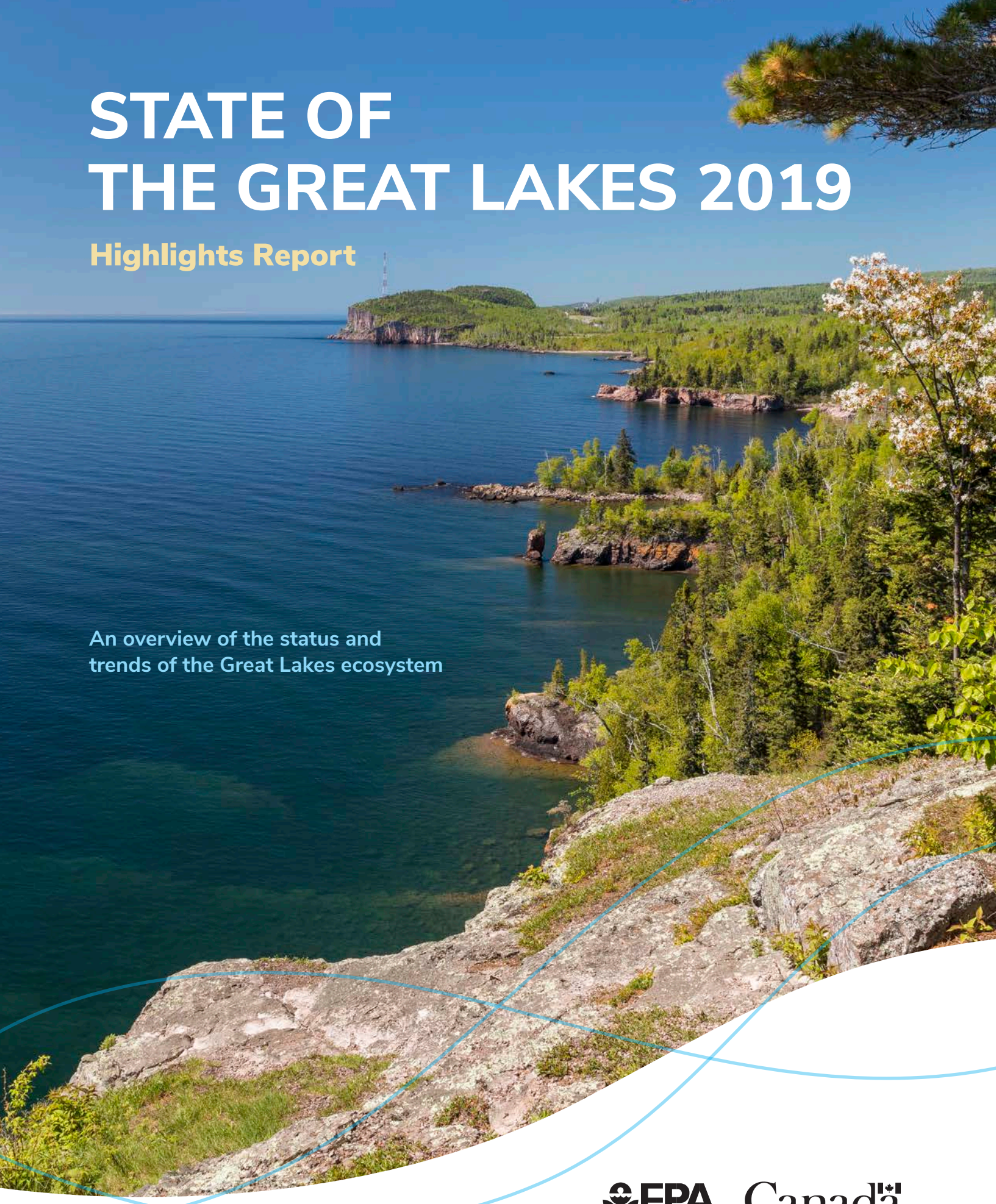
STATE OF THE GREAT LAKES 2019

Highlights Report

An overview of the status and trends of the Great Lakes ecosystem



EPA Canada

What are the Great Lakes Indicators Telling Us?

Can we drink the water?

Yes. The Great Lakes remain a source of high-quality drinking water when treated.

Can we swim at the beaches?

Yes. However, some beaches are occasionally unsafe for swimming due to bacterial contamination.

Can we eat the fish?

Generally, yes. Great Lakes fish can be safely eaten by following consumption guidelines and advisories. However, unrestricted fish consumption is not yet possible, which has a greater impact on communities that heavily rely on fish for food, cultural, economic or spiritual purposes.

Have levels of toxic chemicals declined in the environment?

Generally, yes. Many chemicals, such as PCBs and mercury, have declined significantly in the Great Lakes but concentrations of some toxic chemicals still pose threats to human health and the environment.

Are the lakes supporting healthy wetlands and other habitats for native species?

Yes and no. Healthy coastal wetlands exist in each Great Lake basin. However, Great Lakes coastal wetlands vary in quality with more degraded wetlands in southern locations.

Are nutrients in the lakes at acceptable levels?

Generally, no. High nutrient levels in parts of Lake Erie, and some embayments in other parts of the Great Lakes, are contributing to increases in toxic cyanobacteria. In many offshore regions, nutrient levels are below objectives and may be impairing the food web through lower productivity.

Are we limiting new introductions and the impacts of non-native species?

Yes and no. The rate of introduction of new non-native species has greatly declined. However, the impacts of established invaders persist, and some invaders continue to spread within and between the lakes.

Is groundwater negatively affecting the water quality of the lakes?

Generally, no. Some localized areas with elevated levels of nitrate and chloride in groundwater do exist.

Are land use changes or other stressors impacting the lakes?

Yes. Population growth, development, land-use activities and climate-related shifts are stressing the Great Lakes.

Overall, the Great Lakes are assessed as Fair and Unchanging. While progress to restore and protect the Great Lakes has occurred, including the reduction of toxic chemicals, the indicator assessments demonstrate that there are still significant challenges, including the impacts of nutrients and invasive species. The continued actions of many groups and individuals are contributing to the improvements in the Great Lakes.

Assessing the Great Lakes

Why are the Great Lakes Important?

The Great Lakes contain one fifth of the world's fresh surface water supply and are one of the most ecologically diverse ecosystems on Earth. They provide a source of drinking water to tens of millions of Canadians and Americans and are important to the economies of both Canada and the United States, supporting manufacturing, transportation, farming, tourism, recreation, energy production and other forms of economic growth. The Great Lakes are also culturally significant to the many Indigenous Peoples in the region.

How are Governments Working Together to Protect the Great Lakes?

The Great Lakes Water Quality Agreement signed by the Governments of Canada and the United States commits both countries to work cooperatively to restore and protect the water quality and aquatic ecosystem health of the Great Lakes. Through the Agreement, the Governments of Canada and the United States work with Tribes, First Nations, Métis, provincial, state and municipal governments, watershed management agencies, other local public agencies, industry and the public to ensure that the Great Lakes remain an important and vibrant natural resource for the benefit and enjoyment of current and future generations.

How is the Health of the Great Lakes Assessed?

The Governments of Canada and the United States, together with their many Agreement partners, have established a set of nine overarching indicators of ecosystem health supported by 45 science-based sub-indicators. To create this report, more than 200 government and non-government Great Lakes scientists and other experts analyzed available data and reached consensus on the assessments of each indicator in relation to both current status and trend. Status is defined as Poor, Fair or Good*. Trend is defined as Deteriorating, Unchanging, or Improving* and is generally assessed over a 10-year period. Some sub-indicators are not assessed every reporting cycle due to differences in monitoring frequency. In those cases, the assessment from the previous report is brought forward. *See page 35 for definitions.

How is the Assessment of the Great Lakes Used?

Great Lakes assessments help governments identify current and emerging challenges to Great Lakes water quality and ecosystem health. Assessments also help governments evaluate the effectiveness of environmental programs and policies in place to address challenges. In addition, assessments help inform and engage others, including the public, and provide information that in turn support efforts to restore and protect the Great Lakes.

2019 Assessments of the Nine Great Lakes Indicators of Ecosystem Health

Great Lakes Indicator	Status and Trend
Drinking Water	Status: Good; *Trend*: Unchanging
Beaches	Status: Good; *Trend*: Unchanging
Fish Consumption	Status: Fair; *Trend*: Unchanging
Toxic Chemicals	Status: Fair; *Trend*: Unchanging to Improving
Habitat and Species	Status: Fair; *Trend*: Unchanging
Nutrients and Algae	Status: Fair; *Trend*: Unchanging
Invasive Species	Status: Poor; *Trend*: Deteriorating
Groundwater	Status: Fair; *Trend*: Undetermined
Watershed Impacts and Climate Trends	Watershed Impacts: Status: Fair; *Trend*: Unchanging
	Climate Trends: No Overall Assessment

STATUS

Good Fair Poor Undetermined

DRINKING WATER

The 2012 Great Lakes Water Quality Agreement states that "the Waters of the Great Lakes should be a source of safe, high quality drinking water".

