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ABSTRACT

Phytoplankton:

From 1986 to 1992, forty-two common species and varieties accounted for 91.1% of the total abundance and 88.2% of the total phytoplankton biomass. Mean biomass (mean ± S.E.) for the spring and summer periods were 0.64±0.07 g/m^3 and 0.54±0.03 g/m^3, respectively, while abundance (mean ± S.E.) averaged 2,788±225 and 5,506± 544 cells/mL, respectively, for each respective season. Mesotrophic diatom species accounted for approximately 30.4 ±5.9% (mean ± S.E.) of the phytoplankton biomass while eutrophic diatoms represented less than 10 ±1.5% of the phytoplankton biomass. No changes in the ratio of mesotrophic to eutrophic diatom species in Lake Ontario from 1970 to 1986 was observed. After 1987, an increase in the ratio occurred which suggested a reversal in eutrophy.

A decrease in summer phytoplankton biomass and a change in composition of the phytoplankton community has occurred since the early 1970's. Pyrrophyta relative biomass decreased from 1972/73 (31%) and 1981/82 (mean =21%) to the 1986 -1992 period (mean = 10.2%). Specifically, biomass of Gymnodinium spp., Peridinium spp., and Ceratium hirundinella decreased in the summer plankton. Relative biomass of the chlorophytes and possibly the chrysophytes appear to have increased from the early 1970s and 1980s. For example, Chrysophyta biomass averaged 7.6% of the summer biomass from 1986 to 1992, but it increased from 4.1% of the relative summer biomass in 1986 to 12.4% in the summer of 1991. Species of Chromulina, Ochromonas, Chrysococcus and the Haptophyceae were observed in the 1986-1992 period that were not reported in 1981 and 1982. While Cryptomonas erosa biomass has not changed, summer biomass of Rhodomonas minuta decreased from >79 mg/m^3 in the early 1970s and 1980s to less than 30 mg/m^3 since 1990. Dominant diatom species

composition was similar to the 1970s, although there is evidence that Stephanodiscus alpinus was decreasing, while Aulacoseira islandica was increasing in biomass.

Historical trends in offshore phytoplankton biomass suggest a decrease in summer biomass since the 1970s and early 1980s that was directly correlated (r^2=0.67) with the decrease in spring, open water, total phosphorus concentrations. There is some evidence, although not strong, that the phytoplankton community may also be responding to top-down food web effects. For example, small unicelluar phytoplankton (< 50 µm) decreased in relative biomass from 1986 to 1991/92 (76% to 38% - spring, 61% to 51% - summer), while relative biomass of filamentous and colonial algae increased from 1986 to 1992 (5% to 46% - spring, 24% to 38% - summer). In the spring, the decrease in large and small unicelluar phytoplankton were directly correlated (r^2=0.83) and the increase in filamentous algae within the community were inversely correlated (r^2=0.83) with the increase in the abundance of the crustacean Limnocalanus macrurus.

Zooplankton: From 1986 to 1992, 65 species representing 38 genera from the Calanoida, Cladocera, Cyclopoida, Mysidacea and Rotifera comprised the offshore zooplankton community of Lake Ontario. Twenty-two common species plus their juvenile stages accounted for 97.6% of the total biomass and 96.0% of the total abundance. Average density and biomass for 1986-1992 (spring and summer) was 235.7 organisms/L ± 20.2 (mean ± S.E.) and 90.2 µg/L ± 9.2 (mean ± S.E.), respectively. Biomass was higher in the summer (164 µg/L ± 13.9) than in the spring (9.8 µg/L ± 0.7). Within the pelagic region of Lake Ontario, abundance of smaller zooplankton species decreased and larger cladoceran, calanoid and cyclopoid species became more prevalent. Average length of the cladoceran species increased and was negatively correlated with alewife abundance. In particular, species of Daphnia (D. retrocurva and D.

galeata mendotae) and Bosmina longirostris increased in size by an average of 66% from their minimum mean length in 1987 to their length in 1991. The size of the small species that dominated the zooplankton community prior to 1990 suggested a community characteristic of planktivore-dominated systems where the fish feed selectively on larger individuals. Our data show that after 1990: 1) calanoids were more important in the pelagic region of Lake Ontario than they had been in 20 years; 2) smaller cladocerans decreased in abundance while increasing in size; 3) Daphnia were more prevalent and increased in size as an inverse function of alewife abundance; and 4) large predaceous cladoceran species were more prevalent than they had been prior to 1970. The zooplankton community of Lake Ontario has responded to changes in the forage fish community ultimately caused by continued predation pressure by salmonines.

INDEX WORDS: Lake Ontario, phytoplankton and zooplankton biomass and abundance, historical trends, eutrophication trends, food web changes.

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The U.S. EPA Great Lakes National Program Office acknowledges the contribution to this study of personnel from the Bionetics Corporation (1983-1990), AScI Corporation (1991-1992) and EnviroScience (1993-1994) for their assistance in the collection of samples and their taxonomic identifications of the phytoplankton and zooplankton species. Their perseverance onboard the R/V Roger R. Simons, and later on board the R/V Lake Guardian, under occasional severe weather and sea conditions is deeply appreciated. Also, their adherence to established protocols and standard operating procedures has ensured that the plankton collection, preservation and identification methods have remained consistent over the 10 years of this study.

INTRODUCTION

Results of the Food Web Workshop II (Hartig et al. 1991) indicated that Lake Ontario may be the next Great Lake after Lake Michigan to demonstrate the effects of changing nutrient levels and food web controls. Total phosphorus loads into the lake declined by 80% since 1972 and have approached the target loading set by the Great Lakes Water Quality Agreements between the United States and Canada. Spring total phosphorus levels declined from 25 to 14 µg/L between 1971 and the late 1980s and are currently below 10 µg/L. Although declines in chlorophyll-a were relatively low and transparency has not changed appreciably, there is some evidence that algal biomass has declined. Besides changes in nutrient concentrations, changes in fish abundance has occurred as alewife, slimy sculpin and smelt biomass have decreased, while stocking of coho and chinook salmon increased from 40,000 to 5.4 million from 1968 to 1984 (Hartig et al. 1991). In 1993, the rate of salmonine stocking was reduced (Luckey 1994).

These changes in nutrient status and in the food web of the lake, and the potential for further appreciable change in the biota of Lake Ontario, have directed attention to the long-term data sets of phytoplankton and zooplankton collected by the Great Lakes National Program Office of the U.S. Environmental Protection Agency as indicators of quantitative and compositional changes in plankton community structure. Phytoplankton, which have short carbon turnover rates, are sensitive to water quality conditions and to grazing by zooplankton and thus respond rapidly to perturbations of the lake ecosystem. The determination of phytoplankton abundance and species composition is one method to trace long-term changes in lakes (Munawar and Munawar 1982, Makarewicz 1993, Makarewicz and Bertram 1991). Similarly, whether aquatic ecosystems are perturbed by changes in the top predator fish that cascade down the food web or by nutrients or by other stressors that are expressed from the first trophic level upward, the zooplankton are sensitive integrators of such changes (McNaught and Buzzard 1973). They have also proved useful for complementing phytoplankton data to assess the effects of water quality (Gannon and Stemberger 1978) and fish populations on biota (e.g. Brooks and Dodson 1965). The phytoplankton and zooplankton data sets collected by EPA's Great Lakes National Program Office provide such information and support the International Joint Commission's call for more and better information through monitoring and research on components of the Lake Ontario food web (Hartig et al. 1991). In this study, data about the 1986-92 spring and summer phytoplankton and zooplankton assemblages make it possible to examine the historical, geographic, and seasonal relationships prevailing in Lake Ontario and to compare them, where possible, to previous studies.

METHODS

Phytoplankton

Phytoplankton were collected during 23 cruises during the spring and summer from 1986 to 1992 (Table 1). An 8-L PVC Niskin bottle mounted on a General Oceanics™ Rossette sampler with a Guildline™ electrobathythermograph (EBT) was used to collect phytoplankton. Phytoplankton samples were obtained by compositing equal aliquots of samples collected at depths of 1, 5, 10 and 20m at eight sampling sites (Fig. 1). Thus our species data represent only summer epilimnetic forms and early spring isothermal forms. One-liter samples were immediately preserved with 10 mL of Lugol's solution and formaldehyde was added 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™ mounting medium. Replicate identifications were made by different analysts on every 10th sample and compared for consistency in species nomenclature and abundances. Precision goals between replicates were based on the Relative Percent Deviation (RPD = ((larger count-smaller count)/average)x100). For example, the precision goal for replicated Bacillariophyta counts was ± 15%. Values outside this goal were rejected and the samples recounted unless a clear explanation was available, e.g., very low abundance of forms in any one division. In addition, validation of species identifications between different enumerators over the 6-year period were made to ensure consistency in identifications. Changes in nomenclature, use of synonyms, etc. are discussed in Appendix A-18.

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

The phytoplankton data were computerized. Statistical evaluations and other data manipulations were conducted within the INFO data management system (Henco Software, Inc. 100 Fifth Avenue, Waltham, Mass.). To allow an east-west comparison, Stations 49 and 55 on a north-south axis were averaged to form one site. Picoplankton were defined as rod or spherical shaped Cyanobacteria with a size less than 2μm (unicells or individuals within a colony). They were enumerated but were not included in this report because of very large numbers (e.g. 1986: 22,390 cells/ml, 88% of the total abundance), small biomass (e.g. 2.9% of the total biomass) and because of taxonomic uncertainties.

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 a vertical zooplankton sample at the same stations (Fig. 1 and Table 1) at which phytoplankton were collected during 23 cruises during the spring and summer from 1986 to 1992. Only summer collections were made in 1989, and only spring collections were made in 1992. Vertical tows were taken from 20m to the surface. Filtration volume was determined with a Kahl flow meter (Model 00SWA200) mounted 1/3 of the net diameter from one edge. Following collection, the net contents were quantitatively transferred to 500-mL sample bottles, narcotized with club soda and preserved with 5% formalin.

Enumeration of zooplankton followed Gannon (1971) while identification followed Stemberger (1979) and Edmondson (1959). The volume of each rotifer species was computed by using the geometrical shape that most closely resembled the species (Downing and Rigler 1984). For each cruise, the length of at least 20 specimens of each rotifer species was measured. Width and depth were also measured on one date for each lake to develop length-width and length-depth ratios for use in the simplified formulas of Bottrell et al. (1976).

Assuming a specific gravity of one, volume was converted to fresh weight and to dry weight assuming a ratio of dry to wet weight of 0.1 (Doohan 1973) for all rotifer species except Asplanchna spp. A dry weight/wet weight ratio of 0.039 was used for Asplanchna spp. (Dumont et al. 1975).

Because of the considerable variability in length and thus weight encountered in the Crustacea, the dry weights of Crustacea were calculated using length-weight relationships (Downing and Rigler 1984, Makarewicz and Likens 1979). Up to 20 measurements of individual specimens were used to calculate the average length of crustacean species for each station of each cruise. A comparison of calculated weights to measured weights of individual Crustacea in Lake Michigan suggested good agreement at the minimum weight range (Makarewicz 1988). The weight of the Copepoda nauplii and the veliger of Dreissena followed Hawkins and Evans (1979) and Sprung (1993).

The zooplankton data were computerized. Statistical evaluations and other data manipulations were conducted within the INFO data management system (Henco Software, Inc. 100 Fifth Avenue, Waltham, Mass.). To allow an east-west comparison, Stations 49 and 55 on a north-south axis were averaged to form one site.

All phytoplankton and zooplankton identifications and enumeration were performed for the United States Environmental Protection Agency by the Bionetics Corporation (1983-88), AScI (1989,1990) and Enviroscience Corporation (1991-92).

RESULTS AND DISCUSSION

Phytoplankton

Annual Abundance of Major Algal Groups

From 1986 to 1992, 379 species representing 113 genera from eight divisions comprised the offshore phytoplankton community of Lake Ontario (Tables 2 and 3). Forty-two common species and varieties accounted for 91.1% of the total abundance and 88.2% of the total biomass over the seven-year period (Table 4). Common species for individual years are presented in the Appendix (A1 to A7). Over the seven-year period, the Bacillariophyta contained the greatest number of species (143, Table 2) and the highest relative biomass for the spring (62.2% of the total biomass, range=53.1 to 72.8%, Table 5). Chlorophyta had the second highest number of species (116, Table 2), the highest summer relative biomass during 1987, 1989, and 1990, and the highest average summer relative biomass (29.8% of the total biomass, range=14.9 to 56.9%, Table 6) for the study period. In 1986 and 1991, the Cryptophyta contributed the highest amount of biomass to the summer phytoplankton community while the Bacillariophyta had the greatest relative biomass in 1988 (Table 6). Cyanobacteria accounted for over 40% of the abundance in both spring and summer over the study period (Tables 5 and 6). Stoermer and Ladewski (1978) and Johannsson et al. (1985a) observed similar results for 1972/73 and 1981/82 with diatoms and green algae as the dominant groups (Table 7). Mean biomass (mean ± S.E.) for the spring and summer periods were 0.64±0.07 g/m^3 and 0.54±0.03 g/m^3, respectively, while abundance (mean ± S.E.) averaged 2,788 cells/mLand 5,506 cells/mL (Table 8), respectively .

Geographical Abundance and Distribution of Major Algal Groups

Horizontal distribution of phytoplankton in Lake Ontario was documented by Nalewajko (1966), Munawar and Munawar (1975), Stoermer et al. (1975), and Stoermer and Ladewski

(1978). The horizontal pattern of phytoplankton in Lake Ontario had a seasonal component related to the thermal bar, whereby, shoreside abundance was considerably greater than offshore abundance (Lorifice and Munawar 1974, Robertson and Scavia 1984). However, Makarewicz (1991) demonstrated that phytoplankton abundance and biomass on the south shore of Lake Ontario were statistically different between nearshore and offshore sites only during meteorologic events that disturbed the sediments.

In general, there was no obvious trend in phytoplankton biomass geographically in the offshore region of Lake Ontario for most years (Fig. 2). In the spring of 1990 and the summer of 1989, biomass was considerably higher at mid-lake stations east of the Niagara River (Fig. 1). At the Division level, Cyanophyta, Cryptophyta, Chlorophyta, Pyrrophyta, and Chrysophyta biomass showed no obvious west/east pattern (Fig. 3). The Bacillariophyta appeared to have a higher biomass in the central and eastern portion of the lake; but this difference was not significantly higher ($P>0.05$, ANOVA).

Historical Changes in Species Composition

Phytoplankton studies at water intakes in the nearshore region suggest that the phytoplankton community changed considerably with increased abundance from ~1920 into the 1970s (Schenk and Thompson 1965, International Joint Commission 1969). Near Toronto for example, mean annual abundance doubled between 1923 and 1954, and at a nearby water treatment plant the average annual rate of increase between 1956 and 1966 was over seven times that for the 1923 to 1954 period (Robertson and Scavia 1984). Based on data collected up to 1973, Robertson and Scavia (1984) concluded that Lake Ontario was more severely eutrophic than previously supposed.

Similarly, paleolimnological data indicate Lake Ontario has undergone extensive ecological modification since European settlement (Stoermer et al. 1985). Analysis of algal microfossils in sediments from a 1981 offshore Lake Ontario core (Stoermer et al. 1985) showed that in diatom assemblages dominated by oligotrophic Cyclotella species, Melosira (Aulacoseira) islandica and M. italica were displaced in more recent sediments by taxa common to hyper-eutrophic regions and areas of high conservative ion loadings (Actinocyclus normanii f. subsalsa, Diatoma tenue var. elongatum, Stephanodiscus binderanus, and S. parvus).

In recent years, a literature pertaining to phytoplankton of the offshore waters of Lake Ontario has developed. Vollenweider et al. (1974) reviewed data on phytoplankton composition and biomass in the Great Lakes including Lake Ontario. Lake-wide investigations of Ontario phytoplankton species composition in 1970 was described by Munawar and Nauwerck (1971) and in 1972/73 by Stoermer and Ladewski (1978). In 1972/73, a comparison of phytoplankton biomass and composition at a midlake and nearshore site was undertaken by Munawar et al. (1974). Johannsson et al. (1985a and b), as part of the Canadian BIOINDEX program, monitored four sites, two nearshore and two offshore, in 1981 and 1982. Also in 1982, Gray (1987) compared nearshore and offshore phytoplankton communities.

Because a different technique was used for enumeration, the data of Stoermer and Ladewski (1978) are not used in many of the comparisons made in this report. There is an obvious difference between the two different data sets collected in 1972/73 (Table 7) that may be attributed to the enumeration procedure, especially in regards to the flagellates (Munawar and Munawar 1975). The phytoplankton samples of Munawar et al. (1974, one offshore sampling site), Johannsson et al. (1985a and b, two offshore sampling sites) and those from this study (seven offshore sampling sites) were all counted by the settling chamber procedure and are thus comparable. Differences between data sets do exist as to number of stations and seasonal sampling. Where possible, only data from April and August offshore sites were compared from various studies.

A change in composition of the phytoplankton community has recently occurred. Pyrrophyta relative biomass decreased from the 1972/73 (31%) and the 1981/82 (mean =21%) period to the 1986 -1992 period (mean = 10.2%, Table 7). Relative biomass of the Chlorophyta and possibly the Chrysophyta appeared to have increased from the early 1970s and 1980s. The high interannual variability for the diatoms, cyanobacteria, and the cryptophytes masks any trend that may exist at the division level (Table 7).

Diatoms have been the dominant division since at least 1970. Offshore communities were dominated by Melosira islandica (Aulacoseira islandica) in 1970. Typical inshore species, such as Stephanodiscus binderanus, S. tenuis and S. hantzschii were observed only in small numbers in the offshore area (Munawar and Munawar 1982). Dominant diatoms in 1972/73 included Stephanodiscus astraea var. minutula and Melosira (Aulacoseira) islandica. In addition, species such as Diatoma elongatum, Synedra acus, and Surirella angustata were common, especially in the spring, while cryptomonads, such as Rhodomonas minuta and Cryptomonas erosa contributed very heavily during different seasons (Munawar et al. 1974). Stoermer and Ladewski's (1978) 1972 study suggested that S. binderanus and S. minutus together comprised 20% of the algal standing crop.

Considering only the April and August samples of Johannsson et al. (1985b), diatoms were the dominant division in 1981 (42.5% of the total biomass) as in 1972, but not 1982 where the cryptophytes predominated (38.4% of the total biomass, Table 7). Offshore diatom communities were co-dominated by Melosira islandica (Aulacoseira islandica), Melosira binderana (Stephanodiscus binderanus), Stephanodiscus astraea v. minutula, and Synedra ulna in 1981, while in 1982 Melosira islandica (Aulacoseira islandica) was the dominant species (Tables 9 and 10). In another study at a midlake site in 1982, Gray (1987) concluded that a decrease in eutrophic species, such as Melosira binderana (Stephanodiscus binderanus), Stephanodiscus tenuis, S. hantzschii v. pusilla, and S. alpinus had occurred. Melosira islandica (Aulacoseira islandica) was the dominant diatom at the offshore station in the study by Gray.

In our 1986-92 samples from April and August, either Stephanodiscus alpinus or Aulacoseira islandica was the dominant species considering biomass (Table 11). This was also true on an abundance basis with the exception of 1986 when Fragillaria crotonensis and F. capucina were numerically dominant. Although Aulacoseira islandica was the dominant diatom in 1970, 1981/82 and 1986-92, the spring biomass of this species was greatest from 1990 to 1992 (Table 12). Spring relative biomass averaged 16 to 22% in 1981 and 82 and it increased to over 38% of the spring biomass from 1990 to 1992.

Stephanodiscus alpinus, not prominent in 1972 and 1981/82, was the predominant or second most prominent diatom between 1986 and 1990. This apparent shift in species composition may be a result of classification inconsistencies within the S. astrea entity (Stoermer et al. 1975). It is likely that S. alpinus would be included in the S. astrea complex in previous studies. Stoermer et al. (1975) reported S. alpinus as the dominant winter species in Lake Ontario in 1972, and it was consistently observed in the recent microfossil record (Wolin et al. 1991). If we consider S. astrea to be S. alpinus in 1981 and 1982, biomass in 1981 and 1982 was comparable to biomass after 1986 (Table 12). However, the decrease in biomass of S. alpinus was observed from 1986 (133 mg/m^3) to 1992 (15 mg/m^3, Table 12). S. alpinus was considered a eutrophic species by Yang et al. (1993), but a mesotrophic species tolerant of moderate nutrient enrichment by Tarapchak and Stoermer (1976).

Stephanodiscus binderanus, a co-dominant in 1981 and a eutrophic species, was also observed in fairly large quantities in 1987 (7.1% of the total spring and summer biomass), 1988 (1.1%), 1990 (2.0%), and 1992 (9.5%). Other prevalent diatoms in certain years included Tabellaria flocculosa (5.4%-1986; 6.3%-1987), Fragillaria crotonensis (7.4%-1991), and Stephanodiscus niagarae (5.7%- 1988), another eutrophic species. In regards to diatoms, dominant species composition during this study was similar to that of the 1970s, although biomass of the the eutrophic Stephanodiscus alpinus decreased, while the biomass of the oligotrophic/mesotrophic Aulacoseira islandica increased in biomass. Biomass of the oligotrophic indicator Cyclotella ocellata also appeared to increase since 1987 (Table 12).

Both Rhodomonas minuta (1972-11.0% and 7.0% of the April and July biomass) and Cryptomonas erosa (1972-6.0% of July biomass) were the dominant Cryptophyta in the offshore in 1972 (Munawar et al. 1974), in 1981 and 1982 (Tables 9 and 10). During 1986-92, C. erosa was the dominant cryptophyte in the spring and R. minuta was dominant in the summer (Table 12). However, while C. erosa biomass has not changed, summer biomass of R. minuta has decreased from >79 mg/m^3 in the early 1970s and 1980s to less than 30 mg/m^3 since 1990 (Table 12).

Chrysophytes were generally never observed to be major species in the offshore of Lake Ontario in 1972 and 1981/82 (Table 7). From 1986-92, Chrysophyte biomass averaged 7.6% of the summer biomass, but it increased from 4.1% of the relative summer biomass in 1986 to 12.4% in the summer of 1991 (Table 6). Species of Chromulina, Ochromonas, Chrysococcus and the Haptophyceae were observed from 1986 to 1992 that were not observed in 1981 and 1982 (Table 12).

Relative spring biomass of the Pyrrophyta decreased from over 11% in 1986 to 4.1% in 1992 (Table 5). Gymnodinium helveticum and Peridinium aciculiferum were dominant in 1972 and 1981/82. These same genera were present and prevalent in the 1986-92 period. The biomass of Gymnodinium in the spring and of Gymnodinium spp., Peridinium spp., and Ceratium hirundinella in the summer was highly variable over the course of the study, but was generally lower than reported for 1972 or 1981-1982 (Table 12).

Trophic Status

Paleolimnological and Lake Data: Wolin et al. (1991), in a study of the recent microfossils of Lake Ontario, concluded that abundance of some diatom species associated with grossly polluted areas (hyper-eutrophic) of the Great Lakes, such as Actinocyclus normanii f. subsalsa, Diatoma tenue v. elongatum, Stephanodiscus binderanus and S. parvus, had decreased while the most recently deposited assemblages are composed of species tolerant of eutrophic conditions, i.e. a recovery, albeit small, of the phytoplankton community from high phosphorus loading had occurred. It is difficult to compare quantitative studies based on actual lake samples versus microfossil studies for a number of reasons. A major problem in evaluating lake samples is that we have, in essence, a snapshot of 1972, 1982, 1986, etc.; not a continuous record as sediment profiles provide. However, it is true that the lake samples from the 1986-1992 period were dominated by Stephanodiscus alpinus and Aulacoseira islandica which Wolin et al. (1991) concluded as being indicative of a less eutrophic situation. With the reduction of ambient phosphorus levels in the 1980s (Stevens and Neilson 1987), eurytopic species, such as Aulacoseira islandica, Asterionella formosa and Fragillaria crotonensis, appear to have recovered in the microfossil record (Wolin et al. 1991). This trend was reflected in the quantitative lake data, which indicated that the spring biomass of Asterionella formosa, Fragillaria crotonensis and Aulacoseira islandica has increased from 1981 to 1992 (Table 12). The recent lake data support the conclusion from the paleolimnological data that recent depositional assemblages are composed of species tolerant of less than hyper-eutrophic conditions.

Offshore Lake Data: Because of the limited number of studies of the Lake Ontario offshore phytoplankton assemblage prior to 1970, a limited basis for evaluating the long-term effects of eutrophication and the phosphorus reduction program exists. Considering the April and August period, no changes in the ratio of mesotrophic to eutrophic species in Lake Ontario from 1970 to 1986 had occurred (Table 13). After 1987, an increase in the ratio occurred which suggested a reverse in eutrophy. The increase in species designated as M1 in Table 13 is interesting. M1 species are mesotrophic species that are intolerant of nutrient enrichment. M1 species increased in importance after 1987, while M2 species tolerant of nutrient enrichment, and eutrophic species (E) have decreased since 1982. This observation also suggests a reversal in the trophic status, which is similar to the conclusion of Wolin et al. (1991) based on recent microfossil data. From 1986 through 1992, mesotrophic diatom species accounted for approximately 30.4 ±5.9% of the phytoplankton biomass while eutrophic diatoms represented less than 10 ±1.5% of the phytoplankton biomass (Fig. 4). One oligotrophic species, Cyclotella ocellata, was became more prevalent in the lake after 1987 (Table 12).

Historical trends in offshore phytoplankton biomass indicated a decrease in summer biomass since the 1970s and early 1980s (Fig. 5) that was directly correlated with the decrease in the spring, open water, total phosphorus concentrations (Fig. 6, $r^2 = 0.67$). Because of the considerable variability in the spring biomass data, no clear trend existed over time (Fig. 5). Using the classification scheme of Munawar and Munawar (1982), average biomass for the spring and summer period during the 1986-92 period was suggestive of oligotrophic conditions for the offshore waters. However, without a phytoplankton flora indicative of oligotrophic conditions, this conclusion is unreasonable. The classification scheme of Vollenweider (1968), which is based on the maximum biomass of phytoplankton observed during the year, suggested a mesotrophic status of the offshore waters of Lake Ontario in 1987. Similarly, Taylor et al. (1987) concluded that Lake Ontario was not eutrophic with a total phosphorus concentration of 12 μg/L and chlorophyll concentration of 6 μg/L.

The designation of the offshore waters of Lake Ontario as mesotrophic based on phytoplankton composition and maximum biomass between 1986-92 is also unlike the eutrophic status suggested by Wolin et al. (1991) for the offshore waters based on recent microfossil studies. This discrepancy between the quantitative lake data and the recent microfossil record perhaps is explainable. Both the recent microfossil record and the modern quantitative lake data suggest an improvement in trophic status based on species composition. Based solely on the species composition of the microfossil record, the lake was classified as eutrophic (Wolin et al. 1991), while a number of ecological indicators of the lake (phytoplankton biomass, biomass of mesotrophic species, historic trend in the ratio of mesotrophic to eutrophic species, spring total phosphorus concentrations) suggested mesotrophic conditions.

