Environment and Climate Change Canada
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PHOSPHORUS LEVELS IN THE OFFSHORE WATERS OF THE GREAT LAKES

CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

Canada

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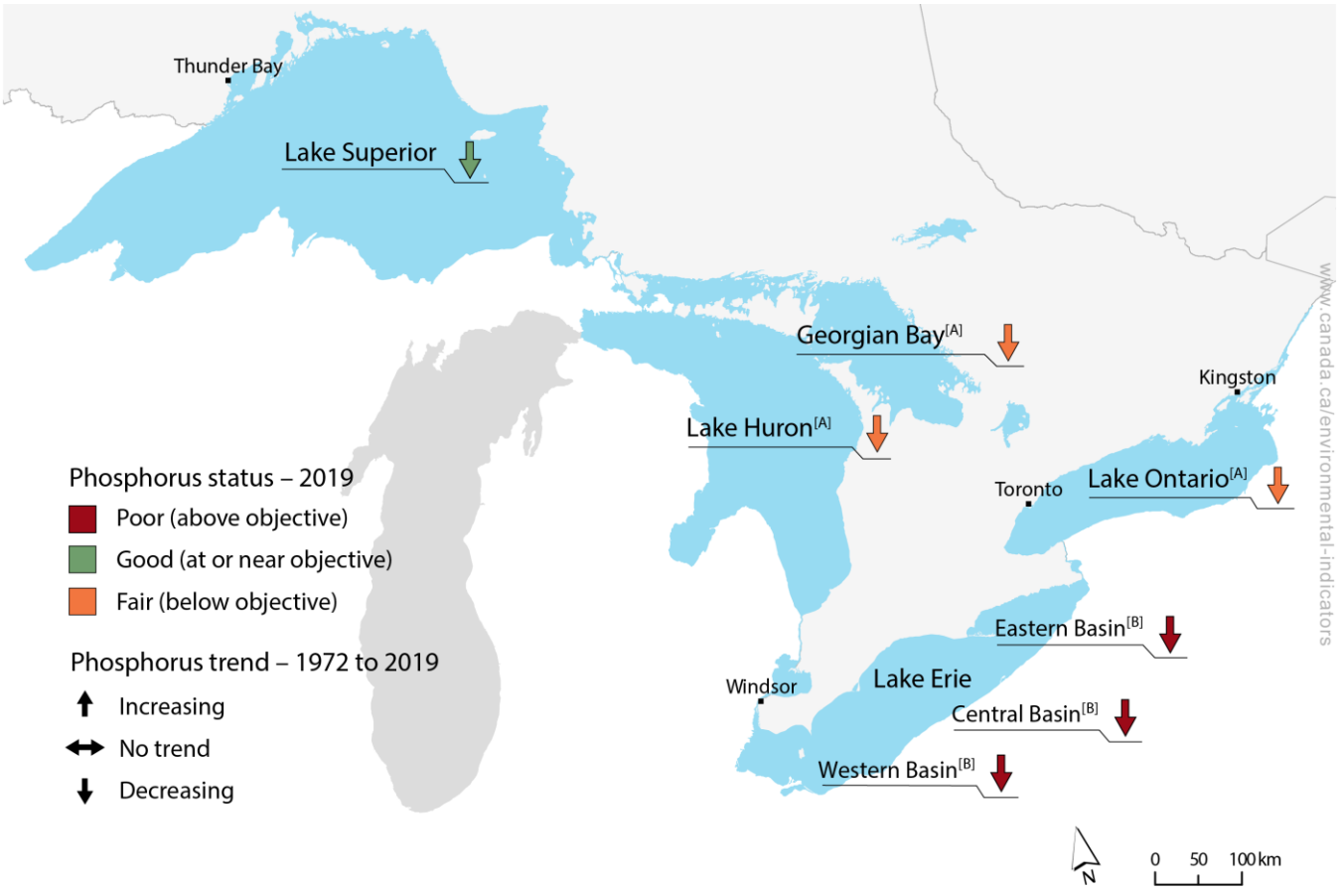
Phosphorus levels in the offshore waters of the Great Lakes

Phosphorus is an essential plant nutrient. When phosphorus levels are too high or too low, they can have harmful impacts on a lake's food web. For example, when phosphorus levels are too high, they can lead to degraded water quality, algal blooms and zones of low oxygen which harm aquatic life. Conversely, when they are too low, they can reduce the lake's productivity. Phosphorus levels are one aspect of the health of the offshore waters of the Great Lakes.