Status: GOOD
Trend: UNCHANGING

8.5 million Canadians and about 30 million Americans get their drinking water from the Great Lakes.

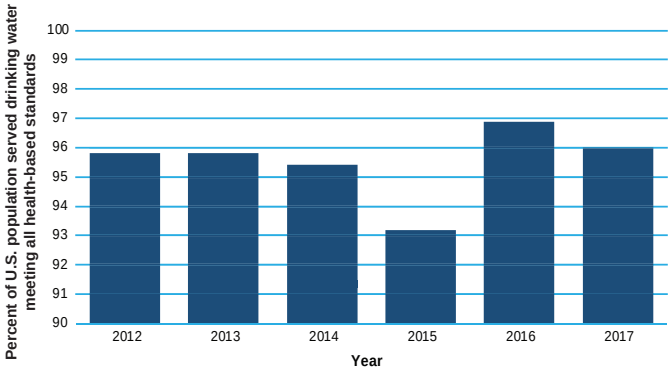
Drinking Water

Assessment Highlights

The status of treated drinking water in both Canada and the U.S. is **Good** and **Unchanging**. The Great Lakes continue to be a source of high-quality drinking water; however, as with all source waters, water from the Great Lakes must be treated to ensure it is safe to consume.

Ontario and U.S. state agencies have different ways of analyzing and reporting on the quality of treated drinking water. However, both compare microbial, radiological and chemical parameters in treated drinking water to health-based standards. In the Province of Ontario, treated water tests met Ontario Drinking Water Quality Standards 99.8% of the time from 2015 to 2017. In the U.S., an average of 95% of the population living within the Great Lakes basin and on public water supplies was serviced with drinking water that met all applicable health-based drinking water quality standards from 2015 to 2017. While basin-wide treated drinking water is assessed as Good, localized exceedances sometimes can occur, impacting drinking water for residents in those areas.

U.S. Great Lakes States Treated Drinking Water is Assessed as Good



Sub-Indicators Supporting the Indicator Assessment					
Sub-Indicator	**Lake Superior**	**Lake Michigan**	**Lake Huron**	**Lake Erie**	**Lake Ontario**
Treated Drinking Water	No lake was assessed separately. Great Lakes Basin assessment is Good and Unchanging.				

STATUS

Good **Fair** **Poor** **Undetermined**

BEACHES

The 2012 Great Lakes Water Quality Agreement states that "the Waters of the Great Lakes should allow for swimming and other recreational use, unrestricted by environmental quality concerns".

Status: GOOD
Trend: UNCHANGING

Great Lakes beaches are enjoyed by millions of residents and tourists each year and contribute significantly to local economies; however, some beaches are unsafe at times for various reasons such as bacterial contamination, nuisance or harmful algae and high water levels.

Beaches

Assessment Highlights

The overall status of Beaches is **Good** and **Unchanging**. The Beaches indicator shows that many monitored beaches in the Great Lakes are safe for swimming and recreational use throughout most of the swimming season.

Approximately 1,000 beaches along the Great Lakes shoreline are monitored for the fecal bacteria *E. coli* each year and these data are used in this assessment. Sources of *E. coli* for all of the Great Lakes can include overflow from wastewater treatment plants, runoff from the land after a heavy rainfall, improperly working septic systems and even large flocks of waterbirds.

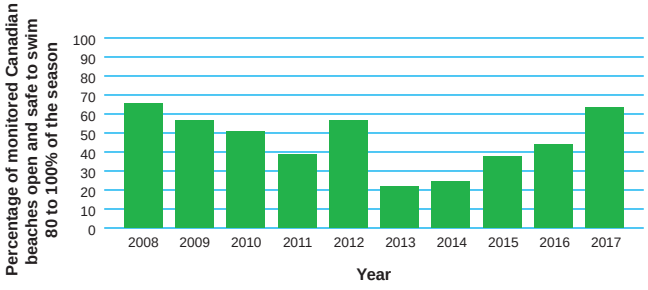
The U.S. and Canada use different bacterial criteria to determine when a beach is unsafe for swimming. In Canada, the Ontario benchmarks used in this assessment are more stringent than U.S. criteria and, therefore, Ontario often has more beach health advisories issued.

From 2015 to 2017, the percentage of days that monitored Canadian Great Lakes beaches met Ontario bacterial standards for swimming averaged 82%. Monitored Canadian beaches in Lakes Erie and Ontario showed an increase in the number of days that beaches were open and safe for swimming since the last assessment in 2017. The U.S. Great Lakes beaches monitored from 2015 to 2017 were open and safe for swimming 93% of the time on average.

Assessing Ontario's Beaches in the Future

The Ontario benchmarks have recently been revised to match the Canadian national guidelines, which will make the benchmarks closer to the U.S. criteria. These new benchmarks will be used in the next reporting cycle.

Monitored Canadian Lake Erie Beaches Show Recent Improvements but 10-Year Trend is Unchanging



Sub-Indicators Supporting the Indicator Assessment

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Beach Advisories	Unchanging to Deteriorating	Unchanging	Unchanging	Unchanging	Improving

STATUS

Good | Fair | Poor | Undetermined

FISH CONSUMPTION

The 2012 Great Lakes Water Quality Agreement states that "the Waters of the Great Lakes should allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants".

Status: FAIR
Trend: UNCHANGING

The Great Lakes support important commercial, recreational and subsistence fisheries; however, some chemicals present in the Great Lakes, including Polychlorinated Biphenyls (PCBs) and mercury, accumulate in fish tissues and may harm human health if consumption advisories are not followed.

Fish Consumption

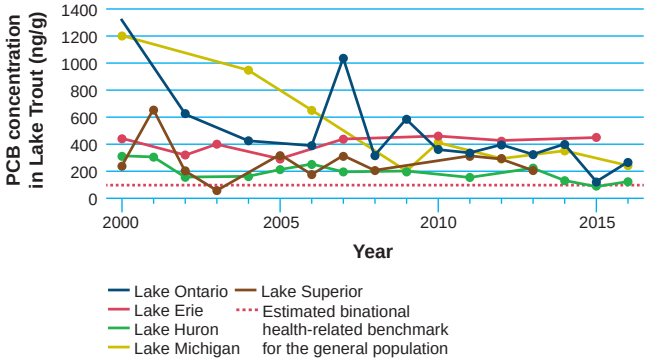
Assessment Highlights

The Fish Consumption indicator is based on the analysis of the fish fillet, the commonly consumed portion of fish, to determine the risks of chemicals to human health. Over the last 40 years, many contaminants in fish fillets have dramatically declined in the Great Lakes but the levels of some contaminants have recently stabilized. The status of contaminants in edible portions of fish is **Fair** and **Unchanging**.

Consumption restrictions of Great Lakes fish primarily result from elevated PCBs and mercury concentrations, with PCBs driving the majority of fish consumption advisories in both the U.S. and Canada. PCB levels in fish fillets have decreased by 90% for some fish species in some lakes, but concentrations are still above consumption benchmarks. Consequently, unrestricted consumption of Great Lakes fish is not yet possible, which has a greater impact on communities that heavily rely on fish for food, cultural, economic, or spiritual purposes.

Over the past 10 years, PCB concentrations in fish fillets have declined in Lakes Michigan and Ontario, and remained stable in Lakes Superior, Huron and Erie. Mercury levels in fish fillets have generally declined over the last four decades and, depending on the fish species and lake, are lower than most fish consumption advisory benchmarks. Other contaminants, such as Per- and Polyfluoroalkyl Substances (PFAS, which have multiple uses including stain and water repellents) continue to be a monitoring priority and will be included in future State of the Great Lakes reporting as necessary. Additional stressors such as invasive species and climate shifts will likely continue to complicate the cycling of contaminants in the Great Lakes and may impact the levels of contaminants in fish.

PCBs in Fish Fillets Have Declined but are Still Above Guidelines



Sub-Indicators Supporting the Indicator Assessment					
Sub-Indicator	**Lake Superior**	**Lake Michigan**	**Lake Huron**	**Lake Erie**	**Lake Ontario**
Contaminants in Edible Fish	Unchanging	Improving	Unchanging	Unchanging	Improving

STATUS

Good | Fair | Poor | Undetermined

TOXIC CHEMICALS

The 2012 Great Lakes Water Quality Agreement states that "the Waters of the Great Lakes should be free from pollutants in quantities or concentrations that could be harmful to human health, wildlife, or aquatic organisms through direct exposure or indirect exposure through the food chain".

Status: FAIR
Trend: UNCHANGING TO IMPROVING

Significant progress has been made in reducing toxic chemicals in the Great Lakes, but some chemicals, such as PCBs, still pose a threat to human health and the environment.

Toxic Chemicals

Assessment Highlights

The Toxic Chemicals indicator shows that Polychlorinated Biphenyls (PCBs) and mercury have decreased over the past 40 years. Other compounds, such as Polybrominated Diphenyl Ethers (PBDEs), have shown slow declines in recent years, although some replacements for these compounds are increasing in the environment. Overall, the status of Toxic Chemicals is **Fair** and **Unchanging to Improving**.

