## Phosphorus Concentrations and Loadings

Indicator #111

**Overall Assessment**

Status: Open Lake **- Mixed**; Nearshore **- Poor**

Trend: Open Lake **– Mixed (Improving or Unchanging)**; Nearshore **- Undetermined**

Rationale: **Strong efforts that began in the 1970s to reduce phosphorus loadings have been successful in maintaining or reducing nutrient concentrations in the Great Lakes, although high concentrations still occur locally in some embayments, harbors and nearshore areas. Conditions in nearshore regions are highly dynamic, therefore an overall trend cannot be defined.**

**Lake-by-Lake Assessment**

**Lake Superior**

Status: Open Lake - Good; Nearshore - Not Assessed

Trend: Open Lake - Unchanging; Nearshore - Undetermined

Rationale: Average phosphorus concentrations in the open waters remain at or below expected levels.

**Lake Michigan**

Status: Open Lake - Good; Nearshore - Poor

Trend: Open Lake - Improving; Nearshore - Undetermined

Rationale: Average phosphorus concentrations in the open waters are at or below expected levels. Concentrations may exceed guidelines in nearshore waters for at least part of the growing season.

**Lake Huron**

Status: Open Lake - Good; Nearshore - Poor

Trend: Open Lake - Unchanging; Nearshore - Undetermined

Rationale: Average phosphorus concentrations in the open waters are at or below expected levels. Most offshore waters meet the desired guideline, but some nearshore areas and embayments experience elevated levels which likely contribute to nuisance algae growths such as the attached green algae, *Cladophora*, and toxic cyanophytes such as *Microcystis.*

**Lake Erie**

Status: Open Lake - Fair-Poor; Nearshore - Poor

Trend: Open Lake - Unchanging; Nearshore - Undetermined

Rationale: Phosphorus concentrations in the three basins of Lake Erie fluctuate from year to year and frequently exceed target concentrations. Extensive lawns of *Cladophora* are common place over the nearshore lakebed in parts of Eastern Lake Erie and are suggestive of phosphorus levels supportive of nuisance levels of algal growth.

**Lake Ontario**

Status: Open Lake - Good; Nearshore - Poor

Trend: Open Lake - Improving; Nearshore - Undetermined

Rationale: Average phosphorus concentrations in the open lake are at or below expected levels. Most offshore waters meet the desired guideline but some nearshore areas and embayments experience elevated

levels which likely contribute to nuisance algae growths such as the attached green algae, *Cladophora* and toxic cyanophytes such as *Microcystis.*

**Purpose**

- To assesses total phosphorus levels in the Great Lakes
- To support the evaluation of trophic status and food web dynamics in the Great Lakes

**Ecosystem Objective**

The goals of phosphorus control are to maintain an oligotrophic state in Lake Superior, Lake Huron and Lake Michigan; to maintain algal biomass below that of a nuisance condition in Lake Erie and Lake Ontario; and to eliminate algal nuisance growth in bays and in other areas wherever they occur (Great Lakes Water Quality Agreement (GLWQA) Annex 3, United States and Canada 1987). Maximum annual phosphorus loadings to the Great Lakes that would allow achievement of these objectives are listed in the GLWQA. The expected concentrations of total phosphorus in the open waters of the Great Lakes, if the maximum annual loads are maintained, are listed in Table 1.

**State of the Ecosystem**

Phosphorus is an essential element for all organisms and is often the limiting factor for aquatic plant growth in the Great Lakes. Although phosphorus occurs naturally, the historical problems caused by elevated levels have originated from anthropogenic sources. Detergents, sewage treatment plant effluent, agricultural runoff and industrial sources have historically introduced large amounts into the Great Lakes.

Strong efforts that began in the 1970s to reduce phosphorus loadings have been successful in maintaining or reducing nutrient concentrations in the Great Lakes, although high concentrations still occur locally in some embayments, harbors and nearshore areas. Annual phosphorus loadings have decreased in part due to changes in agricultural practices (e.g., conservation tillage and integrated crop management), promotion of phosphorus-free detergents, and improvements made to sewage treatment plants and sewer systems.

