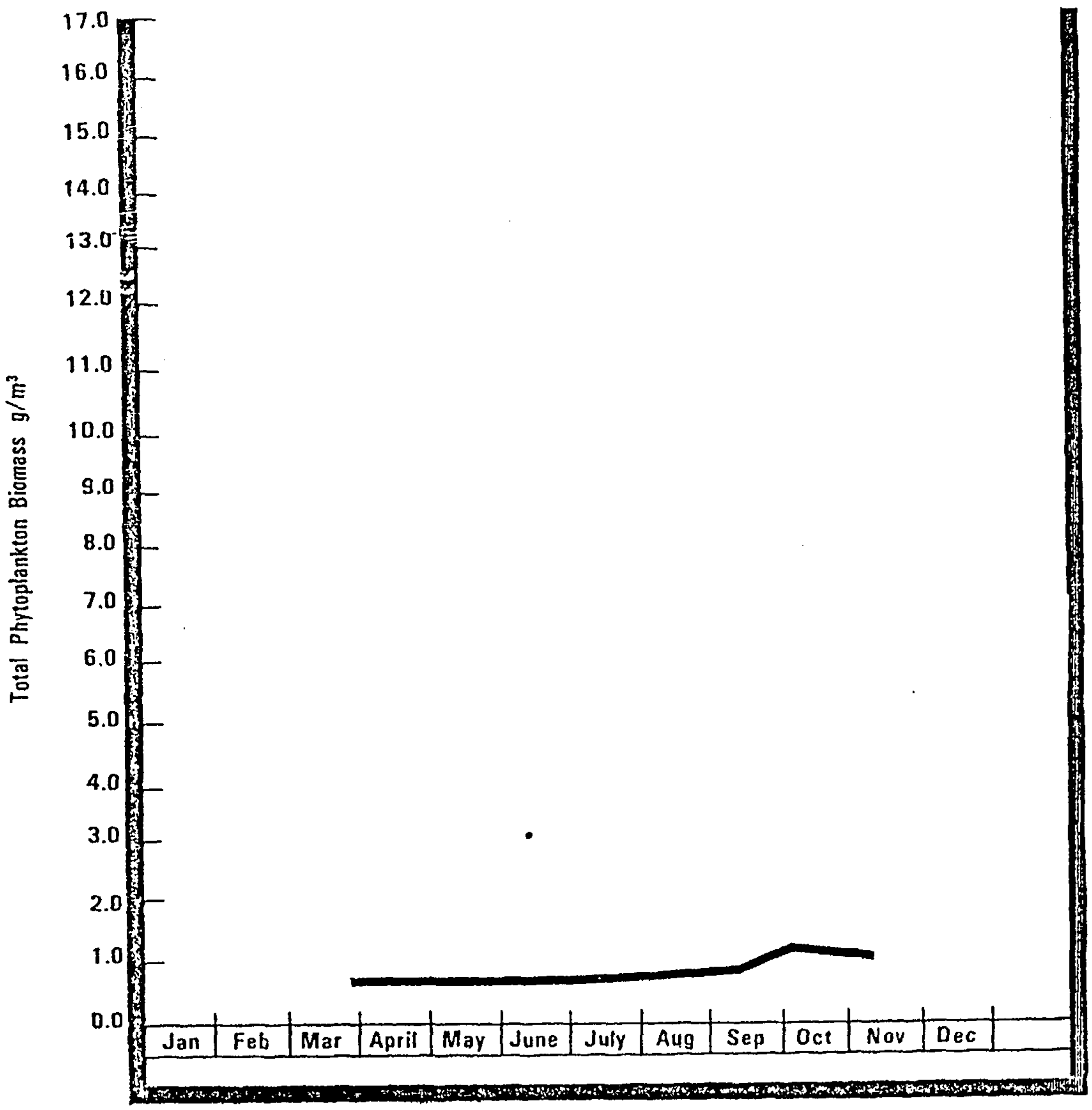

Figure 24

Seasonal Fluctuation in the Major Group Composition of the Phytoplankton in the Eastern Basin in 1979