The long-term trends for many contaminants, such as PCBs and PBDEs, in the offshore waters of the Great Lakes are declining; however, there has been little or no change over the past 10 years. In general, concentrations in the offshore waters are higher in Lakes Erie and Ontario. Contaminants, such as PCBs, in Great Lakes fish (the whole fish, not just fish fillets) and Herring Gull eggs have decreased significantly since the 1970s. Although declines are observed in water, fish and Herring Gull eggs, concentrations of some compounds, including PCBs, still exceed ecosystem-based objectives.

Localized areas of highly contaminated sediment in Areas of Concern (AOCs) continue to act as sources of contaminants to the lakes. PCBs and other chemicals can also be carried by air currents from within and outside the basin to the Great Lakes. In fact, atmospheric deposition is a large source of some toxic chemicals to the Great Lakes and will remain a source of contaminants into the future.

Sub-Indicators Supporting the Indicator Assessment

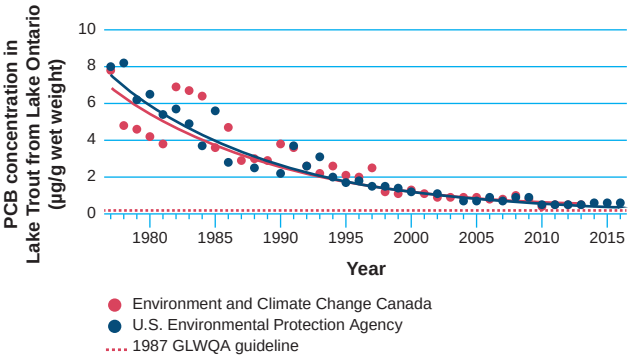
Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Toxic Chemicals in Sediment	Unchanging	Unchanging	Unchanging	Improving	Improving
Toxic Chemicals in Water	Improving	Undetermined	Unchanging	Unchanging	Unchanging
Toxic Chemicals in Whole Fish	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Toxic Chemicals in Herring Gull Eggs	Improving	Improving	Improving	Unchanging	Improving
Toxic Chemicals in the Atmosphere	No lake was assessed separately. Great Lakes Basin assessment is Fair and Improving.				

STATUS

Good | Fair | Poor | Undetermined

Toxic Chemicals

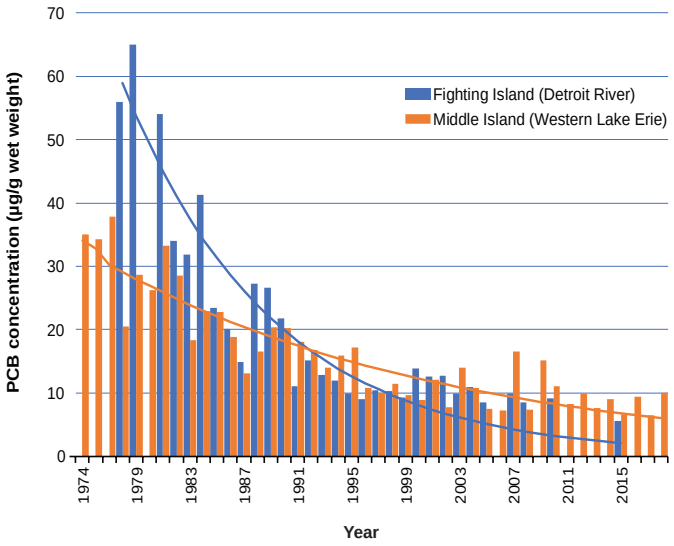
PCBs in Whole Fish Have Decreased



Assessing Toxic Chemicals

Toxic Chemical sub-indicator assessments include some of the binationally designated Chemicals of Mutual Concern (CMCs) and help support the tracking of progress on reducing these chemicals in the Great Lakes. For example, Per- and Polyfluoroalkyl Substances (PFAS), which include three CMCs, are currently being tracked in some components of the Great Lakes ecosystem. Recent data show that some PFAS are increasing in Lakes Erie and Ontario. The sub-indicator reports also include information on other toxic chemicals of interest including current-use pesticides.

PCBs in Herring Gull Eggs are Declining



HABITAT AND SPECIES

The 2012 Great Lakes Water Quality Agreement states that "the Waters of the Great Lakes should support healthy and productive wetlands and other habitats to sustain resilient populations of native species".

Status: FAIR
Trend: UNCHANGING

The Great Lakes are one of the most ecologically diverse ecosystems, supporting rare and unique species and habitats not found anywhere else in the world. Great Lakes coastal wetlands clean water, protect shorelines and provide habitat for many species. The Great Lakes offshore aquatic food web supports commercially and recreationally important fisheries. However, urban and agricultural development, pollution, invasive species and other factors threaten the health of Great Lakes species and their habitats.

Habitat and Species

Assessment Highlights

The Habitat and Species indicator includes assessments of Great Lakes coastal wetlands and components of the offshore aquatic food web. Coastal wetland and food web conditions are variable across the basin, ranging from Good to Poor and Improving to Deteriorating, depending on the lake basin, habitat and species of interest. The health of species in the Great Lakes is reflective of the availability and condition of the habitat that they dwell in. Overall, the Habitat and Species indicator is assessed as **Fair** and **Unchanging**.

Coastal Wetlands

Although coastal wetland restoration and protection efforts have improved certain coastal wetlands, others continue to be degraded. Coastal wetland habitats in Lake Superior and the northern shorelines of Lakes Michigan and Huron are generally in better condition and show fewer signs of impairment than wetlands in Lakes Erie and Ontario. While many wetland invertebrates, birds and plants have experienced long-term declines in abundance, some birds and amphibians are showing a more recent unchanging trend. Abundance of birds and amphibians have been recently assessed to be in Good condition in many wetlands in Lakes Superior, Michigan and Huron.

In Lakes Erie and Ontario, almost all coastal wetlands are degraded by nutrient enrichment, sedimentation, or a combination of both. Past regulation of water levels on Lake Ontario has also adversely affected coastal wetland habitat. However, a new plan has been implemented to allow more natural water level fluctuation patterns. European invasive plant species, such as Common Reed (also known as *Phragmites*), Frog-bit and Water Chestnut, are also a concern in Great Lakes coastal wetlands. These plant species can alter the hydrologic and nutrient cycles and

Sub-Indicators Supporting the Indicator Assessment

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Coastal Wetland Invertebrates	Deteriorating	Undetermined	Deteriorating	Undetermined	Undetermined
Coastal Wetland Fish	Improving	Undetermined	Unchanging	Undetermined	Improving
Coastal Wetland Amphibians	Undetermined	Unchanging	Unchanging	Unchanging	Improving
Coastal Wetland Birds	Undetermined	Undetermined	Unchanging	Unchanging	Improving
Coastal Wetland Plants	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Coastal Wetlands: Extent & Composition	No lake was assessed separately. Great Lakes Basin assessment is Undetermined.				
Aquatic Habitat Connectivity	Improving	Improving	Improving	Improving	Improving

STATUS

Good | Fair | Poor | Undetermined

eliminate native plants, reducing biodiversity and habitat quality. *Phragmites* has expanded to all Great Lakes, while Frog-bit is currently in Lakes Huron, Erie and Ontario wetlands, and Water Chestnut is expanding in the Lake Ontario basin.

Aquatic Food Web

The Great Lakes aquatic food web is made of many interacting species, ranging from tiny plants (phytoplankton) and animals (zooplankton) to top predator fish. Zooplankton feed on phytoplankton and are responsive to changes in the phytoplankton community, but zooplankton dynamics are also affected by fish predation and filtering by invasive Zebra and Quagga Mussels. There have been declines in phytoplankton and zooplankton biomass in Lakes Michigan and Huron in the early 2000s. Zooplankton biomass has remained stable since the initial decline and the communities are now dominated by species, such as calanoid copepods, that have adapted to low nutrient conditions. These zooplankton community shifts are changing the amount of food available to fish. In Lake Erie, phytoplankton communities are in Poor condition due to an increase in harmful cyanobacteria; however, zooplankton communities are in Good condition due to high lake productivity. Both phytoplankton and zooplankton communities in Lakes Superior and Ontario are currently assessed as Good and Unchanging, but Lake Ontario has lost some key species likely due to invasive mussel impacts.

