Environment Canada Environnement Canada

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Data Sources and Methods for the Phosphorus Levels in the Great Lakes Indicator

July 2012

Canada

ISBN : En4-144/46-2012E-PDF
Cat. No.: 978-1-100-21027-8

Aussi disponible en français

1 Introduction

The Phosphorus Levels in the Great Lakes indicator is part of the Canadian Environmental Sustainability Indicators (CESI) program (http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En), which provides data and information to track Canada's performance on key environmental sustainability issues.

2 Description and rationale of the Phosphorus Levels in the Great Lakes indicator

2.1 Description

The Phosphorus Levels in the Great Lakes Indicator compares average spring total phosphorus concentrations in the four Canadian Great Lakes to their water quality objectives to determine the status of phosphorus concentrations in offshore waters in each lake.

Water quality in the center of a lake is considered good (green) when ambient water quality measurements are close to the lake's objective. Lakes where phosphorus levels have dropped below objectives to have negative impacts on the entire offshore ecosystem have been given a caution (yellow) classification and exceedences of a lake's phosphorus objectives are classified as poor (red). Long-term trends are also presented to illustrate how phosphorus concentrations in the middle of the lakes have changed since 1970.

2.2 Rationale

Phosphorus is an essential plant nutrient; however, when concentrations in the environment are too high or too low it can have harmful impacts on the ecosystem. The water in the offshore regions of the Great Lakes has naturally low levels of phosphorus preventing algae from blooming to problem levels. In the 1970s, symptoms of excessive phosphorus concentrations due to human activity were evident in many regions across the Great Lakes. The 1978 *Canada- U.S. Great Lakes Water Quality Agreement* (http://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=88A2F0E3-1) set objectives for offshore phosphorus levels to control algal growth and, hence, the structure of the lakes' food webs. Upgrades to municipal wastewater treatment plants and limits on phosphorus concentrations in detergents started in the 1970s were successful at reducing phosphorus concentrations, particularly in Lakes Ontario and Huron. Continuing to track phosphorus levels allows governments and citizens to remain aware of an important aspect of the environmental condition of the Great Lakes.

The accidental introduction of invasive zebra (*Dreissena polymorpha*) and quagga (*Dreissena bugensis*) mussels to the Great Lakes starting in the late 1980s has dramatically altered how much phosphorus reaches offshore regions of the lakes. These mussels efficiently filter particles and phosphorus from water in the nearshore and convert it to a form that is more bioavailable to aquatic plants and algae. In this way, nuisance aquatic plants and algae can thrive close to shore where most of the mussels live while the phosphorus does not flow out to the center of the lakes for use by food webs there. In Lake Huron, and to a lesser extent Lake Ontario, the lack of phosphorus in the open water is starting to limit the growth of algae which has impacts to the rest of the food web. Important fish, algae and plankton communities are showing clear signs of change more typical of very low phosphorus environments.

3 Data

3.1 Data source

Total phosphorus status and trend data are collected under the Great Lakes Surveillance Program (http://www.ec.gc.ca/scitech/default.asp?lang=en&n=3F61CB56-1) and support the State of the Great Lakes Ecosystem Conference (http://www.ec.gc.ca/scitech/default.asp?lang=en&n=3F61CB56-1) (SOLEC) 2011 Nutrients in Lakes indicator (http://www.solecregistration.ca/en/indicator_reports.asp).

3.2 Spatial coverage

Data for this indicator cover the four Canadian Great Lakes.

3.3 Temporal coverage

Data for this indicator span from 1970 to 2010.

3.4 Data completeness

Currently, each lake is monitored by Environment Canada every two years with several monitoring cruises typically conducted in that year. Gaps exist in the data since the 1970s because of program changes and weather and mechanical issues with the ships used to collect the data. These data gaps have no major impact on the statistical trend analysis because of the length of the phosphorus monitoring record for the Great Lakes.

3.5 Data timeliness

The Phosphorus Levels in the Great Lakes indicator was calculated using the most recent water quality data available for each lake. The trend information was calculated using data from 1970 to 2010.

4 Methods

4.1 Methods

A complete description of how this indicator is calculated is available from 2011 SOLEC Nutrients in Lakes indicator (http://www.solecregistration.ca/en/indicator_reports.asp).

Briefly, average offshore spring total phosphorus concentrations in each lake were compared to water quality objectives for each lake defined in the 1978 *Canada- U.S. Great Lakes Water Quality Agreement* (http://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=88A2F0E3-1) (Table 1). Spring-time phosphorus concentrations are used because they represent the annual maximum concentration.

To calculate the long-term trends, the data were restricted to water samples collected at offshore locations. For Lake Huron and Georgian Bay, these samples were taken from stations with depths ≥ 50 m. Samples taken from stations with depths ≥ 100 m were used for Lake Ontario and depths ≥ 150 m for Lake Superior. Lake Erie is shallow relative to the other lakes and is divided into three basins. Linear regression was used to examine changes in mean phosphorus levels over the entire length of the data record.