Key results

- As of 2019, phosphorus levels were:
  - too high in the offshore waters of Lake Erie, resulting in a Poor status
  - too low in the offshore waters of Lake Ontario, Lake Huron and Georgian Bay, resulting in a Fair status
  - at the level they should be in the offshore waters of Lake Superior, resulting in a Good status

Figure 1. Status and trends of phosphorus levels in the offshore waters of the Canadian Great Lakes, 1972 to 2019



Data for Figure 1

Note: Water quality in the offshore regions of a lake is considered Good when it can support a healthy food web. The classification Fair indicates phosphorus levels are below a lake's phosphorus objectives and negative impacts to the offshore food web have been observed. The classification Poor indicates phosphorus levels are above a lake's phosphorus objectives. Long-term trends on phosphorus levels in the offshore areas of the lakes since 1972 were calculated using linear regression. [A] Decreasing further below the objective. [B] Decreasing over the long-term but still above the objectives.
Source: Environment and Climate Change Canada (2020).

Phosphorus is found in several products including detergents, fertilizers, manure, human waste and decaying plants. Phosphorus reaches rivers and lakes through erosion and leaching from urban areas, farmland runoff, municipal and industrial wastewater discharges, and air pollution. Although governments, municipalities, farmers and citizens are making efforts to reduce releases to water, phosphorus levels continue to be an issue in the offshore areas for 3 of the 4 Canadian Great Lakes.

For Lake Superior, spring average phosphorus levels in offshore waters have declined very slowly since 1972. Over that period, phosphorus levels have remained consistently below the lake's water quality objective of 5 micrograms of phosphorus per litre. However, the phosphorus levels status for Lake Superior is still considered Good, as the lake continues to support a healthy food web, including healthy plankton and preyfish populations.

In the offshore waters of Lake Huron and Georgian Bay, phosphorus levels were close to the objective of 5 micrograms of phosphorus per litre from 1972 until the late 1990s when they started to decline, dropping below the objective. In Lake Ontario's offshore waters, levels have declined from very high levels in 1972, dropped below the phosphorus objective of 10 micrograms of phosphorus per litre in the late 1980s, and continue to decline to historic lows. These 3 systems are given the designation of Fair. This designation means that rather than exceeding the objectives, phosphorus levels fall below objectives. This lack of offshore nutrients is likely having a negative impact on the lake's productivity. For example, open-water plankton, algae and preyfish populations in Lake Huron, Georgian Bay and Lake Ontario are showing signs of the impacts of these declines and low phosphorus levels are contributing to this stress.[1]

In recent years, there has been an increase in toxic and nuisance algae in Lake Erie that has been linked, at least in part, to phosphorus levels. The offshore waters of Lake Erie's eastern, central and western basins continue to have levels exceeding each basin's expected level, giving it a Poor status. While there has been an overall decrease in phosphorus levels from 1972 to 2019, recent changes are difficult to interpret because of the highly variable nature of the data. For example in 2019, a majority of samples taken from the western basin of the lake met the expected level. In contrast, in 2017 and 2013, samples from the same stations were above the expected level. Variations like these may be attributed to changes in the amount and frequency of precipitation from one year to another, which in turn affects runoff from nearby lands into the lakes.

Lake ecosystems are complex, and phosphorus levels in offshore environments can be different from levels measured in nearshore environments. While offshore phosphorus levels are reaching unprecedented lows in some of the lakes, which may be linked to invasive mussel species colonizing the lakes and intercepting the phosphorus, many nearshore regions of the Great Lakes are experiencing nuisance algae problems due to excessive concentrations of nutrients in these areas.[1]

About the indicator

What the indicator measures

This indicator reports total phosphorus levels in the offshore waters of the 4 Canadian Great Lakes.

The indicator assumes water in the Great Lakes would never be above phosphorus water quality objectives in the absence of human development. It provides information on how human activity contributes to phosphorus levels in lakes.

A lake's phosphorus status is determined by comparing spring total phosphorus levels to its water quality objectives and the health of the lake's food web. Failure to meet a water quality objective for phosphorus, either due to levels being too low or too high, suggests a greater risk to the health of the lake ecosystem.

Why this indicator is important

Clean freshwater is an essential resource. It protects aquatic plant and animal biodiversity. We use it for manufacturing, energy production, irrigation, swimming, boating, fishing and for domestic use (for example, drinking, washing). Degraded water quality damages the health of all freshwater ecosystems, such as rivers,

[1] Dove A and Chapra SE (2016) Long-term trends in nutrients and trophic response variables for the Great Lakes. Limnology and Oceanography 60(2):696-721. Retrieved on January 31, 2020.

lakes, reservoirs and wetlands. It can also disrupt fisheries, tourism and agriculture, and make it more expensive to treat to drinking water standards. When phosphorus levels in water become too high, aquatic plant growth can become excessive and harmful. The decay of excess plant material can reduce the amount of oxygen available for fish and other aquatic animals. High nutrient levels can also lead to harmful algal blooms which can kill wildlife that live in or use the water, and affect human health. Conversely, too little phosphorus can result in not enough plant or algal growth to support a lake's food web, which could reduce fish populations and harm local fisheries.