Diporeia, a small bottom-dwelling shrimp-like species and an important source of food for fish, has severely declined in all lakes except Lake Superior. Invasive Zebra and Quagga Mussels have likely compounded this problem. These mussels filter phytoplankton

Sub-Indicators Supporting the Indicator Assessment

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Phytoplankton	Unchanging	Deteriorating	Deteriorating	Deteriorating	Unchanging
Zooplankton	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Benthos	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Diporeia	Unchanging	Deteriorating	Deteriorating	Unchanging	Deteriorating
Lake Sturgeon	Improving	Improving	Improving	Improving	Improving
Prey Fish	Unchanging	Deteriorating	Unchanging	Deteriorating	Unchanging
Lake Trout	Improving	Improving	Improving	Improving	Improving
Walleye	Improving	Unchanging	Unchanging	Unchanging	Unchanging
Fish-Eating & Colonial Nesting Waterbirds	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging

STATUS

Good Fair Poor Undetermined

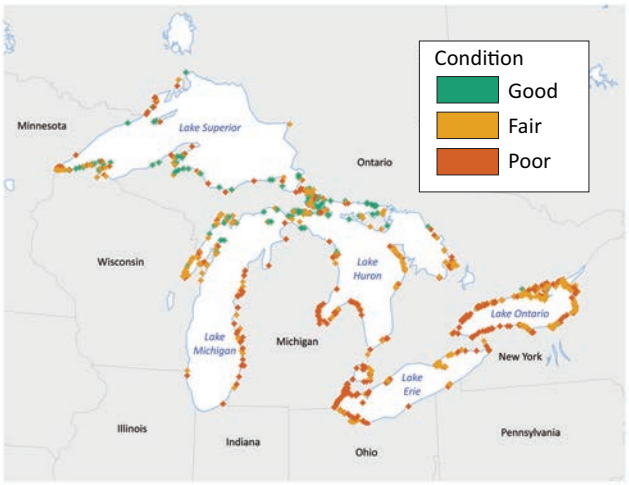
Habitat and Species

and small zooplankton from the water reducing the amount of available food settling to the bottom for other benthic organisms, such as *Diporeia*. The situation is complex and the exact mechanisms causing changes in *Diporeia* and zooplankton have yet to be fully determined.

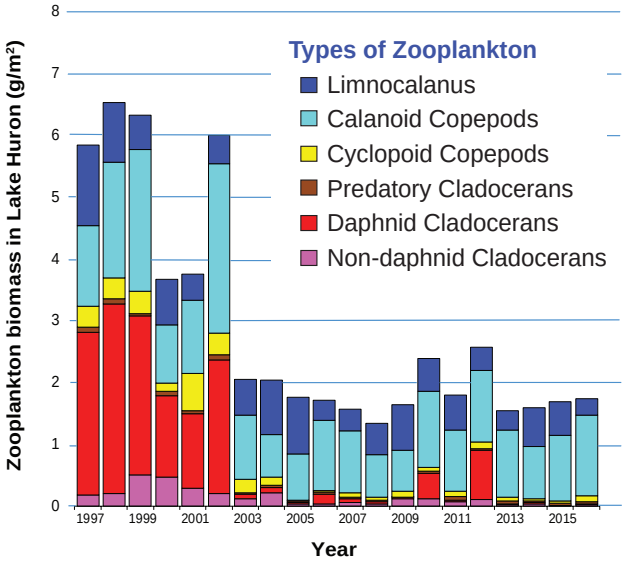
Zooplankton, phytoplankton and benthic communities are important sources of food for prey fish and are essential to sustaining a healthy food web. Prey fish communities across the Great Lakes continue to change, although the direction and magnitude of those changes vary. Despite fluctuations in population levels, the prey fish community is considered Fair overall based on the diversity and the proportion of native prey fish species in the Great Lakes. However, the abundance of prey fish is influenced by both food availability and the number of predator fish such as Lake Trout and Walleye that eat prey fish. A balance between the numbers of predator fish and the available prey fish in the lakes is important for a sustainable Great Lakes fishery.

Sustainable fishery management, on-going Sea Lamprey control, improving water quality and declines in Alewives (a non-native prey fish) have improved Walleye and Lake Trout populations. In the main basin of Lake Huron, wild Lake Trout make up more than 40% of total population in U.S. waters and more than 80% of total catch from Canadian waters. There has also been evidence of naturally reproducing Lake Sturgeon in some Great Lakes tributaries due in part to habitat improvements, dam removals and stocking efforts. Changes in Lake Sturgeon status will take a long time to manifest due to the long life span of the species.

Amphibians are in Good Condition in Many Northern Coastal Wetlands



Zooplankton Communities Have Changed in Lake Huron



NUTRIENTS AND ALGAE

The 2012 Great Lakes Water Quality Agreement 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".

Status: FAIR
Trend: UNCHANGING

Algae occur naturally in freshwater systems and are essential to a healthy aquatic ecosystem. Phosphorus is a key nutrient for the growth of primary producers (such as algae), which form the base of the aquatic food web. However, too much phosphorus can lead to harmful algal blooms and nuisance algae, which can be detrimental to the environment, the economy and human health. Conversely, too little phosphorus can result in not enough algae to support a healthy food web, which can threaten the sustainability of fisheries.

Nutrients and Algae

Assessment Highlights

In the 1980s and early 1990s, basin-wide restoration efforts were successful in reducing high-levels of nutrients which were contributing to the formation of harmful algal blooms, nuisance algae and hypoxic areas (areas of low oxygen) in the Great Lakes. However, there has been a resurgence of nutrient-related impairments due to impacts from invasive species, land use changes, shifting climate trends and other factors. Although nutrients and algal conditions for Lake Superior are generally good, conditions remain poor in Lake Erie. Overall, the Nutrients and Algae indicator is assessed as **Fair** and **Unchanging**.

To support a healthy aquatic food web, a certain level of nutrients is needed. Only in Lake Superior are offshore phosphorus concentrations considered good. The offshore regions of Lakes Michigan, Huron and Ontario have nutrient concentrations below ecosystem objectives. In fact, concentrations may be too low in some areas, resulting in insufficient growth of key phytoplankton species. Nutrient concentrations remain high in Lake Erie and some nearshore regions and embayments of other lakes.

High nutrient concentrations may lead to the formation of harmful algal blooms (HABs) and/or nuisance algae. HABs can include cyanobacteria which sometimes produce toxins such as microcystin. These toxins can impact drinking water safety and can cause gastrointestinal upsets, skin rashes and may be fatal to organisms when present at very high levels. Decomposition of large amounts of algae can also lead to hypoxic zones (such as the central basin of Lake Erie), which can suffocate aquatic organisms. The western basin of Lake Erie has experienced a recent resurgence of HABs although conditions are highly variable from year-to-year. The increase in HABs in the past decade is adversely impacting ecosystem health as well as commercial fishing, municipal drinking water systems and recreational activities. HABs are also a significant concern in some embayments, such as Hamilton Harbour and the Bay of Quinte in Lake Ontario, Saginaw Bay in Lake Huron, and Green Bay in Lake Michigan.

Sub-Indicators Supporting the Indicator Assessment					
Sub-Indicator	**Lake Superior**	**Lake Michigan**	**Lake Huron**	**Lake Erie**	**Lake Ontario**
Nutrients in Lakes	Unchanging	Deteriorating	Deteriorating	Unchanging	Deteriorating
Harmful Algal Blooms	Undetermined	Undetermined	Undetermined	Deteriorating	Deteriorating
Cladophora	Unchanging	Unchanging	Undetermined	Unchanging	Undetermined
Water Quality in Tributaries	Undetermined	Undetermined	Unchanging	Unchanging	Unchanging