Researchers involved with phosphorus load estimation from tributaries to Lake Erie and Lake Michigan have noted that 1) phosphorus loads may be increasing after a long period of decrease and 2) an increasing proportion of the phosphorus is an available, dissolved form. Both these observations have important implications, particularly to the nearshore. More phosphorus entering the nearshore, in a form easily used by algae, could lead to more algal blooms in the lakes.

Average concentrations in the open waters of Lake Superior, Lake Michigan, Lake Huron, and Lake Ontario are at or below expected levels. Concentrations in the three basins of Lake Erie fluctuate from year to year (Figure 1). In the western and central basins, concentrations frequently exceed the target levels; in the eastern basin the target is periodically exceeded. In Lake Ontario and Lake Huron, most offshore waters meet the desired guideline, but some nearshore areas and embayments experience elevated levels which likely contribute to nuisance algae growths such as the attached green algae, *Cladophora,* and toxic cyanophytes such as *Microcystis*. For example, in the Bay of Quinte, Lake Ontario, control strategies at municipal sewage plants have reduced loadings by two orders of magnitude since the early 1970s. In spite of these controls, mean concentrations measured between May and October in the productive upper bay have remained between 30 and 35 µg/L in recent years. This level of total phosphorus is indicative of a eutrophic environment. Typical of other zebra mussel-infested and phosphorus-enriched bays in the Great Lakes, toxic cyanophytes such as *Microcystis* have increased in abundance in recent years with blooms occurring in late August and early September.

Similarly, phosphorus concentrations may exceed the guidelines in Lake Michigan nearshore waters for at least part of the growing season. Waters near Lake Michigan's eastern shoreline, when sampled in June, 2004, had a median concentration of 9µg/L. Summer sampling at the same locations yielded a median concentration of 6µg/L, but a number of sampling locations were at or above the 7 µg/L guideline. By comparison, the average open water concentration during the spring of 2004 was 3.7 µg/L. *Cladophora* growth is a problem on much of this shoreline.

In parts of eastern Lake Erie and Lake Ontario, extensive lawns of *Cladophora* are commonplace and are suggestive of phosphorus levels supportive of nuisance levels of algal growth (Higgins *et al*. 2005 and Wilson *et al*. 2006). Phosphorus levels in the Canadian nearshore of eastern Lake Erie and Lake Ontario are periodically elevated above the basin guideline of 10 µg/L. However, efforts to achieve integrated nearshore assessments of phosphorus levels or to relate phosphorus levels to growth of *Cladophora* are difficult because of the highly dynamic nature of water quality in nearshore areas. Phosphorus concentrations in the nearshore tend to be highly variable due to the influences of tributaries and other shore-based discharges, weather, biological activity and lake circulation Intensive monitoring in Lake Ontario is being undertaken during the 2008 field season to examine the importance of recycling of phosphorus in the nearshore by invasive *Dreissenid* (i.e., zebra and quagga) mussels. *Dreissenid* mussels filter large volumes of water, and in doing so they decrease the concentration of total phosphorus in the water column through the removal of particles, but they excrete soluble (i.e., dissolved) phosphorus, thereby increasing the availability of phosphorus that can be readily utilized by algae such as *Cladophora*.

**Pressures**

Even if current phosphorus controls are maintained, additional loadings can be expected. Increasing numbers of people living along the Great Lakes will exert increasing demands on existing sewage treatment facilities. Even if current phosphorus concentration discharge limits are maintained, increased populations may result in increased loads. Phosphorus management plans with target loads need to be established for major municipalities. Recent research indicates that climate change may be influencing the phosphorus loads to the Great Lakes through changes in snowmelt and storm patterns.