Pristine lakes and rivers

This indicator supports the measurement of progress towards the following 2019 to 2022 Federal Sustainable Development Strategy long-term goal: Clean and healthy lakes and rivers support economic prosperity and the well-being of Canadians.

In addition, the indicator contributes to the Sustainable Development Goals of the 2030 Agenda for Sustainable Development. It is linked to the 2030 Agenda's Goal 6, Clean water and sanitation, and Target 6.3, "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally," and Target 6.6, "By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes."

The indicator also contributes towards reporting on Target 10 of the 2020 Biodiversity goals and targets for Canada: "By 2020, pollution levels in Canadian waters, including pollution from excess nutrients, are reduced or maintained at levels that support healthy aquatic ecosystems."

Related indicators

The Restoring the Great Lakes Areas of Concern indicator assesses progress towards the restoration of Canada's 17 Great Lakes areas of concern.

The Nutrients in the St. Lawrence River and Nutrients in Lake Winnipeg indicators report the status of total phosphorus and total nitrogen levels in these 3 ecosystems.

Reductions in phosphorus loads to Lake Winnipeg reports the amount of phosphorus no longer reaching Lake Winnipeg due to completed stewardship projects

The Water quality in Canadian rivers indicators provide a measure of the ability of river water across Canada to support plants and animals.

Data sources and methods

Data sources

Environment and Climate Change Canada collects the total phosphorus data used to calculate the status and trends in the offshore waters of the 4 Canadian Great Lakes. The indicator is calculated using the most recent data available for each lake.

More information

Total phosphorus ratings reported in the indicator are based on spring measurements taken in 2017 for Lake Huron and Georgian Bay, 2018 for Lake Ontario, and in 2019 for Lake Superior and the western, central and eastern basins of Lake Erie.

The total phosphorus objectives used in this indicator are the interim substance objectives for total phosphorus concentration in open waters published in the 2012 Great Lakes Water Quality Agreement.

For the trend analysis, total phosphorus data from 1972 to 2017 are used for Lake Huron and Georgian Bay, from 1972 to 2018 for Lake Ontario, and from 1972 to 2019 for Lake Superior and the western, central and eastern basins of Lake Erie.

The Great Lakes are monitored by Environment and Climate Change Canada on a schedule that permits the assessment of status and trends. In general, Lake Ontario and Lake Erie tend to be monitored every year or every 2 years, and Lake Huron, Georgian Bay and Lake Superior are monitored every 2 to 3 years. Sampling is typically conducted in both spring and summer. There are gaps in the data collected since the 1970s due to program changes or operational issues, such as weather and mechanical problems with the ships used to collect the data.

Methods

Average open-water, spring-time total phosphorus surface water concentrations in each lake are compared to water quality objectives.[2] The status of phosphorus levels in the offshore waters of the Great Lakes are categorized as Good (at or near the objective), Fair (below the objective) or Poor (above the objective).[3]

For the trend analysis, linear regression is used to examine changes in mean total phosphorus levels over the entire length of the data record.

More information

Calculation of phosphorus status for the Great Lakes

Spring (late March to late May) phosphorus concentrations are compared to water quality objectives because they typically represent the annual maximum concentration of phosphorus in the lakes.

The status categories for this indicator are determined by comparing the most recent average spring total phosphorus concentration to:

- the water quality objectives
- the long-term trends for phosphorus concentrations in the lake
- the trends for related State of the Great Lakes indicators,[4] especially abundance trends for algae and preyfish, as these reflect the lake's ecological health

Phosphorus levels categories are defined as:

- Good (at or near objective), if concentrations are below or close to the lake's objective, and no long-term changes to the lake ecosystems are observed
- Fair (below objective), if concentrations are below the lake's objective and recent deterioration in algal, zooplankton and preyfish populations caused by low phosphorus concentrations are observed
- Poor (above objective), if concentrations are above the lake's objective

Trend Analysis

To calculate the long-term trends, the data are restricted to surface water samples collected at offshore locations, because offshore waters are less influenced by local pollutant discharges than nearshore, shallow waters. For Lake Huron and Georgian Bay, these samples are taken from stations with depths greater than or equal to 50 metres. Samples taken from stations with depths greater than or equal to 100 metres are used for Lake Ontario and depths greater than or equal to 150 metres for Lake Superior. Lake Erie is shallow relative to the other lakes and is instead divided into its 3 basins. Least squares regression is used to examine changes in mean phosphorus concentrations over the entire length of the data record.[5] Recent trends are additionally assessed on a lake-by-lake basis.