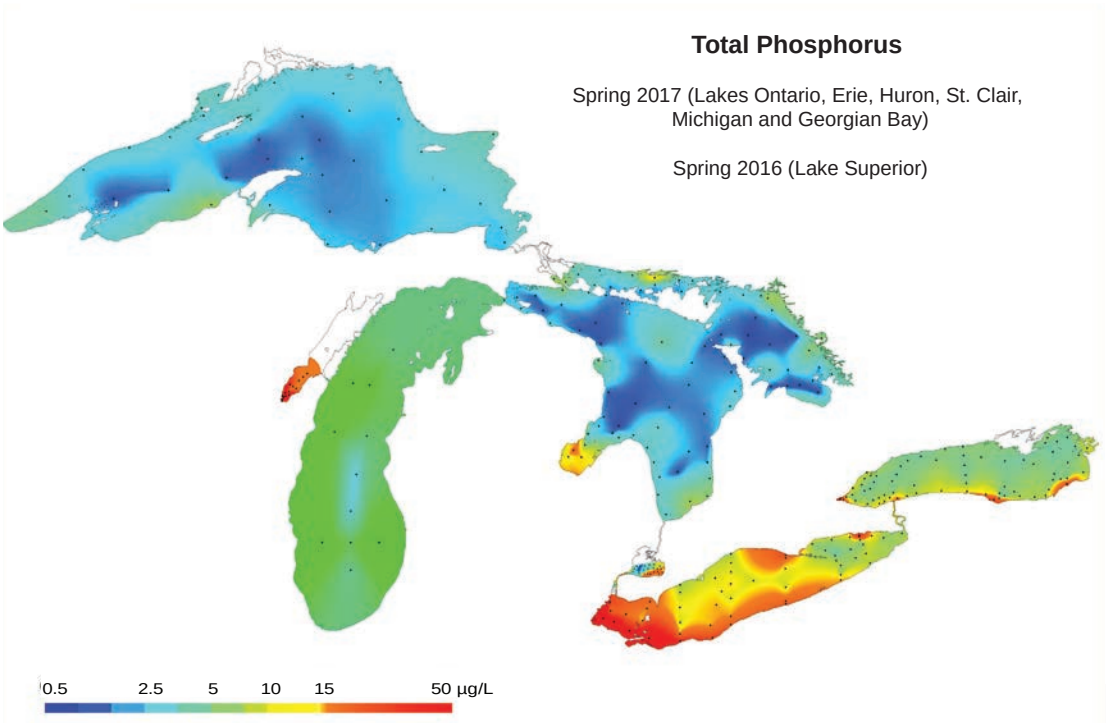
STATUS

Good **Fair** **Poor** **Undetermined**

Cladophora is a nuisance algae that can be broadly distributed over large areas of the nearshore regions of Lakes Erie, Ontario, Huron and Michigan. Excessive *Cladophora* poses many problems including beach and shoreline fouling, clogging of municipal water intakes, and can also impact tourism and recreational fishing. *Cladophora* washed up on shorelines may also harbor pathogens and create an environment conducive to the development of botulism outbreaks which pose a risk mainly for fish and birds. Currently, in some nearshore areas of the Great Lakes, *Cladophora* conditions are comparable to those in the 1960s and 1970s when nutrient concentrations were higher. The introduction of invasive Quagga and Zebra Mussels has changed nutrient dynamics and increased water clarity in many Great Lakes, contributing to increased *Cladophora* growth. However, it also has also been observed that large mats of *Cladophora* can persist despite low nutrient concentrations in the surrounding water, which is further complicating the understanding and management of *Cladophora*.

Warmer water temperatures, higher frequency and intensity of precipitation events, coupled with invasive Zebra and Quagga Mussels, are confounding factors in the cycling and algal uptake of nutrients in the lakes. These factors lead to increased frequency, distribution and severity of HABs, hypoxic zones and *Cladophora*.

Total Phosphorus Concentrations are Variable Across the Great Lakes



INVASIVE SPECIES

The 2012 Great Lakes Water Quality Agreement states that "the Waters of the Great Lakes should be free from the introduction and spread of aquatic invasive species and free from the introduction and spread of terrestrial invasive species that adversely impact the quality of the Waters of the Great Lakes".

Status: POOR
Trend: DETERIORATING

The number of new invasive species entering the Great Lakes has been significantly reduced; however, some invasive species already in the Great Lakes, such as Sea Lamprey, Zebra and Quagga Mussels, and *Phragmites,* continue to cause substantial ecological and economic impacts.

Invasive Species

Assessment Highlights

The Invasive Species indicator highlights that there are significant negative impacts to the Great Lakes ecosystem caused by invasive species. Those invasive species already in the Great Lakes continue to impact biological communities, degrade water quality and alter nutrient cycling. As such, the Invasive Species indicator is assessed as **Poor** and the trend is **Deteriorating**.

To date, over 185 aquatic non-native species have become established in the Great Lakes basin. There has been tremendous success in reducing the introduction of invasive species largely due to the implementation of regulations on ballast water from transoceanic ships. Additionally, Asian carp control actions in the U.S. and Canada, including the electric barrier on the Chicago Sanitary and Ship Canal, continue to be successful in preventing their establishment in the Great Lakes. These activities, along with other binational efforts including early detection and rapid response programs, have been extremely important in preventing the introduction of new non-native species.

New species are still entering the Great Lakes through various pathways, albeit at a much slower rate. There have been recent discoveries of two non-native zooplankton species (*Diaphansosoma fluviatile* and *Mesocyclops pehpeiensis*). These species require further investigation to determine if they will have a negative impact to the ecosystem.

Despite the significant slowdown in introductions, the impacts of established invaders persist and the population ranges of some invaders continue to spread within and between the lakes. It is believed that at least 30% of the aquatic non-native species found in the Great Lakes have significant

Sub-Indicators Supporting the Indicator Assessment

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Rate of Invasion of Aquatic Non-Indigenous Species	No lake was assessed separately. Great Lakes Basin assessment is Good and Undetermined.				
Impacts of Aquatic Invasive Species	Deteriorating	Deteriorating	Deteriorating	Deteriorating	Deteriorating
Sea Lamprey	Unchanging	Improving	Improving	Improving	Improving
Dreissenid Mussels	Unchanging	Deteriorating	Deteriorating	Unchanging	Deteriorating
Terrestrial Invasive Species	Deteriorating	Deteriorating	Deteriorating	Deteriorating	Deteriorating

STATUS

Good | Fair | Poor | Undetermined

Invasive Species

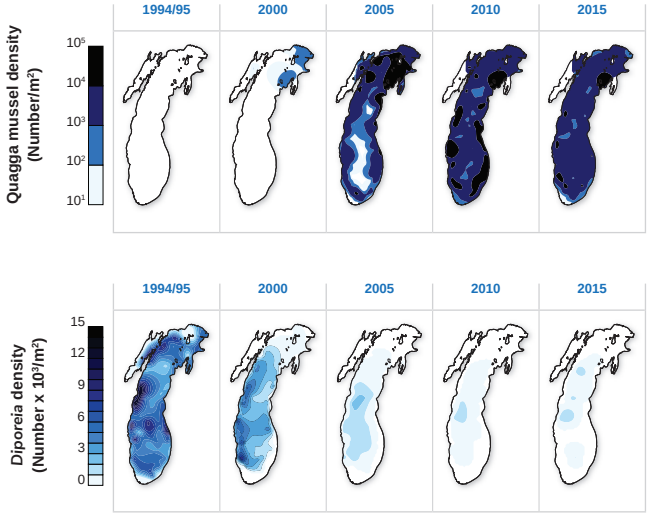
environmental or socioeconomic impact. Limiting the impact of existing invaders is critical for promoting ecosystem health.

Sea Lamprey abundance has been reduced significantly in the five lakes through on-going and basin-wide control measures. However, native fish such as Lake Trout and Lake Sturgeon are still subject to Sea Lamprey predation. Recent Sea Lamprey increases in Lakes Erie and Superior are being observed, but the causes of these changes are not clear. Sea Lamprey remain an impediment to achieving critical fish community and ecosystem objectives.

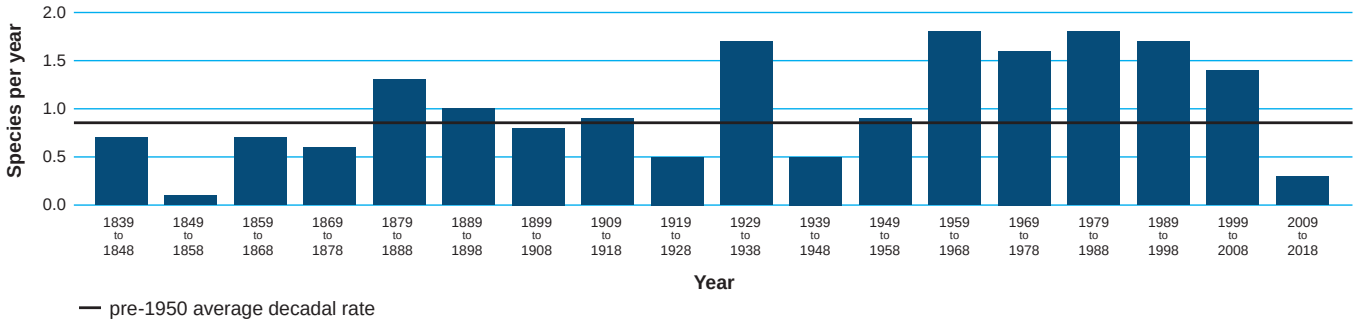
Zebra and Quagga Mussels are two other prominent invasive species in the Great Lakes. In Lake Superior, invasive mussel population densities are low. In Lakes Michigan, Huron and Ontario, populations in the shallow and mid-depth regions appear to be stable or declining, while populations in the deepest regions of these lakes continue to increase. Invasive mussel densities in Lake Erie are lower, especially in hypoxic regions such as the central basin. Invasive mussels continue to have a significant effect on the lakes by impacting nutrient cycling, increasing water clarity and altering zooplankton and phytoplankton communities. These changes have been linked to the proliferation of both harmful algal blooms and nuisance algae. Invasive mussel presence may also be linked to the disappearance of the native species *Diporeia*, an important source of food for fish.

Terrestrial invasive plant species in the Great Lakes basin, such as *Phragmites*, Purple Loosestrife and Garlic Mustard, are widely distributed and have detrimental impacts on the ecosystem including degrading habitat, biodiversity and water quality.

Quagga Mussels are Increasing - *Diporeia* are Declining



Rate of Introduction of New Non-Native Species Has Declined



GROUNDWATER

The 2012 Great Lakes Water Quality Agreement states that "the Waters of the Great Lakes should be free from the harmful impact of contaminated groundwater".

Status: FAIR
Trend: UNDETERMINED

Groundwater can enhance surface water quality of lakes and rivers. Groundwater can also transmit contaminants and nutrients to the Great Lakes.