**Management Implications**

Because of the key role phosphorus exerts as the limiting nutrient for productivity and food web dynamics in the Great Lakes, water management and natural resource agencies must be vigilant to control phosphorus loads. Future activities that are likely to be needed include: 1) Assess the capacity and operation of existing sewage treatment plants in the context of increasing human populations being served. Utilization of state of the art technology to lower effluent concentrations below current targets should be considered for retrofits and upgrades to sewage treatment plants; 2) Conduct studies of the urban and rural nonpoint contributions of phosphorus to better our understanding of their current overall importance, especially with regards to nearshore eutrophication and *Cladophora* abundance, and 3) Conduct sufficient tributary and point source monitoring to track phosphorus loadings and to better understand the relative importance of various sources.

The data needed to support loadings calculations have not been collected since 1991 in all lakes except Lake Erie, which has loadings information up to 2002, and Lake Michigan with information for 1994 and 1995. Efforts to do so are beginning for Lakes Superior, Michigan, Huron and Ontario, and have begun for Lake Erie In addition to estimates of total phosphorus loads, efforts should be undertaken to determine the loads of available phosphorus that are now entering the Great Lakes. This unexpected change in the components of the phosphorus load may be having an influence on the observed *Cladophora* and cyanobacteria growth.

The surveillance of phosphorus concentrations in the Great Lakes is ongoing and the data are considered to be reliable. Enhanced and coordinated monitoring of nearshore sites is being conducted through Cooperative Monitoring and Collaborative Science Initiatives, specifically in Lakes Erie and Ontario. The recent reappearance of *Cladophora* in some areas of the Great Lakes strengthens the need for nearshore measurements to better understand the very dynamic nearshore environment.

**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**

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**Sources**

Dove, A., Water Quality Monitoring and Surveillance, Environment Canada, Burlington, ON.

Higgins, Scott N., Howell, E. Todd, Hecky, Robert E., Guildford, Stephanie J., and Smith, Ralph E. 2005. The Wall of Green: The Status of *Cladophora glomerata* on the Northern Shores of Lake Erie's Eastern Basin, 1995–2002. *J. Great Lakes Res.* 31(4):547-563.

Phosphorus Management Strategies Task Force. 1980. *Phosphorus Management for the Great Lakes.* Final Report to the International Joint Commission, Great Lakes Water Quality Board and Great Lakes Science Advisory Board, Windsor, ON. 125pp.

United States and Canada. 1987. Great Lakes Water Quality Agreement of 1978, as amended by Protocol signed November 18, 1987. Ottawa and Washington.

Warren, G. Great Lakes National Program Office, U.S. Environmental Protection Agency

Wilson, Karen A., Howell, E. Todd, and Jackson, Donald A. 2006. Replacement of Zebra Mussels by Quagga Mussels in the Canadian Nearshore of Lake Ontario: the Importance of Substrate, Round Goby Abundance, and Upwelling Frequency. *J. Great Lakes Res*. 32(1):11-28.

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Source: Phosphorus Management Strategies Task Force, 1980

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Blanks indicate no sampling. Horizontal line on each graph represents the expected phosphorus concentration in each lake if the annual phosphorus loading targets, as listed in the Great Lakes Water Quality Agreement, are maintained. Environment Canada data (white bars) are averages of spring, surface measurements at open lake sites. U.S. Environmental Protection Agency data (black bars) are averages of spring measurements, all depths at open lake sites.
Source: Water Quality Monitoring and Surveillance Division, Environment Canada and Great Lakes National Program Office, U.S. Environmental Protection Agency

**Last Updated**

State of the Lakes Ecosystem Conference (SOLEC) 2008

| Lake | Phosphorus Guideline (µg/L) |
|---|---|
| Superior | 5 |
| Huron | 5 |
| Michigan | 7 |
| Erie - Western Basin | 15 |
| Erie - Central Basin | 10 |
| Erie - Eastern Basin | 10 |
| Ontario | 10 |

