Sub-Indicator: Nutrients in Lakes

Overall Assessment

Status: Fair

Trends:

10-Year Trend: Unchanging

Long-term Trend (1970-2023): Deteriorating

Rationale: Phosphorus remains the growth-limiting nutrient in the Great Lakes. Since the 1970's, phosphorus concentrations were elevated throughout many of the lakes. Presently, the problems of excess phosphorus are still persisting but are confined primarily to some nearshore areas and parts of Lake Erie. In Lakes Michigan, Huron and Ontario, offshore total phosphorus concentrations are currently below objectives and may be too low, negatively impacting lake productivity (phytoplankton, zooplankton and fish production). In Lake Erie, objectives are frequently exceeded. Only in Lake Superior is the offshore objective being met and conditions acceptable. Nearshore, symptoms of nutrient enrichment persist in some locations.

Lake-by-Lake Assessment

Lake Superior

Status: Good

10-Year Trend (2010-2019): Unchanging

Long-term Trend (1970-2019): Unchanging

Rationale: Objectives for phosphorus concentrations have consistently been met, and offshore total phosphorus concentrations are similar to historic values, indicating acceptable conditions. The level of phosphorus in Lake Superior, as an oligotrophic lake, does not negatively impact the overall ecosystem.

Lake Michigan

Status: Fair

10-Year Trend (2010-2019): Unchanging

Long-term Trend (1983-2019): Deteriorating

Rationale: Offshore phosphorus concentrations are well below objectives and have leveled off, with no indication of increasing phosphorus concentrations. Low phosphorus concentrations may be negatively affecting lake productivity and nutrient conditions are therefore assessed as Fair and the long-term trend is assessed as Deteriorating. In some nearshore areas, elevated phosphorus is observed and may be supporting nuisance algae growth. Data from Green Bay indicate eutrophic conditions.

Lake Huron

Status: Fair

10-Year Trend (2013-2022): Unchanging

Long-term Trend (1970-2022): Deteriorating

Rationale: Offshore phosphorus concentrations have declined to values that are well below objectives and there is no indication of a recovery. Concentrations may be too low to support a healthy level of lake productivity based on the historic food web and nutrient conditions are therefore assessed as Fair and the long-term trend is assessed as Deteriorating. In some nearshore areas, elevated nutrients may be contributing to nuisance algae growth.

Lake Erie

Status: Poor

10-Year Trend (2014-2023): No Trend

Long-term Trend (1970-2023): No Trend

Rationale: Total phosphorus objectives continue to be exceeded. Although high values are most frequently observed in the western basin, exceedances of objectives are observed in all three basins of Lake Erie in some years. Harmful algal blooms plague the western basin and parts of the central basin, and nuisance benthic algae have resurged in the eastern basin of Lake Erie. While there is some hint that the long-term trend in total phosphorus has improved, conditions in some years are similar to those observed in the 1970s. Due to highly variable conditions, statistical analysis indicates there is No Trend over the long term or in the most recent 10 years.

Lake Ontario

Status: Fair

10-Year Trend (2014-2023): Unchanging

Long-term Trend (1970-2023): Deteriorating

Rationale: Offshore phosphorus concentrations have declined to values approaching concentrations that may be too low to support healthy offshore lake productivity based on the historic food web and there is no evidence of recovery. Due to the persistence of low phosphorus levels, nutrient conditions are assessed as Fair and the long-term trend is considered Deteriorating. Certain nearshore areas are experiencing recurrent nuisance algae, possibly fueled by local phosphorus discharges or in-lake nutrient cycling.

Since the Last Report: Status and trend assessments have not changed since the previous report.

Status Assessment Definitions

Both nearshore and open water nutrient concentrations are considered in the assessment of nutrient status.

Good: The metrics show that the nutrient concentrations are meeting the ecosystem objectives and they are neither too high nor too low and should be considered in acceptable condition.

Fair: The metrics show that the nutrient concentrations are meeting the ecosystem objectives, but they are exhibiting minimally acceptable conditions and may be negatively impacting the food web.

Poor: The metrics show that the nutrient concentrations are too high and are therefore not displaying minimally acceptable conditions and may be stimulating excessive and possibly toxic algal growth.

Undetermined: Data are not available or are insufficient to assess the condition of the ecosystem components.

Trend Assessment Definitions

Open water concentrations are of primary interest because they describe the main body of each lake and are sufficiently removed from nearshore variability, permitting temporal trends to be observed. Nearshore trends may be considered as the data allow.

Improving: Nutrient concentrations are trending towards the ecosystem objectives, resulting in Improving conditions.

Unchanging: No change in the nutrient concentrations.

No Trend: Phosphorus data are available for a 10-year or longer period but trends are not clearly Improving or Deteriorating due to high variability in the data.

Deteriorating: Nutrient concentrations are trending away from the ecosystem objectives, resulting in Deteriorating conditions.

Undetermined: Insufficient data exist for the determination of a trend.

Endpoints and/or Targets

The Annex 4 Interim Substance Objectives for spring total phosphorus, and the resultant summer chlorophyll a concentration and the trophic state of the open waters of each lake are presented in Table 1. The offshore nutrient objectives represent expected conditions when tributary nutrient loadings targets are achieved. Both the Substance Objectives for Total Phosphorus Concentration in Open Waters and the Phosphorus Load Targets are Interim and set by the GLWQA.

There are currently no nitrogen endpoints, but the total nitrogen (N) to phosphorus (P) ratio is assessed. When nitrogen values are low relative to phosphorus concentrations, this can be associated with growth of harmful-blue green algae. Therefore, maintenance of spring conditions above the Redfield N:P ratio of 7.2 provides some protection against potentially harmful algal blooms.

Sub-Indicator Purpose

The purpose of this sub-indicator is:

- To assess nutrient concentrations in the Great Lakes;
- To assess progress in meeting GLWQA General Objective #6, Lake Ecosystem Objectives and Substance Objectives for nutrient concentrations for the Waters of the Great Lakes;
- To infer progress in meeting nutrient loading targets and allocations;
- To support the evaluation of trophic status and food web dynamics in the Great Lakes; and
- To support assessment of the state of the nearshore waters for the nearshore framework

Ecosystem Objective

General Objective #6 of the 2012 Great Lakes Water Quality Agreement (GLWQA) states that the Waters of the

Great Lakes should “be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote growth of algae and cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem.”