Species composition by itself in the microfossil record can indicate direction of the eutrophication process and provide relative statements about trophic status, i.e. the lake is more or less eutrophic than previously observed. No classification scheme, such as the biomass-based system of Munawar and Munawar (1982) or Vollenweider (1968), exists for microfossils. The paleolimnological data and the modern quantitative lake data both suggest an improvement. However, different methods conflict on the magnitude of the improvement.

Trophic Dynamics

As a result of the phosphorus abatement program, ambient levels of spring total phosphorus in the open waters decreased and were correlated ($r^2 = 0.67$) with a decrease in summer phytoplankton biomass from 1970 to 1991, but not spring biomass (Fig. 5 and 6), thereby implying a controling influence of nutrients. There is some evidence, although not strong, that the phytoplankton community may also have been responding to food-web effects. For example, small unicelluar phytoplankton (< 50 μm) decreased in relative biomass from 1986 to 1991/92 (76% to 38% - spring, 61% to 51% - summer), while relative biomass of filamentous and colonial algae increased from 1986 to 1992 (5% to 46% - spring, 24% to 38% - summer) (Fig. 7). A decrease in small edible phytoplankton and an increase in colonial and filamentous algae, not as easily eaten by zooplankton, would be expected with an increase in larger zooplankton (Bergquist et al. 1985). In the summer, abundance of several species of Daphnia increased but the abundances were only weakly correlated (r^2=0.50) with the decrease in unicelluar algae. In the spring, the decrease in large and small unicelluar phytoplankton were correlated (r^2=0.83) with the increase in the abundance of Limnocalanus macrurus and inversely correlated (r^2= 0.83) with filamentous algae (Fig. 8). L. macrurus is omnivorous, effectively feeding on particles from 4 to 24 μm in diameter (Rigler 1972). In Lake Superior, the diatoms Melosira and Asterionella and a chrysophyte, Dinobryon, comprised 80% of the stomach contents of this species (Berguson 1971).

RESULTS AND DISCUSSION

Zooplankton

Annual Abundance and Biomass of Zooplankton Groups

From 1986 to 1992, 65 species representing 38 genera from the Calanoida, Cladocera, Cyclopoida, Mysidacea, and Rotifera comprised the offshore zooplankton community of Lake Ontario (Table 14). Twenty-two common species plus their juvenile stages accounted for 97.6% of the total abundance and 96.0% of the total biomass (Table 15). Yearly data on common species are presented in Tables A10-A17 in the Appendix. The Rotifera contained the largest number of species (37, Table 14) and accounted for the highest relative abundance (64.2%). The Calanoida, Cyclopoida and the nauplius stage of the copepod represented 26.4% of the total zooplankton abundance during the 1986-1992 period. The Cladocera (40.0%) followed by the Cyclopoida (32.3%) contributed the most biomass to the zooplankton community, while the Rotifera and the Calanoida represented 7.2% and 4.2%, respectively, of the zooplankton biomass (Table 14). These results are similar to distributions observed in 1967 (Patalas 1969): Cyclopoida-57.4%, Cladocera- 39.4%, Calanoida -3.2%. However, they differ considerably from the work of Mazumder et al. (1992) who observed rotifers to represent over 75% of the total zooplankton biomass in 1982. Within the 1986-91 period of this study, composition of the zooplankton community at the Order level or above has varied. Relative biomass of the rotifers decreased steadily, while cladoceran relative biomass declined sharply in 1990 to 11.1% and than rebounded to 63.3% in 1991 (Fig. 9). Average density and biomass for 1986-1992 (spring and summer) was 235.7 organisms/L ± 20.2 (mean ± S.E.) and 90.2 µg/L ± 9.2 (mean ± S.E.), respectively (Table 16). Biomass was higher in the summer (164 µg/L ± 13.9) than the spring (9.8 µg/L ± 0.7) (Tables 17 and 18).

Geographical Distribution of Zooplankton Groups

Trends in horizontal distribution of zooplankton biomass were not observed in each year or season. In the spring there was a tendency for zooplankton biomass to be higher at the eastern end of the lake (Fig. 10). This was particularly true in 1988, 1990 and 1991. Yet in 1992 spring biomass was higher at the western end of the lake (Fig. 10). During the summer little change in zooplankton biomass was observed from west to east with the exception of the summer of 1991 when zooplankton biomass was exceptionally high in the western portion of the lake (Fig. 10). The cause of the higher biomass from west to east in summer of 1991 was due to an increase in the abundance of Daphnia retrocurva and D. galeata mendotae in the western portion of the lake (Fig. 11). Others have observed horizontal differences in distribution that appear to be related to the seasonal thermal cycle (Patalas 1969). For example, in June and July of 1967, zooplankton were more abundant in the eastern end of the lake northeast of Sodus Bay, which is roughly equivalent to Stations 60 and 63 in this study. This distribution was less pronounced in August and September.

Historic Trends in Abundance

Results of zooplankton tows prior to 1986 were with unmetered tow nets. Taylor et al. (1987) demonstrated that an unmetered sample net in Lake Ontario severely underestimated biomass during spring, early summer and fall, when colonial diatoms are abundant and net efficiencies are reduced. This was not the case in August. Thus there is some basis for confidence for comparison of the 1986-91 metered samples with the previously unmetered samples.

A comparison of the August Crustacea biomass of 1970, 1972, 1981, 1982 and 1986-91 suggests there was an increase in zooplankton abundance from 1970 to 1972, but from 1972 to

1991, crustacean abundance remained nearly steady (Fig. 12a). The minimum in zooplankton abundance occurred during the summer of 1987 when Bythotrephes cederstroemi was reported in some portions of Lake Ontario, but not in our samples.

An interesting increase in spring zooplankton abundance started in 1986 (Fig. 12b). Abundance increases in juvenile and adult calanoids (Diaptomus minutus, D. oregonensis, D. sicilis, Limnocalanus macrurus) and cyclopoid copepodites and Cyclops bicuspidatus thomasi appear to be the probable cause (Table 19).

Historical Changes in Species Composition

Rotifera

Nauwerck (1978) studied the composition, abundance, and morphometrical properties of rotifers in Lake Ontario in 1970. Average abundance in April 1970 was 10,500/m^3 with Synchaeta (83% of total abundance) being the overwhelming dominant. In August of 1970, species of Polyarthra accounted for 45% of the abundance followed by species of Keratella. Maximum rotifer abundance occurred in July (220,000/m^3) of 1970 followed by a sharp decline in August to less than 58,400 individuals/m^3. In 1982, Mazumder et al. (1992) observed that rotifer abundance was significantly higher than in 1970, and that species of Polyarthra and Keratella were dominant with Synchaeta sp. contributing only 6% of the spring abundance and Conochilus and Trichocerca contributing as much as 80% of the total spring abundance. In the 1986 to 1991 period, average rotifer abundance in April (6,500/m^3) and August (64,700/m^3) were similar to those in 1970 (April =10,500/m^3; August= 58,400/m^3).

In August of the 1986-1991 period, the dominant (numerically) rotifers in Lake Ontario were two species of Polyarthra (P. vulgaris and P. major) and two species of Keratella (K. crassa and K. cochlearis) that accounted for 45.6% of the total zooplankton abundance and 5.6%

of the total biomass (Appendix A10-A17). As in April of 1970, Synchaeta sp. was the numerically co-dominant rotifer in April of the study period (mean = 15.9% of the total abundance) along with Notholca squamula (12.9%) and Kellicottia longispina (9.3%). Prominent spring and summer rotifer species from 1986 to 1992, in descending rank as abundance, were: Polyarthra vulgaris, Keratella cochlearis, K. crassa, P. major and Kellicottia longispina (Table 15). Of the dominant rotifers, Polyarthra vulgaris, Polyarthra major, and Keratella cochlearis are cosmopolitan, eurytopic species. The eutrophic indicators Filinia longiseta ($334/m^3$), Trichocera cylindrica (mean=$53/m^3$) and Trichocerca multicrinis (mean=$2,630/m^3$) were present in Lake Ontario but had relatively low abundance (i.e. accounted for less than 1.0% of the biomass and abundance). The lack of dominance of eutrophic indicator species for the entire lake suggests that the offshore waters of Lake Ontario during the 1986-92 study period were not eutrophic. This would agree with the conclusion derived from phytoplankton indicator species and the algal biomass classification of trophic status (This study). Taylor et al. (1987) reached a similar conclusion based on total phosphorus and chlorophyll concentrations.

Crustacea

Prior to the 1970s, there were few studies of the zooplankton of Lake Ontario and, in most cases, these were of the nearshore region or attached bays (Marsh 1901, Whipple 1913, Hart 1930, Pritchard 1931, Tressler and Austin 1940, Tressler et al. 1953, Brooks 1957, Anderson and Clayton 1959, Robertson 1966, McNaught and Fenlon 1972, Wilson and Rolf 1973, Czaika 1974). Crustacean studies of the offshore waters of the Lake Ontario basin are fewer in number. Patalas (1969) collected monthly vertical hauls (64 µm net) from 0 to 50m, lakewide, from June to October 1967, while Watson and Carpenter (1974) sampled 33 stations lakewide in 1970 with a 64-µm mesh net. In 1972-73, the most extensive lakewide studies (60 stations, 64-µm net) were undertaken during IFYGL (International Field Year for the Great Lakes, McNaught 1975). More recently, Johannsson et al. (1985a, 1991) sampled at four stations (two nearshore, two offshore) in 1981 and 1982 with a 64 or 70-µm mesh net (0-20m sampling depth) and Taylor et al. (1987) sampled at three stations with a 64-µm mesh net in 1982. August data have been extracted from the previous data sets to allow comparison with the 1986-1991 data sets.

In 1967, Cyclops bicuspidatus thomasi and Tropocyclops prasinus were the most abundant cyclopoids, while Bosmina longirostris and Daphnia retrocurva were the most abundant cladocerans (Patalas 1969). These same four species were predominant in 1970 (Watson and Carpenter 1974), 1981-82 (Johannsson et al. 1985a and b) and 1986-1991 (this study). From 1970 to 1991, Ceriodaphnia lacustris and Eubosmina coregoni were always present but not predominant. Calanoid copepods have not been abundant since at least the late 1960's. However, the calanoids Eurytemora affinis, Diaptomus sicilis, D. oregonensis, D. minutus and Limnocalanus macrurus were caught in all studies, including this one. Calanoids are believed to have been the dominant group in Lake Ontario at one time (Robertson and Scavia 1984), with the shift from a calanoid dominated to a cyclopoid/cladoceran community occurring from 1939 to 1973 (McNaught and Buzzard 1973).

However, there are changes in the August composition and abundance of the zooplankton during the period from 1981-82 to 1986-91. Ceriodaphnia lacustris decreased in abundance from 1981 (2,962/m^3) to 1988 (314/m^3) and was not observed after 1988 (Table 20). Abundance of Bosmina longirostris decreased from the 80,000 to 140,000/m^3 range in 1981-82 to less than 7,500/m^3 in 1991 (Table 20). Abundance of Daphnia retrocurva in 1991

(36,187/m^3), however, was its highest in over 20 years. After 1986, the larger Daphnia galeata mendotae was more prevalent than in the early 1980s and early 1970s with abundance being substantially higher in 1987 (9,200/ m^3) and 1991 (3,500/m^3). Abundance of the cyclopoid Cyclops vernalis was also substantially higher in 1987 and 1991 than at other times over the last 24 years, while Cyclopoida copepodites have averaged around 40,000/m^3 since 1988 compared to 25,000/m^3 prior to 1987. Similarly, the larger bodied Polyphemus pediculus, Holopedium gibberum and Leptodora kindtii appear to be more prevalent in the 1986-1991 period than in 1972 and 1981/82 (Table 20). Abundance of Diaptomus oregonensis, D. minutus, D. sicilis, Eurytemora affinis, the immature stages of the calanoid, and the oligotrophic indicator species Limnocalanus macrurus have increased substantially since 1972 and 1981/82 (Table 20). Abundance of the nauplius stage of the copepod was especially higher in the spring during the study period compared to the early 1980s (Table 20). Calanoida composition and abundance in the summer of1990 and 1991 were more similar to that of 1970 than those of 1980-1981.

The large predaceous cladoceran Bythotrephes cederstroemi was first observed in nearshore waters of Lake Ontario in 1985 (Lange and Cap 1986). Although observed only rarely in our spring and August sampling of the offshore waters of Lake Ontario during the 1986-91 period (Table 20), Bythotrephes cederstroemi was relatively abundant in the autumn of 1987 (102/m^3) (This study). A similar autumn abundance was observed by Johannsson et al. (1991) at another site in Lake Ontario in 1987. In the spring and summer of 1988, B. cederstroemi was not observed in net samples but was found in the guts of alewife (Mills et al. 1992). Abundance in August of 1990 was low (4 individuals /m^3) and they were not observed in 1991.

In general, abundance of smaller species has decreased and larger cladoceran, calanoid and cyclopoid species have become more prevalent within the pelagic region of Lake Ontario from 1970 to 1991. Average length of the cladoceran community increased over the period of this study (Fig. 13) and it was negatively correlated with alewife abundance (Fig. 14). In particular, species of Daphnia (D. retrocurva and D. galeata mendotae) and Bosmina longirostris have increased in size (Fig. 15) by an average of 66% from their minimum length in the 1986 to 1991 period. An apparent negative correlation between average calanoid and cyclopoid length and smelt abundance was not statistically significant (Fig. 14).

General Discussion

The offshore waters of Lake Ontario had two major vertebrate planktivores during the period of this study, the alewife Alosa pseudoharengus and the rainbow smelt Osmerus mordax (Johannsson and O'Gorman 1991) with the alewife being the most abundant fish in the lake (O'Gorman et al. 1987). During summer stratification the smelt are generally found beneath the epilimnion while alewives are confined largely to the epilimnion (Olson et al. 1988). The most important factor determining the zooplankton composition of Lake Ontario during the 1980s and early 1990s was probably the intense planktivory by alewifes (Taylor et al. 1987). Alewives spatially concentrate and are known to locally depress zooplankton body size and abundance in Lake Ontario (O'Gorman et al. 1991). Planktivore abundance in Lake Ontario has varied greatly over time. The late 1960's and the early 1970's were periods of high alewife abundance accompanied by nuisance die-offs. Much lower alewife biomass existed in the mid-1970's possibly due to increased numbers of salmonine fishes but especially following a major episode of winter mortality in 1976 (Taylor et al. 1987). Results from assessment trawling in U.S. waters of Lake Ontario indicate increasing numbers of alewives from 1978 to 1982 (O'Gorman and Schneider 1986). Alewife and rainbow smelt biomass declined irregularly but steadily from 1981 to 1990, and maintained uniformly low levels from 1990 to 1992 (Fig. 16).

Bythotrephes predation on zooplankton can be extensive and affect community species assemblage and abundance (Lehman 1991, Lehman and Caceres 1993, Makarewicz et al. 1996). Its presence in Lake Ontario was brief, however, with maximum abundance limited to the fall of 1987. In fact, Bythotrephes was not observed in our samples in August of 1987, although Makarewicz and Jones (1990) observed it at a single site in 1987. Bythotrephes appeared to have minimal, if any, effect on zooplankton size and composition in August of 1987 or in 1990 when B. cederstroemi reappeared in the water column (mean = 4/m^3). However, zooplankton abundance was lower in 1987 than in 1986 or 1988-1991 (Fig. 12). Abundance of B. cederstroemii in Lake Ontario in August of 1987 and 1990 was apparently below a minimum threshold level to significantly affect zooplankton populations.

O'Gorman et al. (1991) suggest that information on zooplankton size in large, cold-water lakes can be linked to changes in abundance, condition and growth of planktivorous species. For example, Langeland (1978) observed that the mean sizes of D. galeata mendotae and Holopedium gibberum decreased as predation pressure from Arctic char increased. In Lake Michigan, average zooplankton length increased dramatically as alewife abundance decreased (Makarewicz et al. 1995). Other indicators of increased planktivory in planktivore-dominated systems include shifts in Cladocera composition toward smaller species and a decrease in total zooplankton abundance as well as changes in productivity and the the number of eggs per individual (Johannsson et al. 1991, Johannsson and O'Gorman 1991).

In Lake Ontario, the resurgence of larger Calanoida and Cyclopoida in the spring and the increased length of Cladocera suggest a decrease in alewife planktivory. Over the past 10 years, relaxation of alewife predation in Lake Ontario is often cited as the partial cause of either appearance or the higher abundance of large zooplankton species, such as Bythotrephes cederstroemi in 1987 and Mysis relicta in 1984 (Makarewicz and Jones 1990; Shea and Makarewicz 1989, Johanssson et al. 1991). Certainly, the increase in summer abundance of the larger calanoids and the predaceous and herbivorous cladocerans and the increase in length of Daphnia spp. and Bosmina in the early 1990s suggest a scenario of decreasing alewife predation on zooplankton. The changes in zooplankton composition observed were not likely a result of relaxation of invertebrate predation. Abundance of Polyphemus pediculus and Leptodora kindtii increased in abundance rather than decreased. The decrease in abundance of the small cladocerans B. longirostris and C. lacustris during the 1989-1991 period may be due to the increase in abundance of the D. retrocurva and the larger D. galeata mendotae that resulted from relaxation of size-selective predation by alewives on Daphnia. Vanni (1986) demonstrated that a large herbivorous zooplankton, such as Daphnia, can reduce the density of small zooplankton, such as Bosmina by competition for resources.

The changes in the zooplankton community observed do not refute Taylor's et al. (1987) prediction that as planktivory by fish declines, the role of herbivores in the spring and early summer plankton will pass from rotifers and ciliates to calanoid copepods. Such a major change in zooplankton composition has not taken place; although we may be observing the beginning of the process. Abundance of calanoid copepods has clearly increased. Our data demonstrate that the composition and abundance of the zooplankton community of Lake Ontario has changed in response to a relaxation of alewife predation.

Prior to 1990, the size composition of small species that dominated the zooplankton community suggests a community characteristic of planktivore-dominated systems where the fish feed selectively on larger individuals. After 1990, our data show that calanoids are more important in the pelagic of Lake Ontario than they have been in 20 years; that smaller cladocerans are decreasing in abundance while increasing in size; that Daphnia are more prevalent and increasing in size as an inverse function of alewife abundance; and that large predaceous cladoceran species are more prevalent than they have been prior to 1970. The zooplankton community of Lake Ontario has been responding to changes in the forage fish community ultimately caused by continued predation pressure of salmonines.

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Table 1. Lake Ontario phytoplankton and zooplankton sampling dates, 1986 to 1992.

1986	Stations Sampled	1987	Stations Sampled	1988	Stations Sampled
4/20 - 4/21	8	4/21	8	4/11 - 4/12	8
4/24 - 4/25	8	4/23 - 4/24	8	4/13	8
8/9 - 8/10	8	8/2 - 8/3	8	8/14	8
8/12 - 8/13	8	8/14 - 8/15	8	8/16	8

1989	Stations Sampled	1990	Stations Sampled	1991	Stations Sampled
8/15 - 8/16	8	4/13	8	4/8 - 4/9	8
8/17 - 8/18	8	4/14 - 4/15	8	4/11 - 4/13	8
		8/11 - 8/12	8	8/10 - 8/11	8
		8/13 - 8/14	8	8/12 - 8/13	8

1992	Stations Sampled
4/5 - 4/6	8

Table 2. Number of species observed in each algal division or grouping, Lake Ontario, 1986 to 1992. Spring and summer data only. BAC=Bacillariophyta, CHL=Chlorophyta, CHR=Chrysophyta, COL - colorless flagellates, CRY=Cryptophtya, CYA=Cyanophyta, EUG = Euglenophyta, PYR=Pyrrophyta, UNI = unidentified flagellates.

NUMBER OF SPECIES								
	1986	1987	1988	1989	1990	1991	1992	1986-92
BAC	79	70	65	50	56	72	25	143
CHL	40	43	28	44	43	51	16	116
CHR	14	24	20	26	27	18	10	54
COL	5	2	2	1	2	2	2	5
CRY	15	17	11	10	16	17	15	26
CYA	6	7	4	13	11	9	5	19
EUG	1	0	0	1	2	0	0	3
PYR	7	3	4	6	5	5	3	11
UNI	1	0	1	0	0	0	0	2
TOTAL	168	166	135	151	162	174	76	379

Table 3. Number of genera observed in each algal division or grouping, Lake Ontario, 1986 to 1992. Spring and summer data only. BAC=Bacillariophyta, CHL=Chlorophyta, CHR=Chrysophyta, COL - colorless flagellates, CRY=Cryptophtya, CYA=Cyanophyta, EUG = Euglenophyta, and PYR=Pyrrophyta.

NUMBER OF GENERA								
	1986	1987	1988	1989	1990	1991	1992	1986-92
BAC	20	20	19	18	17	21	12	27
CHL	19	17	16	22	20	27	10	38
CHR	8	10	11	12	15	11	9	21
COL	3	2	2	1	2	2	2	5
CRY	2	3	3	3	2	2	2	3
CYA	4	5	3	8	8	7	4	11
EUG	1	0	0	1	2	0	0	2
PYR	5	2	3	4	4	3	3	6
TOTAL	62	59	57	69	70	73	42	113

Table 4. Summary of common phytoplankton species occurence in Lake Ontario, 1986 to 1992. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Common species were arbitrarily defined as having an abundance ≥ 0.5% of the total cells or ≥ 0.5% of the total biovolume.

TAXON		MAXIMUM CELLS/ML	AVERAGE CELLS/ML	% OF TOTAL CELLS	MEAN BIOVOLUME μm^3/mL	% OF TOTAL BIOVOLUME
BACILLARIOPHYTA						
Actinocyclus normanii		201	1.3	0.03	3,766	0.64
Asterionella formosa		224	11.0	0.27	3,468	0.58
Aulacoseira islandica		1095	105.3	2.58	95,277	16.07
Cymatopleura solea		3	0.1	0.00	3,188	0.54
Fragilaria crotonensis		262	30.8	0.75	19,053	3.21
Nitzschia lauenburgiana		17	1.1	0.03	6,667	1.12
Stephanodiscus alpinus		131	7.0	0.17	32,287	5.45
Stephanodiscus binderanus		1426	33.0	0.81	14,981	2.53
Stephanodiscus niagarae		22	0.9	0.02	14,166	2.39
Tabellaria flocculosa		157	12.3	0.30	22,473	3.79
				----------		----------
	Total			4.96		36.31
CHLOROPHYTA						
Chlamydomonas sp.		229	25.1	0.61	1,694	0.29
Gloeocystis sp.		720	35.4	0.87	1,912	0.32
Green coccoid		9254	409.6	10.02	25,193	4.25
Oocystis borgei		205	11.2	0.27	4,091	0.69
Oocystis parva		2602	28.7	0.70	2,311	0.39
Oocystis pusilla		409	44.6	1.09	3,884	0.66
Oocystis solitaria		147	5.5	0.13	3,805	0.64
Pediastrum duplex		655	4.1	0.10	13,736	2.32
Scenedesmus bijuga		998	60.6	1.48	4,621	0.78
Scenedesmus ecornis		2323	51.1	1.25	2,399	0.40
Sphaerocystis schroeteri		2553	75.5	1.85	4,778	0.81
Staurastrum sp.		8	0.2	0.00	18,264	3.08
Tetraedron minimum		205	9.8	0.24	4,455	0.75
				----------		----------
	Total			18.62		15.37
CHRYSOPHYTA						
Chromulina sp.		213	50.3	1.23	5,771	0.97
Haptophyceae		2143	338.6	8.28	7,525	1.27
Ochromonas sp.		573	115.7	2.83	13,631	2.30
				----------		----------
	Total			12.34		4.54
COLORLESS FLAGELLATES						
Colorless flagellate		2470	43.3	1.06	2,011	0.34
CRYPTOPHYTA						
Cryptomonas erosa		245	31.0	0.76	57,503	9.70
Cryptomonas marssonii		90	11.3	0.28	8,358	1.41
Cryptomonas ovata		98	5.2	0.13	7,801	1.32
Cryptomonas phaseolus		90	9.5	0.23	4,062	0.69
Cryptomonas pyrenoidifera		65	6.6	0.16	5,238	0.88
Rhodomonas minuta		2798	286.7	7.01	20,028	3.38
				----------		----------
	Total			8.57		17.37
CYANOPHYTA						
Anacystis montana		26916	1,470.1	35.96	14,433	2.43
Chroococcus sp.		475	22.5	0.55	899	0.15
Oscillatoria limnetica		6496	197.8	4.84	2,716	0.46
Oscillatoria sp.		1014	70.2	1.72	1,628	0.27
Synechococcus sp.		4582	87.2	2.13	4,526	0.76
				----------		----------
	Total			45.20		4.08
PYRROPHYTA						
Ceratium hirundinella		33	0.7	0.02	17,089	2.88
Gymnodinium helveticum		16	0.4	0.01	4,061	0.68
Gymnodinium sp.		41	6.2	0.15	14,176	2.39
Peridinium sp.		57	5.1	0.13	25,058	4.23
				----------		----------
	Total			0.31		10.18
				==========		==========
	Total			91.06		88.20

Table 5. Time trends in spring phytoplankton abundance and biomass for Lake Ontario, 1986 to 1992. NS = no sample. BAC = Bacillariophyta, CHL = Chlorophyta, CHR = Chrysophyta, CYA = Cyanophyta, PYR = Pyrrophyta and CRY = Cryptophyta. (*) Mean biomass and abundances for all divisions.