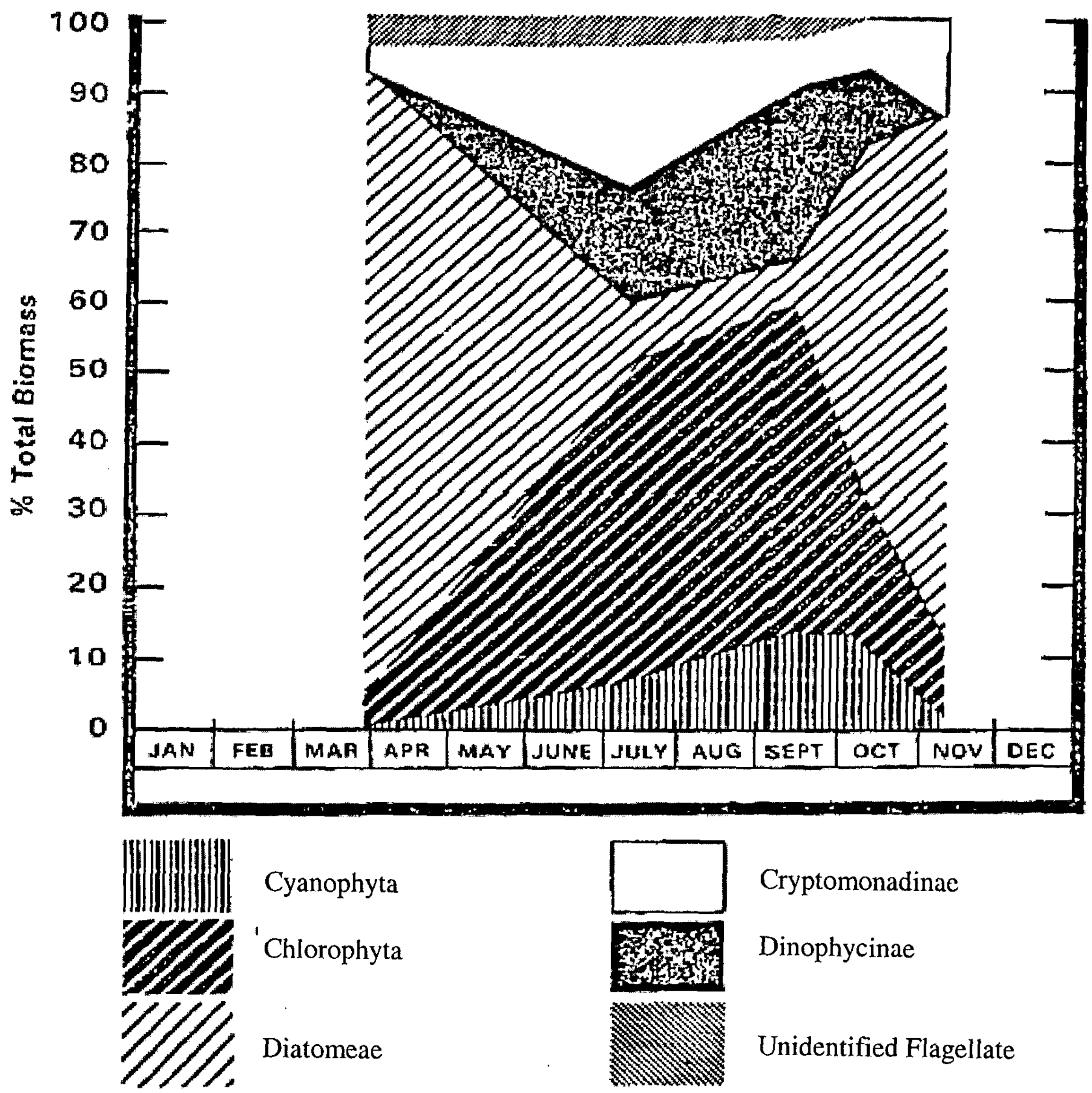

Figure 25

Seasonal Variation in the Diatomeae. Chlorophyta, and Cyanophyta in the Eastern Basin - 1979