Annex 4 of the 2012 GLWQA includes Lake Ecosystem Objectives to: maintain an oligotrophic state, relative algal biomass, and algal species consistent with healthy aquatic ecosystems, in the open waters of Lakes Superior, Michigan, Huron and Ontario (Lake Ecosystem Objective #5); maintain mesotrophic conditions in the open waters of the western and central basins of Lake Erie, and oligotrophic conditions in the eastern basin of Lake Erie (Lake Ecosystem Objective #6).

Interim Substance Objectives for Total Phosphorus concentrations in open waters are additionally established in Annex 4 for each of the Great Lakes. These interim objectives are shown in Table 1 and comprise objectives for both spring total phosphorus concentrations and summer chlorophyll a concentrations. The resultant nutrient (trophic) states corresponding to the objective concentrations are also displayed. Note that there are no objectives for nearshore nutrient concentrations.

There are no current ecosystem objectives for nitrogen. There is a requirement in Annex 4 to establish Substance Objectives for other nutrients, as required, to control the growth of nuisance and toxic algae to achieve Lake Ecosystem Objectives. As an interim measure, and as discussed in Dove and Chapra (2015), the Redfield ratio of 7.2 mgN/mgP is used as a benchmark to assess nitrogen levels; above this level, lakes would tend to be phosphorus limited, below this level, lakes would tend to be nitrogen limited, with nitrogen limitation favouring harmful cyanobacteria (a type of blue-green algae) in general. The goal would be to maintain ratios well above this level.

Methods

This sub-indicator reports on Total Phosphorus (TP) and other nutrients in the waters of the Great Lakes. The condition of the Great Lakes with respect to nutrients is determined using data collected by the federal agencies Environment and Climate Change Canada (ECCC) and the United States Environmental Protection Agency (USEPA) and data from additional nearshore locations, are now included. The determination of the lake’s current status is based on total phosphorus in samples collected during recent spring (late March-May) or summer (generally mid June-September data) seasons and considers data from all available stations to compare the lakewide median to the GLWQA interim substance objectives. Data for the determination of long-term and recent trends are restricted to offshore stations using spring data (see Dove and Chapra, 2015) from the USEPA and ECCC only, to be able to provide a clearer signal of interannual changes. Trends were based on the Spearman correlation between mean annual TP concentration and year.

Discussion

Current Status

The most current Great Lakes total phosphorus (TP) concentrations are shown graphically in Figure 1. Since 2019, TP data from nearshore monitoring programs have been included in this figure. The offshore data comprise surface samples for spring cruises from lakes Superior (2019), Ontario (2022-2023), Huron (2022), Erie (2022-2023) and from Georgian Bay (2022) from ECCC’s Great Lakes Surveillance Program, as well as USEPA’s Great Lakes National Program Office (GLNPO-USEPA) data from spring of 2019 in Lake Superior. All data used to calculate trends for each lake includes data up until the specified dates stated above.

In Lake Superior, GLNPO-USEPA 2019 data was used, along with National Coastal Condition Assessment (NCCA-USEPA) 2020-2021 data. In the St. Mary's River, Great Lakes Surveillance Program (GLSP-ECCC) 2022 data was used along with the Ontario Ministry of the Environment, Conservation, and Parks (MECP) INDEX 2019 data, and NCCA-USEPA 2015-2016 data. In Lake Michigan, GLNPO-USEPA 2019 data was used with NEW Water, the brand of Green Bay Metropolitan Sewerage District 2020-2023 data, Wisconsin Department of Natural Resources 2023 data, and NCCA-USEPA 2020-2022 data. In Lake Huron and Georgian Bay, GLSP-ECCC 2022 data was used with NCCA-USEPA 2020 data. In Lake St. Clair and its corridor, 2017 data from a collaboration between GLSP-ECCC and the MECP was used, along with NCCA-USEPA 2014-2015 data. In Lake Erie, GLSP-ECCC 2023 data was used with NCCA-USEPA 2020-2021 data. In Lake Ontario, GLSP-ECCC 2022-2023 data was used with NCCA-USEPA 2020 data. In instances where multiple data points exist in the same location over different years, the mean was used.

The GLWQA interim substance objectives for total phosphorus (Table 1) are not exceeded in the offshore of the Great Lakes with the exception of Lake Erie. In Lake Erie, objectives have recently been exceeded at about 50% of stations in the central and eastern basins, and almost all stations in the western basin, as shown graphically in Figures 5, 6 and 7. High total phosphorus can fuel algal blooms, and blooms in the western basin of Lake Erie in particular have routinely shown potentially harmful toxicity. In addition, western basin blooms may be playing a role in the development, severity and/or extent of hypoxic conditions in the central basin. For these reasons, conditions are considered Poor in Lake Erie.

In contrast to the elevated nutrients observed in Lake Erie (Figures 5, 6 and 7), the data show that a majority of the offshore regions in Lakes Superior, Huron, Michigan and Ontario are below the objectives for total phosphorus. For Lakes Huron, Michigan and Ontario, levels may indeed have fallen below those needed to sustain healthy offshore planktonic communities based on the historic food web. In some cases, phosphorus concentrations are less than one-half of objectives. In all cases except Lake Superior (figure 2), concentrations are much lower in recent decades compared to historic values. For these reasons, Lake Superior status is considered Good since it is an oligotrophic lake and the low phosphorus levels do not impact the overall ecosystem. The remaining lakes are considered Fair since offshore regions are nutrient deficient, elevated concentrations are observed in some nearshore regions of all the lakes (Figures, 3, 4 and 8). In particular, concentrations appear to be relatively high in Green Bay, a portion of Saginaw Bay**,** the southern portion of Lake St Clair, portions of the St. Mary's River, the western basin of Lake Erie, portions of central Lake Erie and in various nearshore regions of Lake Ontario (Figure 1). Local efforts may be required in these locations to reduce or abate sources and thereby reduce the pressure of elevated nutrients in the nearshore environment.

The rate of change is not ecologically significant.

Temporal Trends

The long-term trends of total phosphorus are shown for the offshore of the Great Lakes in Figures 2 through 8. Statistical analysis of the data indicates long-term declining trends for all lakes. For Lake Superior, the decline is only observed for the very long term (1970 – 2019) in the ECCC dataset and the rate of change is very slow. In lakes Michigan, Huron, Ontario and in Georgian Bay, the long-term trends show significant declines, with the most dramatic declines observed since the mid- to late-1990s. Due to the current low values and significant interannual variability, it is difficult to discern significant 10-year trends in any of the Great Lakes. Of all the Great Lakes, the greatest spatial and inter-annual variability is observed in Lake Erie. The central basin is shown in Figure 5; here, the trends can be interpreted to indicate high concentrations in the 1970s (in the range of 18 µgP/L) and lower concentrations in the 2000s (roughly 12 µgP/L). The variable nature of the data obscures any recent trends in all basins, resulting in an assessment of No Trend conditions for the most recent 10-year period for Lake Erie.