Spring Abundance (Cells/ml)

	BAC	%	CHL	%	CHR	%	CYA	%	PYR	%	CRY	%	Mean*
1986	65	3.5	134	7.2	433	23.4	991	53.5	13	0.7	178	9.6	1854
1987	507	29.8	175	10.3	167	9.8	700	41.1	13	0.8	125	7.4	1702
1988	217	11.2	156	8.1	213	11.0	1020	52.9	15	0.8	270	14.0	1928
1989	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1990	642	19.6	142	4.3	478	14.6	1562	47.6	20	0.6	251	7.7	3281
1991	284	12.3	272	11.8	386	16.8	1053	45.7	13	0.6	276	12.0	2303
1992	841	21.0	253	6.3	526	13.1	1954	48.9	23	0.6	356	8.9	4001
Mean	426	16.2	189	8.0	367	14.8	1213	48.3	16	0.7	243	9.9	2512

Spring Biomass (g/m^3)

	BAC	%	CHL	%	CHR	%	CYA	%	PYR	%	CRY	%	Mean*
1986	0.173	58.7	0.010	3.3	0.022	7.6	0.007	2.4	0.033	11.1	0.049	16.5	0.295
1987	0.407	72.2	0.009	1.6	0.008	1.4	0.006	1.1	0.083	14.7	0.051	9.0	0.564
1988	0.185	53.1	0.015	4.3	0.010	2.9	0.009	2.6	0.042	12.1	0.087	24.8	0.349
1989	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1990	0.638	57.9	0.218	19.7	0.036	3.2	0.035	3.2	0.079	7.1	0.082	7.5	1.103
1991	0.250	58.4	0.018	4.2	0.026	6.2	0.015	3.5	0.020	4.7	0.098	22.9	0.428
1992	0.737	72.8	0.018	1.8	0.045	4.5	0.024	2.3	0.041	4.1	0.145	14.4	1.011
Mean	0.398	62.2	0.048	5.8	0.025	4.3	0.016	2.5	0.050	9	0.085	15.9	0.625

Table 6. Time trends in summer phytoplankton abundance and biomass for Lake Ontario, 1986 to 1992. NS = no sample. BAC = Bacillariophyta, CHL = Chlorophyta, CHR = Chrysophyta, CYA = Cyanophyta, PYR = Pyrrophyta and CRY = Cryptophyta. (*) Mean biomass and abundances for all divisions.

Summer Abundance (Cells/ml)

	BAC	%	CHL	%	CHR	%	CYA	%	PYR	%	CRY	%	Mean*
1986	141	3.3	1176	27.7	760	17.9	1367	32.2	10	0.2	737	17.3	4251
1987	97	1.7	2941	50.2	430	7.3	2011	34.3	1	0.0	358	6.1	5862
1988	258	2.4	1540	14.1	1239	11.4	7315	67.2	12	0.1	505	4.6	10890
1989	83	1.7	1065	22.1	673	14.0	2442	50.7	20	0.4	505	10.5	4816
1990	119	2.8	1121	26.2	709	16.6	1743	40.8	22	0.5	481	11.3	4274
1991	143	3.7	1194	31.0	968	25.1	899	23.3	7	0.2	595	15.5	3851
1992	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	140	2.6	1506	28.6	796	15.4	2629	41.4	12	0.2	530	10.9	5657

Summer Biomass (g/m^3)

	BAC	%	CHL	%	CHR	%	CYA	%	PYR	%	CRY	%	Mean*
1986	0.138	22.9	0.127	21.0	0.025	4.1	0.016	2.7	0.086	14.2	0.211	34.8	0.606
1987	0.053	14.0	0.215	56.9	0.012	3.2	0.021	5.6	0.000	0.1	0.076	20.2	0.379
1988	0.239	35.4	0.101	14.9	0.048	7.2	0.086	12.8	0.100	14.8	0.099	14.7	0.675
1989	0.020	2.5	0.272	33.3	0.064	7.8	0.077	9.5	0.182	22.4	0.196	24.0	0.816
1990	0.080	14.5	0.143	25.9	0.060	10.9	0.050	9.1	0.074	13.4	0.140	25.4	0.552
1991	0.104	18.9	0.146	26.5	0.068	12.4	0.020	3.7	0.038	6.9	0.172	31.4	0.550
1992	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	0.106	18.0	0.167	29.8	0.046	7.6	0.045	7.2	0.080	12.0	0.149	25.1	0.596

Table 7. Relative biomass (% of total biomass) of algal divisions in 1972/73, 1981, 1982 and 1986-1992, Lake Ontario. Only April or May and August data are considered, except for the combined spring and summer data from Munawar et al. (1974). Data are from Munawar et al. (1974), Stoermer and Ladewski (1978), Johansson et al. (1985b) and this study. Because spring and summer samples were not collected, data are not provided for 1989 and 1992 .

	BAC	CHL	CHR	CRY	CYA	PYR
1972/73*	61	10	0	2	2	21
1972/73**	32	7	5	19	2	31
1981	43	6	0	26	2	23
1982	15	19	1	38	7	19
1986	35	15	2	29	3	13
1987	49	24	1	14	3	9
1988	42	11	6	18	9	14
1990	43	22	6	14	5	9
1991	36	17	10	28	4	6

* Stoermer and Ladewski (1978)

** Munawar et al. (1974)

Table 8. Average abundance and biomass (± standard error) for the spring and summer period from 1986 to 1992, Lake Ontario. Average is the weighted average for the number of cruises per season. NS indicates that no samples were taken during that season.

YEAR	SPRING		SUMMER		AVERAGE	
	cells/ml	g/m^3	cells/ml	g/m^3	cells/ml	g/m^3
1986	1824 ± 216	0.30 ± 0.07	4251 ± 708	0.60 ± 0.07	3052 ± 423	0.45 ± 0.06
1987	1702 ± 378	0.56 ± 0.19	5862 ± 638	0.38 ± 0.04	3782 ± 522	0.47 ± 0.10
1988	1928 ± 156	0.35 ± 0.04	10890 ± 2357	0.68 ± 0.11	6409 ± 1413	0.51 ± 0.06
1989	NS	NS	4816 ± 944	0.82 ± 0.19	4816 ± 944	0.82 ± 0.19
1990	3281 ± 468	1.10 ± 0.24	4274 ± 458	0.55 ± 0.06	3777 ± 334	0.83 ± 0.13
1991	2303 ± 241	0.43 ± 0.05	3851 ± 264	0.55 ± 0.04	3077 ± 224	0.49 ± 0.04
1992	4001 ± 420	1.01 ± 0.17	NS	NS	4001 ± 420	1.01 ± 0.17
MEAN	2788 ± 225	0.64 ± 0.07	5506 ± 544	0.54 ± 0.03	4088 ± 302	0.59 ± 0.04

Table 9. Summary of common phytoplankton species from Lake Ontario during 1981. Summary includes the average population biomass and the percent of total biomass for April and August offshore sites only. Common species were arbitrarily defined as contributing 5% of the algal biomass to any sample during the year. Data from Johannsson et al. 1985.

Taxon		Mean Biomass gm/m³	% of Total Biomass
BACILLARIOPHYCEAE			
Asteronella formosa		3.1	0.37
Diatoma elongata		4.7	0.06
Cyclotella sp.		8.5	1.02
Melosira binderana		79.6	9.53
Melosira islandica		83.0	9.94
Fragilaria crotonensis		1.0	0.12
Nitzschia acicularis		1.7	0.20
Stephanodiscus astraea v. minutula		64.2	7.69
Stephanodiscus hantzschii		6.9	0.83
Stephanodiscus niagarae		18.3	2.19
Cymatopleura solea		1.1	0.13
Tabellaria fenestrata		8.7	1.04
Synedra ulna		53.8	6.44
Synedra acus		0.7	0.08
	Total		39.64
CHLOROPHYCEAE			
Pediastrum simplex v. duodenarium		0.5	0.06
Pediastrum duplex v. clathratum		4.9	0.59
Scenedesmus ecornis		1.2	0.15
Staurastrum paradoxum v. parvum		6.7	0.81
Ulothrix variabilis		0.4	0.05
Mougeotia sp.		1.8	0.22
Sphaerocystis schroeteri		2.9	0.34
Coelastrum microporum		1.2	0.14
Oocystis borgei		5.8	0.69
	Total		3.05
CYANOPHYCEAE			
Oscillatoria limnetica		0.2	0.02
Anabaena sp.		14.8	1.77
	Total		1.79
CRYPTOPHYCEAE			
Cryptomonas erosa		123.5	14.80
Rhodomonas minuta		45.4	5.44
Katablepharis ovalis		1.4	0.16
	Total		20.40
DINOPHYCEAE			
Gymnodinium helveticum		37.4	4.47
Gymnodinium uberrimum		23.8	2.85
Peridinium cinctum		6.6	0.79
Peridinium aciculiferum		73.5	8.80
Glenodinium sp.		11.7	1.40
Ceratium hirundinella		15.0	1.80
	Total		20.12
			==========
	Total		85.00

Table 10. Summary of common phytoplankton species from Lake Ontario during 1982. Summary includes the average population biomass and the percent of total biomass for April and August offshore sites only. Common species were arbitrarily defined as contributing 5% of the algal biomass to any sample during the year. The data is from Johannsson et al. 1985.

Taxon		Mean Biomass gm/m3	% of Total Biomass
BACILLARIOPHYCEAE			
Fragilaria capucina		2.0	0.43
Fragilaria crotonensis		6.4	1.36
Tabellaria fenestrata		5.9	1.28
Nitzschia linearis		3.9	0.84
Melosira islandica		22.1	4.76
Melosira binderana		3.5	0.76
Diatoma elongata		3.2	0.69
Stephanodiscus astraea v. minutula		0.7	0.15
Stephanodiscus hantzschii		1.8	0.25
Synedra ulna		5.1	1.10
	Total		11.67
CHLOROPHYCEAE			
Oocystis sp.		18.1	3.90
Staurastrum paradoxum		1.5	0.31
Cosmarium sp.		3.2	0.68
Scenedesmus bijuga		1.2	0.25
Sphaerocystis schroeteri		15.0	3.22
	Total		8.39
CYANOPHYCEAE			
Oscillatoria limnetica		12.8	2.74
Merismopedia sp.		7.5	1.61
Anabaena sp.		6.8	1.47
	Total		5.84
CRYPTOPHYCEAE			
Katablepharis ovalis		5.5	1.19
Cryptomonas erosa		68.7	14.79
Rhodomonas minuta		64.3	13.86
Cryptomonas curvata		1.3	0.28
	Total		30.13
DINOPHYCEAE			
Glenodinium sp.		7.6	1.64
Ceratium hirundinella		3.9	0.84
Peridinium aciculiferum		42.0	9.04
Peridinium cinctum		5.0	1.08
Gymnodinium helveticum		16.2	3.48
	Total		16.10
	Total		72.15

Table 11. Dominant diatom species from 1986 to 1992 in Lake Ontario.

		% of total biomass	% of total abundance
1986	Stephanodiscus alpinus	16.3	0.13
	Tabellaria flocculosa	5.4	0.31
	Fragillaria crotonensis	2.9	0.68
	Fragillaria capucina	0.9	0.43
	Aulacoseira islandica	1.8	0.36
1987	Aulacoseira islandica	16.1	2.69
	Stephanodiscus binderanus	7.1	2.25
	Tabellaria flocculosa	6.3	0.37
	Stephanodiscus alpinus	4.9	0.19
1988	Stephanodiscus alpinus	9.6	0.27
	Aulacoseira islandica	9.0	1.00
	Tabellaria flocculosa	6.8	0.31
	Fragillaria crotonensis	2.0	0.31
	Stephanodiscus binderanus	1.1	0.41
1989	No spring data		
1990	Aulacoseira islandica	26.6	5.63
	Stephanodiscus alpinus	3.3	0.23
	Fragillaria crotonensis	2.4	0.91
	Stephanodiscus binderanus	2.0	0.69
1991	Aulacoseira islandica	17.8	2.92
	Fragillaria crotonensis	7.4	1.7
	Stephanodiscus alpinus	1.9	0.08
	Stephanodiscus parus	0.14	0.55
1992	Aulacoseira islandica	43.8	12.8
	Stephanodiscus binderanus	9.5	3.8
	Tabellaria flocculosa	1.0	6.0
	Stephanodiscus hantzschii	0.54	0.19

Table 12. Spring and summer biomass of selected Lake Ontario phytoplankton species for the period 1972 to 1992. NS = no sample, ND = no data. 1972 data from Munawar et al. (1975). 1981 and 1982 data from Johansson et al. (1985).

		1972	1981	1982	1986	1987	1988	1989	1990	1991	1992
SPRING (April)		Mean Biomass (µg/m³)	Mean Biomass (µg/m³)	Mean Biomass (µg/m³)	Mean Biomass (µg/m³)	Mean Biomass (µg/m³)	Mean Biomass (µg/m³)	Mean Biomass (µg/m³)	Mean Biomass (µg/m³)	Mean Biomass (µg/m³)	Mean Biomass (µg/m³)
Actinocyclus normanii	BAC	ND	ND	ND	583	6,544	0	NS	230	0	0
Asterionella formosa	BAC	ND	5,166	ND	2,390	1,754	6,549	NS	14,171	1,955	15,073
Aulacoseira islandica	BAC	68,425	138,310	57,008	8,573	149,632	46,209	NS	431,534	164,590	442,812
Cyclotella ocellata	BAC	ND	ND	ND	0	0	20	NS	63	221	0
Cymatopleura solea	BAC	ND	1,835	ND	1,874	407	2,312	NS	5,134	7,795	38,277
Diatoma tenue	BAC	ND	ND	ND	51	1,439	1,933	NS	4,337	487	5,496
Fragilaria crotonensis	BAC	ND	813	221	4,298	18,097	7,347	NS	11,849	9,661	6,687
Stephanodiscus alpinus	BAC	83,300*	106,979*	2,063*	133,353	45,667	41,387	NS	52,681	16,380	15,197
Stephanodiscus binderanus	BAC	ND	132,606	9,903	1,572	65,157	6,578	NS	30,515	8,226	96,273
Stephanodiscus hantzschii	BAC	ND	3,878	2,194	647	1,171	1,269	NS	843	455	1,949
Stephanodiscus niagarae	BAC	ND	30,461	ND	1,269	35,235	11,725	NS	5,610	2,487	0
Stephanodiscus parvus	BAC	ND	ND	ND	0	98	3	NS	198	1,086	445
S. transilvanicus	BAC	ND	ND	ND	0	6,325	0	NS	2,279	975	6,375
Tabellaria flocculosa	BAC	ND	ND	ND	7,043	45,014	47,896	NS	23,611	20,349	60,623
Ankistrodesmus falcatus	CHL	ND	ND	ND	0	0	0	NS	616	1,422	2,584
Ankistrodesmus gracilis	CHL	ND	ND	ND	0	19	0	NS	0	1,048	1,342
Chlamydomonas sp.	CHL	ND	ND	ND	961	511	131	NS	1,742	2,040	2,966
Cryptomonas erosa	CRY	ND	18,313	13,649	28,998	24,457	42,770	NS	27,053	34,100	40,444
Gymnodinium spp.	PYR	89,250	62,254	24,702	8,803	40,579	34,600	NS	66,808	17,717	14,201
SUMMER (August)											
Cyclotella ocellata	BAC	ND	ND	ND	0	0.5	68	38	76	229	0
Gymnodinium spp.	PYR	96,900	ND	11,430	3,904	217	2,324	9,321	15,988	2,362	NS
Ceratium hirundinella	PYR	ND	39,460	6,108	68,576	0	86,433	31,558	9,952	0	NS
Peridinium spp.	PYR	114,000	160,542	64,556	8,338	0	11,300	116,726	47,439	29,523	NS
Rhodomonas minuta	CRY	79,800	100,230	86,433	24,896	9,684	20,593	49,444	22,321	28,647	NS

*Identified as *Stephanodiscus astrea*, probably equivalent to *S. alpinus*.

Table 13. Distribution of indicator diatom species in Lake Ontario. The classification scheme of Tarapchak and Stoermer (1976) was utilized except in the case of Surirella angusta. S. angusta was classified as eutrophic following Wolin et al. (1991). M1 = mesotrophic but intolerant of nutrient enrichment, M2 = mesotrophic and tolerant of moderate nutrient enrichment, E = eutrophic. 1970, 1981/82 and 1986/87 data are from Munawar et al. (1974),and Johannsson et al. (1985a and b), this study, respectively. The 1986 to 1992 data are from this study. Values in the columns M1, M2 and E represent April and late July in1972. In 1981, 1982 and 1986 to 1992 April and August values are used in the calculation. There are no April dates in 1989 and no August dates in 1992. Only diatoms contributing > 5% of the biomass of a sampling date were classified.

	M1	M2	E	M1+M2/E
1970	1	1	2	1.0
1981	1	5	4	1.5
1982	1	4	4	1.3
1986	2	2	3	1.3
1987	3	2	2	2.5
1988	3	3	2	3.0
1989	0	1	0	---
1990	2	3	2	2.5
1991	3	2	2	2.5
1992	2	1	1	3.0

Table 14. Number of species and genera observed in each phylum of zooplankton, Lake Ontario 1986 to 1992. ZM = veligers of *Dreissena polymorpha.*

Number of Species

	1986	1987	1988	1989	1990	1991	1992	1986-92
Calanoida	7	8	6	4	7	6	3	8
Cladocera	8	10	10	7	11	9	3	15
Cyclopoida	1	2	1	2	3	2	2	3
Mysidacea	1	0	0	0	1	1	0	1
Rotifera	27	29	26	25	28	21	16	37
ZM	0	0	1	0	1	0	0	1
TOTAL	44	49	44	38	51	39	24	65

Number of Genera

	1986	1987	1988	1989	1990	1991	1992	1986-92
Calanoida	3	4	3	4	5	3	2	5
Cladocera	7	3	8	6	8	7	3	10
Cyclopoida	2	2	2	3	3	2	2	3
Mysidacea	1	0	0	0	1	1	0	1
Rotifera	14	11	13	14	16	12	10	18
ZM	0	0	1	0	1	0	0	1
TOTAL	27	20	27	27	34	25	17	38

Table 15. Summary of common zooplankton species occurrence in Lake Ontario during 1986 to 1992. Species were arbitrarily classified as common if they accounted for ≥ 0.1% of the total abundance or ≥ 1.0% of the total biomass, with the exception of rotifers. Rotifer species were considered common if they accounted for ≥ 1.0% of the total abundance.

TAXON		MAXIMUM DENSITY (#/m³)	AVERAGE DENSITY (#/m³)	% OF TOTAL ABUNDANCE	MEAN BIOMASS (µg/m³)	% OF TOTAL BIOMASS
COPEPODA						
Copepoda - nauplii		203,920	36,667.0	15.56	14,667	16.25
Cyclopoida						
Cyclopoid - copepodite		112,288	18,114.5	7.69	12,695	14.07
Cyclops bicuspidatus thomasi		32,124	4,136.8	1.76	15,019	16.64
Cyclops vernalis		10,751	456.1	0.19	388	0.43
Tropocyclops - copepodite		35,904	965.0	0.41	363	0.40
Tropocyclops prasinus mexicanus		7,715	583.8	0.25	683	0.76
Calanoida						
Diaptomus - copepodite		8,295	837.1	0.36	1,040	1.15
Limnocalanus macrurus		2,077	43.1	0.02	1,165	1.29
				----------		----------
	Total			26.22		50.99
CLADOCERA						
Bosmina longirostris		236,790	12,990.4	5.51	9,421	10.44
Ceriodaphnia sp.		15,430	460.5	0.20	690	0.77
Daphnia galaeta mendotae		41,633	1,139.0	0.48	4,036	4.47
Daphnia retrocurva		131,895	7,120.8	3.02	20,483	22.70
				----------		----------
	Total			9.21		38.37
ROTIFERA						
Ascomorpha ovalis		44,123	3,427.8	1.45	58	0.06
Conochilus unicornis		63,563	3,996.5	1.70	70	0.08
Kellicottia longispina		103,596	9,898.0	4.20	117	0.13
Keratella cochlearis		260,688	26,973.0	11.44	100	0.11
Keratella crassa		174,292	17,757.8	7.53	941	1.04
Keratella earlinae		134,493	7,417.5	3.15	198	0.22
Keratella quadrata		36,999	2,528.6	1.07	192	0.21
Polyarthra major		215,839	17,613.3	7.47	1,984	2.20
Polyarthra remata		36,207	2,363.5	1.00	27	0.03
Polyarthra vulgaris		290,925	45,216.8	19.19	2,034	2.25
Pompholyx sulcata		170,137	2,930.2	1.24	38	0.04
Synchaeta sp.		62,904	3,731.4	1.58	107	0.12
Trichocerca multicrinis		28,620	2,630.3	1.12	124	0.14
				----------		----------
	Total			62.15		6.64
				==========		==========
	Total			97.59		96.01

Table 16. Time trends in zooplankton biomass and abundance of selected phyla in Lake Ontario, 1986 - 1992 (spring and summer data only). ND = no data, ** weighted mean that considers the number of stations sampled each year.

BIOMASS (µg/L)

Year	Calanoida		Cladocera		Copepoda		Cyclopoida		Rotifera		Mean
	µg/L	%	µg/L	%	µg/L	%	µg/L	%	µg/L	%	µg/L
1986	3.7	4.1	21.7	23.6	18.6	20.2	36.5	39.8	11.0	12.0	91.8
1987	3.2	6.2	19.8	39.2	10.7	21.2	10.9	21.5	6.0	11.8	50.5
1988	4.6	5.6	26.9	32.7	15.0	18.2	28.5	34.6	7.3	8.9	82.3
1989[a]	3.5	2.6	55.3	40.6	22.1	16.3	42.9	31.5	12.3	9.0	136.0
1990	2.5	4.5	6.2	11.1	17.8	31.6	25.5	45.3	4.2	7.5	56.3
1991	5.6	3.4	105.1	63.3	10.8	6.5	41.8	25.1	2.8	1.7	166.2
1992	1.1	7.4	0.1	0.6	1.4	9.2	12.4	81.8	0.1	1.0	15.1
1986-92	3.8	4.2	36.1	40.0	14.7	16.3	29.2	32.3	6.5	7.2	90.2**

ABUNDANCE (number/L)

Year	Calanoida		Cladocera		Copepoda		Cyclopoida		Rotifera		Mean
	#/L	%	#/L	%	#/L	%	#/L	%	#/L	%	#/L
1986	1.2	0.4	19.9	6.8	46.5	15.9	20.1	6.9	204.7	70.0	292.4
1987	2.1	1.3	12.1	7.9	26.8	17.4	12.6	8.2	100.6	65.2	154.2
1988	1.1	0.4	42.4	13.6	37.6	12.1	27.6	8.9	201.9	65.0	310.7
1989[a]	1.0	0.2	53.1	12.6	55.3	13.1	46.1	10.9	266.9	63.2	422.4
1990	0.9	0.4	2.1	1.0	44.5	21.3	23.6	11.3	138.1	66.0	209.3
1991	1.6	0.9	23.9	13.8	27.1	15.6	31.0	17.9	89.9	51.9	173.3
1992	0.3	2.0	0.0	0.1	3.5	21.4	6.1	37.5	6.3	38.9	16.2
1986-92	1.3	0.5	22.1	9.4	36.7	15.6	24.3	10.3	151.4	64.2	235.7**

[a] Summer data only. No spring samples were collected.

Table 17. Time trends in zooplankton biomass and abundance of zooplankton groups in Lake Ontario, 1986 - 1992 (spring data only). ND = no data, ** weighted mean that considers the number of stations sampled each year. NS = no spring samples collected in 1989. Copepoda = nauplius stage of the Copepoda.

SPRING BIOMASS (μg/L)

Year	Calanoida		Cladocera		Copepoda		Cyclopoida		Rotifera		Mean
	μg/L	%	μg/L	%	μg/L	%	μg/L	%	μg/L	%	μg/L
1986	1.3	28.5	0.0003	0.007	1.0	21.6	2.2	47.2	0.04	0.8	4.6
1987	2.2	26.9	0.02	0.3	2.6	32.1	2.9	36.3	0.35	4.4	8.1
1988	1.5	12.7	0.02	0.2	1.6	12.9	8.8	72.9	0.15	1.3	12.1
1989	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1990	2.2	21.7	0.02	0.2	1.4	13.5	6.3	62.1	0.22	2.2	10.1
1991	2.8	24.9	0.04	0.3	1.7	15.2	6.6	58.2	0.07	0.6	11.3
1992	1.1	7.4	0.09	0.6	1.4	9.2	12.4	81.8	0.15	1.0	15.1
1986-92	1.9	19.7	0.03	0.3	1.6	16.6	6.0	61.4	0.17	1.7	9.8**

SPRING ABUNDANCE (number/L)

Year	Calanoida		Cladocera		Copepoda		Cyclopoida		Rotifera		Mean
	#/L	%	#/L	%	#/L	%	#/L	%	#/L	%	#/L
1986	0.3	6.3	0.0002	0.003	2.5	46.3	1.0	19.6	1.5	27.8	5.3
1987	0.8	3.6	0.01	0.04	6.5	28.7	1.4	6.3	13.8	61.3	22.5
1988	0.6	4.4	0.02	0.10	3.9	28.4	3.6	25.8	5.7	41.2	13.8
1989	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1990	0.6	3.7	0.01	0.04	3.4	22.9	2.4	15.9	8.6	57.5	15.0
1991	0.5	5.1	0.01	0.10	4.3	41.1	2.8	27.2	2.8	26.5	10.4
1992	0.3	2.0	0.02	0.10	3.5	21.4	6.1	37.5	6.3	38.9	16.2
1986-92	0.5	4.0	0.01	0.10	4.1	29.7	2.6	19.0	6.5	47.2	13.7**

Table 18. Time trends in zooplankton biomass and abundance of selected phyla in Lake Ontario, 1986 - 1992 (summer data only). ND = no data, ** weighted mean that considers the number of stations sampled each year. NS = no summer sample collected in 1992.

SUMMER BIOMASS (µg/L)

Year	Calanoida		Cladocera		Copepoda		Cyclopoida		Rotifera		Mean
	µg/L	%	µg/L	%	µg/L	%	µg/L	%	µg/L	%	µg/L
1986	6.1	3.4	43.3	24.2	36.2	20.2	70.9	39.6	22.0	12.3	179.1
1987	4.1	4.4	39.6	42.6	18.8	20.3	18.8	20.2	11.6	12.5	92.9
1988	7.7	5.1	53.8	35.3	28.5	18.7	48.1	31.5	14.5	9.5	152.5
1989	3.5	2.6	55.3	40.6	22.1	16.3	42.9	31.5	12.3	9.0	136.0
1990	2.8	2.8	12.5	12.2	34.2	33.4	44.7	43.7	8.2	8.0	102.5
1991	8.5	2.6	210.2	65.5	19.9	6.2	77.0	24.0	5.5	1.7	321.1
1992	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1986-92	5.5	3.3	69.1	42.1	26.6	16.2	50.4	30.7	12.3	7.5	164.0**

SUMMER ABUNDANCE (number/L)

Year	Calanoida		Cladocera		Copepoda		Cyclopoida		Rotifera		Mean
	#/L	%	#/L	%	#/L	%	#/L	%	#/L	%	#/L
1986	2.1	0.4	39.8	6.9	90.5	15.6	39.1	6.8	408.0	70.4	579.4
1987	3.3	1.2	24.3	8.5	47.1	16.5	23.9	8.3	187.5	65.6	286.0
1988	1.6	0.0	84.8	14.0	71.2	11.7	51.7	8.5	398.2	65.5	607.5
1989	1.0	0.2	53.1	12.6	55.3	13.1	46.1	10.9	266.9	63.2	422.4
1990	1.2	0.3	4.2	1.0	85.6	21.2	44.9	11.1	267.5	66.3	403.7
1991	2.6	0.8	47.8	14.2	49.8	14.8	59.1	17.6	177.0	52.6	336.2
1992	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1986-92	2.0	0.5	42.3	9.6	66.6	15.2	44.1	10.0	284.2	64.7	439.2**

Table 19. Mean spring abundance (#/m^3) for selected Crustacea species. 1981 and 1982 data is from Johannson et al. (1985b). Note there were no spring samples taken in 1989.

