PHYTOPLANKTON, ZOOPLANKTON, AND BENTHOS

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No specific FCOs for phytoplankton, zooplankton, and benthos exist. However, FCOs call for balancing predator abundance with prey-fish production, which is a function of plankton and benthos production. The Great Lakes National Program Office (GLNPO) of the U.S. Environmental Protection Agency has conducted regular surveillance monitoring of Lake Huron since 1983. The monitoring effort is focused on whole-lake responses to changes in loadings of anthropogenic substances, so sampling is restricted largely to the relatively homogeneous offshore waters. Data presented in this report are for phytoplankton and zooplankton communities sampled at 14 sites lakewide during spring (20-21 April) and summer (15-17 August), 1999. Sampling methods and limnological conditions during the surveys are described in Barbiero and Tuchman (2001) and Barbiero et al. (2001). The description of the benthos community is consolidated from a variety of unrelated studies.

Phytoplankton

We found 161 phytoplankton taxa in the spring, with a range of 64 to 84 taxa at individual sites. Phytoplankton biomass in spring was relatively uniform among sites, varying only between 0.24 and 0.57 gm•m^{-3} (Fig. 7). The median biomass of 0.44 gm•m^{-3} was similar to that of Lake Michigan (0.62 gm•m^{-3}) and substantially higher than that of Lake Superior (0.065 gm•m^{-3}). All sites were dominated by diatoms, with *Aulacoseira islandica* and the pennate *Tabellaria flocculosa* contributing 67% of the lakewide biomass. Much smaller, but still substantial, populations of *Fragilaria crotonensis* and *A. subarctica* were also found. Non-diatom taxa were represented primarily by the genera *Dinobryon, Cryptomonas*, *Oscillatori*a and several genera of Pyrrophyta.

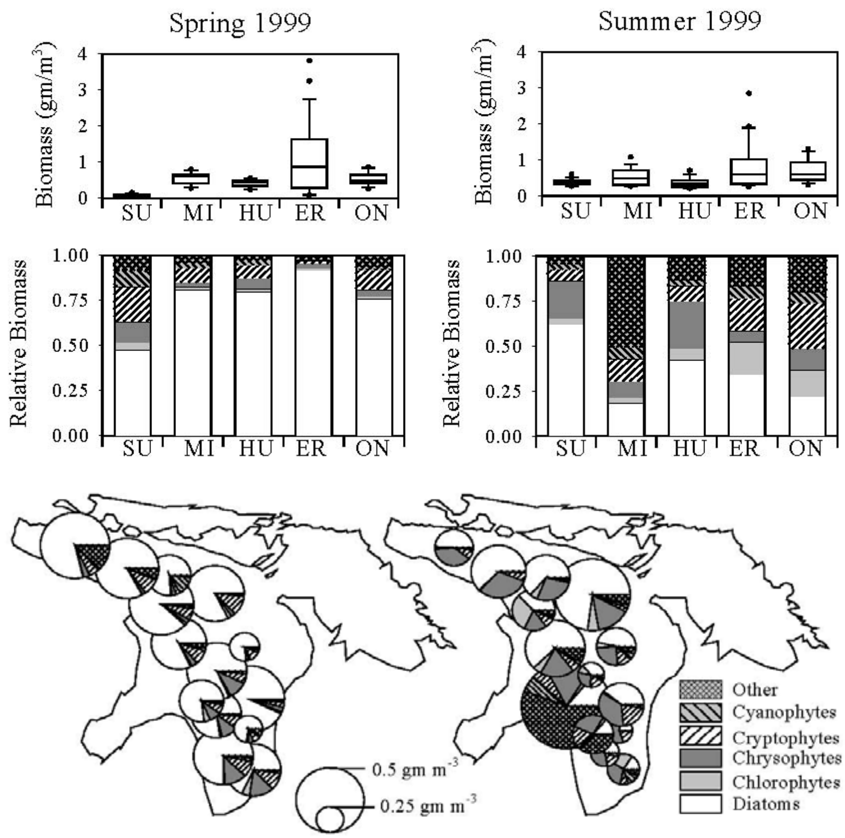

Fig. 7. Upper panel: box plots of phytoplankton biomass across the Great Lakes in spring and summer, 1999. Boxes denote 25th and 75th percentiles; lines denote median; whiskers denote 10th and 90th percentiles; individual points denote outliers. Middle panel: whole-lake average relative biomass of major phytoplankton groups for spring and summer, 1999. Lower panel: biomass of major phytoplankton groups at each site for spring and summer, 1999.