Trends of spring nitrogen levels are represented here as nitrate (NO_3). There are excellent, long-term records of nitrate available by both federal agencies, and nitrate represents more than 95% of the total oxidized nitrogen in the Great Lakes. Unlike phosphorus, concentrations of nitrate have increased over the long-term, until just recently over the past 5-10 years. Concentrations of nitrate are lowest in Lake Erie, the most productive of the lakes, where it is taken up by algae, phytoplankton and other consumers. There is some evidence that the growth of certain algal species may be fueled by nitrogen, but in general high nitrate is thought to be more protective against blue-green algae blooms, because these algae have a competitive advantage in their ability to use atmospheric nitrogen when nitrogen is low in the water. Because nitrate has increased over time and phosphorus has declined, it is therefore phosphorus, not nitrogen, which is increasingly limited in the Great Lakes (Dove and Chapra, 2015). Nutrient management is therefore most aptly targeted at phosphorus controls. Currently, all of the lakes are phosphorus limited, with the most extreme limitation occurring in the upper Great Lakes. However, since 2008, nitrogen limitation has started to occur in some parts of the central basin of Lake Erie. The ecosystem objective to maintain ratios above the Redfield ratio of 7.2 is currently being met in all of the lakes, with Lake Erie showing greatest risk (Figures 9, 10).

Inferred Nutrient Loadings

The existing GLWQA nutrient objectives for the Great Lakes offshore regions represent expected conditions when tributary nutrient loadings targets are achieved. Recent phosphorus loads are not available for the Great Lakes, with the exception of Lake Erie. The lack of sufficient and appropriate information upon which to directly compute loads remains a major shortcoming for much of the Great Lakes basin. Moreover, there is increasing evidence of algal imbalances in the lakes; that is, eutrophic (nutrient-rich) nearshore conditions may be persisting (or resurging) despite low offshore nutrient concentrations. In this way, the existing objectives may not be sufficient to protect all areas of the lakes. Insufficient monitoring of loadings, especially in the upper Great Lakes, combined with an incomplete understanding of changing in-lake nutrient dynamics, makes the previously-held models upon which nutrient budgets are understood insufficient for nutrient management currently and into the future.

Both the Substance Objectives for Total Phosphorus Concentration in Open Waters and the Phosphorus Load Targets are updated and revised as necessary for the Great Lakes. Loadings targets have been set for Lake Erie in 2016; these call for a 40% reduction in annual total phosphorus loads to the western and central basins of Lake Erie and a 40% reduction in spring total and soluble reactive phosphorus loads from selected priority tributaries. These targets are intended to reduce loadings and thereby alleviate the issue of excessive phosphorus in Lake Erie. In the other Great Lakes, however, offshore phosphorus may be too far below objectives while certain nearshore areas may still receive excessive phosphorus loadings and suffer from the harmful effects of nutrient enrichment and excessive algal growth. This “feast and famine” dichotomy may require a different approach for nutrient management and environmental agencies are meanwhile faced with the challenge of effectively managing watershed nutrient sources.

Lake trophic status

A lake’s trophic state describes its nutritional or growth status. Ranges of phosphorus, together with the response variables of chlorophyll a (an indicator of the amount of algae and phytoplankton in a sample) and Secchi disk depth (an indicator of water clarity) are used in combination to determine the trophic status. The objectives vary between each of the Great Lakes and for Lake Erie the objectives vary by basin. Collectively, the information shows that the open portions of Lakes Superior, Michigan and Huron are in the ultraoligotrophic range (i.e., very low in nutrients and below the objective of oligotrophy), Lake Ontario is in the oligotrophic range (i.e., nutrient poor and below the objective) and Lake Erie ranges from eutrophic in the west (nutrient rich and exceeding the objective) to mesotrophic in the central basin (exceeding the objective) and oligotrophic in the east (at or below objective). This

indicates that the offshore regions of the Great Lakes are nutrient deficient with the exception of Lake Erie which suffers from elevated nutrient conditions.

Linkages

Concentrations of nutrients in the Great Lakes are linked directly to several abiotic and biotic processes. The following is a list of processes and other ecosystem components that are linked to nutrient concentrations. Many, but not all, are evaluated in other SOGL sub-indicator reports.

- Benthos – nutrient concentrations impact benthic community abundance and composition.
- *Cladophora* – high nutrients in the nearshore favour the proliferation of nuisance benthic algae.
- Dreissenid Mussels – Dreissenids influence the cycling of phosphorus, which may alter in-lake concentrations, the relationship between concentrations and loads and may enhance the growth of *Cladophora.*
- Algal Bloom Extent – nutrient concentrations impact the development, timing and severity of algal blooms.
- Phytoplankton (open water) – nutrient concentrations impact phytoplankton community abundance and composition.
- Water Quality in Tributaries – tributary nutrient concentrations impact nutrient concentrations in Great Lakes Waters.
- Zooplankton – nutrient concentrations impact zooplankton community abundance and composition via the food web.
- Surface Water Temperatures – increased lake temperatures may be enhancing plankton and algal growth rates. Where abundant nutrients exist (e.g., nearshore regions), further loadings may exacerbate impairments under higher water temperatures.
- Precipitation Amounts – an increase in extreme events, could result in large inputs of nutrient-rich waters, potentially fueling nearshore algal blooms.
- Wastewater treatment can reduce the nutrient loading to the lakes.

Assessing Data Quality

Data Characteristics	Agree	Neutral or Unknown	Disagree	Not Applicable
Data are documented, validated, or quality-assured by a recognized agency or organization	X			
Data are from a known, reliable and respected generator of data and are traceable to original sources	X			

Geographic coverage and scale of data are appropriate to the Great Lakes Basin	X			
Data obtained from sources within the U.S. are comparable to those from Canada		X		
Uncertainty and variability in the data are documented and within acceptable limits for this sub-indicator report	X			
Data used in assessment are openly available and accessible	Yes	ECCC Data Catalogue https://login.glnpo.net/		

Notes on Accessing Data

ECCC Nutrient data is openly available to the public in the website linked above. For EPA nutrient data, users will need to create a free account before downloading data.

Data Limitations

The federal long-term monitoring records of total phosphorus that are shown here comprise high quality and spatially comprehensive datasets. The data are quality-assured and laboratories undergo rigorous testing and comparisons. Interagency field comparisons have been conducted and additional studies are ongoing. Additional nearshore data from Provincial, State and other agencies are now included; these are also high-quality datasets and some but not all may have been tested for inter-comparability.