Taxon	Group	1981 (#/m^3)	1982 (#/m^3)	1986 (#/m^3)	1987 (#/m^3)	1988 (#/m^3)	1990 (#/m^3)	1991 (#/m^3)
Eurytemora affinis	CAL	0	0	0	0	0	0	0
Diaptomus minutus	CAL	0	0	1	1	4	1	12
Diaptomus oregonensis	CAL	6	1	59	50	53	35	37
Diaptomus sicilis	CAL	21	13	97	73	68	134	146
Limnocalanus macrurus	CAL	2	2	8	20	13	21	27
Calanoid - copepodite	CAL	102	33	171	675	462	364	309
Copepoda - nauplii	COP	491	332	2,471	6,469	3,918	3,418	4,286
Tropocyclops prasinus mexicanus	CYC	25	29	22	14	14	14	23
Cyclops bicuspidatus thomasi	CYC	613	494	345	555	1,598	1,147	1,221
Cyclopoid - copepodite	CYC	389	652	669	852	1,950	1,214	1,587

Table 20. Comparison of abundance of selected species of Crustacea for the sampling period in August of 1970 (Watson and Carpenter 1974), 1972 (McNaught et al. 1975), 1981, 1982 (Station 12 and 41 only) Johannsson et al. 1985b) and 1986 to 1991August data are reported. Values are #/m^3. Values in 1970, 1972, 1981, and 1982 are not corrected for filtration efficiency. Values in parentheses are depths of tow. NC= not counted.

	1970 (0-50m)	1972 (0-5m)	1981 (0-20m)	1982 (0-20m)	1986 (0-20m)	1987 (0-20m)	1988 (0-20m)	1989 (0-20m)	1990 (0-20m)	1991 (0-20m)
Cladocera										
Bosmina longirostris	19,210	63,691	82,930	141,914	24,067	4,873	72,640	40,033	666	7,081
Bythotrephes cederstroemi	0	0	0	0	0	0	0	0	4	0
Eubosmina coregoni	306	1,453	200	50	197	388	32	158	123	331
Daphnia retrocurva	6,868**	11,965	5,250	814	13,788	9,528	11,584	8,116	2,694	36,187
Daphnia longiremis		0	9	11	0	0	4	0	7	0
Daphnia galeata mendotae		99	0	0	165	9,228	87	105	2	3509
Ceriodaphnia lacustris	448	4,202	2,962	1,452	1,323	119	314	0	0	0
Polyphemus pediculus	0	3	4	29	43	37	19	0	103	42
Holopedium gibberum	0	7	0	0	61	0	0	19	103	197
Leptodora kindtii	98	0	8	0	108	34	81	88	55	135
Cyclopoida										
Cyclops bicuspidatus thomasi	3,371	12,113	8,771	2,497	5,574	2,292	6,698	4,672	8,287	12,785
Cyclops vernalis	616	643	0	6	0	1,345	0	0	8	5,232
Tropocyclops prasinus mexicanus	548	3,510	485	255	429	2,141	132	2,284	376	1,378
Mesocyclops edax	207	NC	0	11	0	0	0	4	32	0
Cyclopoid copepodites	21,316	29,143	34,629	20,840	32,264	18,088	44,883	39,069	36,176	41,063
Copepoda nauplii	NC	NC	8,719	14,275	90,469	47,064	71,187	55,268	85,567	49,825
Calanoida										
Diaptomus minutus	204	74	0	0	0	7	0	0	17	80
Diaptomus sicilis	60***	17	0	0	15	0	45	8	33	403
Diaptomus oregonensis		108	21	0	271	174	75	88	147	144
Limnocalanus macrurus	185	6	0	0	100	17	178	46	25	41
Calanoid copepodites	725	116	82	215	1,371	2,681	1,287	257	895	1,317
Eurytemora affinis	401	0	0	22	352*	377*	63*	333*	88*	16*

* Includes Copepodites of Eurytemora sp.
** Daphnia spp.
*** D.sicilis plus D.oregonensis

STATION	DEPTH (m)
12	102
25	108
33	129
41	122
49	50
63	82
60	143

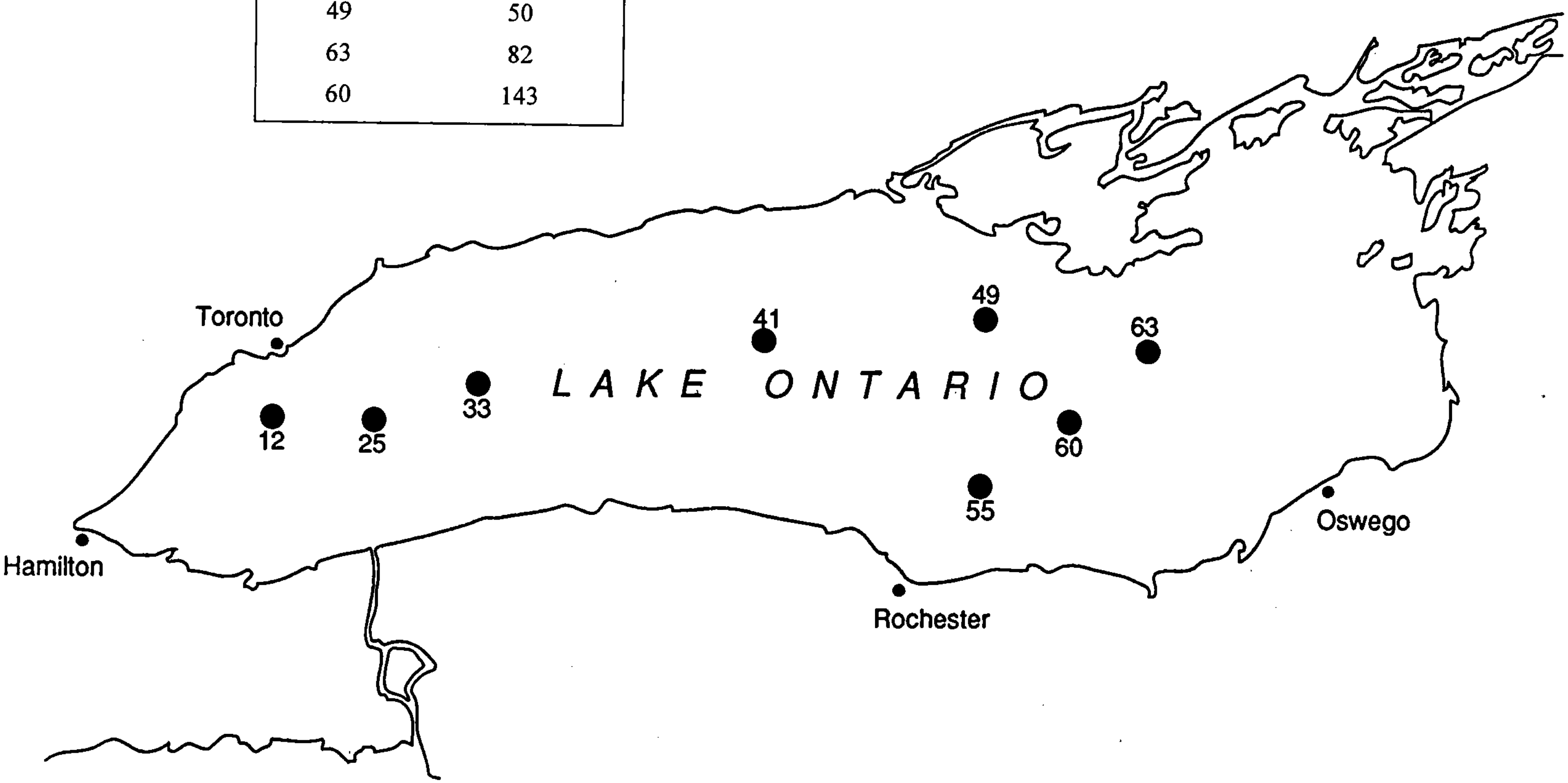

Figure 1. Lake Ontario sampling stations, 1986-1992.

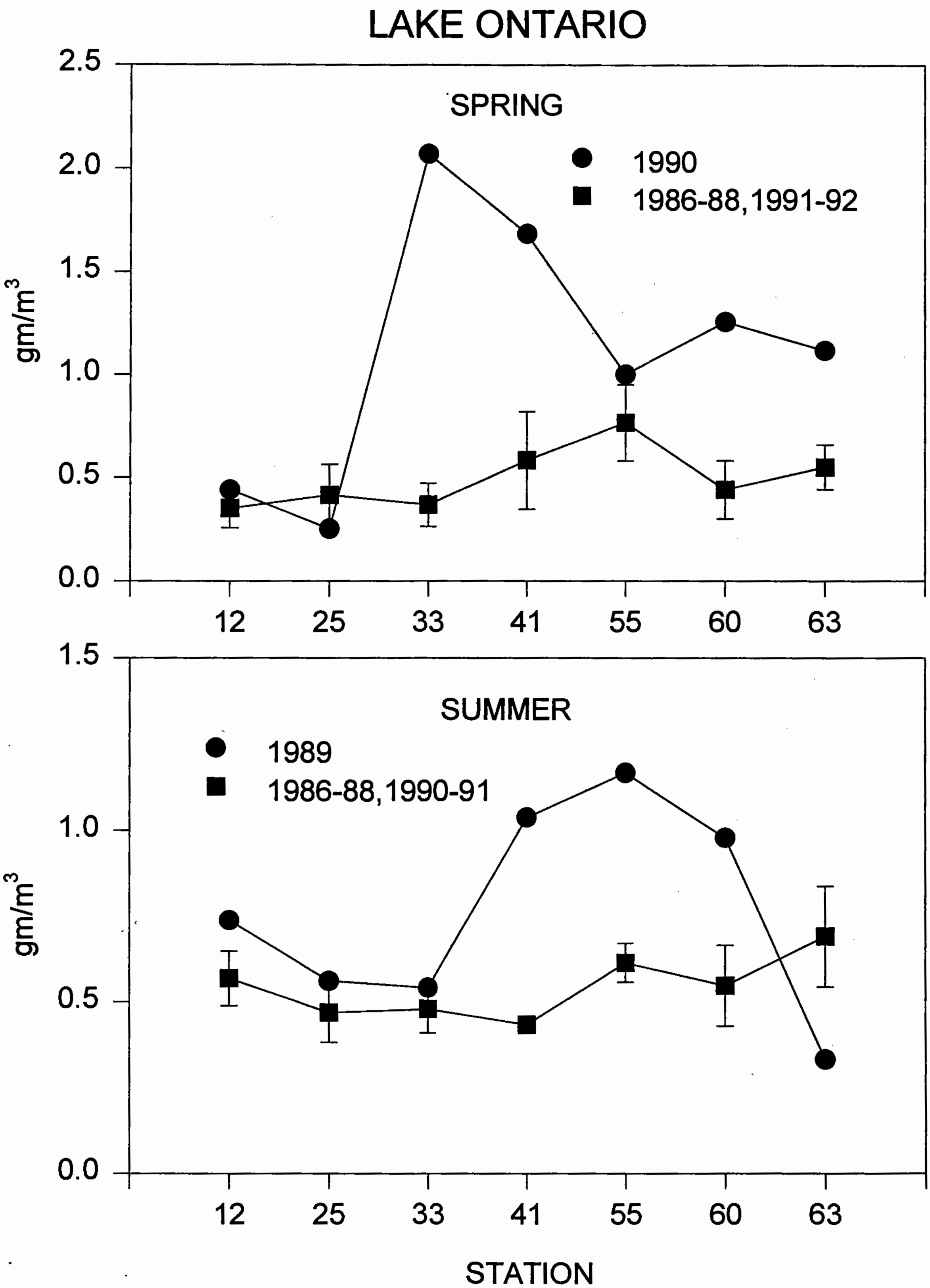

Figure 2. Geographical distribution of phytoplankton biomass in Lake Ontario, 1986-1992. Values are the mean ± S.E.

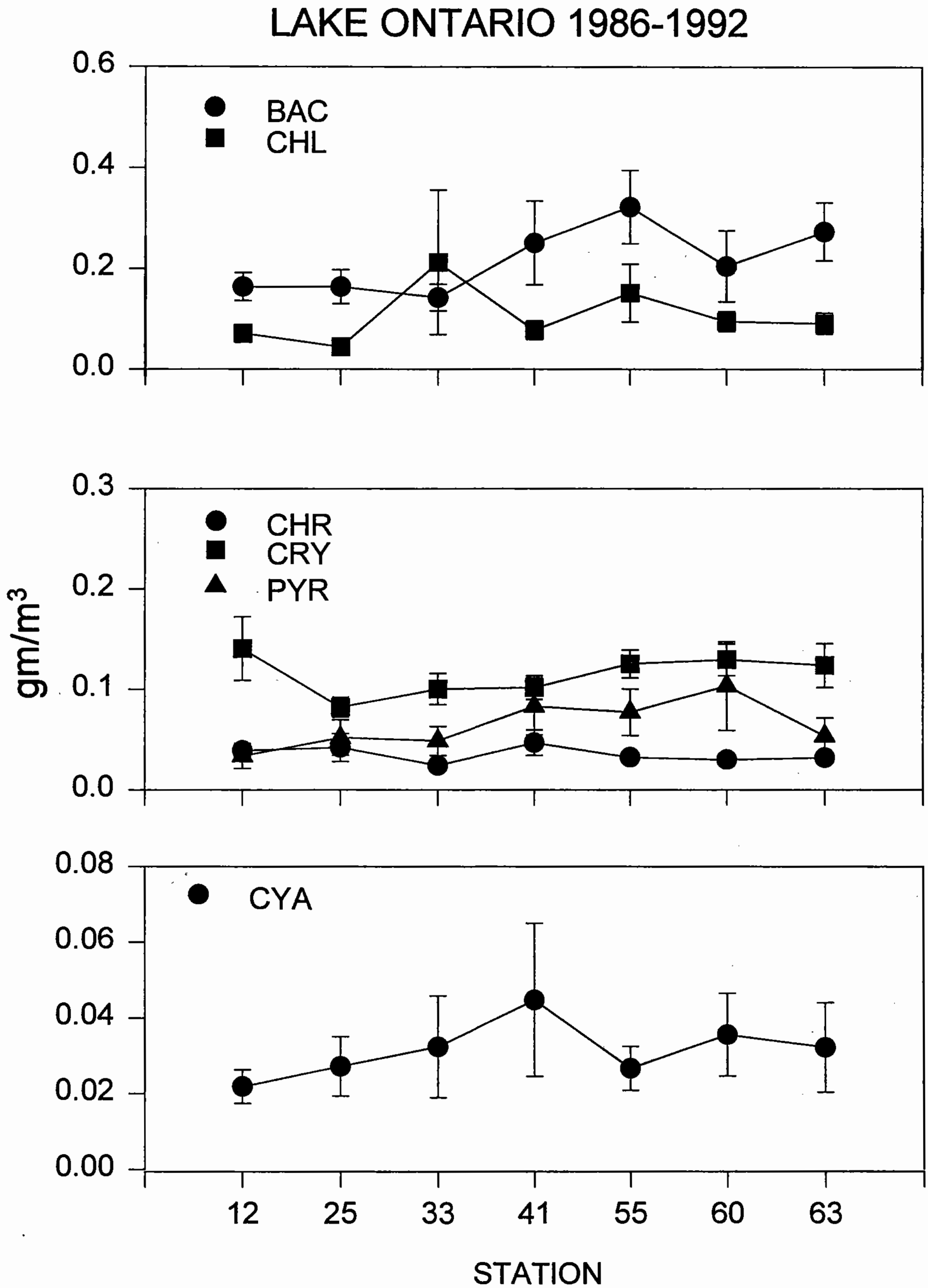

Figure 3. Geographical distribution of selected phytoplankton divisions in Lake Ontario, 1986-1992. Values are the mean biomass ± S.E.

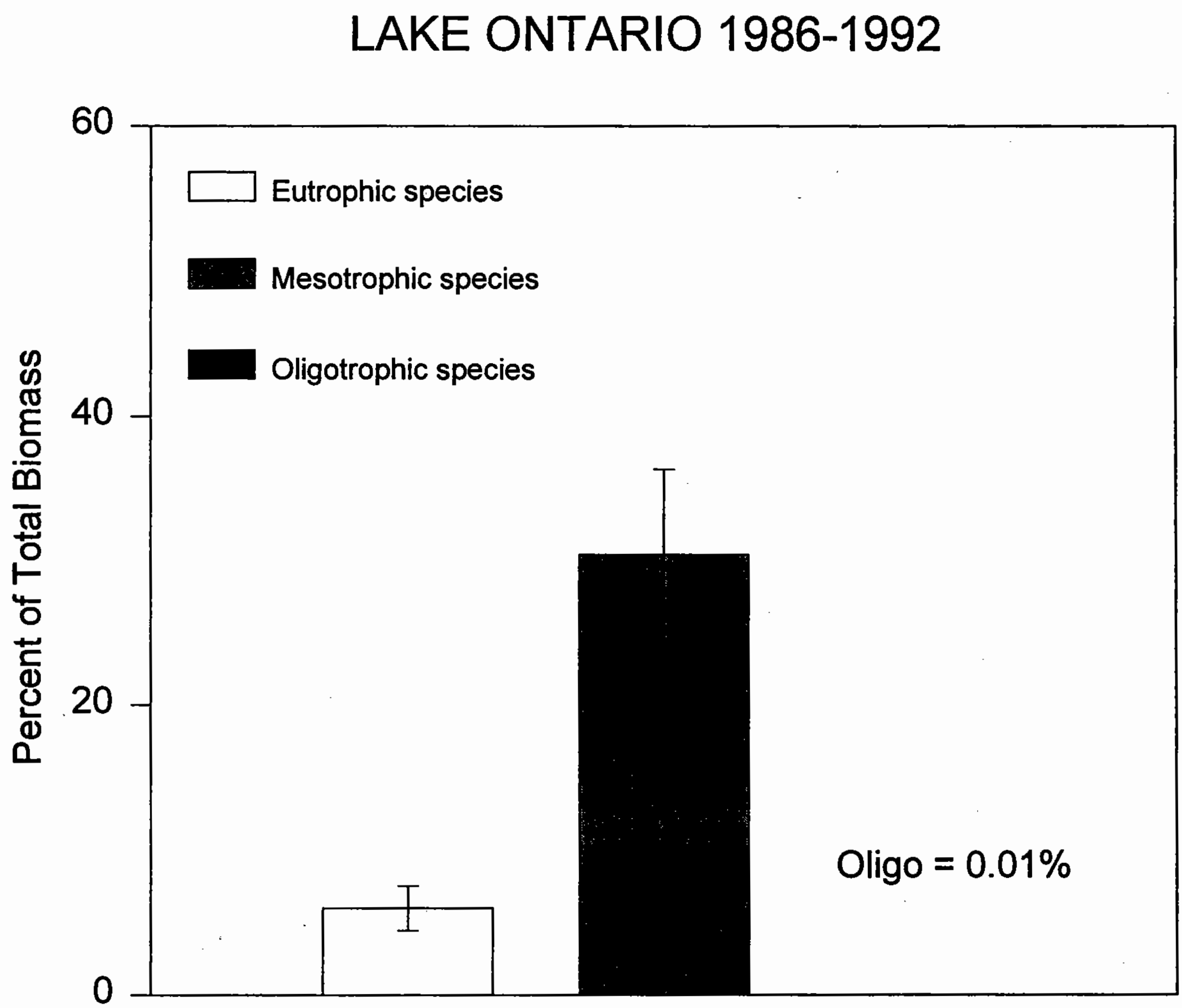

Figure 4. Average relative biomass of eutrophic, mesotrophic and oligotrophic diatom species in Lake Ontario, 1986-1992. Values are the mean + S.E.

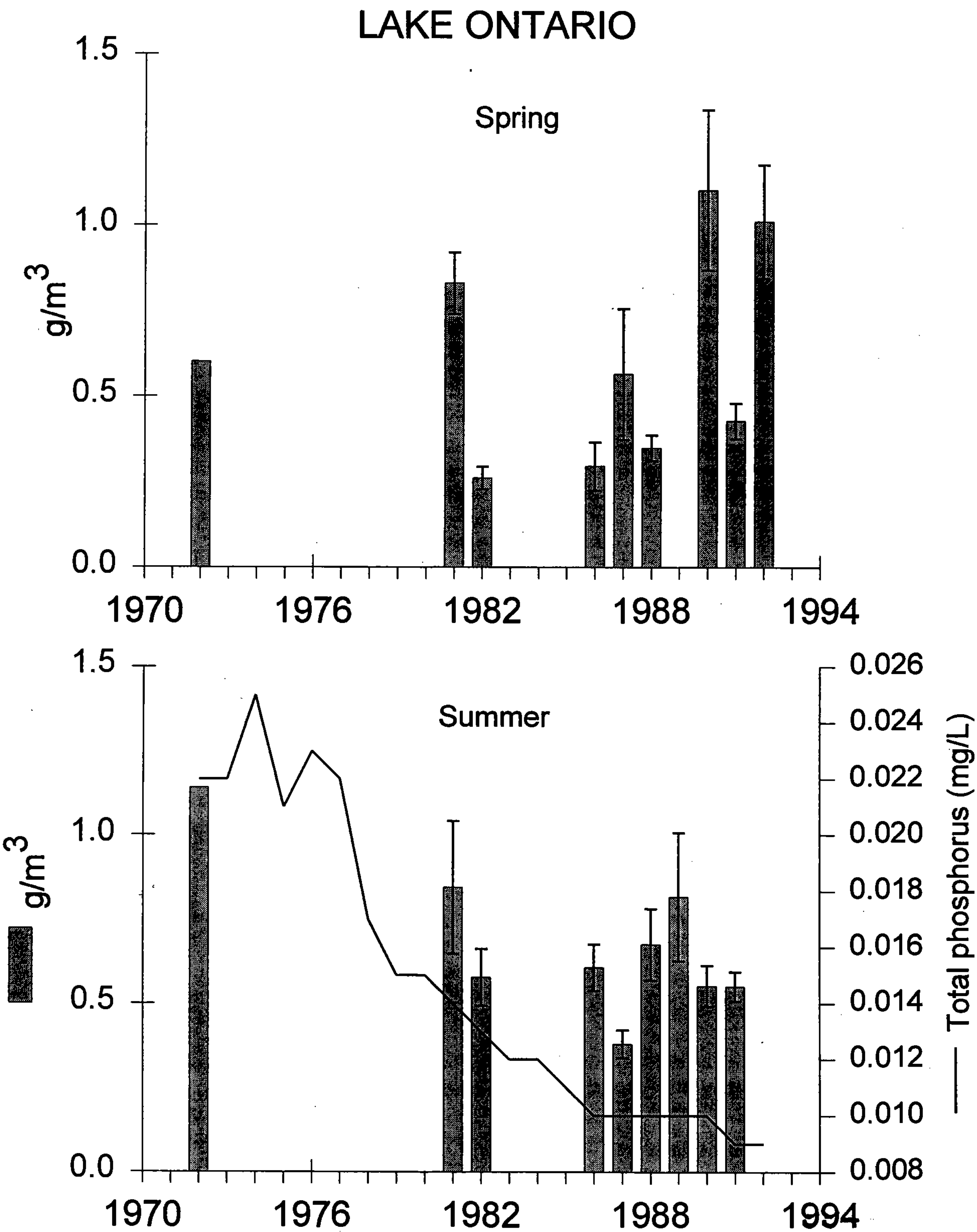

Figure 5. Historical trends in offshore phytoplankton biomass in Lake Ontario. Values represent the mean ± S.E. of the April (spring) and August (summer) data of Johannsson et al. (1985), this study and the April and late July data of Munawar et al. (1974). Total phosphorus data are from Glumac (1994) and represent spring values at a 1-meter depth.

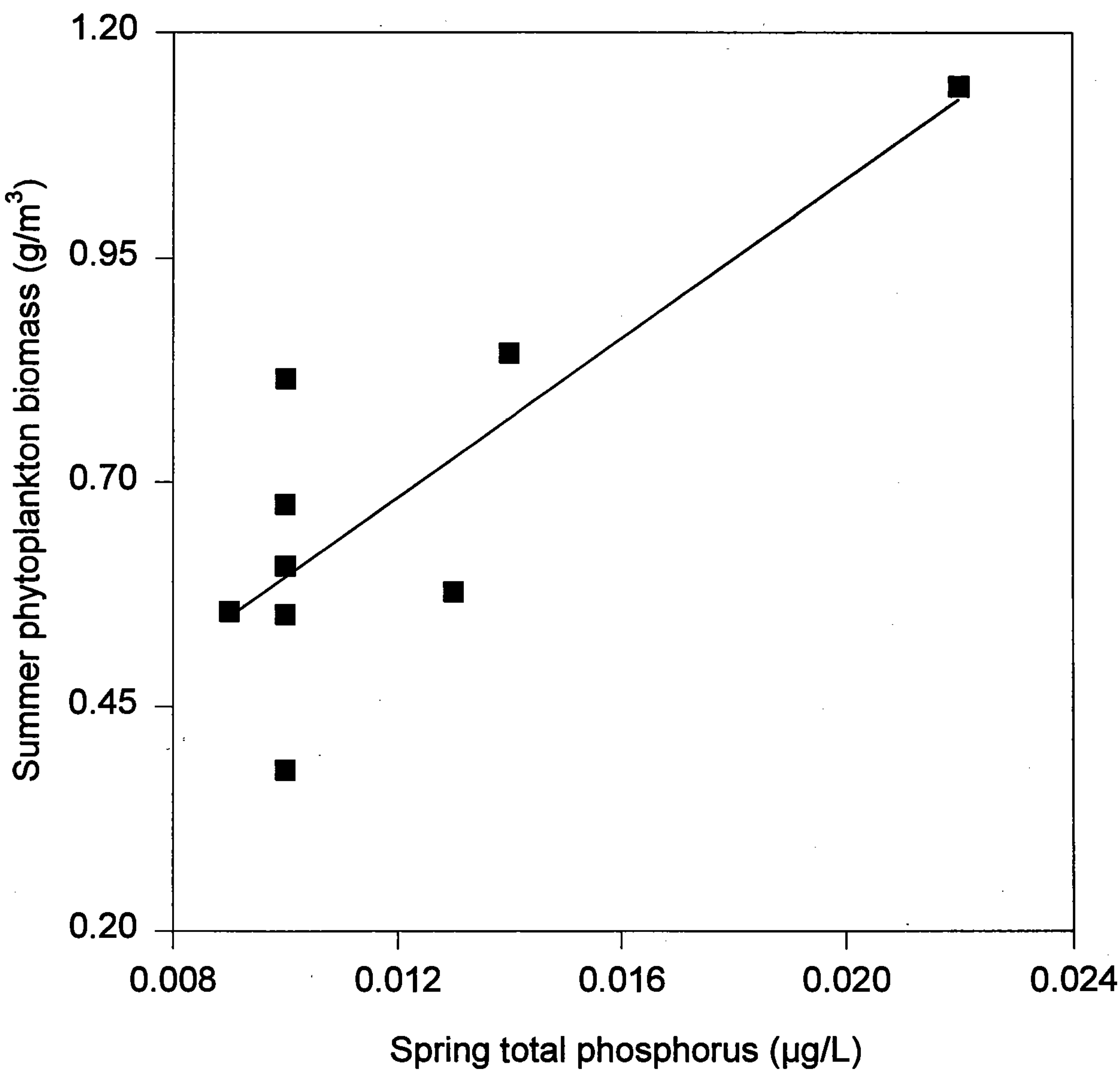

Figure 6. Regression (r^2= 0.67) of summer phytoplankton biomass (August data) on spring total phosphorus concentrations. Total phosphorus data are from Glumac (1994) and represent spring values at a 1-meter depth.

