Environment and Climate Change Canada
Environnement et Changement climatique Canada

PHOSPHORUS LEVELS IN THE OFFSHORE WATERS OF THE GREAT LAKES

CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

Canada

Suggested citation for this document: Environment and Climate Change Canada (2025) Canadian Environmental Sustainability Indicators: Phosphorus levels in the offshore waters of the Great Lakes. Consulted on *Month day, year*.
Available at: www.canada.ca/en/environment-climate-change/services/environmental-indicators/phosphorus-levels-off-shore-great-lakes.html.

Cat. No.: En4-144/46-2025E-PDF
ISBN: 978-0-660-74444-5
Project code: EC24019

Environment and Climate Change Canada
Public Inquiries Centre
Place Vincent Massey Building
351 Saint-Joseph Boulevard
Gatineau QC K1A 0H3
Toll Free: 1-800-668-6767
Email: enviroinfo@ec.gc.ca

Aussi disponible en français

CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

PHOSPHORUS LEVELS IN THE OFFSHORE WATERS OF THE GREAT LAKES

January 2025

Table of contents

List of Figures

List of Tables

Phosphorus levels in the offshore waters of the Great Lakes

Phosphorus is an essential and naturally occurring nutrient in aquatic ecosystems and an important water quality parameter that can be an indicator of the health of a lake. 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 the levels are too low, there are less plants or algae to support the lake's food web which could reduce the populations of fish and plankton.

This indicator presents the status and trends of spring phosphorus levels in the offshore waters of the Canadian Great Lakes. Offshore rather than nearshore phosphorous levels are used because they better represent long-term trends, and are less influenced by local pollutant sources that are found in Lake's nearshore.

Status and trends of phosphorus levels

Phosphorus status is provided for each Canadian Great Lake by comparing the phosphorus spring level with the objectives for the lakes. Spring levels are used for this indicator because they typically represent the annual maximum levels of phosphorus in the lakes.

Status assessments are defined as follows: Good when the phosphorus level meets the lake objective, and it is neither too high nor too low. Fair when the phosphorus level meets the lake objective, but it is low enough to show negative impacts on algal, zooplankton and preyfish populations. Poor when the phosphorus level is above the lake objective and shows negative impacts such as stimulating excessive and possibly toxic algal growth.

Key results

As of 2023, phosphorus levels were:

- too high in the offshore waters of Lake Erie[1], 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 or near the objective for Lake Superior, resulting in a Good status