Nitrates are used in place of total nitrogen because there is a good long-term record for nitrates measured by both US and Canadian federal agencies and because nitrate alone can be used as an estimate of bioavailable nitrogen in the Great Lakes (Dove and Chapra, 2015). However, the USEPA has been measuring total nitrogen since 2014; Canada has total nitrogen data available through calculation since 1983 for Lake Ontario, 1989 in Lakes Superior and Huron and 1994 in Lake Erie.

Additional Information

Continued water quality monitoring at a basin-wide scale in Great Lakes waters is required for informed nutrient management, to track progress and update status and trend information. Ongoing efforts are required to maintain and improve the monitoring programs upon which this sub-indicator is successfully based.

The management of excessive nutrients is important in many nearshore areas of the Great Lakes, in particular in Lake Erie. Tracking the lake response to nutrient loading changes will help to assess if meeting the nutrient loading targets are resulting in improved conditions. Additional monitoring and/or improved monitoring coordination and data integration is warranted to improve our ability to detect meaningful change in such a dynamic system. For the other Great Lakes, loading targets revisions have been or will be considered by GLWQA Annex 4. Improved understanding of nutrient dynamics in the Great Lakes is necessary in order to improve the information basis upon which critical nutrient management decisions are made.

Integrating nutrient loading information to this sub-indicator will be a challenge without concerted efforts to improve load monitoring in the basin. Important work to coordinate, collect and manage such information has been initiated for Lake Erie but is largely lacking in all of the other Great Lakes on a lake-wide scale.

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New Water Green Bay Metropolitan Sewerage District, Nearshore Data, 2020-2023

National Oceanic and Atmospheric Administration (NOAA), Michigan, 2022

Ohio Environmental Protection Agency (Ohio EPA), 2021-2023

United States Geological Survey, New York (USGS NY), Nearshore Data, 2023

Wisconsin Department of Natural Resources (DNR), Nearshore Data, 2023

Ministry of the Environment, Conservation and Parks (MECP), Nearshore Data, 2016-2019

References

Dove, A. and Chapra, S.C. 2015. Long-term trends of nutrients and trophic response variables for the Great Lakes. Limnology and Oceanography. 60(2): 696-721. http://dx.doi.org/10.1002/lno.10055.

U.S. Environmental Protection Agency. 2021. National Coastal Condition Assessment: A Collaborative Survey of the Nation's Estuarine and Great Lakes Nearshore Waters. EPA 841-R-21-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC https://www.epa.gov/national-aquatic-resource-surveys/national-coastal-condition-assessment-2015-report

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Table 1. Interim Substance Objectives for Spring Total Phosphorus and Summer Chlorophyll a Concentrations (for offshore waters), with resultant Trophic State.

Source: 2012 Great Lakes Water Quality Agreement.

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Figure 1. Spatial distribution of total phosphorus (µg/L) in the Great Lakes from 2019-2023. Sampling stations are shown as black dots.

Offshore data sources: Environment and Climate Change Canada and The United States Environmental Protection Agency. Nearshore data sources are listed in the Current Status section.

Figure 2. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in Lake Superior (µg/L). The interim GLWQA TP objective of 5 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency.

Note: *Offshore data has not been updated since SOGL 2022*

Figure 3. Federal (US) long-term record of offshore, spring (April - May) total phosphorus in Lake Michigan (µg/L). The interim GLWQA TP objective of 7 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: U.S. Environmental Protection Agency.

Note: *Offshore data has not been updated since SOGL 2022*

Figure 4. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in Lake Huron (µg/L). The interim GLWQA TP objective of 5 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed. Georgian Bay data are not shown but the temporal trends closely match those in Lake Huron.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency

Figure 5. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in the central basin of Lake Erie (µg/L). The interim GLWQA TP objective of 10 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency

Figure 6. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in the eastern basin of Lake Erie (µg/L). The interim GLWQA TP objective of 10 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency

Figure 7. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in the western basin of Lake Erie (µg/L). The interim GLWQA TP objective of 15 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency

Figure 8. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in Lake Ontario (µg/L). The interim GLWQA TP objective of 10 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency

Figure 9. Trends of open lake, spring ratios of median NO3:TP for Lakes Superior, Michigan, Huron and Ontario. The Redfield ratio of 7.2 mgN/mgP is superimposed as an estimate of the level above which lakes would tend to be phosphorus limited. Phosphorus limitation is beneficial because nitrogen limitation would favor potentially toxic blue-green algae (cyanobacteria). After Dove and Chapra (2015).

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency

Figure 10. Trends of open lake, spring ratios of median NO3:TP for the Eastern, Central and Western Basins of Lake Erie. The Redfield ratio of 7.2 mgN/mgP is superimposed as an estimate of the level above which lakes would tend to be phosphorus limited. Phosphorus limitation is beneficial because nitrogen limitation would favor potentially toxic blue-green algae (cyanobacteria). After Dove and Chapra (2015).

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency

Last Updated

State of the Great Lakes 2025 Report

Table 1. Interim Substance Objectives for Spring Total Phosphorus and Summer Chlorophyll a Concentrations (for offshore waters), with resultant Trophic State.

Source: 2012 Great Lakes Water Quality Agreement.

Basin	**Total Phosphorus (*ug/L*)**	**Chlorophyll a (*ug/L*)**	**Trophic State**
Lake Superior	5	1.3	Oligotrophic
Lake Michigan	7	1.8	Oligotrophic
Lake Huron	5	1.3	Oligotrophic
Western Lake Erie	15	3.6	Mesotrophic
Central Lake Erie	10	2.6	Oligomesotrophic
Eastern Lake Erie	10	2.6	Oligomesotrophic
Lake Ontario	10	2.6	Oligomesotrophic

