## Zooplankton Populations
Indicator #116

**Overall Assessment**
Status: **Mixed**
Trend: **Undetermined**
Rationale: **Changes in community structure are occurring in Lake Michigan, Lake Huron, and Lake Ontario due to declines in cyclopoid copepods and cladocerans. Summer mean size has increased in these lakes concurrent with the increase in the percent of calanoid copepods.**

**Lake-by-Lake Assessment**
**Lake Superior**
Status: Good
Trend: Unchanging
Rationale: Stable summer zooplankton community is dominated by large calanoid copepods.

**Lake Michigan**
Status: Not Assessed
Trend: Undetermined (changing)
Rationale: Total summer biomass has been declining since 2004 due to fewer cladocerans and cyclopoid copepods. Summer mean size of zooplankton is increasing as a result of increases in the large calanoid *Limnocalanus macrurus*.

**Lake Huron**
Status: Not Assessed
Trend: Undetermined (changing)
Rationale: Total summer biomass has declined dramatically since 2003 due to fewer *Daphnia*, bosminids, and cyclopoid copepods. Summer mean size of zooplankton is increasing.

**Lake Erie**
Status: Not Assessed
Trend: Undetermined
Rationale: Variable biomass and composition of summer crustacean zooplankton community in each basin. Most diverse zooplankton community in the Great Lakes. Very low biomass in Western basin in August, 2001.

**Lake Ontario**
Status: Not Assessed
Trend: Undetermined (changing)
Rationale: Lowest percentage of calanoid copepods of all Great Lakes. Total summer biomass has declined since 2004 due to a decline in cyclopoid copepods.

**Purpose**
- To directly measure changes in community composition, mean individual size and biomass of zooplankton

populations in the Great Lakes basin
- To indirectly measure zooplankton production
- To infer changes in food-web dynamics due to changes in vertebrate or invertebrate predation, system productivity, the type and intensity of predation, and the energy transfer within a system

**Ecosystem Objective**

Ultimately, analysis of this indicator should provide information on the biological integrity of the Great Lakes and lead to the support of a healthy and diverse fishery. Suggested metrics include zooplankton mean length, the ratio of calanoid copepod abundance to that of cyclopoid copepods plus cladocerans, and zooplankton biomass. However, the relationships between these objectives and the suggested metrics have not been fully worked out, and no specific criteria have yet been identified for these metrics.

Planktivorous fish often feed size selectively, removing larger cladocerans and copepods. High densities of planktivores therefore can result in a reduction of the mean size of zooplankton in a community. A mean individual size of 0.8 mm has been suggested as "optimal" for zooplankton communities sampled with a 153 µm mesh net, indicating a balance between planktivorous and piscivorous fish (Mills *et al.* 1987). Declines in mean size of crustacean zooplankton between spring and late summer may indicate increased predation by young fish or the presence of a greater proportion of immature zooplankton. Interpretation of deviations from this average size objective, and the universality of this objective remain unclear at this time. In particular, questions regarding its applicability to systems impacted by predaceous cladocereans and dreissenids as well as planktivorous fish have been raised.

Gannon and Stemberger (1978) found that cladocerans and cyclopoid copepods are more abundant in nutrient enriched waters of the Great Lakes, while calanoid copepods dominate oligotrophic communities. They reported that areas of the Great Lakes where the density of calanoid copepods comprises over 50% of the summer crustacean zooplankton community (or the ratio calanoids/(cyclopoids + cladocerans) is greater than 1) could be classified as oligotrophic. As with individual mean size though, clear objectives have not presently been defined.

**State of the Ecosystem**

Summer biomass of crustacean zooplankton communities in the offshore waters of Lake Superior has remained at a relatively low but stable level since at least 1998 (Figure 1). The plankton community is dominated by large calanoid copepods (*Leptodiaptomus sicilis* and *Limnocalanus macrurus*) that are characteristic of oligotrophic, cold water ecosystems. Biomass is generally higher in the nutrient enriched lower lakes with more annual variation produced by seasonal increases in cladocerans, primarily daphnids and bosminids. Since 2003 the biomass of cladocerans and cyclopoid copepods in Lake Huron has declined dramatically. Data from 2005 and 2006 suggest that a similar decline may now be occurring in Lake Michigan, although this has been offset somewhat by an increase in the biomass of *L. macrurus*. Cyclopoid abundance has also begun to decline in Lake Ontario. Mechanisms for these declines are not known at this time, but they may be related to changes in nutrient levels, phytoplankton composition, exotic species interactions, or fish predation pressure.