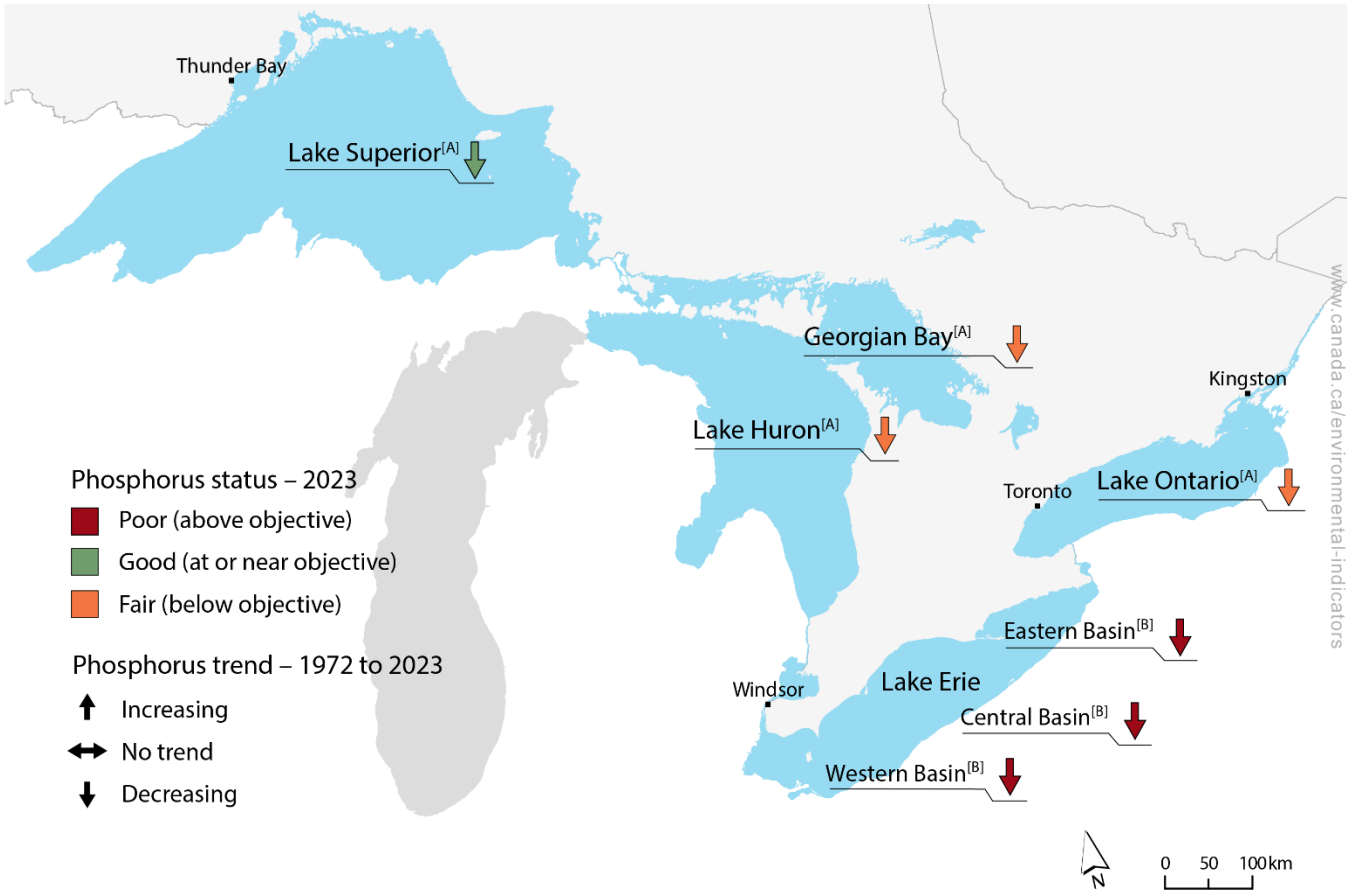
Long-term trends (1972-2023) of phosphorus levels in the offshore areas of the lakes are defined as increasing, decreasing or not showing changes. Improvement or deterioration will depend on whether the trends bring levels nearer to or further from the lake's objectives.

Between 1972 and 2023:

- All lakes except Lake Erie showed decreasing levels, further below the lakes' objectives
- Lake Erie also showed decreasing levels, but they are still over the lake's objective

[1] Although the Phosphorus concentration value is slightly lower and below target in the western basin, there is not enough change in value and limited data in this update for a status change.

Figure 1. Status and trends of phosphorus levels in the offshore waters of the Canadian Great Lakes, 1972 to 2023



Data for Figure 1

Note: The classification Good indicates that phosphorus levels in the offshore regions of a lake are close to the lake's objective and it contributes to a healthy food web. The classification Fair indicates that 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 (2024).

Phosphorus is found in several substances 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, dropping below the objective of 10 micrograms of phosphorus per litre in the late 1980s and continues 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 and food web. 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.[2]

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 2023, it has not been consistent over the years. For example, in 2023, 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. Offshore phosphorus levels are reaching unprecedented lows in some of the lakes. These conditions are in part linked to well-established invasive mussel populations that are intercepting phosphorus in the nearshore. Many nearshore regions of the Great Lakes are experiencing elevated nutrient levels and problems from nuisance algae growth and accumulation.[2]

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 insight 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, 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 and algae 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 affect local fisheries.

Related initiatives

This indicator contributes to the Sustainable Development Goals of the 2030 Agenda for Sustainable Development. It is linked to Goal 6, Clean water and sanitation, 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."

In addition, the indicator contributes towards reporting on Target 7 of Canada's 2030 Nature Strategy: "Pollution and Biodiversity". This target is related to Target 7 of the Kunming-Montreal Global Biodiversity Framework:

[2] 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 October 23, 2024.

"Reduce pollution risks and the negative impact of pollution from all sources, by 2030, to levels that are not harmful to biodiversity and ecosystem functions and services, considering cumulative effects, including: reducing excess nutrients lost to the environment by at least half including through more efficient nutrient cycling and use; reducing the overall risk from pesticides and highly hazardous chemicals by at least half including through integrated pest management, based on science, taking into account food security and livelihoods; and also preventing, reducing, and working towards eliminating plastic pollution."