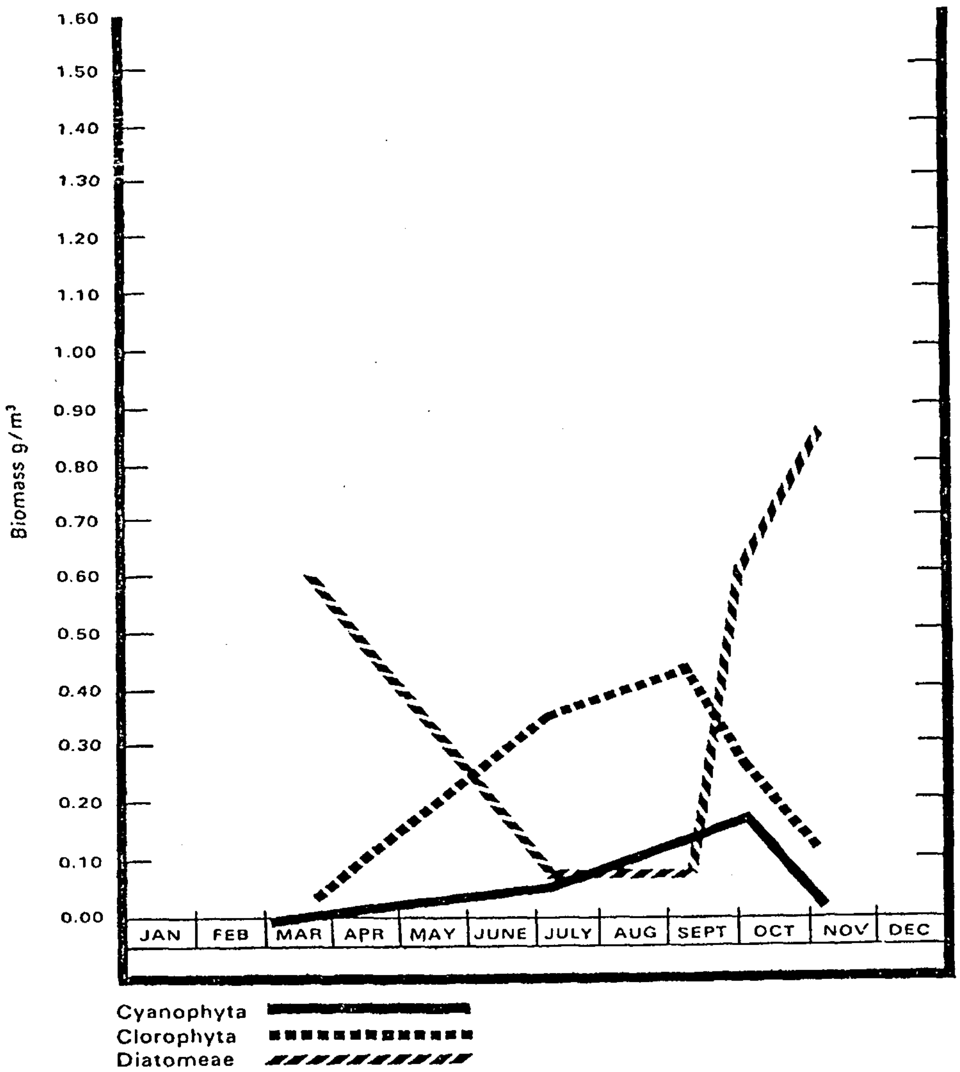

Figure 26

Seasonal Variation in the Dinophycinae, Chrysomonadinae, and Cryptomonadinae in the Eastern Basin - 1979