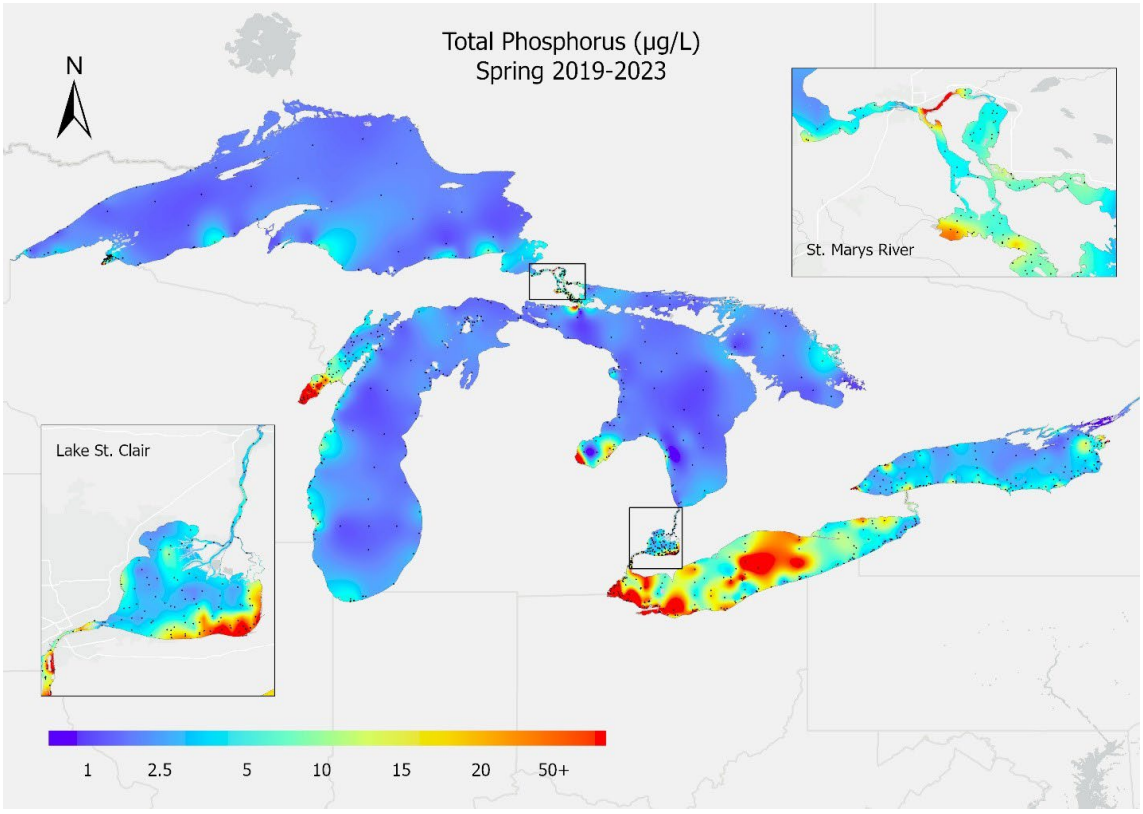

Figure 1. Spatial distribution of total phosphorus (µg/L) in the Great Lakes from 2019-2023. Sampling stations are shown as black dots.

Offshore data sources: Environment and Climate Change Canada and The United States Environmental Protection Agency. Nearshore data sources are listed in the Current Status section.

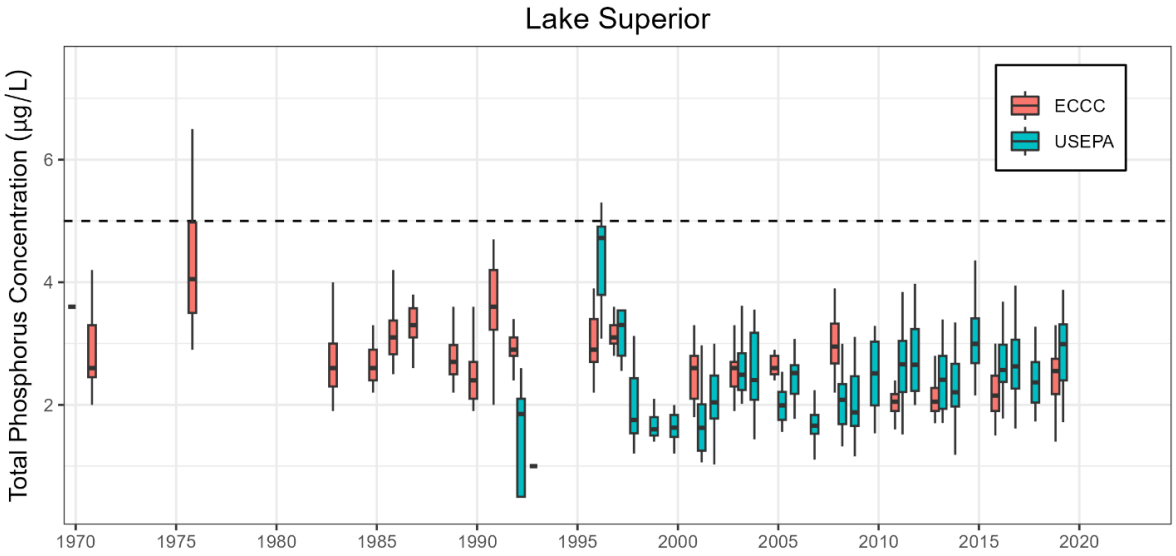

Figure 2. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in Lake Superior (µg/L). The interim GLWQA TP objective of 5 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency.

*Offshore data has not been updated since SOGL 2022

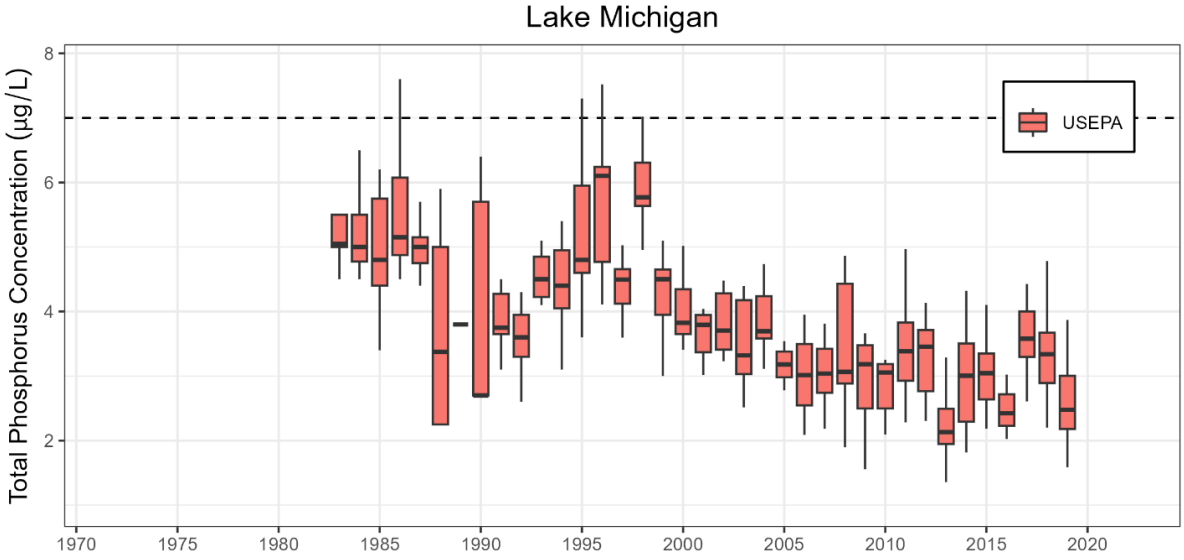

Figure 3. Federal (US) long-term record of offshore, spring (April - May) total phosphorus in Lake Michigan (µg/L). The interim GLWQA TP objective of 7 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: U.S. Environmental Protection Agency.