We identified 156 phytoplankton taxa from samples taken during the summer survey; taxa numbers at individual sites ranged between 45 and 66. Although taxa richness decreased slightly from spring to summer on a per-site basis, dominance in summer was distributed over a broader range of species from a greater variety of higher-taxonomic divisions, and diatoms were more prominent at northern sites (Fig. 7). Phytoplankton biomass exhibited a greater difference among sites in summer; biomass ranged between 0.20 and 0.71 gm•m^{-3}, with a median value of 0.34 gm•m^{-3}. This median biomass was lower than in Lake Superior (0.39 gm•m^{-3}) and Lake Michigan (0.58 gm•m^{-3}). Most diatom biomass in Lake Huron was from the typical summer genus *Cyclotella* and the eurytopic *F. crotonensis.* Chrysophytes, which also contributed a large percentage of biomass, were represented by *Chrysosphaerella longispina* and several species of *Dinobryon*. The large dinoflagellate *Ceratium hirundinella* and the cryptophyte *Cryptomonas erosa* also figured prominently at several sites. The large proportion of diatoms in the summer phytoplankton community in Lake Huron can be taken as evidence that the open–water portion of the lake has not experienced the increased productivity fostered by anthropogenic phosphorus loadings reported in Lake Michigan (Schelske 1988).

Zooplankton

Biomass of crustaceans (excluding nauplii) in spring ranged from 1.43 to 3.84 gm dry weight•m^{-2} among sites and was the highest of the five Great Lakes (Fig. 8). The median biomass of 2.30 gm dry weight•m^{-2} was more than twice that of Lake Ontario, nearly four times higher than that of Lake Michigan, and the second-largest crustacean community among the Great Lakes. Crustacean community diversity was low, as is typical in spring, with all sites having 7 or 8 taxa for a lakewide total of 11 taxa. Copepods accounted for nearly all of the non-nauplii crustaceans and were evenly divided between cyclopoids and calanoids. Cyclopoids were represented almost exclusively by *Diacyclops thomasi* and calanoids mostly by the diaptomids *Leptodiaptomus ashlandi, L. minutus,* and *L. sicilis*.