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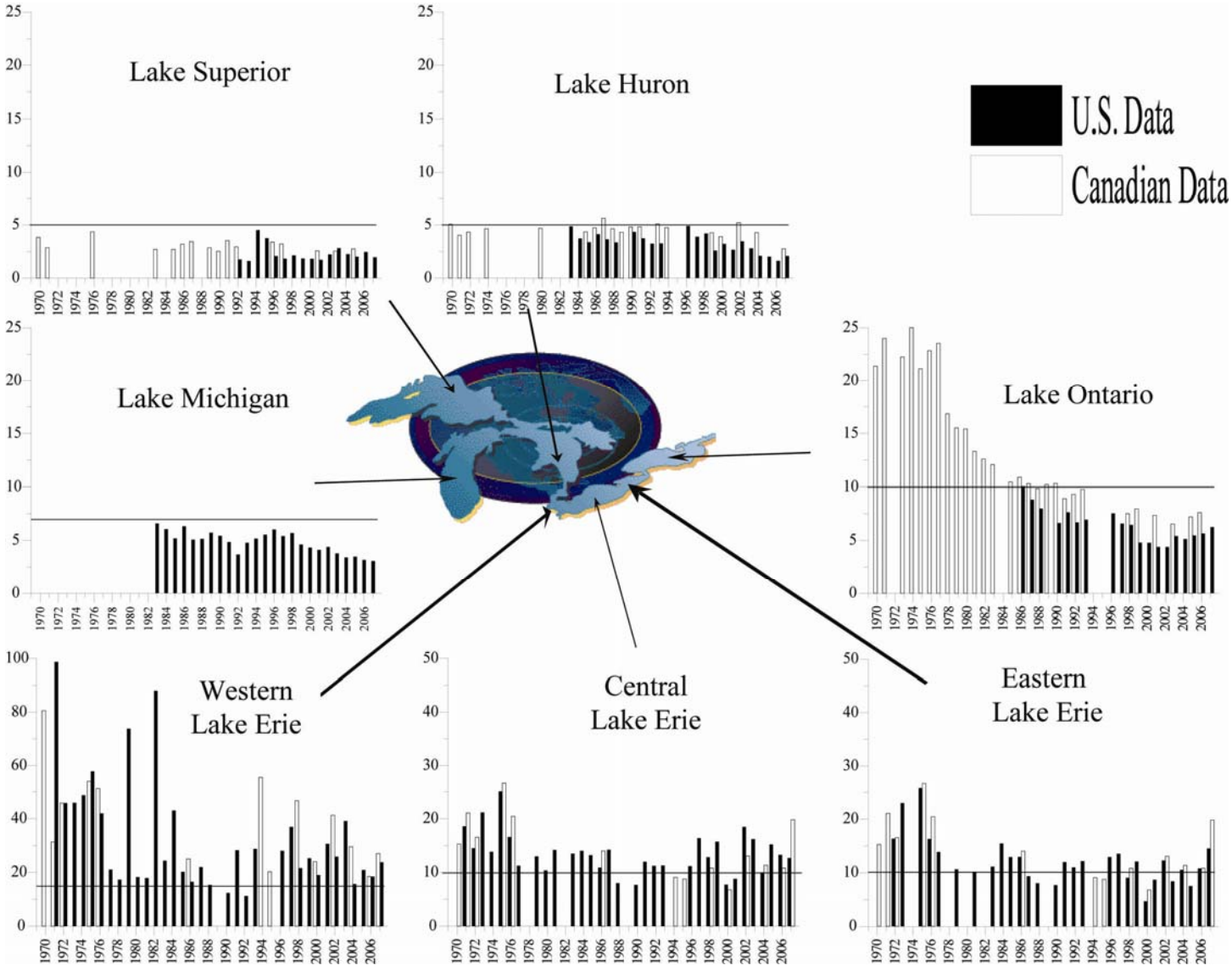
Source: Phosphorus Management Strategies Task Force, 1980

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