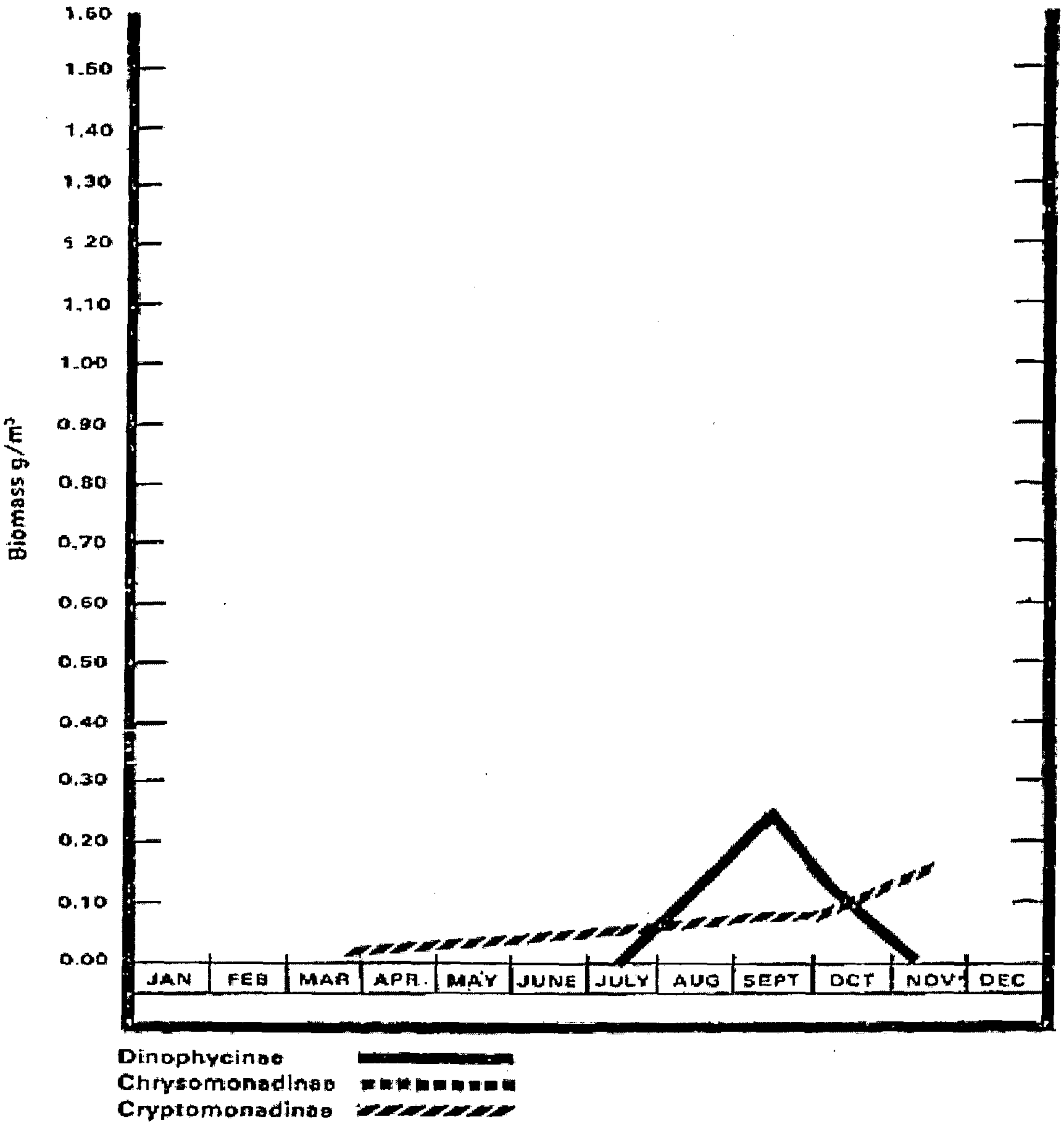

Figure 27

Seasonal Variation in the Horizontal Distribution of Total Phytoplankton Biomass in the Epilimnetic Waters of Lake Erie - 1978