The proportion of calanoid copepods in Lake Superior has remained fairly stable at 70%, indicating oligotrophic conditions (Figure 2). Summer zooplankton communities in Lake Michigan and Lake Huron have shown an increasing proportion of calanoid copepods in recent years, which ostensibly suggests an improved trophic state. In the case of Lake Michigan, this has been due both to an increase in *L. macrurus*, and a decline in cladoceran populations. The increased proportion of calanoids in Lake Huron has resulted primarily from substantial declines in both cladoceran and cyclopoid copepod populations. Lake Ontario has the lowest proportion of calanoids, followed closely by the nutrient enriched western basin of Lake Erie. Values for the central and eastern basins of Lake Erie are at intermediate levels and exhibit considerable annual variation.

Historical comparisons of this metric are difficult to make because most historical data on zooplankton populations in the Great Lakes seem to have been generated using shallow (20 m) tows. Calanoid copepods tend to be deep living organisms. Therefore, the use of data generated from shallow tows would tend to contribute a strong bias to this metric. This problem is largely avoided in Lake Erie, particularly in the western and central basins, where most sites are shallower than 20 m. Comparisons in those two basins have shown a statistically significant increase in the ratio calanoids/(cladocerans + cyclopoids) between 1970 and 1983-1987, with this increase sustained throughout the 1990s. A similar increase was seen in the eastern basin, although some of the data used to calculate the ratio were generated from shallow tows and are therefore subject to doubt.

Mean length of crustacean zooplankton in the offshore waters of the Great Lakes is generally greater in the spring than during the summer (Figure 3). In the spring, mean zooplankton size in all of the Great Lakes is near the suggested level of 0.8 mm. Mean length in Lake Superior declines during the summer due to the production of immature copepodids, but it is still above the criterion. Summer mean lengths in Lake Huron and Lake Michigan remain high and have begun to show increases in recent years, most likely due to the increased importance of *L. macrurus* noted above. In Lake Erie and Lake Ontario, the mean length of zooplankton declines considerably in the summer. Whether this decline is due to predation pressure or to the increased abundance of bosminids (0.4 mm mean length) and immature cyclopoids (0.65 mm mean length) is unknown.

Historical data from the eastern basin of Lake Erie, from 1985 to 1998, indicate a fair amount of interannual variability in zooplankton mean length, with values from offshore sites ranging from about 0.5 to 0.85 mm (Figure 4). As noted above, interpretation of these data is currently problematic.

**Pressures**

The zooplankton community might be expected to respond to changes in nutrient and phytoplankton concentrations in the lakes, although the potential magnitude of such "bottom up" effects is not well understood. The most immediate potential threat to the zooplankton communities of the Great Lakes is posed by invasive species. The continued proliferation of dreissenid populations can be expected to impact zooplankton communities through the alteration of the structure and abundance of the phytoplankton community, upon which many zooplankton depend for food. Predation from the exotic cladocerans *Bythotrephes longimanus* and *Cercopagis pengoi* may also have an impact on zooplankton abundance and community composition. *Bythotrephes* has been in the Great Lakes for approximately twenty years and is thought to have had a major impact on zooplankton community structure (Barbiero and Tuchman 2004). *Cercopagis pengoi* was first noted in Lake Ontario in 1998 and has now spread to the other lakes, although in much lower densities. Continuing changes in predation pressure from planktivorous fish may also impact the system.

**Management Implications**

Continued monitoring of the offshore zooplankton communities of the Great Lakes is critical, particularly considering the current expansion of the range of the non-native cladoceran *Cercopagis* and the probability of future invasive non-native zooplankton and fish species.

**Comments from the author(s)**

Currently the most critical need is for the development of quantitative, objective criteria that can be applied to the zooplankton indicator. The applicability of current metrics to the Great Lakes is largely unknown, as are the limits that would correspond to acceptable ecosystem health.

The implementation of a long-term monitoring program on the Canadian side is also desirable to expand both the spatial and in particular the temporal coverage currently provided by American efforts. Since the interpretation of various indices is dependent to a large extent upon the sampling methods employed, coordination between these two programs, both with regard to sampling dates and locations, and especially with regard to methods, would be highly recommended.