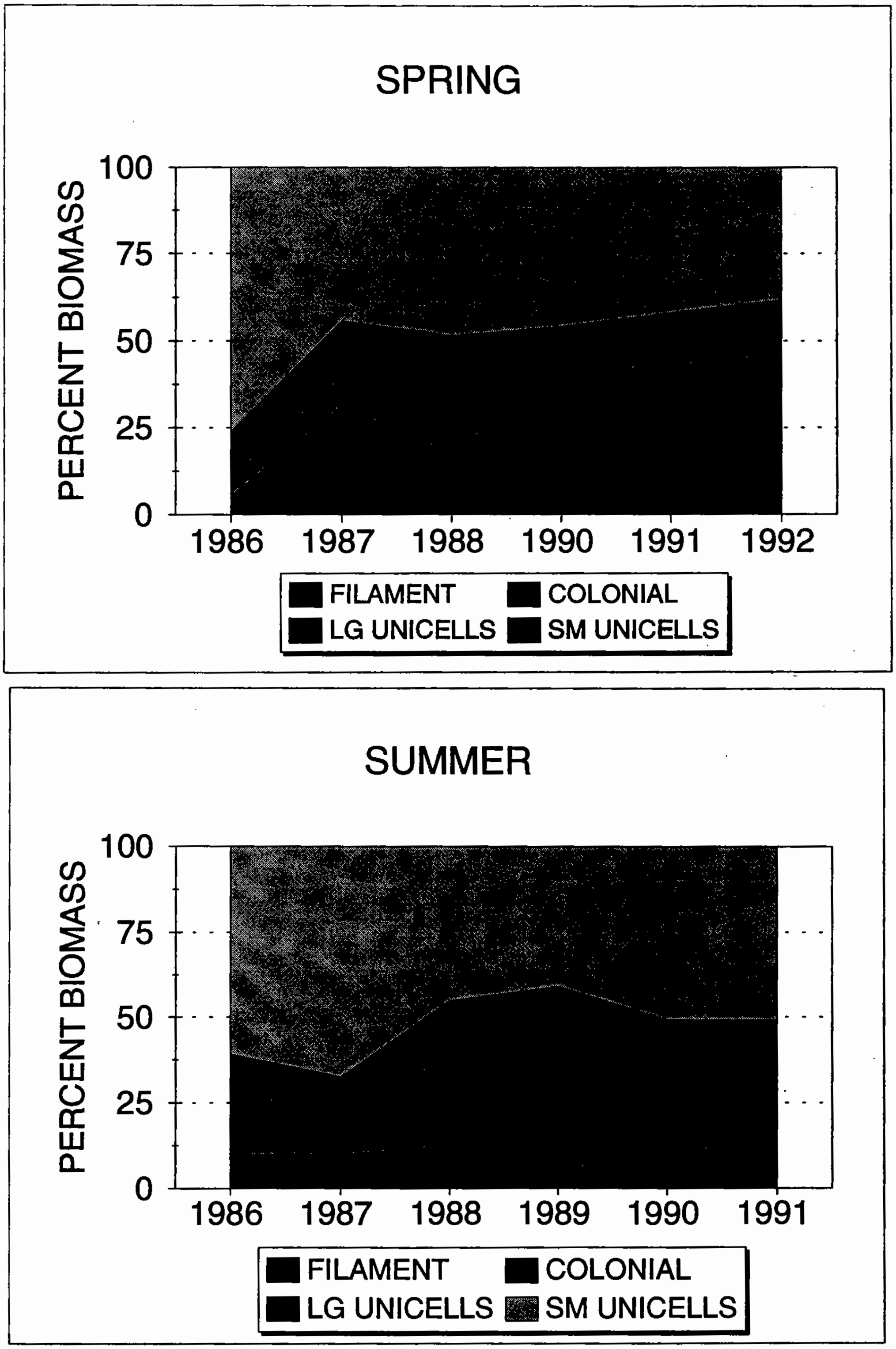

Figure 7. Relative biomass of filamentous, colonial, and small (<50 µm) and large unicelluar algae (>50µm) in Lake Ontario, 1986-1992.

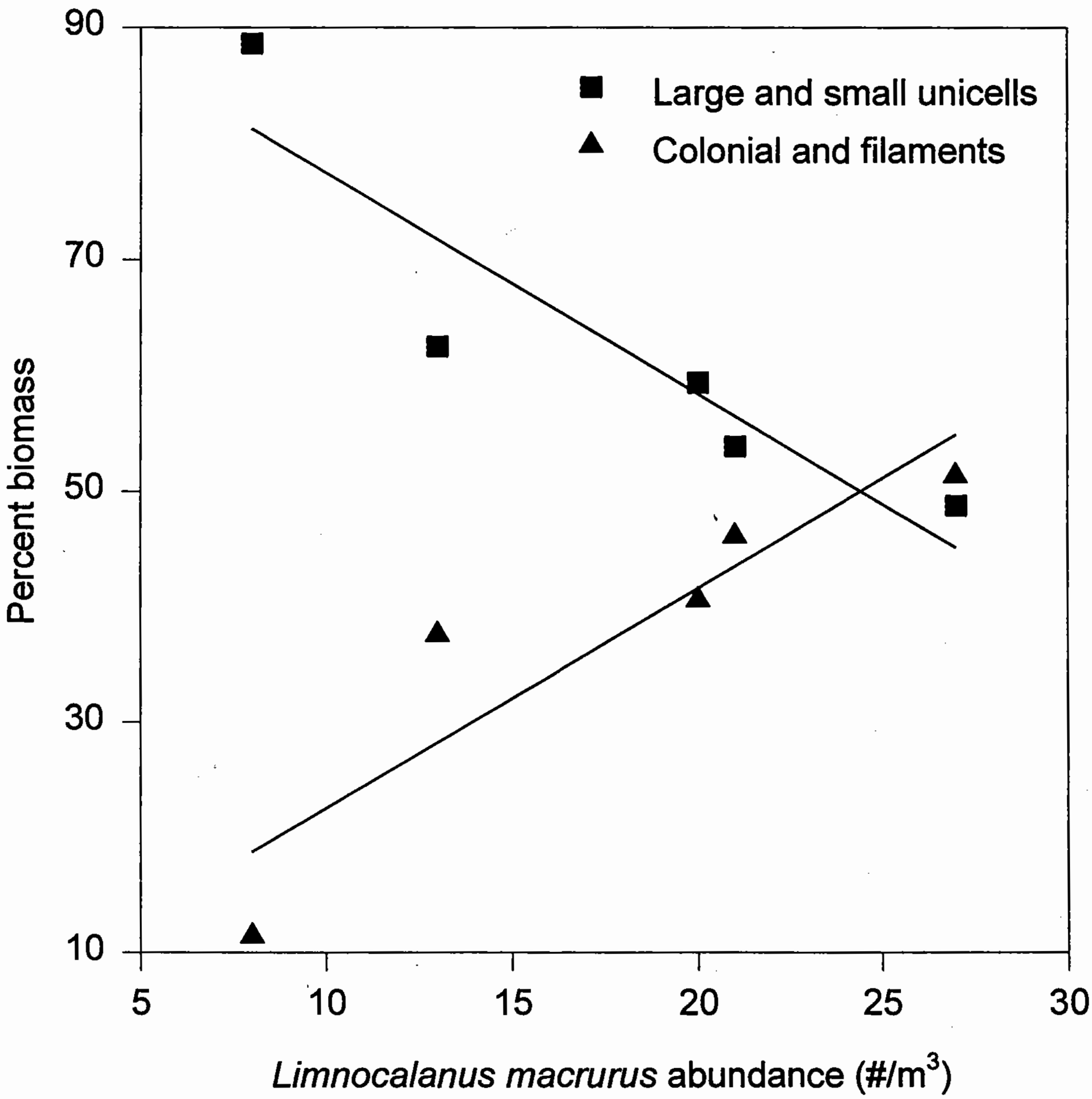

Figure 8. Relationship between Limnocalanus abundance and relative biomass of spring unicelluar algae ($r^2 = 0.83$) and relative biomass of spring colonial/filamentous algae ($r^2 = 0.83$).

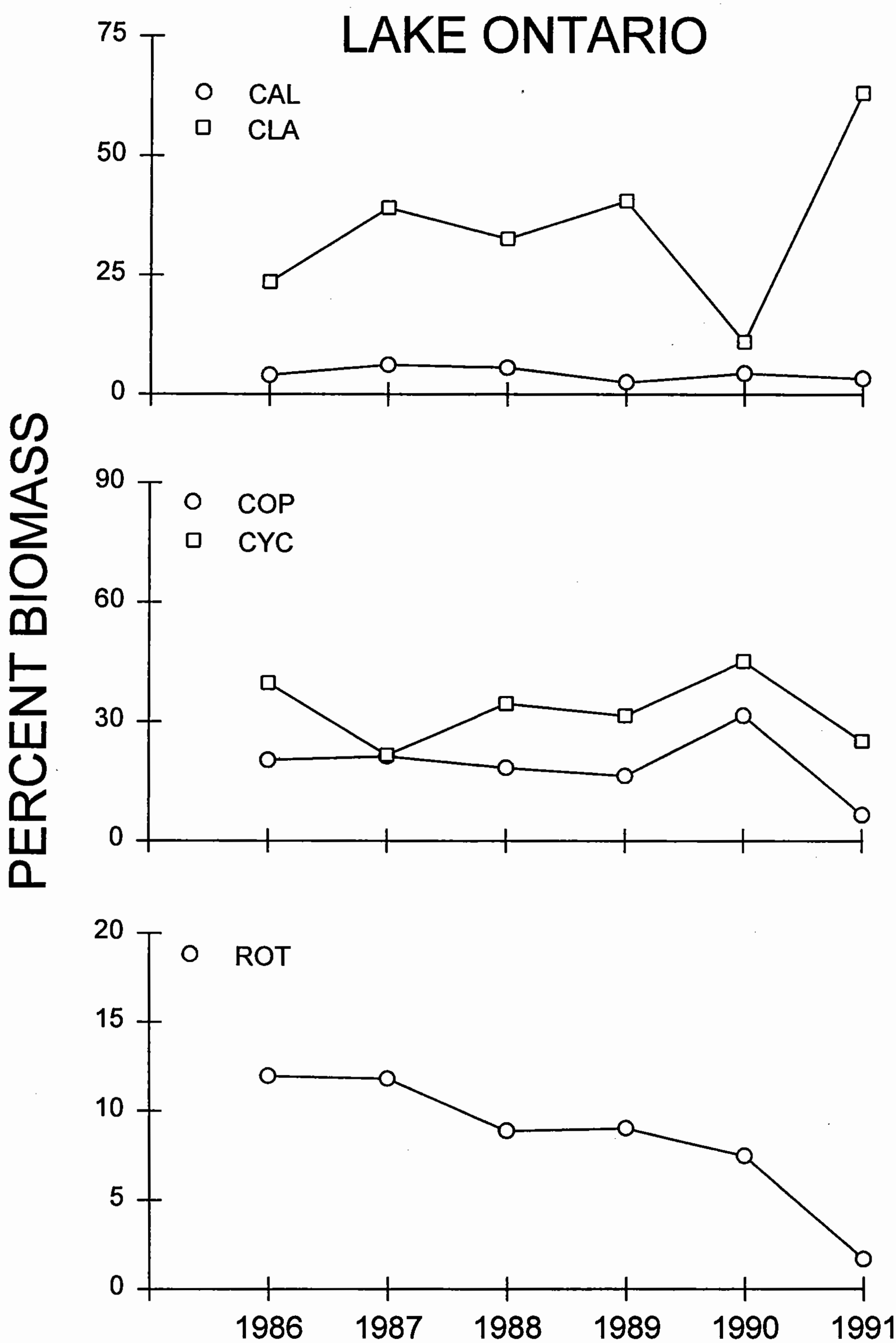

Figure 9. Yearly trends in relative biomass of zooplankton phyla, 1986-1991.

LAKE ONTARIO

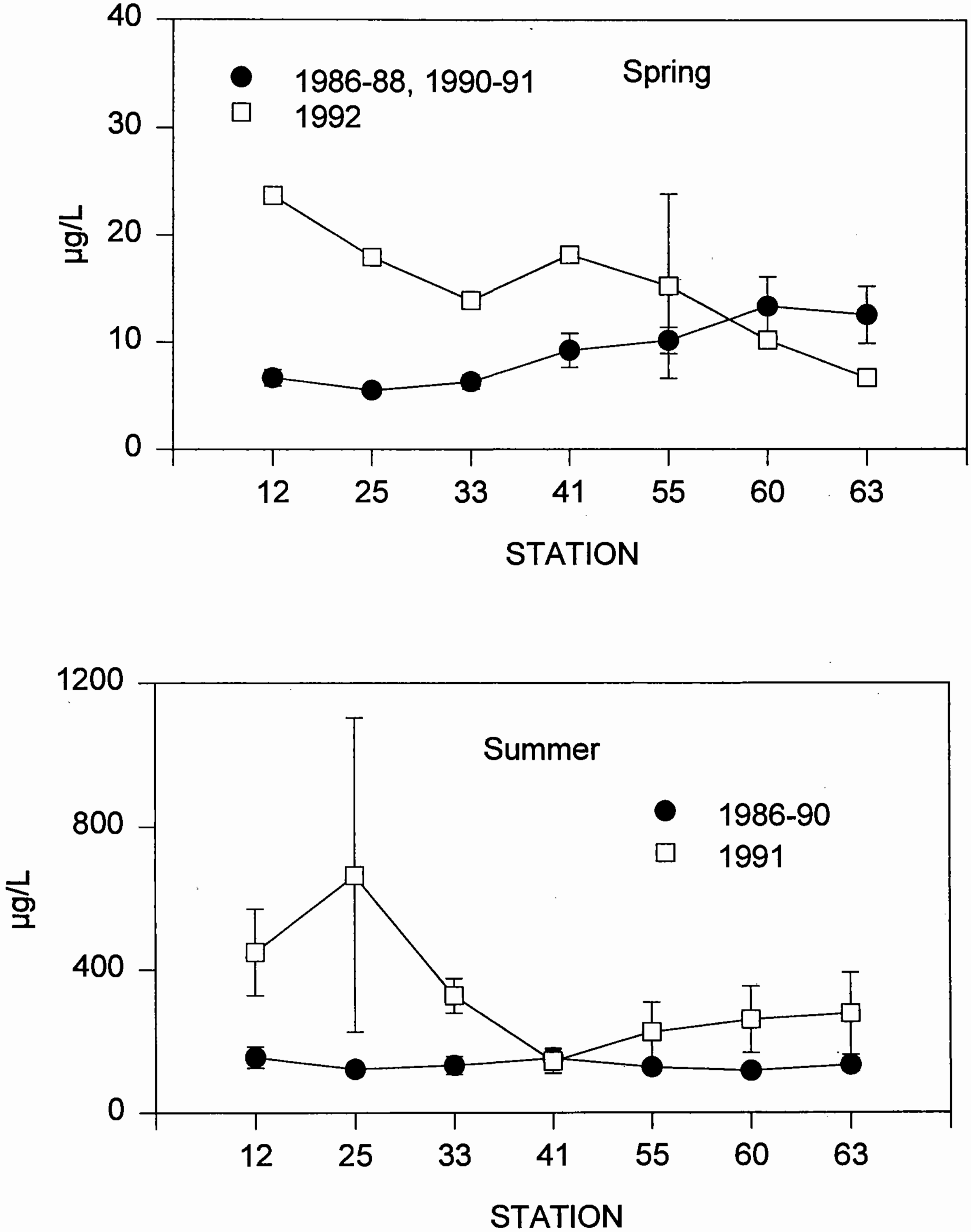

Figure 10. Geographical distribution of zooplankton biomass in Lake Ontario, 1986-1991. Values are the mean ± S.E.

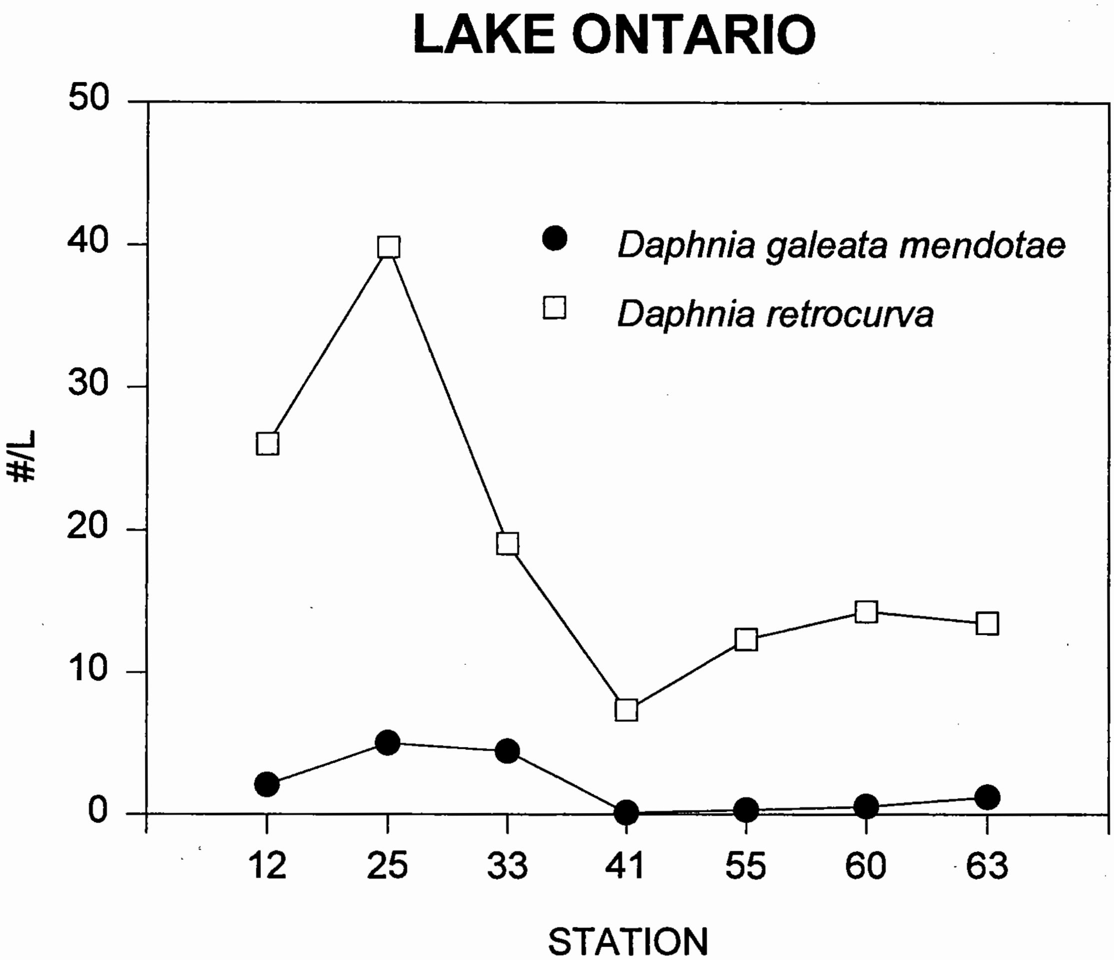

Figure 11. Geographical distribution of Daphnia galeata mendotae and D. retrocurva in Lake Ontario in 1991.

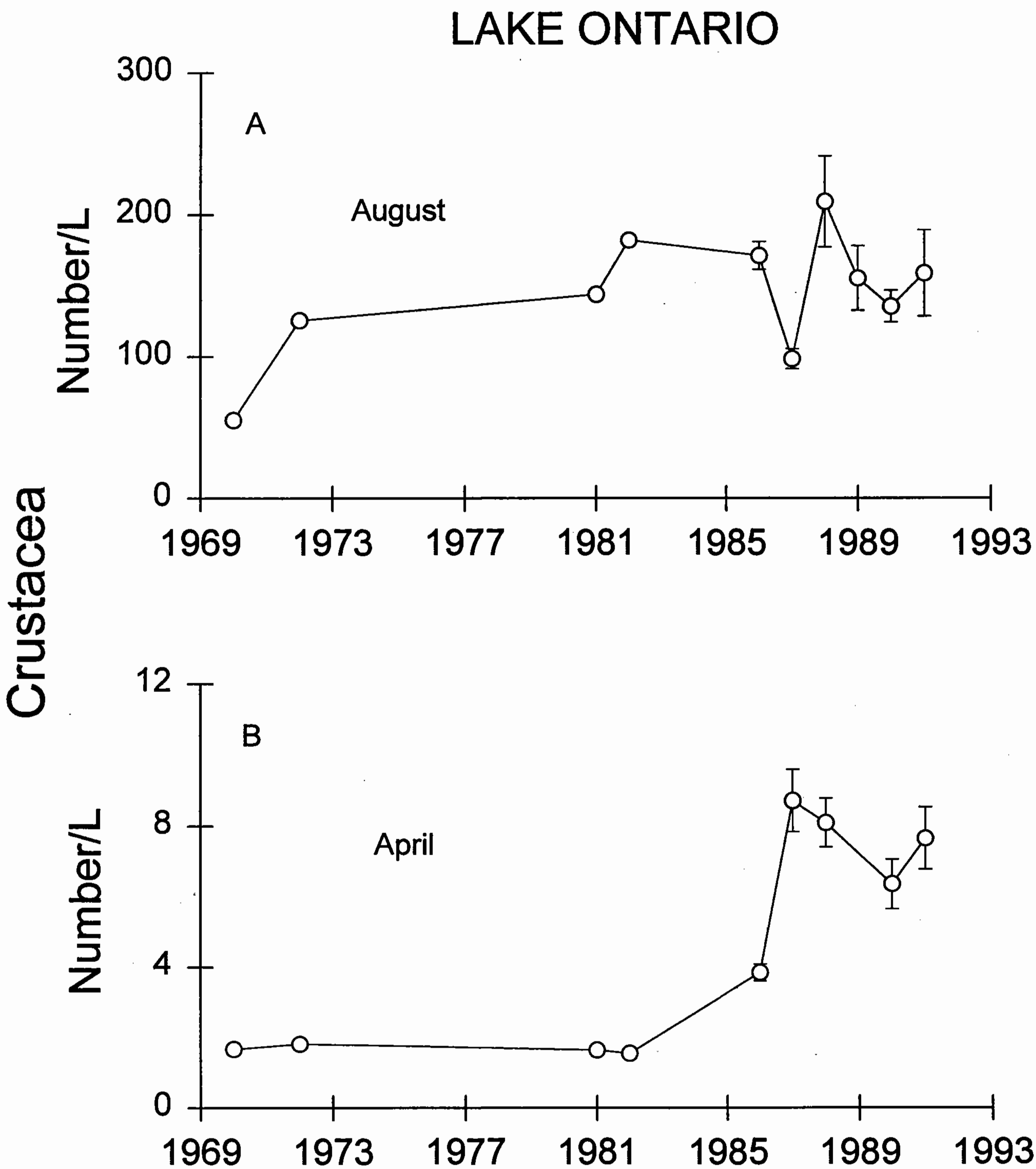

Figure 12. Historical offshore zooplankton abundance trends in Lake Ontario. April and August data. 1986-1991 data are the mean±S.E. Data are from Patalas (1970), Watson and Carpenter (1974), McNaught et al. (1975), Johannsson et al. (1985) and this study.

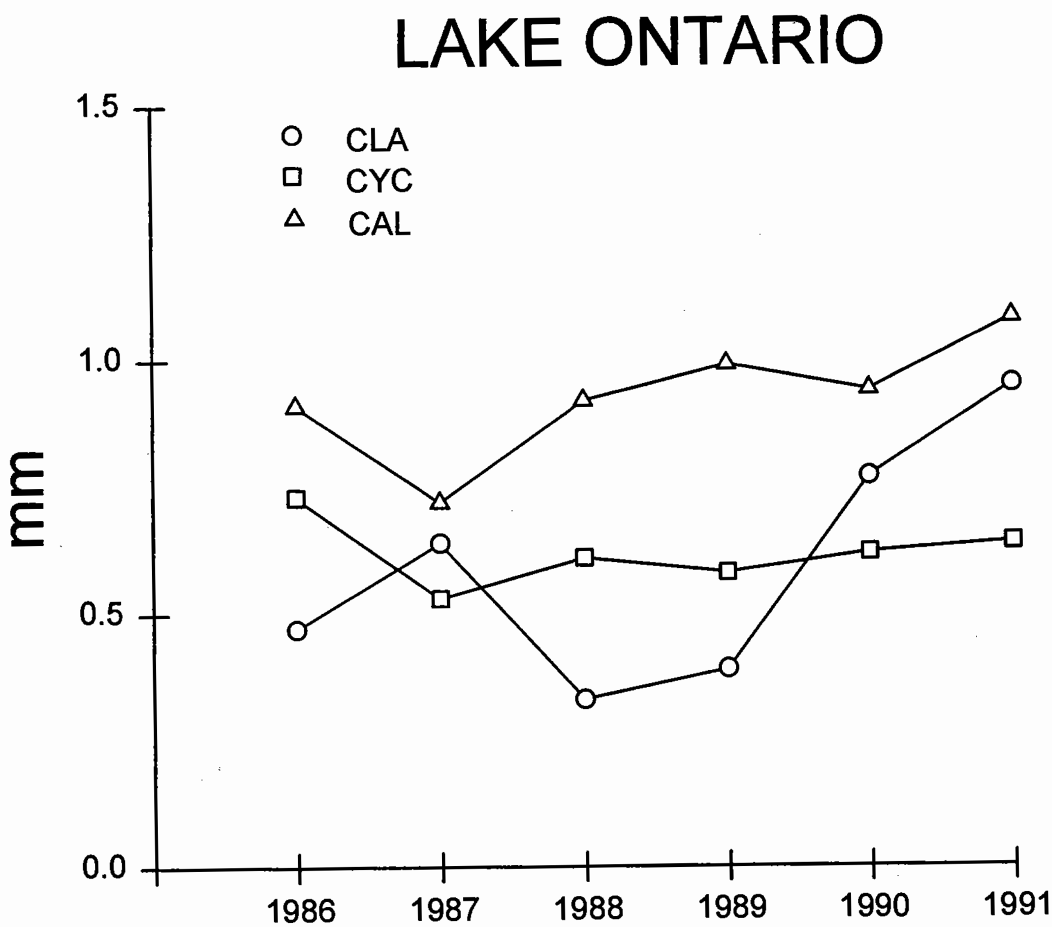

Figure **13**. Annual weighted mean length of Cladocera, Cyclopoida and Calanoida in Lake Ontario, 1986-91. Bythotrephes cederstroemi is not included in the Cladocera measurements.