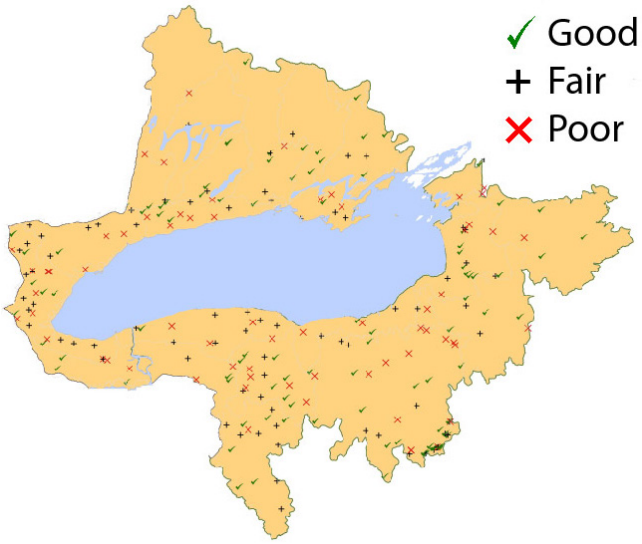
Groundwater

Assessment Highlights

The Groundwater Quality indicator is assessed as **Fair** but the trend is **Undetermined** due to insufficient long-term data. The concentrations of nitrate, primarily from agricultural practices, and chloride, mainly from the urban use of road de-icing salt, are used to assess regional groundwater quality. Elevated concentrations of both of these constituents in water can have detrimental impacts to ground- and surface water quality, aquatic ecosystems and human health.

Portions of the Great Lakes basin with more intense development, such as areas within the basins of Lakes Michigan, Erie and Ontario, are generally assessed as Fair. Groundwater quality is generally assessed as good in the less developed areas, such as portions of the Lake Huron basin. There is also limited data coverage, especially in the Lake Superior basin, where the assessment is Undetermined. A better understanding about the impacts of contaminated groundwater and its interaction with the waters of the Great Lakes is needed, particularly for the nearshore zone.

Groundwater Quality Assessment for Lake Ontario is Fair



Sub-Indicators Supporting the Indicator Assessment					
Sub-Indicator	**Lake Superior**	**Lake Michigan**	**Lake Huron**	**Lake Erie**	**Lake Ontario**
Groundwater Quality	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined

STATUS

Good | Fair | Poor | Undetermined

WATERSHED IMPACTS AND CLIMATE TRENDS

The 2012 Great Lakes Water Quality Agreement states that "the Waters of the Great Lakes should be free from other substances, materials or conditions that may negatively impact the chemical, physical or biological integrity of the Waters of the Great Lakes".

Status: FAIR
Trend: UNCHANGING

The number of people living in the Great Lakes basin has increased by about 20 percent since the 1970s, resulting in significant changes to land use. Climate trends are also shifting across the Great Lakes basin, including warming temperatures, changing precipitation patterns, decreased ice coverage, and greater fluctuations of water levels. Changes in land use and shifting climate trends can have a profound effect on Great Lakes water quality.

Watershed Impacts and Climate Trends

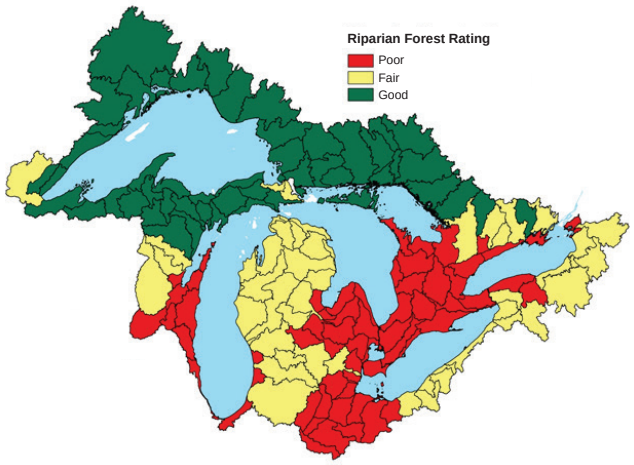
Assessment Highlights

Land based stressors which can affect water quality are **Fair** and **Unchanging**. Climate trends are also tracked through the Watershed Impacts and Climate Trends indicator, however, they are assessed differently.

Watershed Impacts

The northern lake basins remain largely undeveloped and dominated by natural cover. The southern lake basins are more populated with less natural cover. Population, development, agriculture and road density are stressors on the Great Lakes ecosystem, especially in areas with larger populations. Urban and agricultural lands are important to the Great Lakes region because they help support people and the economy; however, the water quality in these areas is more likely to be impaired. Rapid population growth, as seen in the western end of Lake Ontario, can further stress the environment and water quality.

Forest Cover Helps to Improve Water Quality



Across the entire basin, there is a trend of increasing development, resulting in a loss of agricultural, forested and other natural lands. Tributary flashiness, or short-term changes in stream flow in response to storm events, varies across the Great Lakes

Sub-Indicators Supporting the Indicator Assessment

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Forest Cover	Unchanging	Unchanging	Unchanging	Improving	Deteriorating
Land Cover	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Hardened Shorelines	Undetermined	Undetermined	Undetermined	Undetermined	Deteriorating
Watershed Stressors	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Baseflow Due to Groundwater	No lake was assessed separately. Great Lakes Basin assessment is Undetermined.				
Tributary Flashiness	No lake was assessed separately. Great Lakes Basin assessment is Unchanging.				
Human Population	Unchanging	Increasing	Increasing	Unchanging	Increasing

STATUS

Good | Fair | Poor | Undetermined

depending on the land cover, land use and soil type. In general, higher tributary flashiness can impact water quality and aquatic life by increasing the delivery of contaminants and sediments to the lakes. Tributary flashiness has been Unchanging in most of the assessed rivers; however, there are a few rivers where tributary flashiness has been increasing which may be indicative of changing land uses.

Research has shown that an increase in forest cover improves water quality. In particular, forest cover within a riparian zone (i.e., land along a lake, river or stream) plays a key role in stabilizing soil and can help reduce runoff, nutrient loading and other non-point source pollutants. Forest cover in riparian zones varies, with the Lake Superior watershed having the greatest amount and the Lake Erie watershed having the least. With half of the Great Lakes basin currently in agricultural or developed land use, and with much less forest cover in the more southern parts of the Great Lakes basin, it is evident that land-based pressures can significantly impact water quality.

Climate Trends

Long-term climate data generally show basin-wide increases in precipitation, increases in surface water temperatures for Lakes Superior, Michigan and Huron, and a reduction in Great Lakes ice cover. In general, water levels in Lakes Superior, Michigan and Huron show no significant change over the last 100 years, while Lakes Erie and Ontario have seen increasing water levels. However, short-term trends can be quite variable. For example, water levels in Lakes Superior, Michigan, Huron and Erie have increased over the past 10 years. In addition, Lake Ontario experienced its highest monthly mean levels in 100 years during May to July of 2017. Due to the many hydrological influences on lake levels, it is difficult to determine with certainty if these water level trends are within natural climatic variability or are longer-term trends that will continue in the future.

Shifts in climate can affect Great Lakes habitats including impacting spawning and other habitats for fish species, the extent and quality of coastal wetlands, and forest composition. Shifts in climate can also alter biological communities, such as

Sub-Indicators Supporting the Indicator Assessment					
Sub-Indicator	**Lake Superior**	**Lake Michigan**	**Lake Huron**	**Lake Erie**	**Lake Ontario**
Precipitation Amounts (1948-2015)	No lake was assessed separately. Great Lakes Basin trend is Increasing.				
Water Levels (1918-2017)	Unchanging	Unchanging	Unchanging	Increasing	Increasing
Surface Water Temperature (1980-2017)	Increasing	Increasing	Increasing	Unchanging	Undetermined
Ice Cover (1973-2018)	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing

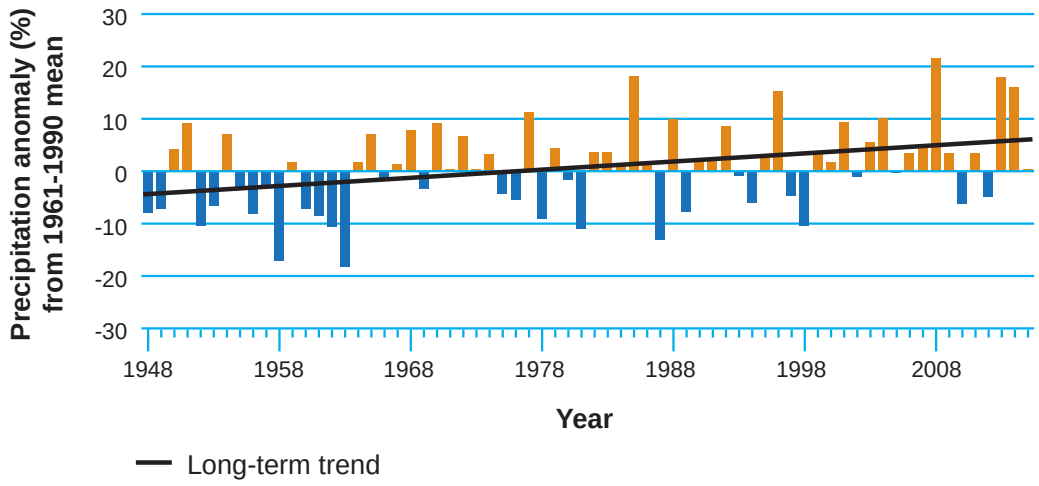
Watershed Impacts and Climate Trends

contributing to the northward migration of native and invasive species and creating conditions that favor some invaders over native species. Great Lakes water quality can also be impacted by shifts in climate due to increases in runoff, changes to contaminant and nutrient cycling and increases in algal blooms. Increases in the intensity and frequency of storm events can exacerbate the impacts to habitats, biological communities and water quality.