*Offshore data has not been updated since SOGL 2022

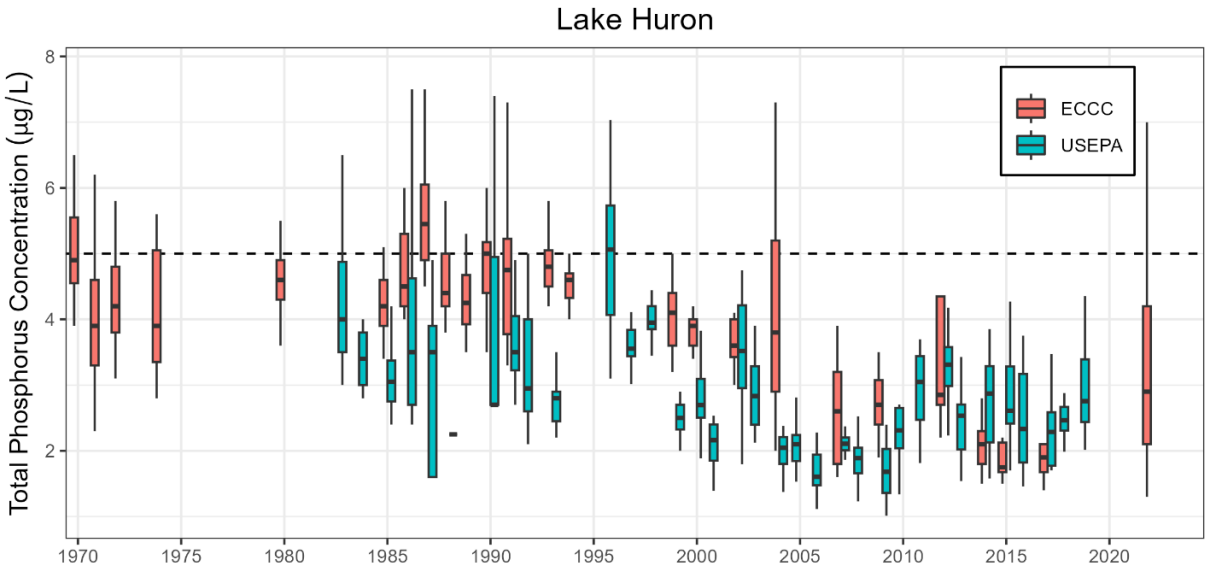

Figure 4. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in Lake Huron (µg/L). The interim GLWQA TP objective of 5 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed. Georgian Bay data are not shown but the temporal trends closely match those in Lake Huron.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency.

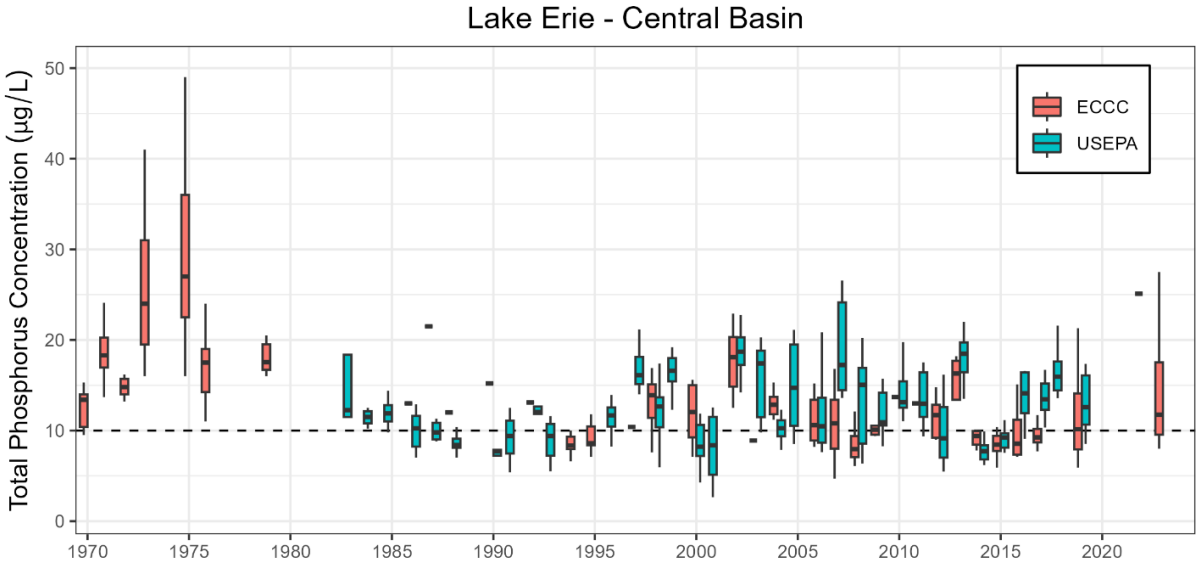

Figure 5. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in the central basin of Lake Erie (µg/L). The interim GLWQA TP objective of 10 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency.