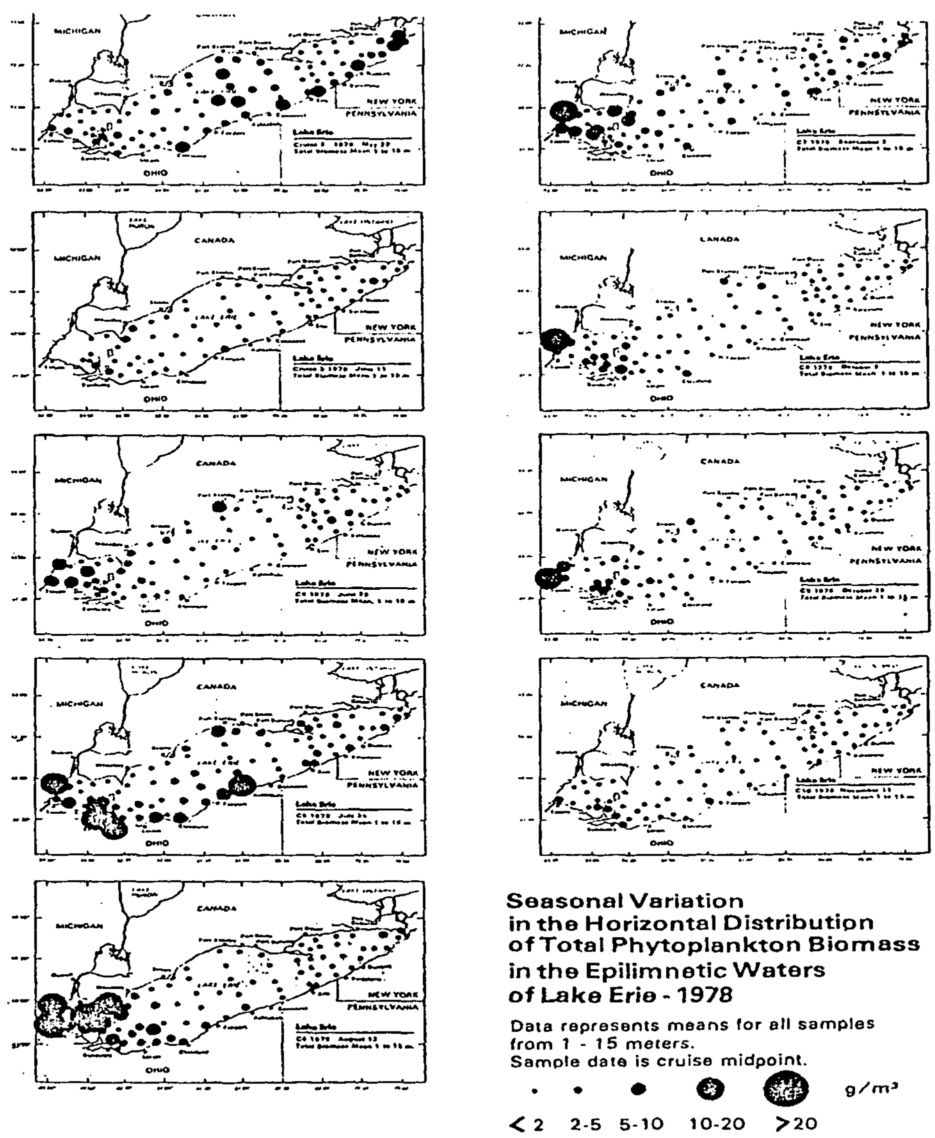

Figure 28

Seasonal Variation in the Horizontal Distribution of Total Phytoplankton Biomass - 1979