**Assessing Data Quality**

Insert "x" under the statement that best corresponds with each data characteristic

| Data Characteristics | Strongly Agree | Agree | Neutral or Unknown | Disagree | Strongly Disagree | Not Applicable |
|---|---|---|---|---|---|---|
| 1. Data are documented, validated, or quality-assured by a recognized agency or organization | | X | | | | |
| 2. Data are traceable to original sources | | X | | | | |
| 3. The source of the data is a known, reliable and respected generator of data | | X | | | | |
| 4. Geographic coverage and scale of data are appropriate to the Great Lakes basin | | X | | | | |
| 5. Data obtained from sources within the U.S. are comparable to those from Canada | | | | | | X |
| 6. Uncertainty and variability in the data are documented and within acceptable limits for this indicator report | | X | | | | |
| Clarifying Notes: | | | | | | |

**Acknowledgments**

Authors and Contributors:

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**Sources**

Barbiero, R.P., and Tuchman, M.L. 2004. Changes in the crustacean communities of Lakes Michigan, Huron, and Erie following the invasion of the predatory cladoceran *Bythotrephes longimanus*. *Can. J. Fish. Aquat. Sci.* 61:2111-2125.

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**List of Figures**

Figure 1. Average composition of crustacean zooplankton biomass at Great Lakes offshore stations sampled in August of each year.
Samples were collected with 153 µm mesh net tows to a depth of 100 m or the bottom of the water column, whichever was shallower.
Source: U.S. Environmental Protection Agency, Great Lakes National Program Office

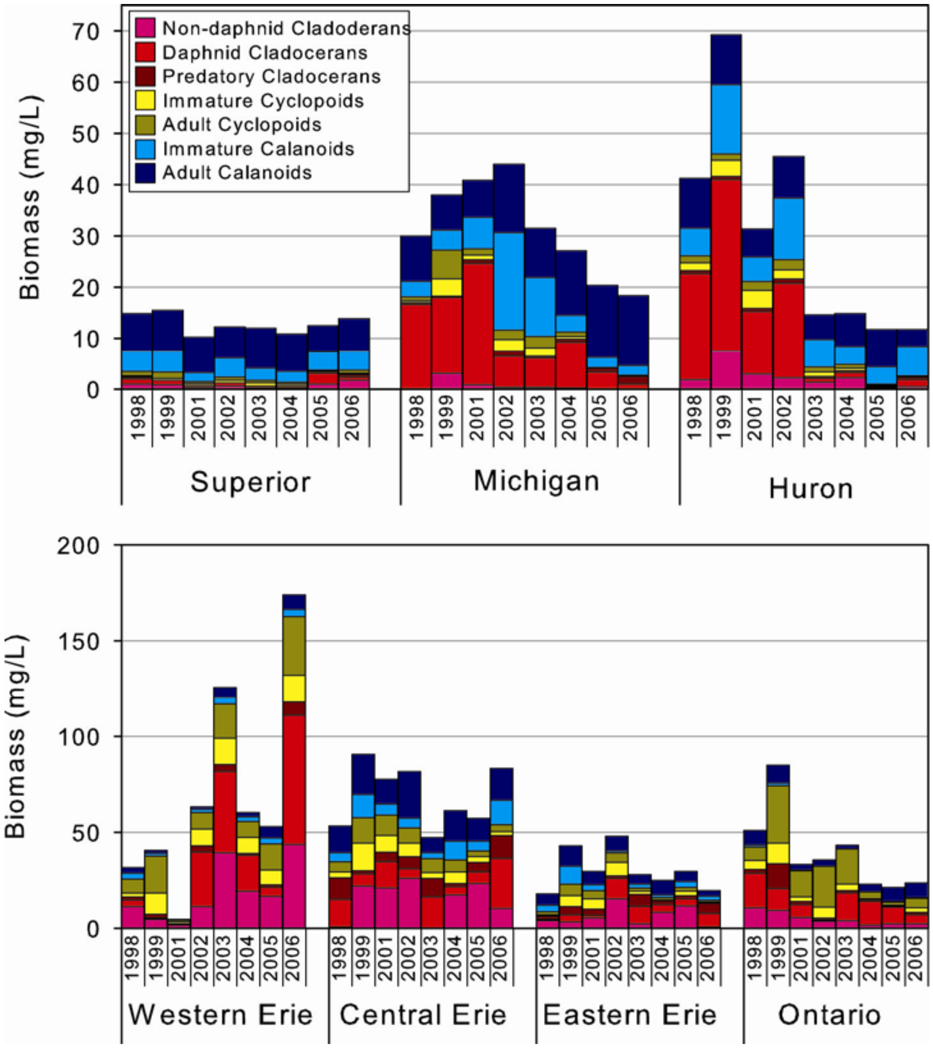
Figure 2. Average percentage of calanoid copepods (by abundance) in crustacean zooplankton communities from Great Lakes offshore stations sampled in August/September for 1998-2006 (excluding 2000).
Samples were collected with 153µm mesh net tows to a depth of 100 m or the bottom of the water column, whichever was shallower. Line at 50% level is the suggested criterion for oligotrophic lakes.
Source: U.S. Environmental Protection Agency, Great Lakes National Program Office