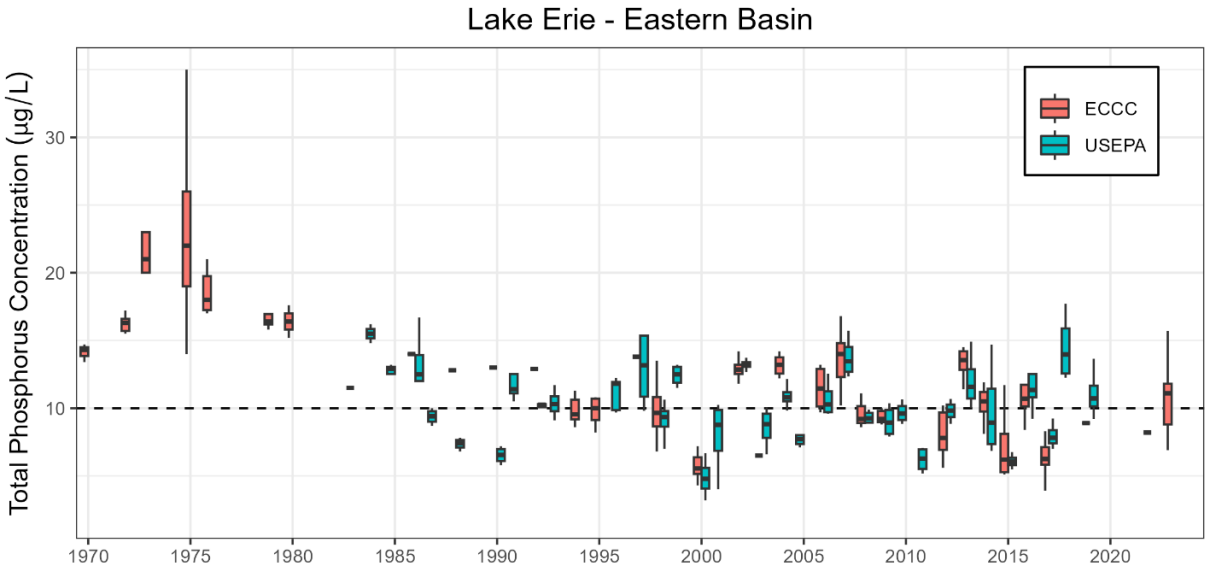

Figure 6. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in the eastern basin of Lake Erie (µg/L). The interim GLWQA TP objective of 10 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency.

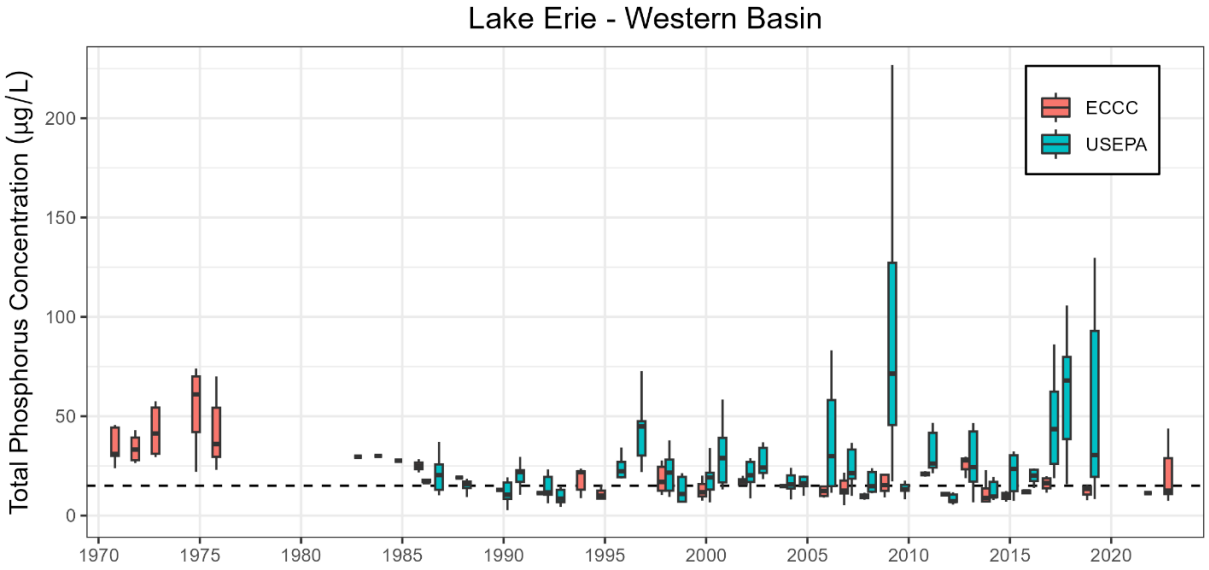

Figure 7. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in the western basin of Lake Erie (µg/L). The interim GLWQA TP objective of 15 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency.

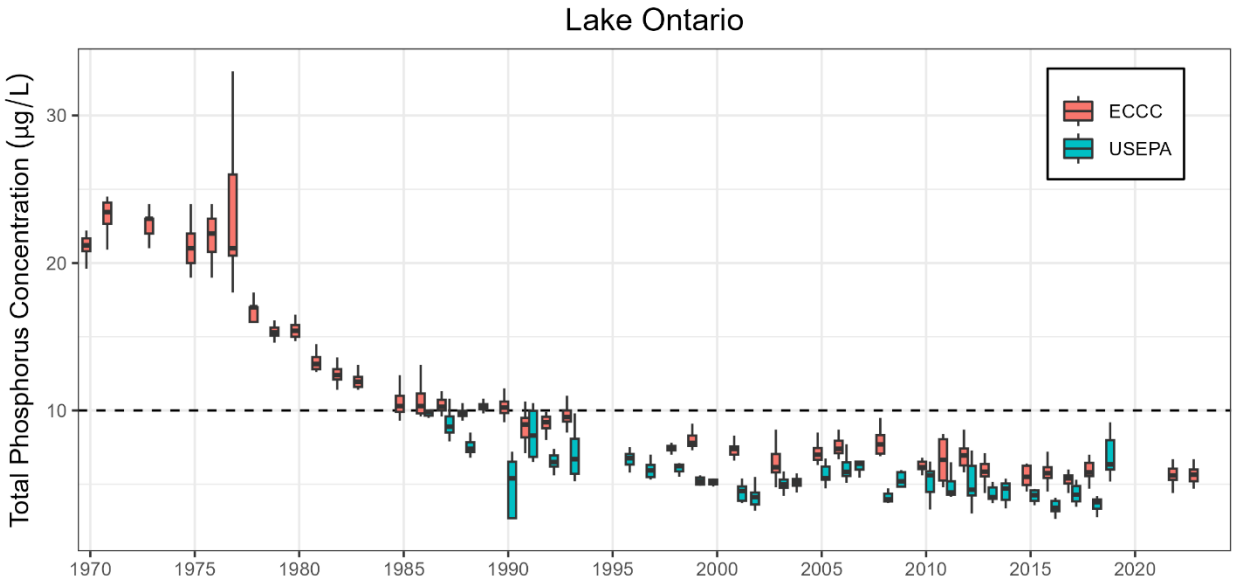

Figure 8. Federal (US and Canada) long-term record of offshore, spring (April - May) total phosphorus in Lake Ontario (µg/L). The interim GLWQA TP objective of 10 µg/L is shown as the horizontal dashed line. Boxes show the median values and interquartile range. Outliers (upper and lower 5% of values) have been removed.