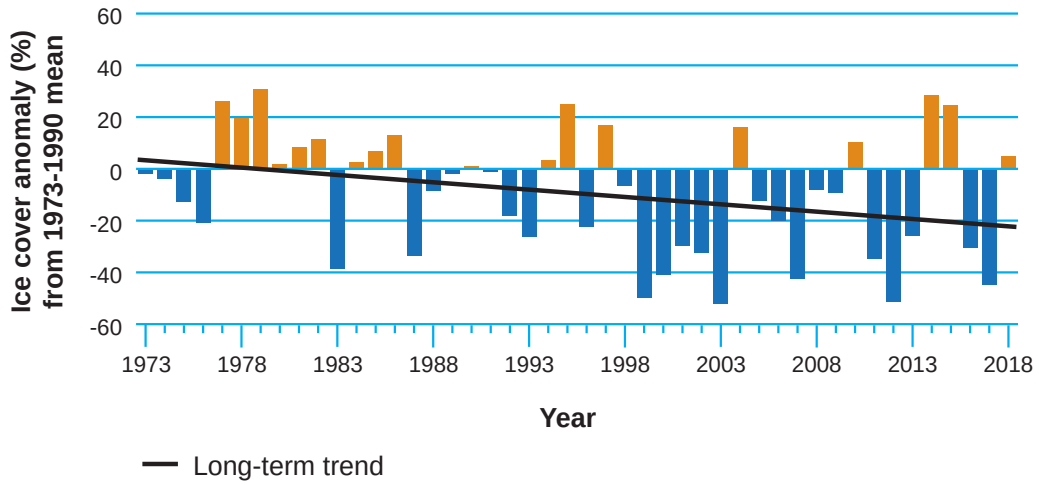
Assessing Climate Trends

Climate information is not assessed in the same manner as other indicators in this report. The ecosystem has adapted to and needs variable conditions and therefore climate sub-indicators cannot be assessed as **Good** or **Poor**. However, extreme conditions may cause stress to the ecosystem. Therefore, climate trends are simply assessed as **Increasing**, **Unchanging** or **Decreasing**.

Total Annual Precipitation is Increasing

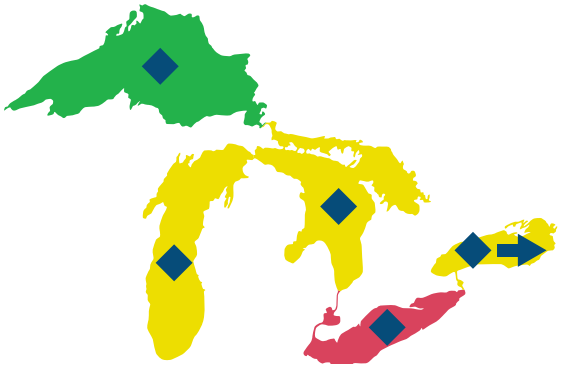


Ice Cover is Decreasing



LAKE ASSESSMENTS

Lake Assessments



STATUS

Good Fair Poor Undetermined

TREND

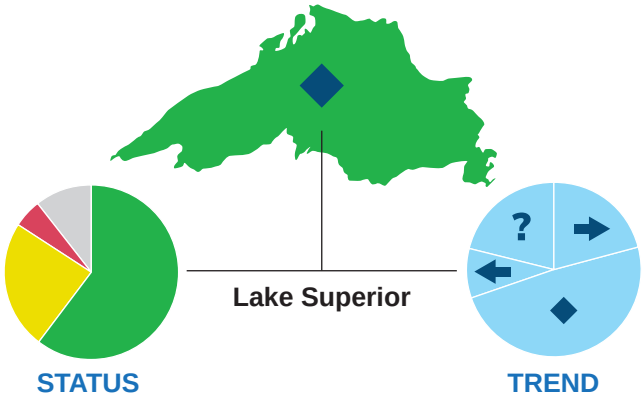
Improving Unchanging Deteriorating ? Undetermined

The same suite of indicators and supporting sub-indicators used to assess the overall condition of the Great Lakes is used to assess each individual lake. Each Great Lake has unique status and trend assessments for each sub-indicator and these contribute to the overall lake assessments.

Lake Superior's Ecosystem is in Good Condition and the Trend is Unchanging

Lake Superior continues to be a good source of high-quality drinking water and has beaches and nearshore areas that continue to provide good opportunities for swimming and recreational use. Toxic chemicals are generally lower in Lake Superior and continue to decline; however, fish consumption advisories continue to be in effect. Overall, the Lake Superior basin supports many habitats, including coastal wetlands which are in Good condition and support native species. However, the loss of habitat connectivity between the tributaries and the lake is impacting some native fish such as Lake Sturgeon. Lake Trout are in Good condition. They are supported by a stable and diverse prey fish population. The lower food web is healthy, with the small, shrimp-like species of *Diporeia* at Good levels. Nutrient concentrations in the lake are similar to historic values, indicating acceptable ecosystem conditions. Harmful algal blooms and nuisance algae are generally not a concern in the lake. However, some short-lived non-toxic blooms of cyanobacteria occur in the area between Duluth Harbor and Apostle Islands. Invasive species, particularly Sea Lamprey, are still causing harm to predatory fish such as Lake Trout. The status and trend for groundwater quality is Undetermined as there are limited data for a lakewide assessment. Due to the high percentage of natural land cover, watershed-based stressors are not as significant in the Lake Superior basin. However, the lake is experiencing changes due to long-term climate shifts, such as warming waters and decreases in ice cover.

Status and Trend of Lake Superior is Good and Unchanging Based on the Assessed Sub-Indicators



STATUS

Good Fair Poor Undetermined

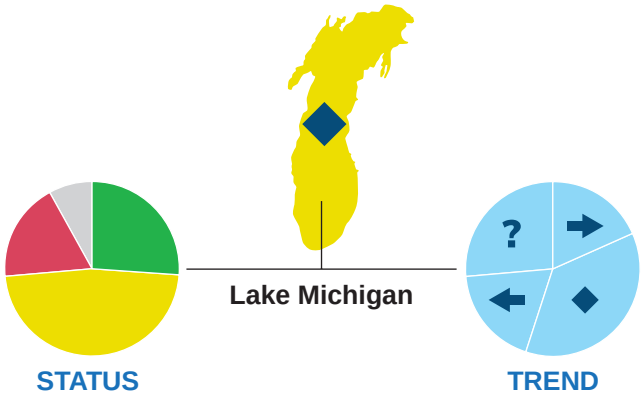
TREND

Improving Unchanging Deteriorating ? Undetermined

Lake Michigan's Ecosystem is in Fair Condition and the Trend is Unchanging

Lake Michigan continues to be a good source of high-quality drinking water and has beaches and nearshore areas that continue to provide good opportunities for swimming and recreational use. Toxic chemicals continue to decline in the environment due to regulations, voluntary actions and sediment remediation; however, fish consumption advisories continue to be in effect. Coastal wetland bird and amphibian communities are in Good condition while coastal wetland plant communities are in Fair condition. However, high water levels in Lake Michigan from 2014 through 2017 resulted in erosion of wetland vegetation from the more exposed marshes. Over the past 20 years, the aquatic food web has been significantly impacted by filter-feeding Zebra and Quagga Mussels. In some nearshore areas, there is excessive growth of *Cladophora*.

Status and Trend of Lake Michigan is Fair and Unchanging Based on the Assessed Sub-Indicators



STATUS

Good Fair Poor Undetermined

TREND

Improving Unchanging Deteriorating ? Undetermined

Offshore, a combination of low phosphorus levels and mussel feeding contribute to reduced phytoplankton biomass. In the mid-2000s, zooplankton biomass rapidly declined and the zooplankton community shifted towards species better adapted to oligotrophic conditions; zooplankton biomass has since remained low but stable. Long-term declines of zooplankton and *Diporeia*, both important sources of food for fish, contribute to the low abundances of prey fish populations. Increased natural reproduction of Lake Trout is evident, due in part to the successful control of Sea Lamprey. Lake Trout is an important species of the multi-million dollar Lake Michigan sport fishery. Groundwater quality is Fair for areas of the basin that were assessed. Land-based stressors will continue to impact the Lake Michigan basin. Shifts in long-term climate trends, such as increasing water temperatures and decreases in ice cover, may have ecosystem implications.