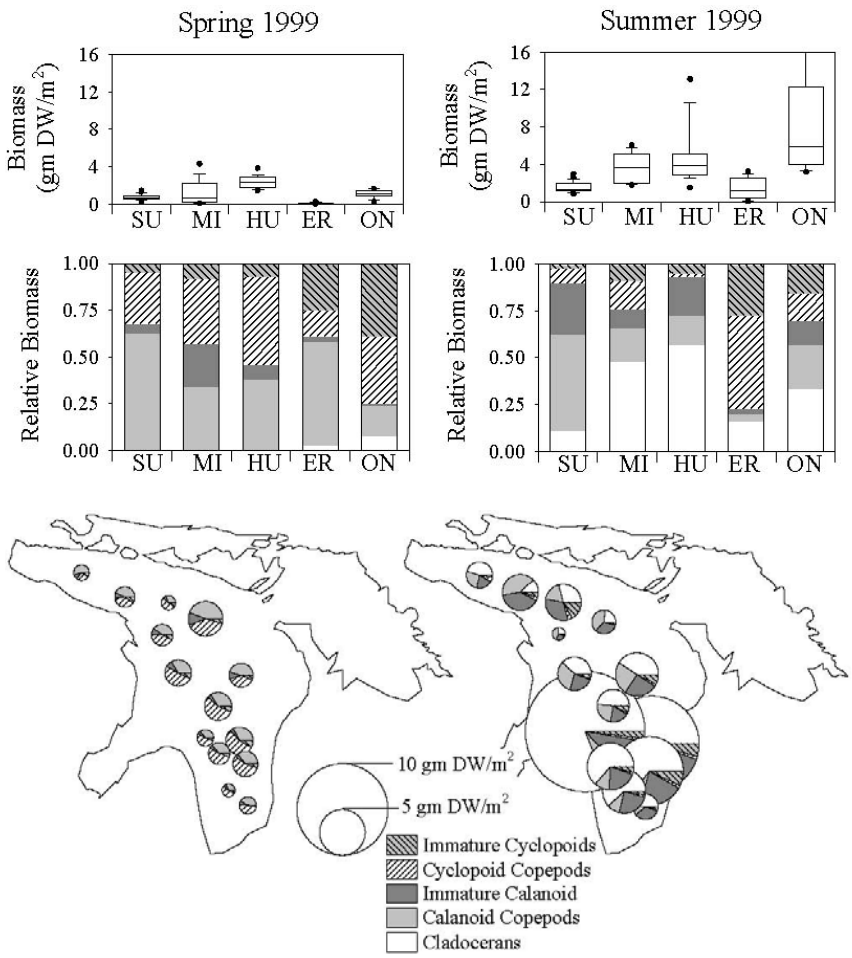

Fig. 8. Upper panel: box plots of zooplankton biomass across the Great Lakes in spring and summer, 1999. Boxes denote 25th and 75th percentiles; lines denote median; whiskers denote 10th and 90th percentiles; individual points denote outliers. Middle panel: whole-lake average relative biomass of major zooplankton groups for spring and summer, 1999. Lower panel: biomass of major zooplankton groups at each site for spring and summer, 1999.

Crustacean biomass increased in summer, ranging between 1.49 and 13.10 gm dry weight•m^{-2} (Fig. 8). The median biomass of 3.92 gm dry weight•m^{-2} was similar to that of Lake Michigan but lower than that of Lake Ontario (highest in the Great Lakes). Crustacean communities were more diverse in the summer (15 taxa) due to the appearance of additional cladoceran taxa. Dominant species included the cyclopoid and calanoid species found in spring and two additional cladoceran taxa (*Daphnia galeata mendotae* and *Bosmina* spp.). These dominant species accounted for over 98% of the non-nauplii crustaceans in summer. The spiny water flea was present at all sites. Abundance was fairly low; the lakewide average of 314 individuals m^{-2} represented less than 0.02% of all crustacean individuals and accounted for only 1-2% of total crustacean biomass.

The differences in crustacean communities between 1998 and 1999 suggest that inter-annual variability in these communities can be substantial. In 1998, the summer cladoceran community was dominated by larger *Daphnia* (Barbiero et al. 2001). The dominance by *Bosmina* spp. in the summer of 1999 and the unusually large cyclopoid populations in the spring were also observed in Lake Michigan in 1999 (J. Cavaletto, Great Lakes Environmental Research Laboratory, 2205 Commonwealth Blvd., Ann Arbor, Michigan, 48105, personal communication).

Benthos

The benthic macroinvertebrate community of Lake Huron has been the least studied in the Great Lakes. Some studies were conducted in the main basin or in specific bays during the early 1970s (Batchelder 1973; Schelske and Roth 1973; Shrivastava 1974; Loveridge and Cook 1976). More recently, two sampling programs were initiated to examine distributions and temporal trends in macroinvertebrate populations. In 1987-1996, annual surveys were conducted in Saginaw Bay to assess the response of the macroinvertebrate community to nutrient abatement efforts and to colonization by the zebra mussel. In 1997, GLNPO began annual surveys of macroinvertebrates in main-basin waters 45 m and deeper.

The benthic macroinvertebrate assemblages within the inner and outer portions of Saginaw Bay reflect the distinct physical and chemical features of the bay. The inner bay is warm and shallow with a mean depth of 5 m, and benthic communities here are heavily influenced by inputs of nutrients and organic material from the Saginaw River. The outer bay has a mean depth of 14 m and is influenced by the colder, less-productive waters of the main basin.

There were large fluctuations in densities of some major groups in the inner bay during 1987-1996, which were related to the introduction and rapid expansion of zebra mussels. Zebra mussel populations were first found in the bay in 1990, increased in 1991, peaked in 1992, and then declined to stable levels during 1993-1996 (Nalepa et al. 1999). At sites with hard substrates (sand, gravel) in the inner bay, the most significant change after the peak in zebra mussel abundance in 1992 was a six-fold increase in the density of the amphipod *Gammarus* spp. Density increased from a mean of $65 \bullet m^{-2}$ during 1987-1990 to $400 \bullet m^{-2}$ during 1993-1996. *Gammarus* benefited from the habitat complexity created by zebra mussel clusters and/or from increased food availability from mussel biodeposits (Ricciardi et al. 1997). Oligochaete densities at sites with a soft bottom (silt) decreased from $22{,}000 \bullet m^{-2}$ in 1988 to $1{,}200 \bullet m^{-2}$ in 1994, then returned to near pre-zebra mussel levels by 1996. Because these soft-bottom sites are located in the deeper depositional zone of the bay, the filtering activities of the peak zebra mussel populations in the shallower regions resulted in diminished organic inputs to the depositional zone and fewer oligochaetes.