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency.

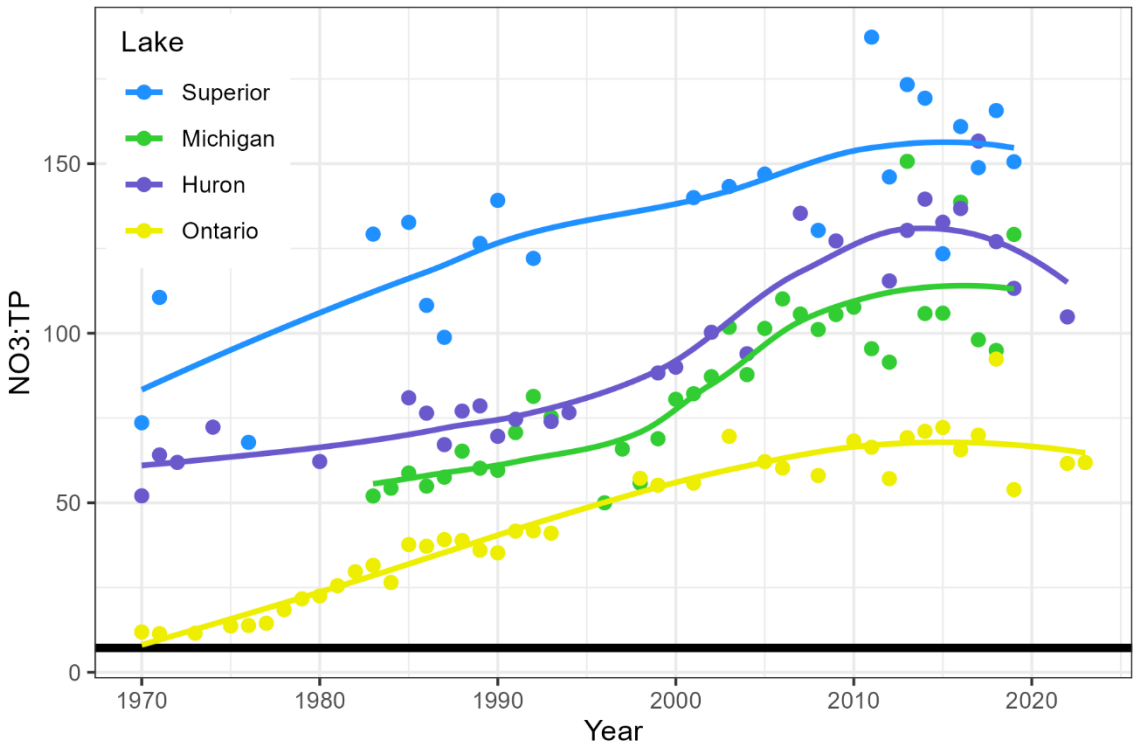

Figure 9. Trends of open lake, spring ratios of median NO3:TP for Lakes Superior, Michigan, Huron and Ontario. The Redfield ratio of 7.2 mgN/mgP is superimposed as an estimate of the level above which lakes would tend to be phosphorus limited. Phosphorus limitation is beneficial because nitrogen limitation would favor potentially toxic blue-green algae (cyanobacteria). After Dove and Chapra (2015).

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency.

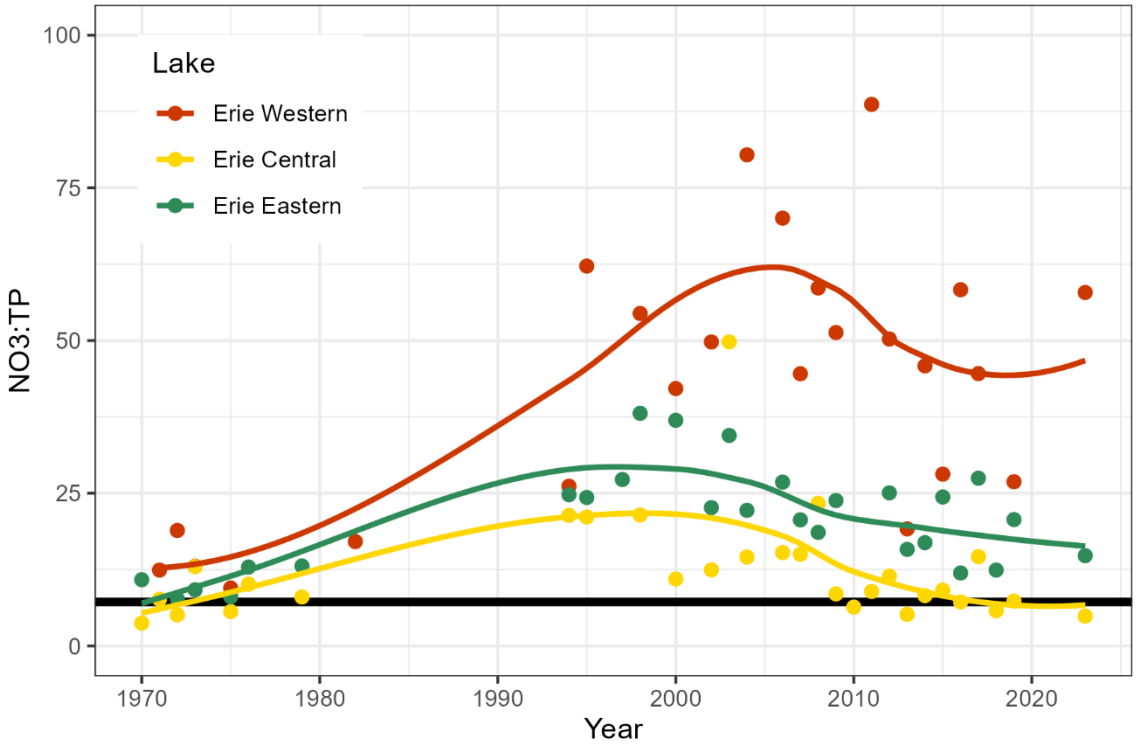

Figure 10. Trends of open lake, spring ratios of median NO3:TP for the Eastern, Central and Western Basins of Lake Erie. The Redfield ratio of 7.2 mgN/mgP is superimposed as an estimate of the level above which lakes would tend to be phosphorus limited. Phosphorus limitation is beneficial because nitrogen limitation would favor potentially toxic blue-green algae (cyanobacteria). After Dove and Chapra (2015).

Data source: Environment and Climate Change Canada and U.S. Environmental Protection Agency.