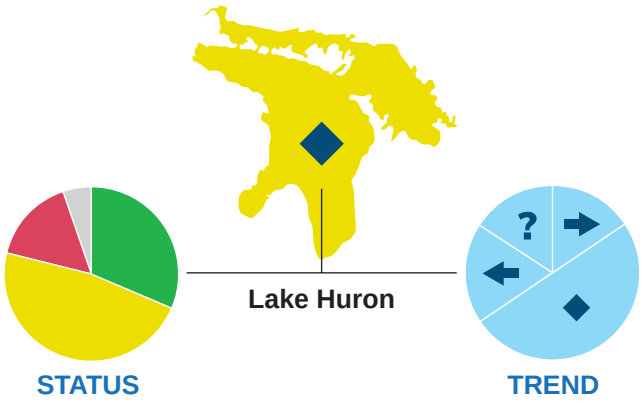
Lake Huron's Ecosystem is in Fair Condition and the Trend is Unchanging

Lake Huron continues to be a good source of high-quality drinking water and has beaches and nearshore areas that continue to provide opportunities for swimming and recreational use. Concentrations of toxic chemicals are much lower compared to the 1970s; however, fish consumption advisories continue to be in effect. Lake Huron has some examples of intact, high quality habitats, including many coastal wetlands. In the south, agricultural stressors contribute to habitat degradation. Populations of fish, as well as species of the lower food web, have remained low in the offshore waters since the mid-2000s. Fish populations in the nearshore waters, including Walleye, have not been significantly impacted by the changes in the lower food web. Phosphorus concentrations remain very low in the offshore

Lake Assessments

waters. Invasive species, particularly the filter feeding Quagga Mussel, are contributing to the low productivity in offshore waters, and nuisance algae in some nearshore waters. The invasive Sea Lamprey is a continuing threat to large predator fish such as Lake Trout. Groundwater is in good condition with low chloride and nitrate levels in the areas assessed. Land-based stressors continue to impact the Lake Huron basin. Shifts in long-term climate trends, such as increasing water temperatures and decreases in ice cover, may have ecosystem implications.

Status and Trend of Lake Huron is Fair and Unchanging Based on the Assessed Sub-Indicators



STATUS

Good Fair Poor Undetermined

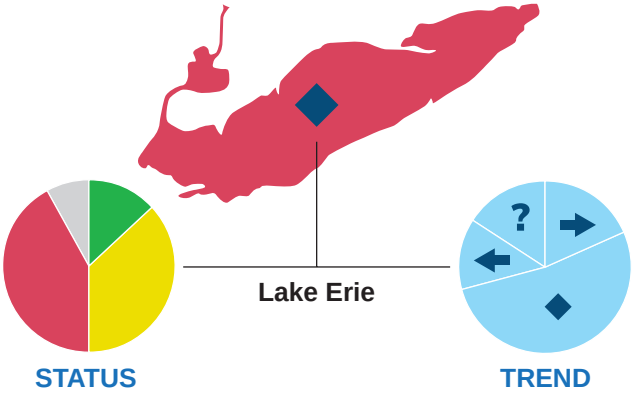
TREND

Improving Unchanging Deteriorating ? Undetermined

Lake Erie's Ecosystem is in Poor Condition and the Trend is Unchanging

Lake Erie continues to be a good source of high-quality drinking water and has beaches and nearshore areas that continue to provide opportunities for swimming and recreational use. Canadian monitored beaches have shown a recent increase in the number of days that beaches are open and safe for swimming. Toxic chemicals continue to decline in the environment; however, fish consumption advisories continue to be in effect. Harmful algal blooms resulting from excessive nutrients occur regularly in the western basin of Lake Erie during the summer months. Excessive growth of *Cladophora* continues to be a problem in the eastern basin of the lake. Prey fish diversity and the proportion of native prey fish species have declined, but despite a changing prey fish community, Lake Erie supports the largest self-sustaining Walleye population in the world. Lake Trout abundance has increased, due in part to declines in Sea Lamprey populations, but there is no evidence of natural reproduction. Self-sustaining populations of Lake Sturgeon are found in St. Clair River, Detroit River and the Upper Niagara River. Increased aquatic habitat connectivity due to dam removal and mitigation projects is further supporting the increasing predator

Status and Trend of Lake Erie is Poor and Unchanging Based on the Assessed Sub-Indicators



STATUS

Good Fair Poor Undetermined

TREND

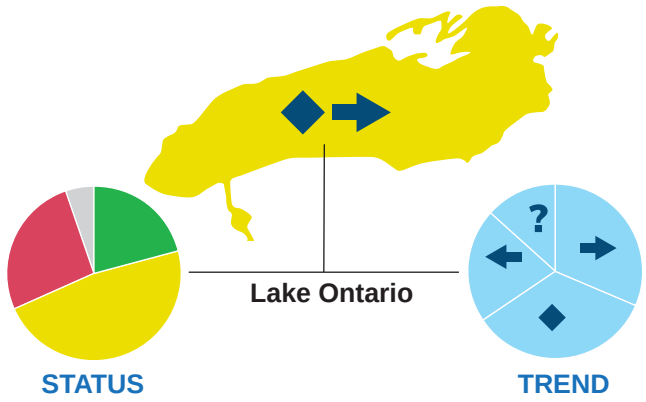
Improving Unchanging Deteriorating ? Undetermined

and prey fish populations in the lake. Coastal wetland conditions range from Fair to Poor. Invasive species, particularly Sea Lamprey, are still causing harm to predatory fish. The status of nitrate and chloride in groundwater is Fair for areas of the basin that were assessed. Land-based stressors continue to impact Lake Erie. Shifts in climate trends such as earlier onset of stratification and decreases in ice cover, may also have ecosystem implications.

Lake Ontario's Ecosystem is in Fair Condition and the Trend is Unchanging to Improving

Lake Ontario continues to be a good source of high-quality drinking water and has beaches and nearshore areas that continue to provide good opportunities for swimming and recreational use. Over the past 10 years, Canadian Lake Ontario monitored beaches are improving with an increase in the number of days that beaches are open and safe for swimming. Toxic chemicals continue to decline in the environment leading to less restrictive fish consumption advisories. Coastal wetlands have been impacted by development, regulated water levels and invasive species such as *Phragmites* and cattails. However, coastal wetland fish, amphibians and birds are showing improving trends. Impaired habitat connectivity between the tributaries and the lake are impacting some native species. Lake Trout populations are improving, due in part to the successful Sea Lamprey control. Prey fish are in Poor condition. However, some native prey fish, such as Deepwater Sculpin, are recovering naturally and restoration efforts for populations of other native prey fish are proving successful. Lake Sturgeon populations are showing some signs of recovering. *Diporeia*, an important component of the lower food web and a major food source for prey fish, is rarely found during regular sampling. Nutrient issues in the lake continue to be a challenge. Offshore phosphorus concentrations are below the target objective and are limiting productivity. *Cladophora* is problematic in some nearshore areas due in part to increased water clarity caused by the filtering effects of invasive mussels. Harmful algal blooms occur in some embayments of the lake. Invasive species, including the Sea Lamprey, invasive mussels and *Phragmites*, have significantly changed the habitat and food web in Lake Ontario. The status of groundwater quality is Fair but the trend is Undetermined as there is not enough data to make a lakewide assessment. Land-based stressors continue to impact Lake Ontario, including the rapid population growth in the western part of the basin. Shifts in climate trends such as decreases in ice cover may have ecosystem implications.

Status and Trend of Lake Ontario is Fair and Unchanging to Improving Based on the Assessed Sub-Indicators



Participating Organizations

Many people have been involved with the development of the State of the Great Lakes 2019 Reports. Thank you to the authors and advisory committee members, as represented by the organization logos below, for their continued support.

Definitions

Status[+] terms are generally defined as:

Good: Most or all ecosystem components are in acceptable condition.
Fair: Some ecosystem components are in acceptable condition.
Poor: Very few or no ecosystem components are in acceptable condition.
Undetermined: Data are not available or are insufficient to assess condition of the ecosystem components.

Trend[+] terms are generally defined as:

Improving: Metrics show a change toward more acceptable conditions.
Unchanging: Metrics generally show no overall change in condition.
Deteriorating: Metrics show a change away from acceptable condition.
Undetermined: Metrics do not indicate a clear overall trend, or data are not available to report on a trend.

[+]see individual sub-indicator reports for more detail on Status and Trend definitions.

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The *State of the Great Lakes 2019 Highlights Report* is a summary of science-based information from 45 sub-indicator reports. These sub-indicator reports are included in their entirety in the *State of the Great Lakes 2019 Technical Report*.
For more information about the state of the Great Lakes reporting, visit the following websites:
www.binational.net
www.canada.ca/great-lakes-protection
www.epa.gov/greatlakes

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