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 Phosphorus loading to Lake Erie indicators report on the total phosphorus loadings flowing directly into Lake Erie or from its tributary rivers.

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.

The Risk to soil and water quality from agriculture indicators provide Agri-environmental performance indices for soil and water quality in Canada.

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 statuses reported in the indicator are based on spring measurements taken in 2019 for Lake Superior, in 2022 for Lake Huron and Georgian Bay and in 2023 for Lake Ontario 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 level in open waters published in the 2012 Great Lakes Water Quality Agreement.

For the trend analysis, total phosphorus data from 1972 to 2019 are used for Lake Superior, from 1972 to 2022 for Lake Huron and Georgian Bay, and from 1972 to 2023 for Lake Ontario 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, while 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. Due to health measures related to COVID-19, some sampling activities and laboratory analyses were cancelled in 2020 and 2021 for all lakes, and in 2022 for Lake Erie and Lake Superior.

Methods

Average open-water, spring-time total phosphorus surface water levels in each lake are compared to water quality objectives.[3] 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).[4]

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 levels are compared to water quality objectives because they typically represent the annual maximum level of phosphorus in the lakes.

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

- the water quality objectives
- the long-term trends for phosphorus levels in the lake
- the trends for related State of the Great Lakes indicators,[5] especially abundance trends for algae and preyfish, as these reflect the lake's ecological health

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

[4] 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.

[5] Environment and Climate Change Canada and the U.S. Environmental Protection Agency (2022) State of the Great Lakes 2022 Nutrients in Lakes Technical Report (PDF; 2.8 MB). Retrieved on October 24, 2024.

Phosphorus levels categories are defined as:

- Good (at or near objective), if levels are meeting the lake objective, and it is neither too high nor too low, and no long-term changes to the lake ecosystems are observed
- Fair (below objective), if levels are meeting the lake objectives and recent deterioration in algal, zooplankton and preyfish populations caused by low phosphorus levels are observed
- Poor (above objective) if levels are above the lake's objective and exhibit negative impacts such as stimulating excessive and possibly toxic algal growth

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. These surface water samples were taken at stations with various depths, depending on the lake:

- Lake Huron and Georgian Bay: stations with depths greater than or equal to 50 metres
- Lake Ontario: stations with depths greater than or equal to 100 metres
- Lake Superior: stations with depths greater than or equal to 150 metres
- 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 levels over the entire length of the data record.[6] Recent trends are additionally assessed on a lake-by-lake basis.

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 Canadian 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 levels. These levels 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 levels to the lake's water quality objective. This differs from assessing water quality for a river system, where total phosphorus levels 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 October 23, 2024.

Environment and Climate Change Canada (2015) Phosphorus in Canada's aquatic ecosystems. Retrieved on October 23, 2024.

[6] 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 October 23, 2024.

Environment and Climate Change Canada and the U.S. Environmental Protection Agency (2022) State of the Great Lakes 2022 Technical Report: Nutrients in Lakes (PDF; 2.8 MB). Retrieved on October 23, 2024.

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 October 23, 2024.

U.S. Environmental Protection Agency (2024) Recommended Binational Phosphorus Targets. Retrieved on October 23, 2024

Related information

Canada Water Agency

How the Great Lakes are doing

Great Lakes Freshwater Ecosystem Initiative

Canada-Ontario Lake Erie action plan

State of the Great Lakes 2022 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 2023

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[B]
Huron	5	2.9	2022	Fair	Decreasing[B]
Georgian Bay	5	2.9	2022	Fair	Decreasing[B]
Erie: Western basin	12[A]	9.5[D]	2023	Poor	Decreasing[D]
Erie: Central basin	6[A]	14.7	2023	Poor	Decreasing[C]
Erie: Eastern basin	6[A]	10.5	2023	Poor	Decreasing[C]
Ontario	10	5.9	2023	Fair	Decreasing[B]

Note: The classification Good indicates that phosphorus levels in the offshore regions of a lake are close to the lake's objective and it contributes to 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.[D] Although the value is slightly lower and below target, there is not enough change in value/limited data in this update for a status change.
Source: Environment and Climate Change Canada (2024).

Additional information can be obtained at:

Environment and Climate Change Canada
Public Inquiries Centre

Place Vincent Massey Building
351 Saint-Joseph Boulevard
Gatineau QC K1A 0H3
Toll Free: 1-800-668-6767
Email: enviroinfo@ec.gc.ca