Figure 3. Average individual mean lengths of crustacean zooplankton in the Great Lakes in April/May and August/September for 1998-2006 (excluding 2000).
Length estimates were generated from data collected with 153 µm mesh net tows to a depth of 100 m or the bottom of the water column, whichever was shallower. Values are arithmetic averages of all sites sampled within each basin. Line at 0.8 mm is the suggested criterion for a balanced fish community.
Source: U.S. Environmental Protection Agency, Great Lakes National Program Office

Figure 4. Trend in Jun27-Sep30 mean zooplankton length.
New York Department of Environmental Conservation data (circles) collected with 153 µm mesh net, Department of Fisheries and Oceans (Canada) data (diamonds) converted from 64 µm to 153 µm mesh equivalent. Open symbols = offshore, solid symbols = nearshore (<12m). 1985-1988 are means +/- 1 S.E.
Source: Johannsson et al. (1999)

**Last Updated**

State of the Lakes Ecosystem Conference (SOLEC) 2008

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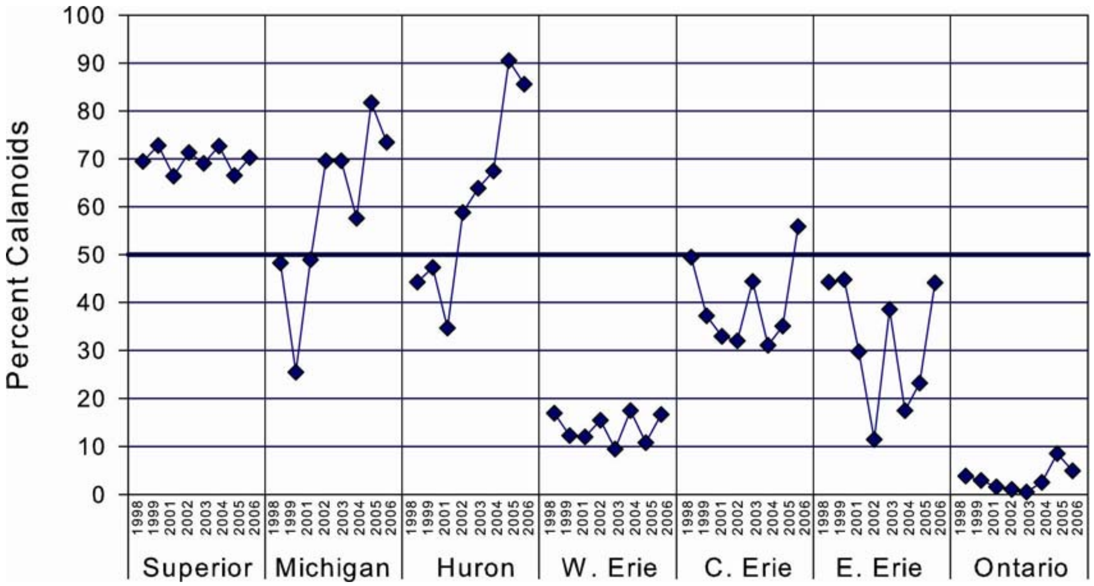