Only a few individuals of the burrowing mayfly *Hexagenia* spp. were collected during the entire 1987-1996 sampling period. This important fish-food organism was abundant in the bay until the mid-1950s. At that time, populations essentially disappeared because of pollution and lakebed degradation. A similar decline occurred in western Lake Erie in the mid-1950s, but these populations recovered to former densities by the mid-1990s (Schloesser et al. 2001). There was no indication of a similar recovery of *Hexagenia* in Saginaw Bay as of 1996.

In the outer bay, the most significant change after zebra mussels became established was a decreased abundance at the sites greater than 20- to 30-m deep of the amphipod *Diporeia* spp. Mean density of *Diporeia* was $800 \bullet m^{-2}$ in the pre-zebra mussel period but declined to $80 \bullet m^{-2}$ by 1996. *Diporeia* biomass declined from 0.24 g ash-free dry weight (AFDW) $\bullet m^{-2}$ and 54% of total benthic biomass to 0.02 g AFDW$\bullet m^{-2}$ and just 11% of total benthic biomass.

The benthic community of the main basin is typical of that found in offshore waters of the other upper lakes. At depths below the thermocline (>30 m), amphipods (*Diporeia* spp.) are dominant, and oligocheates, sphaeriids, and chironomids follow in order of importance (Table 2). During 1997-1999, *Diporeia* densities generally decreased, but there were no consistent trends among densities of the other benthic groups. Densities of benthic groups, including *Diporeia*, in 1997-1999 were comparable to densities at similar depth intervals sampled in the early 1970s (Nalepa and Tuchman 2000). However, densities at similar depths in the early 1970s were highly variable, making it difficult to define a baseline.

Table 2. Mean (± 2SE) densities of the major macroinvertebrate groups in the main basin of Lake Huron, 1997-1999. Numbers in parenthesis indicate the number of sites in each of the three depth intervals.

Depth (m)	Species	1997	1998	1999
30-50	*Diporeia* spp.	2,610 ± 469	3,429 ± 414	2,945 ± 294
(2)	Oligochaeta	617 ± 109	493 ± 182	1,730 ± 864
	Sphaeridae	89 ± 46	61 ± 4	67 ± 35
	Chironomidae	73 ± 16	124 ± 3	86 ± 54
51-90	*Diporeia* spp.	3,353 ± 464	2,274 ± 696	1,027 ± 299
(5)	Oligochaeta	516 ± 115	368 ± 107	737 ± 254
	Sphaeridae	231 ± 85	185 ± 63	169 ± 61
	Chironomidae	31 ± 8	33 ± 14	25 ± 7
>90 m	*Diporeia* spp.	4,266 ± 738	2,949 ± 570	2,067 ± 235
(3)	Oligochaeta	520 ± 254	340 ± 154	756 ± 203
	Sphaeridae	33 ± 8	25 ± 4	18 ± 10
	Chironomidae	98 ± 33	59 ± 26	26 ± 10

Recommendations

1. Continue monitoring the status of plankton and benthos at index sites in offshore waters
2. Expand current monitoring of plankton and benthos to nearshore waters
3. Establish regular monitoring programs for plankton and benthos in the North Channel and Georgian Bay
4. Analyze all historical data on plankton and benthos
5. Develop better communication and coordination between researchers working on crustaceans and those working on fish

THE STATE OF LAKE HURON IN 1999

Great Lakes Fishery Commission

SPECIAL PUBLICATION 05-02

The Great Lakes Fishery Commission was established by the Convention on Great Lakes Fisheries between Canada and the United States, which was ratified on October 11, 1955. It was organized in April 1956 and assumed its duties as set forth in the Convention on July 1, 1956. The Commission has two major responsibilities: first, develop coordinated programs of research in the Great Lakes, and, on the basis of the findings, recommend measures which will permit the maximum sustained productivity of stocks of fish of common concern; second, formulate and implement a program to eradicate or minimize sea lamprey populations in the Great Lakes.

The Commission is also required to publish or authorize the publication of scientific or other information obtained in the performance of its duties. In fulfillment of this requirement the Commission publishes the Technical Report Series, intended for peer-reviewed scientific literature; Special Publications, designed primarily for dissemination of reports produced by working committees of the Commission; and other (non-serial) publications. Technical Reports are most suitable for either interdisciplinary review and synthesis papers of general interest to Great Lakes fisheries researchers, managers, and administrators, or more narrowly focused material with special relevance to a single but important aspect of the Commission's program. Special Publications, being working documents, may evolve with the findings of and charges to a particular committee. Both publications follow the style of the *Canadian Journal of Fisheries and Aquatic Sciences.* Sponsorship of Technical Reports or Special Publications does not necessarily imply that the findings or conclusions contained therein are endorsed by the Commission.

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