Epilimnetic Phytoplankton and Zooplankton Biomass and Species Composition In Lake Ontario, 1986 to 1992.

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July 1995

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ABSTRACT

Phytoplankton:

From 1986 to 1992, forty-two common species and varieties accounted f'or 9 1. 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 rcspcctivc season. Mesotrophic diatom species accounted for approximately 30.4 ±5.9% (mean ± S.E.) of the phytoplankton biomass while eutrophic diatoms rcprescntcd less than 10 ±1.5% of the phytoplankton biomass. No changes in the ratio of mcsotrophic 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 cutrophy.

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 (3 1%) and 198 1/82 (mean =2 I %) to the 1986 -1992 period (mean = 10.2%). Specifically, biomass of Gymnodinium spp., Peridinium spp., and Ceratium hirundinella decreased in the summer plankton. Rclativc 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. I % of the relative summer biomass in 1986 to 12.4% in the summer of 199 1. Species of Chromulina, Ochromonas, Chrvsococcus and the Haptophyceae were observed in the 1986-1992 period that were not reported in 198 1 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 unicellular phytoplankton (< SO 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 unicellular 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 199 1. 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 strcssors that are cxprcsscd from the first trophic level upward, the zooplankton arc 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 collcctcd by EPA's Great Lakes National Program Office provide such information and support the International Joint Con-mission's call for more and better information through monitoring and research on components of' the Lake Ontario food web (Hartig et al. 199 1). 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 collcctcd during 23 cruises during the spring and summer from 1986 to 1992 (Table I). 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. I). Thus our species data represent only summer cpilimnctic forms and early spring isothermal forms. One-liter samples were immediately prcscrvcd 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 (cxccpt f'or 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,. 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 $\pm$ 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. arc discussed in Appendix A- IX.

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 .O 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 cast-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 (197 1) 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 spccif'ic 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 Asnlanchna spp. A dry weight/wet weight ratio of' 0.039 was used for Asnlanchna spp. (Dumont et al. 1975).

Because of' the considerable variability in length and thus weight encountered in the Crustacca, the dry weights of' Crustacca 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 Crustacca in Lake Michigan suggested good agreement at the minimum weight range (Makarewicz 1988). The weight of the Copcpoda nauplii and the vcligcr of Dreissena followed Hawkins and Evans (1979) and Sprung (1993).

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All phytoplankton and zooplankton identif'ications and enumeration were performed f'or the United States Environmental Protection Agency by the Bionctics Corporation (1983-88), AScI (1989,1990) and Enviroscience Corporation (1991-92).