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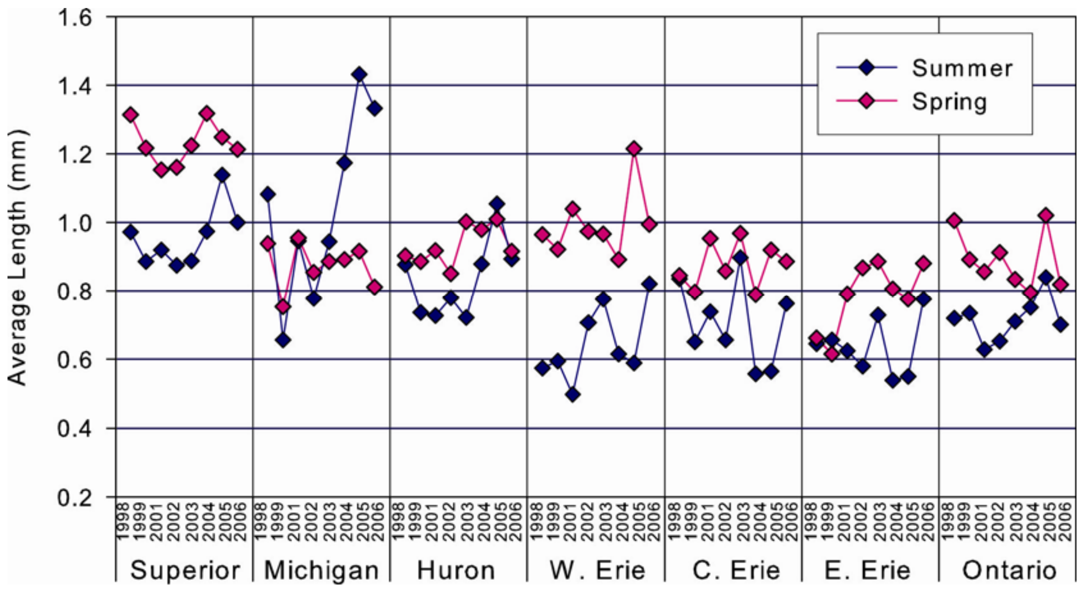


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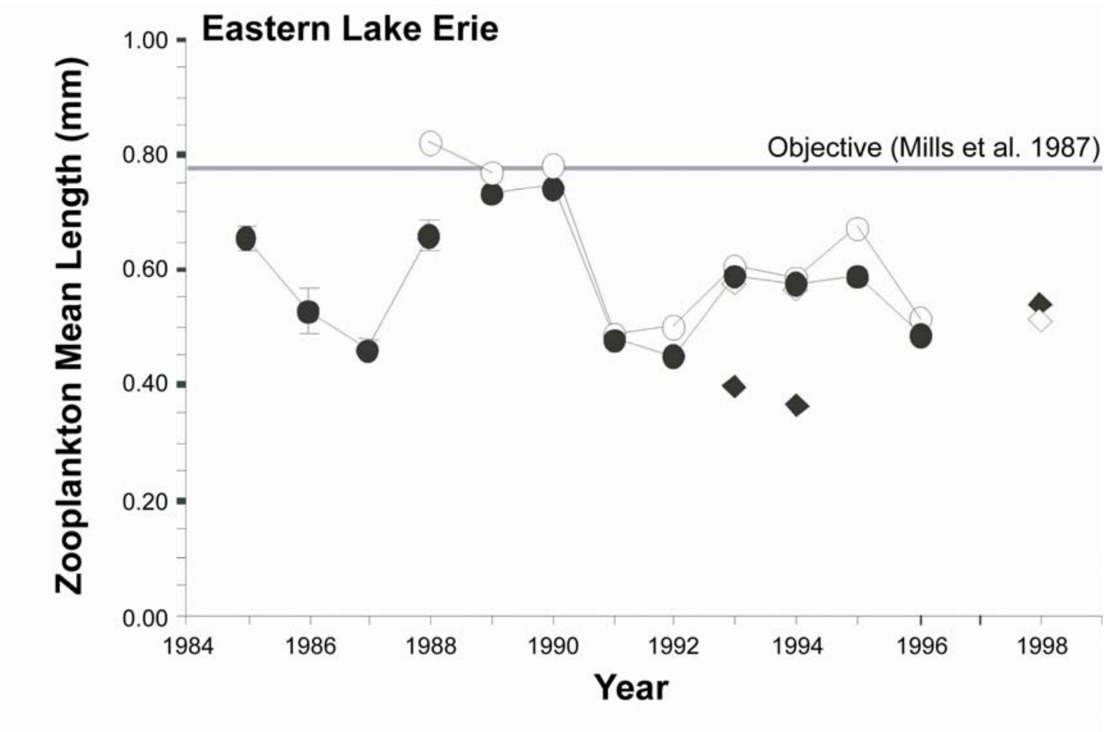


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