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[2] The water quality objectives are the level of nutrient loadings expected for the lake's ecological functions to operate at acceptable levels.

[3] Due to the complex nature of the lake's ecosystem, the categories Good, Fair, and Poor do not have numerical values associated to them; rather, they provide a qualitative indication of the health of the lake.

[4] Environment and Climate Change Canada and the U.S. Environmental Protection Agency (2017) State of the Great Lakes 2017 Technical Report (PDF; 22.7 MB). Retrieved on January 31, 2020.

[5] Dove A and Chapra SE (2016) Long-term trends in nutrients and trophic response variables for the Great Lakes. Limnology and Oceanography 60(2):696-721. Retrieved on January 31, 2020.

Although some gaps exist in the data collected since the 1970s, these have no major impact on the statistical trend analysis because of the length of the phosphorus monitoring record for the Great Lakes.

Caveats and limitations

The indicator reflects the overall state of phosphorus levels in the offshore waters of the Great Lakes and only includes data collected by Environment and Climate Change Canada. Offshore data from the United States are not included in this indicator, unless they were collected by Environment and Climate Change Canada in United States waters, in which case they have been included for all lakes. The indicator excludes nearshore phosphorus levels because there are currently no nearshore water quality objectives.

The indicator reflects the state of water quality in the Great Lakes based on total phosphorus concentrations. These concentrations do not show the effects of spills or other transient events, unless these are frequent or long-lasting.

Comparing this indicator with similar indicators for rivers requires a degree of caution. In lakes, suspended particles tend to settle out. Water quality for each Great Lake is determined by comparing average, spring-time 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 to determine the classifications are clear.

Resources

References

Dove A and Chapra SE (2016) Long-term trends in nutrients and trophic response variables for the Great Lakes. Limnology and Oceanography 60(2): 696-721. Retrieved on January 31, 2020.

Environment and Climate Change Canada (2015) Phosphorus in Canada's aquatic ecosystems. Retrieved on January 31, 2020.

Environment and Climate Change Canada and the U.S. Environmental Protection Agency (2017) State of the Great Lakes 2017 Technical Report (PDF; 22.7 MB). Retrieved on January 31, 2020.

Hinderer JM, Murray MW and 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 January 31, 2020.

Related information

How the Great Lakes are doing
Great Lakes protection
Recommended binational phosphorus targets
Canada-Ontario Lake Erie action plan
State of the Great Lakes 2017 Technical Report
State of the Great Lakes 2019 Highlights Report

Annex

Annex A. Data table for the figure presented in this document

Table A.1. Data for Figure 1. Status and trends of phosphorus levels in the offshore waters of the Canadian Great Lakes, 1972 to 2019

Lake	Phosphorus water quality objective (micrograms of phosphorus per litre)	Spring phosphorus level (micrograms of phosphorus per litre)	Year of most recent measurement	Status for offshore waters	Long-term trend (1972 to present)
Superior	5	2.5	2019	Good	Decreasing
Huron	5	2.1	2017	Fair	Decreasing[B]
Georgian Bay	5	2.2	2017	Fair	Decreasing[B]
Erie: Western basin	12[A]	12.2	2019	Poor	Decreasing[C]
Erie: Central basin	6[A]	11.9	2019	Poor	Decreasing[C]
Erie: Eastern basin	6[A]	8.9	2019	Poor	Decreasing[C]
Ontario	10	6.3	2018	Fair	Decreasing[B]

Note: Water quality in the offshore regions of a lake is considered Good when it can support a healthy food web. The classification Fair indicates phosphorus levels are below a lake's phosphorus objectives and negative impacts to the offshore food web have been observed. The classification Poor indicates phosphorus levels are above a lake's phosphorus objectives. Long-term trends on phosphorus levels in the offshore areas of the lakes since 1972 were calculated using linear regression. [A] Interim phosphorus water quality objectives for Lake Erie basins are based on the recommended binational phosphorus targets: https://www.epa.gov/glwqa/recommended-binational-phosphorus-targets. [B] Decreasing further below the objective. [C] Decreasing over the long-term but still above the objectives.
Source: Environment and Climate Change Canada (2020) and interim phosphorus water quality objectives for Lake Erie basins are based on the recommended binational phosphorus targets: https://www.epa.gov/glwqa/recommended-binational-phosphorus-targets.

Additional information can be obtained at:

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