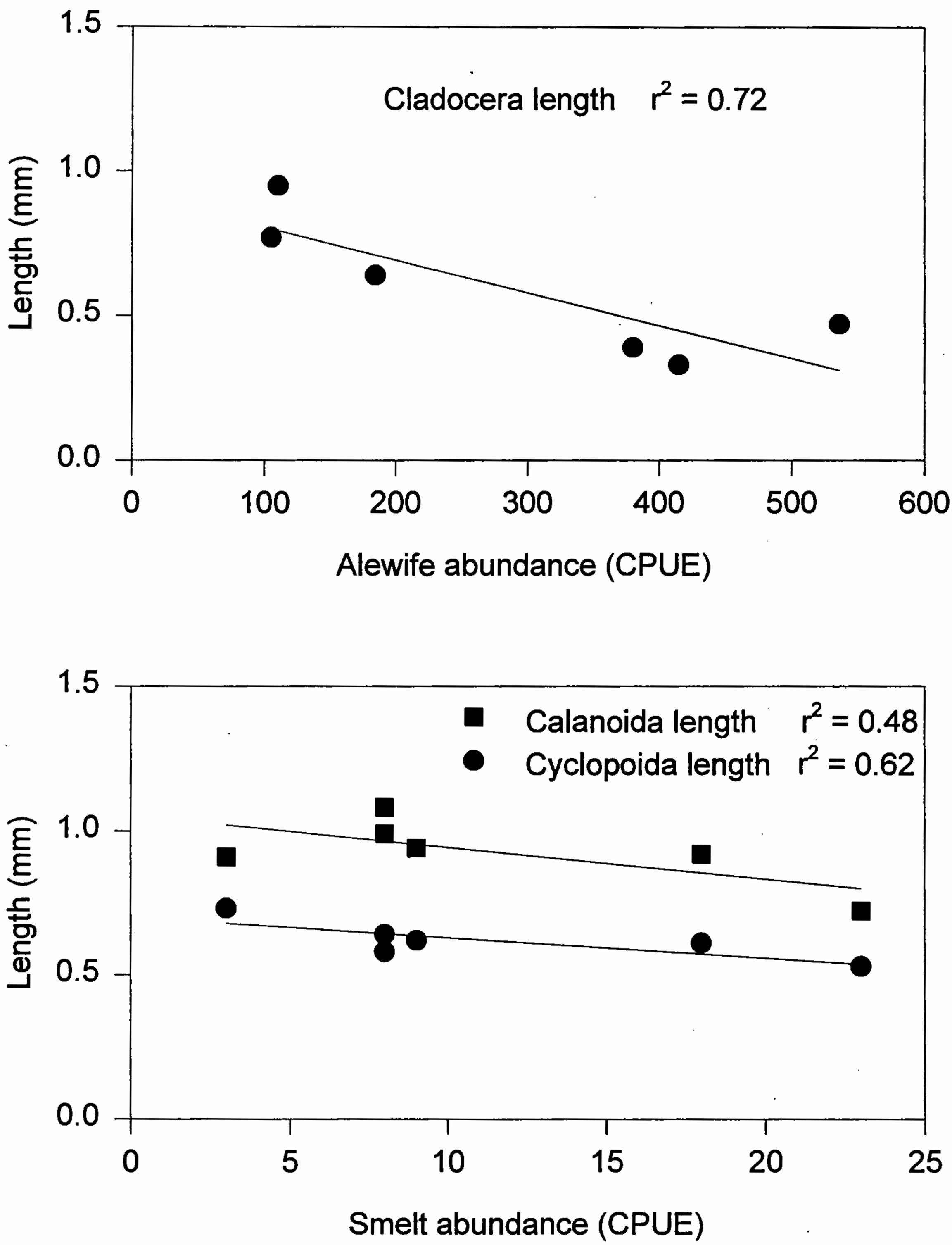

Figure 14. Relationship between alewife and smelt abundance and Cladocera, Calanoida and Cyclopoida length. The Cladocera versus alewife abundance regression is significant ($P<0.05$).

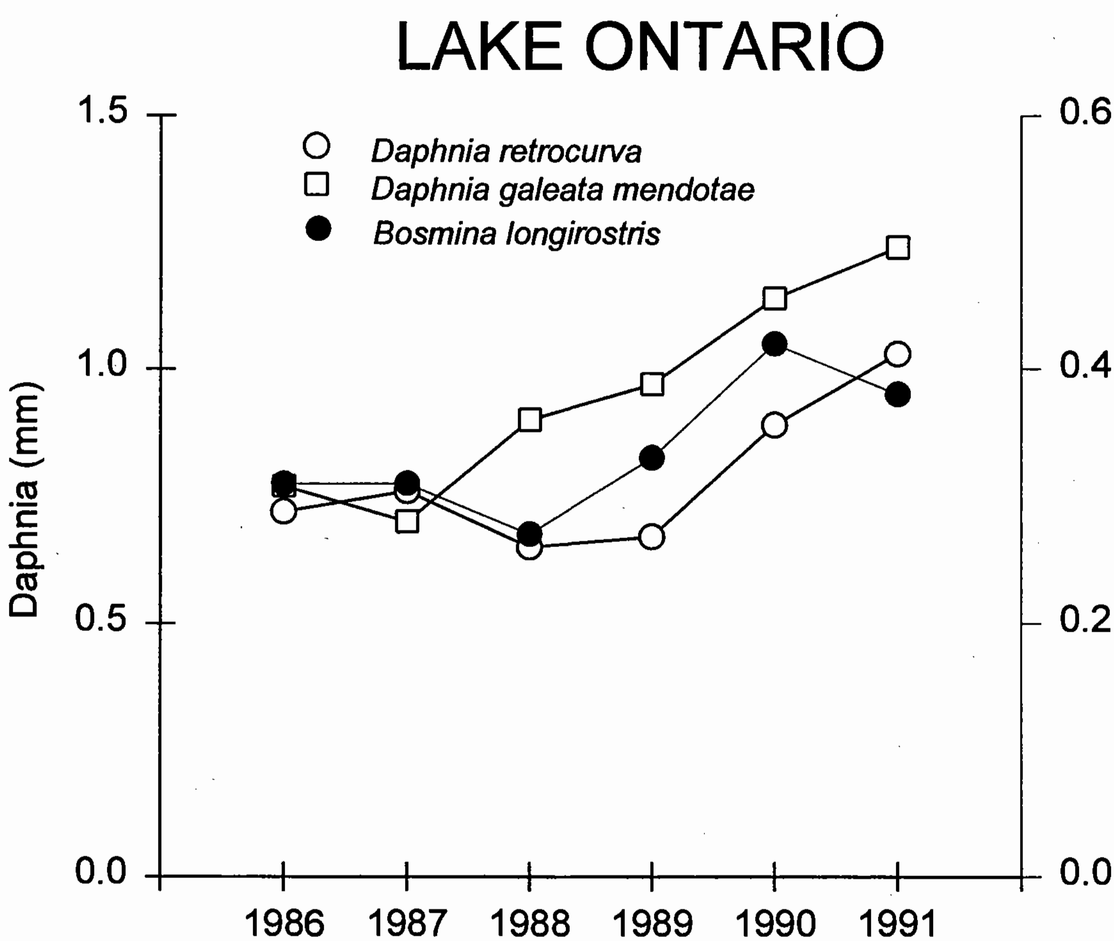

Figure 15. Annual weighted mean length of Daphnia retrocurva, D. galeatae mendotae and Bosmina longirostris, 1986 -1991.

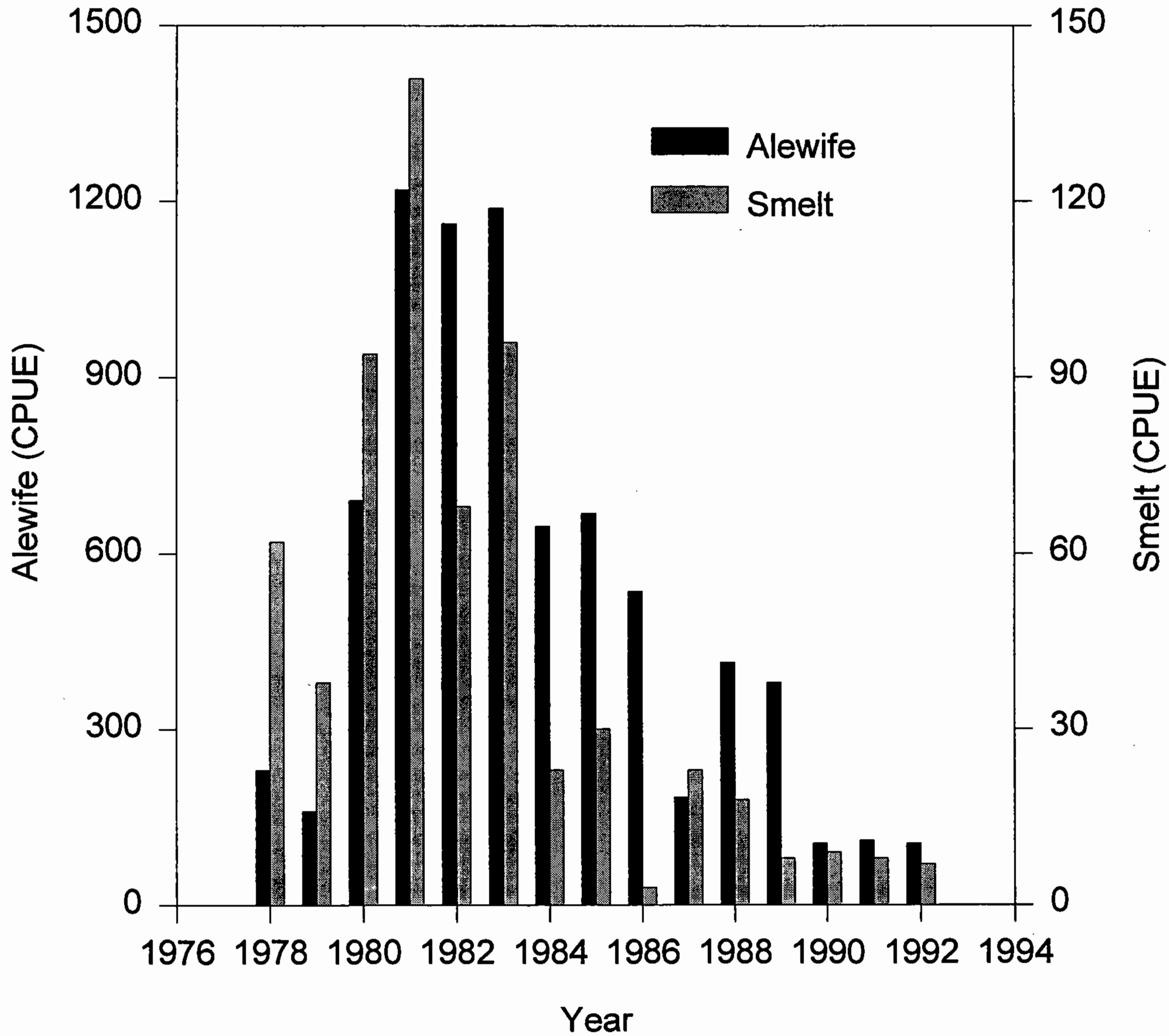

Figure 16. Number of alewife >164mm and rainbow smelt >149mm caught per standard trawl during the spring in U.S. waters of Lake Ontario. Data are from Johannsson et al. (1991), Great lakes Fishery Commission (1992) and NYSDEC (1992).

Appendix

Table A1. Summary of common phytoplankton species occurence in Lake Ontario during April and August, 1986. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Common species were arbitrarily defined as having an abundance ≥ 0.5% 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		18	6.7	0.22	2,479	0.55
Diatoma tenue		50	6.2	0.20	5,238	1.16
Fragilaria capucina		229	13.1	0.43	4,213	0.94
Fragilaria crotonensis		150	20.8	0.68	13,215	2.93
Melosira islandica		54	11.1	0.36	7,886	1.75
Nitzschia sublinearis		12	2.8	0.09	3,168	0.70
Stephanodiscus alpinus		40	4.1	0.13	73,379	16.29
Stephanodiscus binderanus		31	4.1	0.14	2,408	0.53
Stephanodiscus niagarae		3	0.3	0.01	11,552	2.57
Tabellaria flocculosa		91	9.6	0.31	24,212	5.38
				----------		----------
	Total			2.58		32.81
CHLOROPHYTA						
Chlamydomonas sp.		49	16.3	0.53	949	0.21
Cosmarium sp.		8	0.3	0.01	2,409	0.54
Green coccoid		9254	476.3	15.60	31,952	7.10
Monoraphidium setiformae		8	1.4	0.05	3,520	0.78
Scenedesmus ecornis		106	23.0	0.75	1,041	0.23
Sphaerocystis schroeteri		376	25.6	0.84	5,181	1.15
Tetraedron minimum		205	17.4	0.57	9,283	2.06
				----------		----------
	Total			18.35		12.07
CHRYSOPHYTA						
Chromulina sp.		172	72.3	2.37	5,184	1.15
Haptophyceae		802	306.0	10.02	5,138	1.14
Ochromonas sp.		385	137.8	4.51	11,364	2.52
Unidentified coccoids		205	65.2	2.14	1,278	0.28
				----------		----------
	Total			19.04		5.10
COLORLESS FLAGELLATES						
Colorless flagellates		123	37.0	1.21	1,426	0.32
CRYPTOPHYTA						
Cryptomonas erosa		245	50.9	1.67	82,491	18.32
Cryptomonas marssonii		90	14.1	0.46	9,750	2.17
Cryptomonas ovata		25	4.0	0.13	7,340	1.63
Cryptomonas phaseolus		41	4.6	0.15	3,277	0.73
Cryptomonas sp.		25	4.7	0.16	2,389	0.53
Rhodomonas minuta		1325	358.3	11.74	17,799	3.95
				----------		----------
	Total			14.30		27.32
CYANOPHYTA						
Anabaena sp.		368	35.3	1.16	4,265	0.95
Anacystis montana		3502	807.1	26.44	5,336	1.18
Oscillatoria limnetica		1734	325.7	10.67	2,005	0.45
				----------		----------
	Total			38.27		2.58
PYRROPHYTA						
Ceratium hirundinella		16	1.1	0.04	34,288	7.61
Gymnodinium sp.		18	4.2	0.14	6,353	1.41
Peridinium sp.		41	3.6	0.12	11,985	2.66
Peridinium sp. #02		25	1.3	0.04	3,176	0.71
				----------		----------
	Total			0.33		12.39
				==========		==========
	Total			94.09		92.58

Table A2. Summary of common phytoplankton species occurence in Lake Ontario during April and August, 1987. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Common species were arbitrarily defined as having an abundance ≥ 0.5% 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		8	0.6	0.01	3,399	0.72
Aulacoseira islandica		1095	101.7	2.69	75,910	16.11
Fragilaria crotonensis		241	37.3	0.99	22,938	4.87
Nitzschia lauenburgiana		17	1.6	0.04	9,855	2.09
Stephanodiscus alpinus		94	7.2	0.19	23,207	4.93
Stephanodiscus binderanus		1426	85.1	2.25	33,629	7.14
Stephanodiscus niagarae		10	0.7	0.02	18,083	3.84
Stephanodiscus transilvanicus		3	0.2	0.00	3,163	0.67
Tabellaria flocculosa		127	14.1	0.37	29,812	6.33
				----------		----------
	Total			6.57		46.70
CHLOROPHYTA						
Cosmarium subcostatum		8	0.3	0.01	2,775	0.59
Green coccoid		4524	1,246.2	32.95	80,588	17.11
Oocystis parva		74	14.1	0.37	2,376	0.50
Oocystis pusilla		393	33.0	0.87	5,256	1.12
Scenedesmus ecornis		205	63.3	1.67	1,682	0.36
Sphaerocystis schroeteri		2120	121.5	3.21	7,502	1.59
				----------		----------
	Total			39.09		21.27
CHRYSOPHYTA						
Chromulina sp.		106	39.0	1.03	1,811	0.38
Chrysophycean coccoids		254	19.7	0.52	331	0.07
Haptophyceae		401	116.2	3.07	1,855	0.39
Ochromonas sp.		295	107.1	2.83	3,967	0.84
				----------		----------
	Total			7.46		1.69
CRYPTOPHYTA						
Chroomonas norstedtii		131	28.4	0.75	812	0.17
Cryptomonas erosa		82	24.3	0.64	35,052	7.44
Cryptomonas marssonii		41	10.9	0.29	7,987	1.70
Rhodomonas minuta		393	140.3	3.71	9,372	1.99
				----------		----------
	Total			5.39		11.30
CYANOPHYTA						
Anacystis montana		5964	1,173.0	31.01	9,188	1.95
Coelosphaerium naegelianum		785	24.5	0.65	103	0.02
Oscillatoria limnetica		744	118.6	3.14	1,317	0.28
				----------		----------
	Total			34.80		2.25
PYRROPHYTA						
Gymnodinium sp.		41	4.6	0.12	20,398	4.33
Peridinium aciculiferum		8	0.3	0.01	6,023	1.28
Peridinium sp.		16	1.9	0.05	15,106	3.21
				----------		----------
	Total			0.18		8.82
				==========		==========
	Total			93.48		92.02

Table A3. Summary of common phytoplankton species occurence in Lake Ontario during April and August, 1988. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Common species were arbitrarily defined as having an abundance ≥ 0.5% 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		201	6.8	0.11	17,472	3.41
Asterionella formosa		102	11.5	0.18	3,849	0.75
Aulacoseira islandica		413	61.9	0.97	46,204	9.03
Fragilaria crotonensis		80	20.0	0.31	10,617	2.07
Stephanodiscus alpinus		131	17.2	0.27	48,922	9.56
Stephanodiscus binderanus		168	30.2	0.47	5,483	1.07
Stephanodiscus niagarae		22	2.6	0.04	29,231	5.71
Tabellaria flocculosa		152	19.7	0.31	34,591	6.76
	Total			2.65		38.38
CHLOROPHYTA						
Cosmarium sp.		33	1.6	0.03	4,559	0.89
Green coccoid		965	178.9	2.79	8,614	1.68
Oocystis parva		2602	125.7	1.96	8,686	1.70
Oocystis pusilla		393	46.0	0.72	5,596	1.09
Pediastrum simplex		524	16.4	0.26	4,469	0.87
Scenedesmus ecornis		2323	190.6	2.97	9,835	1.92
Sphaerocystis schroeteri		2553	206.1	3.22	7,361	1.44
	Total			11.94		9.60
CHRYSOPHYTA						
Chromulina sp.		147	41.1	0.64	2,719	0.53
Haptophyceae		1439	473.4	7.39	9,625	1.88
Ochromonas sp.		573	161.6	2.52	13,930	2.72
	Total			10.55		5.13
CRYPTOPHYTA						
Cryptomonas erosa		82	24.2	0.38	45,822	8.96
Cryptomonas marssonii		65	15.4	0.24	12,749	2.49
Cryptomonas ovata		33	4.9	0.08	7,602	1.49
Cryptomonas sp.		65	20.0	0.31	5,289	1.03
Rhodomonas minuta		941	302.9	4.73	17,698	3.46
	Total			5.73		17.42
CYANOPHYTA						
Anacystis montana		26916	3,691.7	57.60	36,103	7.06
Oscillatoria limnetica		6496	461.6	7.20	10,371	2.03
	Total			64.81		9.08
PYRROPHYTA						
Ceratium hirundinella		33	1.5	0.02	43,217	8.45
Gymnodinium sp.		33	8.2	0.13	18,462	3.61
Peridinium aciculiferum		16	0.5	0.01	2,570	0.50
Peridinium sp.		16	3.1	0.05	6,834	1.34
	Total			0.21		13.89
	Total			95.89		93.51

Table A4. Summary of common phytoplankton species occurence in Lake Ontario during August, 1989. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Common species were arbitrarily defined as having an abundance ≥ 0.5% 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
BACILLARIOPHYT						
Fragilaria crotonensis		123	17.9	0.37	10,030	1.23
CHLOROPHYTA						
Chlamydomonas sp.		229	36.4	0.76	6,003	0.74
Coelastrum microporum		262	44.8	0.93	7,080	0.87
Green coccoid		3338	743.2	15.43	37,242	4.57
Monoraphidium minutum		82	25.8	0.54	402	0.05
Oocystis borgei		49	8.5	0.18	5,509	0.68
Oocystis gigas v. incrassata		82	5.1	0.11	8,549	1.05
Oocystis solitaria		106	29.1	0.61	23,200	2.84
Pediastrum duplex		655	40.9	0.85	157,105	19.26
Sphaerellopsis sp.		245	15.3	0.32	4,112	0.50
	Total			19.71		30.56
CHRYSOPHYTA						
Chromulina sp.		164	24.0	0.50	8,666	1.06
Chrysococcus sp.		270	49.3	1.02	9,855	1.21
Haptophyceae		2143	440.4	9.14	9,651	1.18
Ochromonas sp.		295	75.0	1.56	24,744	3.03
	Total			12.22		6.49
COLORLESS FLAGELLATES						
Colorless flagellate		98	27.3	0.57	3,618	0.44
CRYPTOPHYA						
Cryptomonas erosa		131	41.8	0.87	101,722	12.47
Cryptomonas ovata		98	27.4	0.57	32,616	4.00
Cryptomonas phaseolus		82	9.9	0.21	6,044	0.74
Rhodomonas minuta		2798	406.0	8.43	49,444	6.06
	Total			10.07		23.28
CYANOPHYTA						
Anabaena flos-aquae		1694	105.8	2.20	3,547	0.43
Anacystis montana		4434	1,425.6	29.60	18,884	2.32
Aphanizomenon flos-aquae		736	53.3	1.11	21,067	2.58
Chroococcus limneticus		311	26.0	0.54	4,665	0.57
Coelosphaerium dubium		908	68.0	1.41	5,735	0.70
Oscillatoria limnetica		2863	428.4	8.90	2,844	0.35
Synechococcus sp.		1620	252.8	5.25	12,153	1.49
	Total			49.00		8.45
PYRROPHYTA						
Ceratium hirundinella		16	1.2	0.03	31,558	3.87
Glenodinium sp.		16	1.7	0.04	15,388	1.89
Gymnodinium helveticum		3	0.2	0.00	8,218	1.01
Peridinium - cyst		20	2.0	0.04	9,371	1.15
Peridinium sp.		57	13.6	0.28	116,726	14.31
	Total			0.39		22.23
	Total			92.34		92.67

Table A5. Summary of common phytoplankton species occurence in Lake Ontario during April and August, 1990. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Common species were arbitrarily defined as having an abundance ≥ 0.5% 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		224	25.6	0.68	7,140	0.86
Aulacoseira islandica		1041	212.5	5.63	220,059	26.61
Fragilaria crotonensis		240	34.5	0.91	19,978	2.42
Nitzschia lauenburgiana		16	2.9	0.08	17,861	2.16
Stephanodiscus alpinus		48	8.6	0.23	26,957	3.26
Stephanodiscus binderanus		171	26.0	0.69	16,303	1.97
Stephanodiscus niagarae		11	1.2	0.03	17,441	2.11
Tabellaria flocculosa		74	10.1	0.27	12,374	1.50
				----------		----------
	Total			8.51		40.88
CHLOROPHYTA						
Chlamydomonas sp.		115	41.7	1.10	1,664	0.20
Coelastrum microporum		262	21.5	0.57	1,296	0.16
Cosmarium depressum		8	1.0	0.03	5,780	0.70
Gloeocystis planktonica		434	44.5	1.18	3,593	0.43
Gloeocystis sp.		605	45.0	1.19	2,196	0.27
Green coccoid		172	38.4	1.02	3,295	0.40
Oocystis borgei		205	24.5	0.65	10,572	1.28
Oocystis pusilla		270	69.4	1.84	3,941	0.48
Oocystis solitaria		147	10.1	0.27	4,552	0.55
Scenedesmus bijuga		998	208.5	5.52	18,368	2.22
Sphaerocystis schroeteri		164	20.0	0.53	1,932	0.23
Staurastrum sp.		3	0.1	0.00	104,408	12.62
Tetraedron minimum		65	13.7	0.36	6,605	0.80
				----------		----------
	Total			14.25		20.34
CHRYSOPHYTA						
Chromulina sp.		213	62.5	1.65	8,942	1.08
Chrysococcus sp.		188	36.3	0.96	1,960	0.24
Haptophyceae		589	276.7	7.32	6,697	0.81
Ochromonas sp.		524	116.5	3.08	19,982	2.42
Stichogloea sp.		1718	53.7	1.42	5,527	0.67
				----------		----------
	Total			14.44		5.21
COLORLESS FLAGELLATES						
Colorless flagellate		2470	129.0	3.41	6,032	0.73
CRYPTOPHYTA						
Cryptomonas caudata		131	16.9	0.45	4,682	0.57
Cryptomonas erosa		98	24.4	0.65	45,919	5.55
Cryptomonas marssonii		82	10.4	0.27	7,028	0.85
Cryptomonas ovata		16	2.8	0.07	4,440	0.54
Cryptomonas phaseolus		90	19.9	0.53	6,604	0.80
Cryptomonas pyrenoidifera		65	14.6	0.39	11,663	1.41
Rhodomonas minuta		664	259.0	6.86	17,596	2.13
				----------		----------
	Total			9.21		11.84
CYANOPHYTA						
Anacystis montana		2389	1,089.2	28.83	12,354	1.49
Aphanothece gelatinosa		655	20.5	0.54	337	0.04
Chroococcus sp.		475	40.9	1.08	1,069	0.13
Coelosphaerium naegelianum		785	71.0	1.88	4,422	0.53
Oscillatoria sp.		769	98.3	2.60	4,274	0.52
Synechococcus sp.		4582	297.4	7.87	16,454	1.99
				----------		----------
	Total			42.81		4.70
PYRROPHYTA						
Ceratium hirundinella		8	0.6	0.02	4,976	0.60
Gymnodinium helveticum		16	2.0	0.05	16,410	1.98
Gymnodinium sp.		25	8.9	0.24	24,988	3.02
Peridinium sp.		57	9.4	0.25	29,381	3.55
				----------		----------
	Total			0.55		9.16
				==========		==========
	Total			93.19		92.87

Table A6. Summary of common phytoplankton species occurence in Lake Ontario during April and August, 1991. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Common species were arbitrarily defined as having an abundance ≥ 0.5% of the total cells or ≥ 0.5% of the total biovolume.