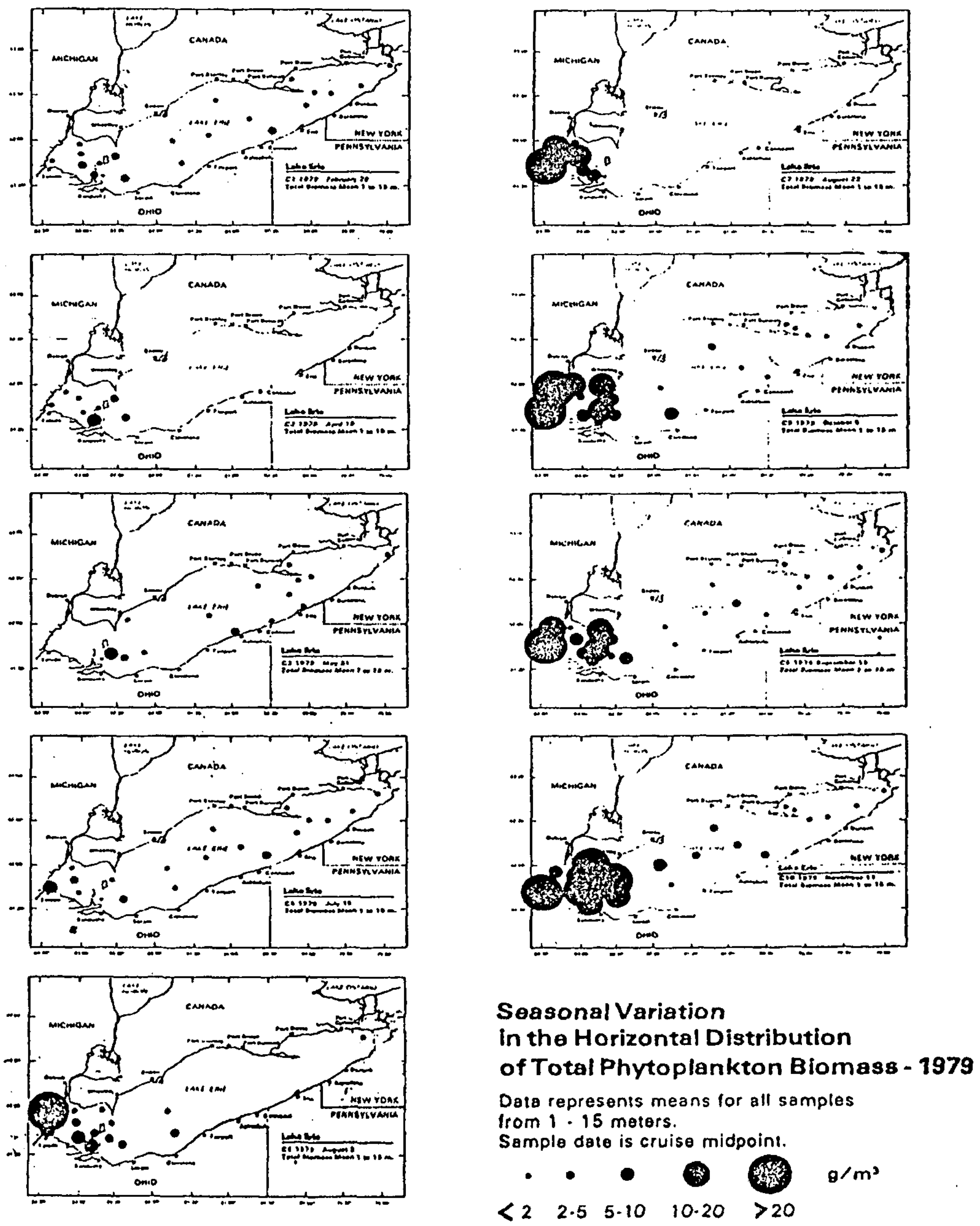

Figure 29

Mean Epilimnetic Biomass in the Western Basin of Lake Erie in 1970, 1978 and 1979