The status of phosphorus levels in the Great Lakes were categorized into three categories: good (green), caution (yellow) and poor (red). These assessed categories differ slightly from designations used in SOLEC. The caution category has been used to signal recent changes to the lake ecosystems based on the concentration of phosphorus in offshore water. The status categories for this indicator were determined by comparing the most recent average spring total phosphorus concentration to:

1. the water quality objectives as the maximum acceptable level;
2. the 40-y trend for phosphorus levels as a reference point of a possible optimal level for phosphorus in a given lake; and
3. trends for related SOLEC indicators, especially abundance trends for algae and preyfish species dependent on algal populations.

4.2 Discussion of the results

For Lake Superior, spring average total phosphorus concentrations have not changed significantly since 1970 and have never approached the water quality object of 5 µg P/L. Plankton and preyfish populations are healthy in Lake Superior resulting in the good classification.

For Lake Huron and Georgian Bay, total phosphorus concentrations were close to the objective from 1970 until 1998 when they started to decline. For Lake Ontario, total phosphorus concentrations have declined from very high levels in 1970, dropping below the objective and continuing to decline to historic lows. Open water plankton, algae and preyfish populations in Lake Huron, Georgian Bay and Lake Ontario are showing signs of decline and low total phosphorus levels are contributing to this decline[1][2]; thus, these three systems were given the caution designation.

Lake Erie's western and central basins continue to have average spring total phosphorus concentrations greater than twice the basin's water quality objective and received the poor designation. In Lake Erie's deeper eastern basin average spring total phosphorus concentrations continue to decline and, although the rate of decline has recently slowed, it was classified as good.

[1] Barbiero RP (2011) Phytoplankton Populations. Draft State of the Great Lakes 2012 Indicator. State of the Lakes Ecosystem Conference 2011. Erie, Pennsylvania. Retrieved on 21 March 2012. Available from: http://www.solecregistration.ca/en/indicator_reports.asp.

[2] Gorman, OT (2011) Preyfish Populations. Draft State of the Great Lakes 2012 Indicator. State of the Lakes Ecosystem Conference 2011. Erie, Pennsylvania. Retrieved on 21 March 2012. Available from: http://www.solecregistration.ca/en/indicator_reports.asp.

Table 1: Average, spring total phosphorus concentrations for the open waters of the Canadian Great Lakes and their total phosphorus water quality objectives.

Lake	Total Phosphorus Water Quality Objective (µg P/L)	Average Spring Total Phosphorus Concentration (µg P/L)	Year of Most Recent Measurement	Status
Superior	5	3	2008	Good
Huron	5	2.7	2009	Caution
Georgian Bay	5	2.6	2009	Caution
Erie – Western Basin	15	58	2009	Poor
Erie – Central Basin	10	22.7	2009	Poor
Erie – Eastern Basin	10	9.4	2009	Good
Ontario	10	6.4	2010	Caution

5 Caveats and Limitations

The categories used to describe the lakes in this indicator differ from those used in the 2011 SOLEC Nutrients in Lakes indicator (http://www.solecregistration.ca/en/indicator_reports.asp). The SOLEC indicators categorize lakes as good, fair or poor based on the proximity of the average, spring total phosphorus concentrations to their respective objectives. The issue of having too little phosphorus was not conceived of when the 1978 *Canada- U.S. Great Lakes Water Quality Agreement* (http://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=88A2F0E3-1) was written. Recent changes to the phosphorus concentrations in Lakes Ontario and Huron ecosystems are highlighted by including the caution category.

The Phosphorus Levels in the Great Lakes Indicator reflects the overall state of phosphorus levels in the offshore of the Great Lakes and does not indicate nearshore phosphorus levels. Nearshore phosphorus levels for the Great Lakes are reported in the SOLEC Nutrient in Lakes Indicator but are not included here because there are currently no nearshore water quality objectives. Similarly, offshore data from the United States are not included in this indicator.

Comparisons with river systems may be challenging. In lake ecosystems suspended particles will always settle out. Water quality for each Great Lake is determined by comparing average, spring offshore total phosphorus concentrations to the lake's water quality objective. This differs from assessing water quality for a river system, where total phosphorus concentrations are influenced by suspended particles in the water that increase during high-flow events. It is still reasonable to compare lake and river systems as long as the methods are clear and documented.

6 References and further reading

6.1 References

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6.2 Further reading

Environment Canada (2011) Phosphorus in Canada's Aquatic Ecosystems. Retrieved on 20 March 2012.
Available from: http://www.ec.gc.ca/eaudouce-freshwater/default.asp?lang=En&n=B61C9777-1.

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Hinderer JM, Murray MW, & Becker T (2011) Feast and Famine in the Great Lakes: How Nutrients and Invasive Species Interact to Overwhelm the Coasts and Starve Offshore Waters. Retrieved on 3 May 2012.
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Additional information can be obtained at:
Environment Canada
Inquiry Centre
10 Wellington Street, 23rd Floor
Gatineau, QC K1A 0H3
Telephone: 1-800-668-6767 (in Canada only) or 819-997-2800
Fax: 819-994-1412
TTY: 819-994-0736
Email: Enviroinfo@ec.gc.ca