TAXON	MAXIMUM CELLS/ML	AVERAGE CELLS/ML	% OF TOTAL CELLS	MEAN BIOVOLUME μm^3/mL	% OF TOTAL BIOVOLUME
BACILLARIOPHYTA					
Aulacoseira islandica	487	89.8	2.92	86,987	17.79
Cyclotella comta	28	1.5	0.05	5,533	1.13
Cymatopleura solea	3	0.1	0.00	3,897	0.80
Fragilaria crotonensis	262	52.2	1.70	36,123	7.39
Stephanodiscus alpinus	12	2.4	0.08	9,275	1.90
Stephanodiscus binderanus	79	6.6	0.21	4,197	0.86
Stephanodiscus niagarae	2	0.4	0.01	5,125	1.05
Stephanodiscus parvus	121	17.1	0.55	693	0.14
Tabellaria flocculosa	38	5.5	0.18	11,499	2.35
Total			5.70		33.41
CHLOROPHYTA					
Ankistrodesmus falcatus	90	15.4	0.50	761	0.16
Ankistrodesmus gracilis	82	18.9	0.61	572	0.12
Chlamydomonas globosa	33	3.2	0.10	3,259	0.67
Chlamydomonas sp.	131	44.9	1.46	2,416	0.49
Cosmarium depressum	16	1.0	0.03	3,076	0.63
Gloeocystis sp.	720	154.6	5.02	8,377	1.71
Green coccoid	106	36.2	1.17	1,470	0.30
Monoraphidium contortum	90	15.9	0.52	401	0.08
Oocystis borgei	90	27.1	0.88	8,094	1.66
Oocystis elliptica	180	9.2	0.30	6,236	1.28
Oocystis pusilla	409	93.1	3.02	6,340	1.30
Oocystis solitaria	57	6.9	0.22	5,729	1.17
Scenedesmus bijuga	303	117.1	3.81	6,677	1.37
Sphaerocystis schroeteri	344	60.1	1.95	5,446	1.11
Tetraedron minimum	98	17.4	0.57	7,710	1.58
Total			20.18		13.62
CHRYSOPHYTA					
Chromulina sp.	172	51.2	1.66	8,173	1.67
Chrysococcus sp.	123	28.2	0.92	1,914	0.39
Haptophyceae	1137	484.0	15.73	12,165	2.49
Mallomonas sp.	8	0.6	0.02	8,677	1.78
Monosiga ovata	82	16.1	0.52	980	0.20
Ochromonas sp.	180	82.4	2.68	12,645	2.59
Total			21.53		9.11
COLORLESS FLAGELLATES					
Colorless flagellate	90	31.4	1.02	1,001	0.20
CRYPTOPHYTA					
Cryptomonas caudata	41	9.1	0.30	2,522	0.52
Cryptomonas erosa	74	29.2	0.95	60,384	12.35
Cryptomonas marssonii	41	13.5	0.44	10,279	2.10
Cryptomonas ovata	25	3.5	0.11	7,030	1.44
Cryptomonas parapyrenoidifera	16	2.0	0.06	2,501	0.51
Cryptomonas phaseolus	65	16.4	0.53	6,360	1.30
Cryptomonas pyrenoidifera	49	13.8	0.45	13,152	2.69
Cryptomonas reflexa	16	1.5	0.05	3,628	0.74
Rhodomonas minuta	1244	325.3	10.57	21,661	4.43
Total			13.46		26.09
CYANOPHYTA					
Anacystis montana	1808	582.0	18.92	6,221	1.27
Chroococcus sp.	425	73.9	2.40	2,659	0.54
Oscillatoria sp.	1014	214.2	6.96	4,043	0.83
Synechococcus sp.	172	69.8	2.27	3,152	0.64
Total			30.55		3.29

Table A6(cont.). Summary of common phytoplankton species occurence in Lake Ontario during 1991. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Common species were arbitrarily defined as having an abundance ≥ 0.5% 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
PYRROPHYTA					
Glenodinium sp.	8	0.3	0.01	2,927	0.60
Gymnodinium helveticum	8	0.3	0.01	2,832	0.58
Gymnodinium sp.	25	6.3	0.20	7,207	1.47
Peridinium sp.	16	2.9	0.09	16,033	3.28
Total			0.31		5.93
Total			92.76		91.65

Table A7. Summary of common phytoplankton species occurence in Lake Ontario during April, 1992. Summary includes the maximum population density encountered, the average population density and biovolume, and the relative abundance (% of total cells and % of total biovolume). Common species were arbitrarily defined as having an abundance ≥ 0.5% 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		145	41.3	1.03	15,073	1.49
Aulacoseira islandica		1029	512.2	12.80	442,812	43.79
Cymatopleura solea		2	0.5	0.01	38,277	3.78
Diatoma tenue		14	5.6	0.14	5,496	0.54
Fragilaria crotonensis		21	12.6	0.31	6,687	0.66
Nitzschia lauenburgiana		11	4.8	0.12	25,025	2.47
Nitzschia sublinearis		29	13.4	0.34	16,277	1.61
Stephanodiscus alpinus		10	3.3	0.08	15,197	1.50
Stephanodiscus binderanus		767	150.8	3.77	96,273	9.52
Stephanodiscus hantzschii		127	21.7	0.54	1,949	0.19
Stephanodiscus transilvanicus		24	7.1	0.18	6,375	0.63
Tabellaria flocculosa		157	42.5	1.06	60,623	5.99
				----------		----------
	Total			20.40		72.19
CHLOROPHYTA						
Ankistrodesmus gracilis		74	51.1	1.28	1,342	0.13
Chlamydomonas sp.		98	45.0	1.12	2,966	0.29
Green coccoid		49	31.7	0.79	1,286	0.13
Oocystis pusilla		106	27.6	0.69	981	0.10
Scenedesmus bijuga		98	49.1	1.23	1,784	0.18
				----------		----------
	Total			5.11		0.83
CHRYSOPHYTA						
Chromulina sp.		90	45.0	1.12	8,094	0.80
Chrysococcus sp.		180	73.6	1.84	4,204	0.42
Haptophyceae		393	282.3	7.06	11,858	1.17
Ochromonas sp.		131	90.0	2.25	16,483	1.63
				----------		----------
	Total			12.27		4.02
COLORLESS FLAGELLATES						
Colorless flagellate		64	37.7	0.94	986	0.10
CRYPTOPHYTA						
Cryptomonas brevis		16	6.1	0.15	29,382	2.91
Cryptomonas caudata		49	15.3	0.38	6,849	0.68
Cryptomonas curvata		8	1.0	0.03	5,482	0.54
Cryptomonas erosa		41	16.4	0.41	40,444	4.00
Cryptomonas phaseolus		49	27.6	0.69	12,386	1.22
Cryptomonas pyrenoidifera		25	13.3	0.33	10,769	1.06
Rhodomonas minuta		360	240.3	6.01	25,238	2.50
				----------		----------
	Total			8.00		12.91
CYANOPHYTA						
Anacystis montana		2430	1,588.2	39.70	17,382	1.72
Oscillatoria limnetica		180	22.5	0.56	1,113	0.11
Oscillatoria sp.		875	301.7	7.54	3,470	0.34
Synechococcus sp.		65	31.7	0.79	1,359	0.13
				----------		----------
	Total			48.60		2.31
PYRROPHYTA						
Gymnodinium sp.		25	13.3	0.33	14,201	1.40
Peridinium sp.		16	8.2	0.20	25,530	2.52
				----------		----------
	Total			0.54		3.93
				==========		==========
	Total			95.85		96.28

Appendix A8. SPECIES LIST - LAKE ONTARIO PHYTOPLANKTON (1986- 1992)

DIVISION	TAXON	AUTHORITY
BACILLARIOPHYTA		
	Achnanthes affinis	Grun.
	Achnanthes biasolettiana	(Kutz.) Grun.
	Achnanthes brevipes	
	Achnanthes clevei	Grun.
	Achnanthes conspicua	A. Mayer
	Achnanthes didyma	
	Achnanthes exigua	Grun.
	Achnanthes kryophila	
	Achnanthes lanceolata	(Breb.) Greg.
	Achnanthes linearis	(W. Sm.) Grun.
	Achnanthes minutissima	Kutz.
	Achnanthes oestrupii	(Backm. & A. Cl.) Hust.
	Achnanthes sp.	
	Achnanthes sp. #1	
	Achnanthes sublaevis	Hust.
	Actinocyclus normanii	
	Amphipleura pellucida	(Kutz.) Kutz.
	Amphora ovalis	(Kutz.) Kutz.
	Amphora perpusilla	(Grun.) Grun.
	Amphora sp.	
	Amphora thumensus	(Mayer) A. Cl.
	Anomoeoneis vitrea	(Grun.) Patr. & Reim.
	Asterionella formosa	Hass.
	Aulacoseira granulata	(Ehr.) Ralfs
	Aulacoseira islandica	O. Mull.
	Aulacoseira italica	(Ehr.) Kutz.
	Aulacoseira sp.	
	Cocconeis diminuta	Pant.
	Cocconeis pediculus	Ehr.
	Cocconeis placentula	Ehr.
	Coscinodiscus lacustris	Grun.
	Coscinodiscus sp.	
	Coscinodiscus volthii v. septentrionalis	
	Cyclostephanos dubius	(Fricke) Round
	Cyclostephanos tholiformis	
	Cyclotella atomus	Pant.
	Cyclotella comensis	Grun.
	Cyclotella comta	(Ehr.) Kutz.
	Cyclotella cryptica	Reim. et al.
	Cyclotella delicatula	Hust.
	Cyclotella krammeri	
	Cyclotella meneghiniana	Kutz.
	Cyclotella michiganiana	Skv.
	Cyclotella ocellata	Pant.
	Cyclotella pseudostelligera	Hust.
	Cyclotella sp.	
	Cyclotella sp. #1	
	Cyclotella sp. #2	
	Cyclotella sp. #4	
	Cyclotella stelligera	(Cl. & Grun.) V.H.
	Cyclotella unipunctata	
	Cyclotella woltereckí	Hust.
	Cymatopleura solea	(Breb. & Godey) W. Sm.
	Cymbella affinis	Kutz.
	Cymbella microcephala	Grun.
	Cymbella minuta	Hilse
	Cymbella prostrata	(Berk.) Cl.
	Cymbella sp.	
	Denticula sp.	
	Diatoma hiemale	(Lyng.) Heib.
	Diatoma tenue	Ag.
	Diatoma vulgare	Bory
	Eunotia sp.	
	Fragilaria brevistriata	Grun.
	Fragilaria capucina	Desm.
	Fragilaria construens	(Ehr.) Grun.
	Fragilaria crotonensis	Kitton
	Fragilaria intermedia	Grun.
	Fragilaria pinnata	Ehr.

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DIVISION	TAXON	AUTHORITY
BACILLARIOPHYTA		
	Fragilaria vaucheriae	(Kutz.) Peters.
	Fragilaria virescens	Ralfs
	Gomphonema olivaceum	(Lyngb.) Kutz.
	Gomphonema simus	
	Gomphonema sp.	
	Gomphonema tenellum	Kutz.
	Gyrosigma sciotense	(Sulliv. & Wormley) Cl.
	Navicula cryptocephala	Kutz.
	Navicula decussis	Ostr.
	Navicula gregaria	Donk.
	Navicula lanceolata	(Ag.) Kutz.
	Navicula menisculus	Schum.
	Navicula minima	Grun.
	Navicula odiosa	Wallace
	Navicula radiosa	Kutz.
	Navicula reinhardtii	(Grun.) Grun.
	Navicula seminuloides	Hust.
	Navicula sp.	
	Navicula splendicula	Vanland.
	Navicula submuralis	Hust.
	Navicula subtilissima	Cl.
	Navicula viridula	(Kutz.) Ehr.
	Nitzschia acicularis	(Kutz.) W. Sm.
	Nitzschia amphibia	Grun.
	Nitzschia angustata	(W. Sm.) Grun.
	Nitzschia capitellata	Hust.
	Nitzschia confinis	Hust.
	Nitzschia denticula	Grun.
	Nitzschia dissipata	(Kutz.) Grun.
	Nitzschia fonticola	Grun.
	Nitzschia frustulum	(Kutz.) Grun.
	Nitzschia gandersheimiensis	Krasske
	Nitzschia graciliformis	Lang.-Bert. & Simon.
	Nitzschia kuetzingiana	Hilse
	Nitzschia lacuum	
	Nitzschia lauenburgiana	Hust.
	Nitzschia palea	(Kutz.) W. Sm.
	Nitzschia pilum	
	Nitzschia pura	Hust.
	Nitzschia recta	Hantz.
	Nitzschia rostellata	Hust.
	Nitzschia sp.	
	Nitzschia sp. #01	
	Nitzschia sp. #02	
	Nitzschia sp. #03	
	Nitzschia subacicularis	Hust.
	Nitzschia sublinearis	Hust.
	Nitzschia subrostrata	Hust.
	Nitzschia tropica	Hust.
	Nitzschia tryblionella	
	Rhizosolenia longiseta	Zach.
	Rhoicosphenia sp.?	
	Stephanodiscus alpinus	Hust.
	Stephanodiscus binderanus	(Kutz.) Krieg.
	Stephanodiscus hantzschii	Grun.
	Stephanodiscus minutulus	Hak.
	Stephanodiscus niagarae	Ehr.
	Stephanodiscus parvus	Hak. + Stoerm.
	Stephanodiscus sp.	
	Stephanodiscus tenuis	Hust.
	Stephanodiscus transilvanicus	Pant.
	Surirella ovata	Kutz.
	Synedra acus	Kutz.
	Synedra cyclopum	Brutschy
	Synedra delicatissima	W. Sm.
	Synedra filiformis	Grun.
	Synedra ostenfeldii	(Krieg.) A. Cl.
	Synedra radians	Kutz.
	Synedra socia	
	Synedra sp.	

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DIVISION	TAXON	AUTHORITY
BACILLARIOPHYTA		
	Synedra tenera	W. Sm.
	Synedra ulna	(Nitz.) Ehr.
	Tabellaria flocculosa	(Roth) Kutz.
CHLOROPHYTA		
	Ankistrodesmus falcatus	(Corda) Ralfs
	Ankistrodesmus gracilis	(Reinsch) Kors.
	Ankistrodesmus sp.	
	Ankistrodesmus stipitatus?	(Chod.) Kom.-Legn.
	Ankyra lanceolata	(Kors.) Fott
	Ankyra sp.	
	Carteria cordiformis	(Carter) Dill.
	Carteria sp.	
	Carteria wisconsinensis	Huber-Pest.
	Chlamydocapsa planktonica	(W. & G.S. West) Fott
	Chlamydocapsa sp.	
	Chlamydomonas globosa	Snow
	Chlamydomonas planktonica	(West & West) Fott
	Chlamydomonas sp.	
	Chlorella sp.	
	Closteriopsis longissima?	Lemm.
	Closteriopsis sp.	
	Closterium aciculare	T. West
	Closterium sp.	
	Coelastrum astroideum	
	Coelastrum cambricum	Arch.
	Coelastrum microporum	Nag. in A. Braun
	Coelastrum morus	
	Coelastrum reticulatum	
	Coelastrum sp.	
	Cosmarium depressum	
	Cosmarium sp.	
	Cosmarium subcostatum	
	Crucigenia quadrata	Morren
	Crucigenia rectangularis	A. Braun
	Dictyosphaerium ehrenbergianum	Naeg.
	Dictyosphaerium pulchellum	Wood.
	Elakatothrix gelatinosa	Wille
	Elakatothrix genevensis	
	Eudorina elegans	Ehr.
	Franceia droescheri	(Lemm.) G.M. Sm.
	Gloeocystis major	
	Gloeocystis planktonica	
	Gloeocystis sp.	
	Gloeocystis sp. #1	
	Gloeocystis sp. #2	
	Gloeocystis sp. #3	
	Golenkinia radiata	(Chod.) Wille
	Green coccoid	
	Green filament	
	Green flagellate - sphere	
	Kirchneriella contorta	(Schmid.) Bohlm
	Kirchneriella sp.	
	Lagerheimia ciliata	(Lagerh.) Chod.
	Lagerheimia citriformis	(Snow) G.M. Sm.
	Lagerheimia genevensis	(Chod.) Chod.
	Lagerheimia longiseta	(Lemm.) Printz
	Lagerheimia quadriseta	(Lemm.) G.M. Sm.
	Lagerheimia sp.	
	Lagerheimia subsalsa	Lemm.
	Lagerheimia subsalsa - autospore	
	Micractinium pusillum	Fresenius
	Monoraphidium Braunii	(Nag.) Kom.-Legn.
	Monoraphidium arcuatum	
	Monoraphidium contortum	(Thur.) Kom.-Legn.
	Monoraphidium gracilis	
	Monoraphidium irregulare	(G.M. Sm.) Kom.-Legn.
	Monoraphidium minutum	(Nag.) Kom.-Legn.
	Monoraphidium pusillum	(Printz.) Kom.-Legn.
	Monoraphidium setiformae	(Nyg.) Kom.-Legn.

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DIVISION	TAXON	AUTHORITY
CHLOROPHYTA		
	Monoraphidium tortile	(W. & W.) Kom.-Legn.
	Nephrocytium Agardhianum	Nag.
	Nephrocytium limneticum	(G.M. Sm.) G.M. Sm.
	Oedogonium sp.	
	Oocystis sp.	
	Oocystis borgei	Snow
	Oocystis crassa	Wittr. in Wittr. & Nord.
	Oocystis elliptica	W. West
	Oocystis gigas v. incrassata	
	Oocystis lacustris	Chod.
	Oocystis nodulosa	
	Oocystis parva	West & West
	Oocystis pusilla	Hansg.
	Oocystis pyriformis	
	Oocystis solitaria	Wittr. in Wittr. & Nord.
	Oocystis submarina	Lagerh.
	Pediastrum boryanum	(Turp.) Menegh.
	Pediastrum duplex	Meyen
	Pediastrum simplex	(Meyen) Lemm.
	Pyramidomonas sp.	
	Quadrigula closteriodes	(Bohl.) Printz
	Quadrigula lacustris	(Chod.) G.M. Sm.
	Scenedesmus arcuatus	Lemm.
	Scenedesmus armatus	(Chod.) G.M. Sm.
	Scenedesmus bicaudatus	(Hansg.) Chod.
	Scenedesmus bijuga	(Turp.) Lagerh.
	Scenedesmus brevispina	(G.M. Sm.) Chod.
	Scenedesmus denticulatus	Lagerh.
	Scenedesmus ecornis	(Ralfs) Chod.
	Scenedesmus microspina	
	Scenedesmus opoliensis	P. Richt.
	Scenedesmus quadricauda	(Turp.) Breb.
	Scenedesmus sp.	
	Scenedesmus spinosus	Chod.
	Schroederia setigera	(Schroed.) Lemm.
	Selenastrum sp.	
	Sphaerellopsis sp.	
	Sphaerocystis schroeteri	Chod.
	Sphaerocystis sp.	
	Staurastrum sp.	
	Stichococcus sp.	
	Tetraedron minimum	(A. Braun) Hansg.
	Tetraedron minimum - autospore	
	Tetraedron muticum	(A. Braun) Hansg.
	Tetraedron regulare	
	Tetraedron trigonum	(Nag.) Hansg.
	Treubaria setigera	(Arch.) G.M. Sm.
	Treubaria sp.	
	Treubaria triappendiculata	Ber.
	Trochiscia sp.	
	Ulothrix sp.	
CHRYSOPHYTA		
	Bitrichia longispina	
	Chromulina erkensis	
	Chromulina sp.	
	Chromulina vagans	
	Chrysarachnion insidians	
	Chrysococcus sp.	
	Chrysolykos planktonicus	Mack.
	Chrysolykos sp.	
	Chrysophycean coccoids	
	Chrysosphaerella longispina	Laut. em. Nich.
	Chrysosphaerella sp.	
	Desmarella brachycalyx	
	Desmarella sp.	
	Dinobryon - cyst	
	Dinobryon acuminatum	Rutt.
	Dinobryon bavaricum	Imhof
	Dinobryon borgei	Lemm.

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DIVISION	TAXON	AUTHORITY
CHRYSOPHYTA		
	Dinobryon crenulatum	
	Dinobryon cylindricum	Imhof
	Dinobryon divergens	Imhof
	Dinobryon sociale	Ehr.
	Epipyxis sp.	
	Haptophyceae	
	Kephyrion boreale	Skuja
	Kephyrion cupuliformae	Conr.
	Kephyrion doliolum	Conr.
	Kephyrion littorale	Lund.
	Kephyrion ovale	
	Kephyrion sp.	
	Kephyrion sp. #2	
	Kephyrion sp. #3	
	Mallomonas sp.	
	Monosiga ovata	S. Kent
	Monosiga sp.	
	Ochromonas sp.	
	Ochromonas sp. #4	
	Paraphysomonas sp.	
	Pseudokephryion entzii	Conr.
	Pseudokephyrion attenuatum	
	Pseudokephyrion conicum	(Schill.) Schum.
	Pseudokephyrion ellipsoideum	
	Pseudokephyrion latum	(Schill.) Schum.
	Pseudokephyrion millerense	Nich.
	Salpingoeca gracilis	Clark
	Spiniferomonas sp.	
	Stichogloea sp.	
	Synura sp.	
	Unidentified chrysophyte	
	Unidentified coccoid - ovoid	
	Unidentified coccoid - sphere	
	Unidentified coccoids	
	Unidentified loricate - ovoid	
	Unidentified loricate - ovoid flagellate	
	Unidentified loricate - sphere	
COLORLESS FLAGELLATES		
	Bicoeca petiolata	(Stein) Pringsh.
	Bicoeca sp.	
	Bicoeca tubiformis	Skuja
	Colorless flagellate	
	Stelexmonas dichotoma	Lack.
CRYPTOPHYTA		
	Chroomonas acuta	Uterm.
	Chroomonas norstedtii	Hansg.
	Chroomonas sp.	
	Cryptomonas brevis	Schill.
	Cryptomonas caudalus	
	Cryptomonas caudata	Schill.
	Cryptomonas curvata	Ehr.
	Cryptomonas erosa	Ehr.
	Cryptomonas marssonii	Skuja
	Cryptomonas ovata	Ehr.
	Cryptomonas parapyrenoidifera	Skuja
	Cryptomonas phaseolus	Skuja
	Cryptomonas platyuris	Skuja
	Cryptomonas pyrenodiosa	
	Cryptomonas pyrenoidifera	Geitl.
	Cryptomonas reflexa	Skuja
	Cryptomonas rostratiformis	Skuja
	Cryptomonas sp.	
	Cryptomonas sp. #1	
	Cryptomonas sp. #3	
	Cryptomonas tenuis	Pasch.
	Cryptomonas tetrapyrenoidiosa	Skuja
	Rhodomonas lacustris	Pasch. & Rutt.
	Rhodomonas lens	Pasch. & Rutt.

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DIVISION	TAXON	AUTHORITY
CRYPTOPHYTA		
	Rhodomonas minuta	Skuja
	Rhodomonas pusilla	
CYANOPHYTA		
	Anabaena circinalis	Rabenhorst
	Anabaena flos-aquae	(Lyngb.) Breb.
	Anabaena sp.	
	Anabaena spiroides	Kleb.
	Anacystis montana	Dr. & Daily
	Anacystis thermalis	(Menegh.) Dr. & Daily
	Aphanizomenon flos-aquae	(L.) Ralfs
	Aphanothece gelatinosa	(Henn.) Lemm.
	Chroococcus dispersus	
	Chroococcus limneticus	Lemm.
	Chroococcus sp.	
	Coelosphaerium dubium	Grun. in Rabh.
	Coelosphaerium naegelianum	Unger
	Gloeothece ruprestris	(Lyngb.) Born.
	Gomphosphaeria aponina	Kutz.
	Oscillatoria limnetica	Lemm.
	Oscillatoria sp.	
	Spirulina sp.	
	Synechococcus sp.	
EUGLENOPHYTA		
	Phacus sp.	
	Trachelomonas sp.	
	Trachelomonas volvocina	
PYRROPHYTA		
	Amphidinium sp.	
	Ceratium hirundinella	(O.F.Mull.) Schrank
	Dinoflagellate cyst	
	Glenodinium sp.	
	Gymnodinium helveticum	Pen.
	Gymnodinium sp.	
	Peridinium - cyst	
	Peridinium aciculiferum	Lemm.
	Peridinium sp.	
	Peridinium sp. #02	
	Peridinium viguieri	Lef.
UNIDENTIFIED		
	Unidentified colony	
	Unidentified flagellate - triangular	

APPENDIX A-9. LAKE ONTARIO ZOOPLANKTON SPECIES LIST (1986 - 1992)

DIVISION	TAXON
Calanoida	Diaptomus - copepodite
	Diaptomus ashlandi
	Diaptomus minutus
	Diaptomus oregonensis
	Diaptomus sicilis
	Diaptomus siciloides
	Epischura - copepodite
	Epischura lacustris
	Eurytemora - copepodite
	Eurytemora affinis
	Limnocalanus - copepodite
	Limnocalanus macrurus
	Senecella - copepodite
Cladocera	Bosmina longirostris
	Bythotrephes cederstroemi
	Ceriodaphnia lacustris
	Ceriodaphnia sp.
	Daphnia galaeta mendotae
	Daphnia longiremis
	Daphnia pulicaria
	Daphnia retrocurva
	Diaphanosoma birgei
	Diaphanosoma sp.
	Eubosmina coregoni
	Holopedium gibberum
	Leptodora kindtii
	Polyphemus pediculus
	Scapholeberis aurita
Copepoda	Copepoda - nauplii
Cyclopoida	Cyclopoid - copepodite
	Cyclops bicuspidatus thomasi
	Cyclops vernalis
	Mesocyclops - copepodite
	Mesocyclops edax
	Tropocyclops - copepodite
	Tropocyclops prasinus mexicanus
Mysidacea	Mysis relicta
Rotifera	Ascomorpha ovalis
	Ascomorpha saltans
	Asplanchna priodonta
	Collotheca sp.
	Conochiloides sp.
	Conochilus unicornis
	Encentrum sp.
	Filina longiseta

GREAT LAKES ZOOPLANKTON SPECIES LIST
LAKE ONTARIO
(1986 - 1992)

DIVISION	TAXON
Rotifera	Gastropus stylifer
	Hexarthra mira
	Kellicottia longispina
	Keratella cochlearis
	Keratella crassa
	Keratella earlinae
	Keratella hiemalis
	Keratella quadrata
	Lecane flexilis
	Notholca acuminata
	Notholca foliacea
	Notholca laurentiae
	Notholca squamula
	Ploesoma hudsoni
	Ploesoma lenticulare
	Ploesoma truncatum
	Polyarthra dolichoptera
	Polyarthra euryptera
	Polyarthra major
	Polyarthra remata
	Polyarthra vulgaris
	Pompholyx sulcata
	Synchaeta sp.
	Trichocerca cylindrica
	Trichocerca multicrinis
	Trichocerca pusilla
	Trichocerca rousoletti
	Trichocerca similis
	Trichocerca sp.
Mollusca	Dreissena polymorpha - veliger

APPENDIX A-9. LAKE ONTARIO ZOOPLANKTON SPECIES LIST (1986 - 1992)

DIVISION	TAXON
Calanoida	Diaptomus - copepodite
	Diaptomus ashlandi
	Diaptomus minutus
	Diaptomus oregonensis
	Diaptomus sicilis
	Diaptomus siciloides
	Epischura - copepodite
	Epischura lacustris
	Eurytemora - copepodite
	Eurytemora affinis
	Limnocalanus - copepodite
	Limnocalanus macrurus
	Senecella - copepodite
Cladocera	Bosmina longirostris
	Bythotrephes cederstroemi
	Ceriodaphnia lacustris
	Ceriodaphnia sp.
	Daphnia galaeta mendotae
	Daphnia longiremis
	Daphnia pulicaria
	Daphnia retrocurva
	Diaphanosoma birgei
	Diaphanosoma sp.
	Eubosmina coregoni
	Holopedium gibberum
	Leptodora kindtii
	Polyphemus pediculus
	Scapholeberis aurita
Copepoda	Copepoda - nauplii
Cyclopoida	Cyclopoid - copepodite
	Cyclops bicuspidatus thomasi
	Cyclops vernalis
	Mesocyclops - copepodite
	Mesocyclops edax
	Tropocyclops - copepodite
	Tropocyclops prasinus mexicanus
Mysidacea	Mysis relicta
Rotifera	Ascomorpha ovalis
	Ascomorpha saltans
	Asplanchna priodonta
	Collotheca sp.
	Conochiloides sp.
	Conochilus unicornis
	Encentrum sp.
	Filina longiseta

APPENDIX A-9. LAKE ONTARIO SPECIES LIST

(1986 - 1992)

DIVISION	TAXON
Rotifera	Gastropus stylifer
	Hexarthra mira
	Kellicottia longispina
	Keratella cochlearis
	Keratella crassa
	Keratella earlinae
	Keratella hiemalis
	Keratella quadrata
	Lecane flexilis
	Notholca acuminata
	Notholca foliacea
	Notholca laurentiae
	Notholca squamula
	Ploesoma hudsoni
	Ploesoma lenticulare
	Ploesoma truncatum
	Polyarthra dolichoptera
	Polyarthra euryptera
	Polyarthra major
	Polyarthra remata
	Polyarthra vulgaris
	Pompholyx sulcata
	Synchaeta sp.
	Trichocerca cylindrica
	Trichocerca multicrinis
	Trichocerca pusilla
	Trichocerca rousoletti
	Trichocerca similis
	Trichocerca sp.
Mollusca	Dreissena polymorpha - veliger

Table A-10. Summary of common zooplankton species occurrence in Lake Ontario during April and August, 1986. Species were arbitrarily classified as common if they accounted for ≥ 0.1% of the total abundance or ≥ 1.0% of the total biomass, with the exception of rotifers. Rotifer species were considered common if they accounted for ≥ 1.0% of the total abundance.

TAXON		MAXIMUM DENSITY (#/m³)	AVERAGE DENSITY (#/m³)	% OF TOTAL ABUNDANCE	MEAN BIOMASS (µg/m³)	% OF TOTAL BIOMASS
COPEPODA						
Copepoda - nauplii		132,045	46,469.9	15.89	18,588	20.24
Cyclopoida						
Cyclopoid - copepodite		52,855	16,751.4	5.73	25,055	27.28
Cyclops bicuspidatus thomasi		10,445	2,959.4	1.01	11,129	12.12
Calanoida						
Diaptomus - copepodite		2,635	744.9	0.25	1,017	1.11
Limnocalanus macrurus		408	53.8	0.02	1,248	1.36
	Total			22.90		62.11
CLADOCERA						
Bosmina longirostris		97,624	12,033.7	4.12	9,386	10.22
Ceriodaphnia lacustris		4,709	661.5	0.23	675	0.73
Daphnia retrocurva		28,931	6,893.8	2.36	10,341	11.26
	Total			6.70		22.21
ROTIFERA						
Conochilus unicornis		63,426	5,000.7	1.71	105	0.11
Kellicottia longispina		40,986	12,442.7	4.26	158	0.17
Keratella cochlearis		208,453	37,887.1	12.96	181	0.20
Keratella crassa		129,908	18,378.6	6.29	954	1.04
Polyarthra major		215,839	42,049.6	14.38	5,305	5.78
Polyarthra vulgaris		290,925	71,029.3	24.29	2,912	3.17
Pompholyx sulcata		95,310	4,439.5	1.52	67	0.07
	Total			65.40		10.54
	Total			95.01		94.86

Table A-11. Summary of common zooplankton species occurrence in Lake Ontario during April and August, 1987. Species were arbitrarily classified as common if they accounted for ≥ 0.1% of the total abundance or ≥ 1.0% of the total biomass, with the exception of rotifers. Rotifer species were considered common if they accounted for ≥ 1.0% of the total abundance.

TAXON		MAXIMUM DENSITY (#/m³)	AVERAGE DENSITY (#/m³)	% OF TOTAL ABUNDANCE	MEAN BIOMASS (µg/m³)	% OF TOTAL BIOMASS
COPEPODA						
Copepoda - nauplii		90,974	26,766.2	17.35	10,706	21.21
Cyclopoida						
Cyclopoid - copepodite		28,162	7,577.8	4.91	2,496	4.94
Cyclops bicuspidatus thomasi		8,902	2,093.4	1.36	6,952	13.77
Tropocyclops - copepodite		8,716	1,891.9	1.23	469	0.93
Tropocyclops prasinus mexicanus		4,127	1,077.4	0.70	940	1.86
Calanoida						
Diaptomus - copepodite		8,295	1,560.9	1.01	1,521	3.01
Eurytemora - copepodite		809	172.4	0.11	115	0.23
	Total			26.67		45.96
CLADOCERA						
Bosmina longirostris		28,001	2,439.5	1.58	1,851	3.67
Daphnia galaeta mendotae		41,633	4,614.2	2.99	8,494	16.83
Daphnia retrocurva		29,781	4,761.0	3.09	8,581	17.00
Eubosmina coregoni		1,908	194.2	0.13	419	0.83
	Total			7.79		38.32
ROTIFERA						
Ascomorpha ovalis		30,253	6,271.0	4.07	127	0.25
Asplanchna priodonta		3,084	255.8	0.17	770	1.53
Conochilus unicornis		63,563	4,330.3	2.81	66	0.13
Kellicottia longispina		33,048	6,226.0	4.04	86	0.17
Keratella cochlearis		43,063	11,141.5	7.22	38	0.08
Keratella crassa		40,861	8,405.5	5.45	417	0.83
Keratella earlinae		51,075	4,326.6	2.81	97	0.19
Notholca squamula		33,382	2,236.9	1.45	54	0.11
Polyarthra major		103,139	18,828.1	12.21	2,900	5.74
Polyarthra vulgaris		157,277	24,615.5	15.96	781	1.55
Synchaeta sp.		62,904	7,995.5	5.18	181	0.36
	Total			61.36		10.93
	Total			95.81		95.21

Table A-12. Summary of common zooplankton species occurrence in Lake Ontario during April and August, 1988. Species were arbitrarily classified as common if they accounted for ≥ 0.1% of the total abundance or ≥ 1.0% of the total biomass, with the exception of rotifers. Rotifer species were considered common if they accounted for ≥ 1.0% of the total abundance.

TAXON		MAXIMUM DENSITY (#/m³)	AVERAGE DENSITY (#/m³)	% OF TOTAL ABUNDANCE	MEAN BIOMASS (µg/m³)	% OF TOTAL BIOMASS
COPEPODA						
Copepoda - nauplii		144,037	37,552.0	12.09	15,021	18.25
Cyclopoida						
Cyclopoid - copepodite		99,701	23,365.9	7.52	13,567	16.48
Cyclops bicuspidatus thomasi		17,210	4,147.8	1.34	14,784	17.96
Calanoida						
Diaptomus - copepodite		4,109	831.0	0.27	1,101	1.34
Limnocalanus macrurus		2,077	95.3	0.03	2,675	3.25
	Total			21.25		57.28
CLADOCERA						
Bosmina longirostris		236,790	36,327.0	11.69	19,011	23.09
Daphnia retrocurva		20,771	5,792.0	1.86	6,647	8.07
	Total			13.56		31.17
ROTIFERA						
Kellicottia longispina		103,596	16,408.2	5.28	180	0.22
Keratella cochlearis		260,688	31,535.5	10.15	101	0.12
Keratella crassa		134,048	27,195.8	8.75	1,876	2.28
Keratella earlinae		96,196	11,883.8	3.83	386	0.47
Keratella quadrata		36,999	3,578.4	1.15	237	0.29
Polyarthra major		88,796	22,545.0	7.26	1,526	1.85
Polyarthra remata		36,207	4,631.0	1.49	51	0.06
Polyarthra vulgaris		266,389	58,505.9	18.83	2,270	2.76
Pompholyx sulcata		170,137	10,713.9	3.45	129	0.16
Trichocerca multicrinis		19,733	3,382.9	1.09	115	0.14
	Total			61.28		8.35
	Total			96.08		96.78

Table A-13. Summary of common zooplankton species occurrence in Lake Ontario during August, 1989. Species were arbitrarily classified as common if they accounted for ≥ 0.1% of the total abundance or ≥ 1.0% of the total biomass, with the exception of rotifers. Rotifer species were considered common if they accounted for ≥ 1.0% of the total abundance.

TAXON		MAXIMUM DENSITY (#/m³)	AVERAGE DENSITY (#/m³)	% OF TOTAL ABUNDANCE	MEAN BIOMASS (µg/m³)	% OF TOTAL BIOMASS
COPEPODA						
Copepoda - nauplii		93,077	55,267.7	13.08	22,107	16.25
Cyclopoida						
Cyclopoid - copepodite		83,678	32,699.8	7.74	19,489	14.33
Cyclops bicuspidatus thomasi		14,540	4,671.7	1.11	17,424	12.81
Tropocyclops - copepodite		35,904	6,388.9	1.51	2,791	2.05
Tropocyclops prasinus mexicanus		7,715	2,284.1	0.54	3,135	2.30
Calanoida						
Diaptomus - copepodite		2,374	549.2	0.13	1,139	0.84
	Total			24.11		48.58
CLADOCERA						
Bosmina longirostris		171,510	40,032.5	9.48	37,720	27.73
Ceriodaphnia sp.		15,430	4,583.4	1.09	6,392	4.70
Daphnia retrocurva		38,121	8,115.8	1.92	9,913	7.29
	Total			12.48		39.71
ROTIFERA						
Conochilus unicornis		13,724	4,446.1	1.05	59	0.04
Kellicottia longispina		38,668	10,782.0	2.55	132	0.10
Keratella cochlearis		77,819	30,783.5	7.29	78	0.06
Keratella crassa		174,292	48,527.9	11.49	1,795	1.32
Keratella earlinae		134,493	39,291.8	9.30	854	0.63
Polyarthra major		41,004	13,563.7	3.21	816	0.60
Polyarthra vulgaris		231,115	95,197.2	22.54	7,539	5.54
Trichocerca multicrinis		21,123	6,584.0	1.56	294	0.22
	Total			58.99		8.50
	Total			95.59		96.80

Table A-14. Summary of common zooplankton species occurrence in Lake Ontario during April and August, 1990. Species were arbitrarily classified as common if they accounted for ≥ 0.1% of the total abundance or ≥ 1.0% of the total biomass, with the exception of rotifers. Rotifer species were considered common if they accounted for ≥ 1.0% of the total abundance.

TAXON		MAXIMUM DENSITY (#/m³)	AVERAGE DENSITY (#/m³)	% OF TOTAL ABUNDANCE	MEAN BIOMASS (µg/m³)	% OF TOTAL BIOMASS
COPEPODA						
Copepoda - nauplii		169,360	44,492.4	21.25	17,797	31.62
Cyclopoida						
Cyclopoid - copepodite		48,301	18,501.4	8.84	9,542	16.96
Cyclops bicuspidatus thomasi		13,110	4,716.7	2.25	15,612	27.74
Calanoida						
Diaptomus - copepodite		1,924	595.9	0.28	736	1.31
Limnocalanus macrurus		84	22.7	0.01	607	1.08
	Total			32.64		78.71
CLADOCERA						
Bosmina longirostris		3,184	334.4	0.16	523	0.93
Ceriodaphnia sp.		1,937	212.8	0.10	445	0.79
Daphnia retrocurva		8,521	1,346.8	0.64	3,907	6.94
Polyphemus pediculus		470	51.0	0.02	608	1.08
	Total			0.93		9.74
ROTIFERA						
Ascomorpha ovalis		25,564	3,088.2	1.48	42	0.07
Conochilus unicornis		42,426	3,584.0	1.71	68	0.12
Kellicottia longispina		53,758	9,453.3	4.52	106	0.19
Keratella cochlearis		145,649	38,186.2	18.24	139	0.25
Keratella crassa		56,708	18,167.8	8.68	965	1.72
Keratella earlinae		27,476	3,684.7	1.76	126	0.22
Keratella quadrata		35,428	5,156.5	2.46	402	0.71
Polyarthra major		43,006	5,895.6	2.82	676	1.20
Polyarthra remata		35,839	4,853.0	2.32	51	0.09
Polyarthra vulgaris		126,630	33,091.9	15.81	1,114	1.98
Synchaeta sp.		17,527	4,210.4	2.01	135	0.24
Trichocerca multicrinis		14,799	3,296.7	1.57	145	0.26
	Total			63.38		7.05
	Total			96.95		95.51

Table A-16. Summary of common zooplankton species occurrence in Lake Ontario during April and August, 1991. Species were arbitrarily classified as common if they accounted for ≥ 0.1% of the total abundance or ≥ 1.0% of the total biomass, with the exception of rotifers. Rotifer species were considered common if they accounted for ≥ 1.0% of the total abundance.

TAXON		MAXIMUM DENSITY (#/m³)	AVERAGE DENSITY (#/m³)	% OF TOTAL ABUNDANCE	MEAN BIOMASS (µg/m³)	% OF TOTAL BIOMASS
COPEPODA						
Copepoda - nauplii		203,920	27,055.1	15.61	10,822	6.51
Cyclopoida						
Cyclopoid - copepodite		112,288	20,635.4	11.91	11,753	7.07
Cyclops bicuspidatus thomasi		32,124	7,002.6	4.04	26,932	16.21
Cyclops vernalis		10,751	2,615.6	1.51	2,196	1.32
Tropocyclops prasinus mexicanus		2,964	700.7	0.40	887	0.53
Cyclopoida						
Diaptomus - copepodite		3,537	754.4	0.44	975	0.59
Diaptomus sicilis		2,964	274.4	0.16	1,765	1.06
Limnocalanus - copepodite		2,251	347.4	0.20	1,258	0.76
	Total			34.26		34.05
CLADOCERA						
Bosmina longirostris		46,682	3,543.1	2.04	4,540	2.73
Daphnia galaeta mendotae		17,413	1,754.5	1.01	14,116	8.49
Daphnia retrocurva		131,895	18,093.1	10.44	83,347	50.15
	Total			13.50		61.38
ROTIFERA						
Ascomorpha ovalis		44,123	6,691.6	3.86	90	0.05
Conochilus unicornis		45,316	5,732.5	3.31	108	0.07
Kellicottia longispina		64,396	6,483.1	3.74	73	0.04
Keratella cochlearis		156,220	20,824.4	12.01	76	0.05
Keratella crassa		53,663	5,695.9	3.29	303	0.18
Polyarthra major		52,100	5,175.1	2.99	594	0.36
Polyarthra vulgaris		155,027	24,831.0	14.33	836	0.50
Synchaeta sp.		25,043	5,255.0	3.03	168	0.10
Trichocerca multicrinis		28,620	3,215.6	1.86	141	0.08
	Total			48.41		1.44
	Total			96.17		96.87

Table A-17. Summary of common zooplankton species occurrence in Lake Ontario during April, 1992. Species were arbitrarily classified as common if they accounted for ≥ 0.1% of the total abundance or ≥ 1.0% of the total biomass, with the exception of rotifers. Rotifer species were considered common if they accounted for ≥ 1.0% of the total abundance.

TAXON	MAXIMUM DENSITY (#/m³)	AVERAGE DENSITY (#/m³)	% OF TOTAL ABUNDANCE	MEAN BIOMASS (µg/m³)	% OF TOTAL BIOMASS
COPEPODA					
Copepoda - nauplii	7,204	3,463.6	21.44	1,385	9.17
Cyclopoida					
Cyclopoid - copepodite	8,261	3,905.7	24.17	3,362	22.25
Cyclops bicuspidatus thomasi	3,702	2,123.5	13.14	8,944	59.18
Tropocyclops prasinus mexicanus	55	25.0	0.15	35	0.23
Calanoida					
Diaptomus - copepodite	511	207.9	1.29	241	1.59
Diaptomus sicilis	130	36.8	0.23	240	1.59
Limnocalanus - copepodite	111	61.5	0.38	441	2.92
			----------		----------
			60.81		96.93
CLADOCERA					
Eubosmina coregoni	29	16.5	0.10	78	0.51
ROTIFERA					
Kellicottia longispina	3,554	2,036.1	12.60	23	0.15
Keratella cochlearis	1,507	513.9	3.18	2	0.01
Notholca squamula	1,809	945.0	5.85	18	0.12
Polyarthra vulgaris	2,532	1,299.0	8.04	44	0.29
Synchaeta sp.	2,067	1,307.4	8.09	42	0.28
			----------		----------
			37.76		0.85
			==========		==========
			98.66		98.29

Table A18. Changes made in the data base to accomodate changes in species identifications. Decisions were based on recounts between years and discussions between Dr. Paul Bertram, Dr. Kit Yung and Dr. Joe Makarewicz. NIR= Not included in the report. Unless stated otherwise, changes were not made in the data base; that is the changes discussed below were only made for the report.

I. Picoplankton (Since 1989) are defined as

A. Unicellular Cyanobacteria

B. Either spherical or rod shape

C. Size less than or equal to 2 µm

D. Colonials with indiviual cells less than 2 µm

E. Decision: Based on discussion with P. Bertram. All picoplankton will not be considered in our report, but will be included in the electronic data base. For the report, the following decisions were made with individual species:

1. *Anacystis marina* = picoplankton sphere (size .50-1.5 µm)-NIR
2. *Coccochloris peniocysts* = picoplankton rods (size 1-2 µm)-NIR
3. *Anacystis incerta* adopted in 1989 = colonial picoplankton (colony=20µm; indiv.=<2 µm)-NIR
4. *Gleocapsa* (1-2 µm=indiv.)-NIR . Memo of 21 Dec. 93
5. *Anacystis cyanea* (average=2.2 µm sphere- NIR (Phone call with Paul Bertam)
6. *Agmenellum quadruplicatum* (1.5 µm sphere)-NIR
7. *Aphanocapsa delicatissima* (0.7 µm sphere)-NIR
8. *Aphanotheca clathrata* (1.7 X .6 µm ovoid)-NIR
9. *Microcystis elachista* (1.9 X 1.4 µm ovoid)-NIR
10. *Microcystis aeruginosa (1.2 µm) - NIR*
11. *Microcystis* sp. - (2.0 µm) - NIR

II. *Melosira*

A. *Melosira varians* and *Melosira undulata* are unchanged as to nomenclature.

B. All other *Melosira* will change to the genus *Aulacoseira* (Letter- from Kit Yung).

III. *Stephanodiscus subtransilvanicus* is changed & combined with *Stephanodiscus transylvanicus* (Letter of 1/94 from Kit Yung)

IV. *Oscillatoria minima* is changed to *Oscillatoria* sp. (Letter of 1/94 from Kit Yung)

V. *Gymnodinium* sp.#2 - group "all" *Gymnodinium species* as *Gymnodinium* sp.

VI. *Rhizosolenia longiseta* - leave as is (Letter of 1/94 from Kit Yung)

VII. *Melosira subarctica* is to be changed to *Melosira italica* subsp. *subarctica* - Ted, this is a permanent change & should be done in the original data base and species list

VIII. *Mallomonas* sp. stays the same

IX. *Synechococcus* sp. is Cyanophyta not a green

A. Make this change in species list

X. Ovoid unidentified flagellates in UNI should be changed to *Ochromonas* sp. (Letter from Kit 1/94). Species affected:

Unidentified flagellate - ovoid
Unidentified flagellate #01

XI. Spherical unidentified flagellates in UNI should be changed to *Chromulina* sp. ? (Letter from Kit 1/94). Species affected:

Unidentified flagellate	Unidentified flagellate #19	Unidentified flagellate #38
Unidentified flagellate - spherical	Unidentified flagellate #20	Unidentified flagellate #39
Unidentified flagellate #02	Unidentified flagellate #21	Unidentified flagellate #40
Unidentified flagellate #03	Unidentified flagellate #22	Unidentified flagellate #41
Unidentified flagellate #04	Unidentified flagellate #23	Unidentified flagellate #42
Unidentified flagellate #05	Unidentified flagellate #24	Unidentified flagellate #43
Unidentified flagellate #06	Unidentified flagellate #25	Unidentified flagellate #44
Unidentified flagellate #07	Unidentified flagellate #26	Unidentified flagellate #45
Unidentified flagellate #08	Unidentified flagellate #27	Unidentified flagellate #47
Unidentified flagellate #09	Unidentified flagellate #28	Unidentified flagellate #48
Unidentified flagellate #10	Unidentified flagellate #29	Unidentified flagellate #49
Unidentified flagellate #12	Unidentified flagellate #31	Unidentified flagellate #50
Unidentified flagellate #13	Unidentified flagellate #32	Unidentified flagellate #51

Unidentified flagellate #14
Unidentified flagellate #15
Unidentified flagellate #16
Unidentified flagellate #17
Unidentified flagellate #18
Unidentified flagellate #33
Unidentified flagellate #34
Unidentified flagellate #35
Unidentified flagellate #36
Unidentified flagellate #37
Unidentified flagellate #52
Unidentified flagellate #53
Unidentified flagellate #55
Unidentified flagellate (w/spines)

XII. *Staphanodiscus parvus* was not described until late 1984. The name was not used prior to 1985.

XIII. *Cyclotella comensis* var. 1 & *C. comensis* var. 2.

A. Confusion in 1989 samples per letter of Kit Yung (2/94) seemed to have been straightened out. We will combine into *Cyclotella comensis*

XIV. In 1992, Kit Yung (2/94) began to adopt the name "Unidentified Chrysophyte #5" for an alga that resembled algal spore. In recounts it was found in 1989 & 1991.

XV. *Gomphosphaeria lacustris* prior to 1990 & 1991 should be called *Coelosphaerium naegelianum*.

A. Kit Yung re-examined four 1988 Lake Michigan samples with a relatively high *Gomphosphaeria* count. He could only find colonies of *Coelosphaerium naegelianum*, a closely related colonial cyanophyte (2/94 from Kit). Also, prior to 1989 *C. naegelianum* is not found but *Gomphosphaeria* is. After 1990 *Gomphosphaeria* is not found while *Coelosphaerium* is.

XVI. Group together Green Coccoid bacilliforms, ovoid and sphere as Green Coccoids

XVII. Colorless flagellates - all #s group together

XVIII. *Stephanodiscus hantzschii* and *Stephanodiscus hantzschii* var. *hantzschii* group together as *S. hantzschii*

XIX. *Cryptomonas erosa* and *Cryptomonas erosa* var. *reflexa* group together as *C. erosa*

XX. Group <u>all</u> varieties of a species into a single species e.g. *S. tenuis* var. 1, *S. tenuis* var. 2 and *S. tenuis* var. 3 simply report as *S. tenuis*

XXI. The *Cyclotella* complex is still confusing. Will call Bertram.

A. Will leave as is. Discussion with P. Bertram and letter of K. Yung (4 March 1994)

XXII. The *Cryptomonas* complex

A. *Cryptomonas pusilla* is changed to *Rhodomonas minuta*. Letter from K. Jung.

B. All other species of *Cryptomonas* are left the same. Discussion between T. Lewis and P. Bertram.

XXIII. *Stephanodiscus minutus* will be changed to *Stephanodiscus minutulus*. Letter from K. Yung 31 October 1991.

XXIV. *Stephanodiscus subtilis* and *S. hantzschia f. tenuis* (fine form) will be combined into *Cyclostephanos tholiformis*. Letter from K. Yung 31 October 1991.

Appendix 19. Lake Ontario water chemistry, 1986 to 1992. Average of samples taken at 3 meter depth from sites listed in Table 1. NS = no sample.

Year	Temperature (°C)		Turbidity (NTU)		Nitrate + Nitrite (mg N/L)		Total Phosphorus (µg P/L)		Dissolved orthophosphate (µg P/L)		Dissolved Silicon (µg Si/L)		Chlorophyll *a* (µg/L)	
	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
1986	2.4	19.9	0.24	1.64	0.40	0.16	10.0	11.0	4.0	0.0	283.5	47.1	1.1	3.9
1987	3.6	22.2	0.35	1.51	0.37	0.12	9.0	8.0	3.0	1.0	235.9	74.0	2.7	2.9
1988	2.5	22.3	0.42	1.49	0.36	0.16	8.0	8.0	2.0	0.0	271.4	39.1	2.3	2.3
1989	NS	20.9	NS	1.32	NS	0.15	NS	9.0	NS	0.0	NS	38.9	NS	7.2
1990	2.4	22.4	0.62	0.96	0.34	0.29	7.0	9.0	2.0	0.0	197.8	40.4	1.2	0.6
1991	3.1	21.5	0.37	0.78	0.37	0.15	8.0	7.0	3.0	1.0	233.3	33.6	2.8	2.9
1992	2.1	NS	0.36	NS	0.36	NS	7.0	NS	2.0	NS	219.9	NS	3.5	NS