STATE OF THE GREAT LAKES 2022 REPORT

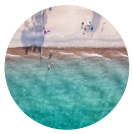
An overview of the status and trends of the Great Lakes ecosystem

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 indicating pathogen risks.

Can we eat the fish?

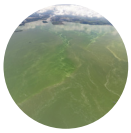
Generally, yes. Great Lakes fish can be safely eaten by following consumption guidelines and advisories. However, unrestricted fish consumption is not yet possible, which has a greater impact on communities that heavily rely on fish for food, and cultural, spiritual, or economic purposes.

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 populations of native species?

Yes and no. Healthy coastal wetlands exist in each Great Lake basin. However, Great Lakes coastal wetlands vary in quality with the healthiest in northern locations where the footprint of human activity is the lowest. Changes have taken place in the food webs of the Great Lakes to varying degrees and the impacts of stressors such as invasive dreissenid mussels (zebra and quagga mussels) and climate change continue. Native fish species such as Lake Trout and Lake Sturgeon are responding well to restoration efforts in several areas across the Great Lakes.



Are nutrients in the lakes at acceptable levels?

No. High nutrient levels in parts of Lake Erie, and some embayments in other parts of the Great Lakes, are contributing to blooms of toxic cyanobacteria and nuisance algae. On the other hand, very low nutrient levels in the offshore waters of lakes Michigan, Huron, and Ontario have resulted in productivity (algal and organism growth rates) below desired levels. Only Lake Superior has relatively good nutrient conditions, which helps to maintain a healthy food web.

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

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

Is groundwater negatively affecting the water quality of the lakes?

Generally, no. Groundwater typically provides good quality water to tributaries in the basin and to the Great Lakes. In some areas of the Great Lakes watershed, however, groundwater has elevated levels of pollutants, such as nitrate and chloride. There are also contaminated groundwater sites being actively investigated and remediated.

Are land use changes or other stressors impacting the lakes?

Yes. Watershed stressors such as population growth, habitat loss and degradation, land-use activities, as well as climate change, can impair Great Lakes water quality and ecosystem health.

Overall, the Great Lakes are assessed by the State of the Great Lakes indicators as Fair and the trend is Unchanging. There has been tremendous progress to restore and protect the Great Lakes, including the reduction of toxic chemicals, and a reduction in the establishment of new non-native aquatic species. However, some indicator assessments demonstrate that there are still significant challenges, including the impacts of nutrients, especially in Lake Erie and localized areas, and the impacts of invasive species. Climate change is already exacerbating some threats. The continued actions of many groups and individuals are contributing to further improvements in the Great Lakes.

What Is the Status of Each Lake?

Lake Superior's forested watershed and coastal wetlands help maintain water quality and a healthy aquatic ecosystem – Lake Superior is assessed as **Good** and **Unchanging.**

Lake Michigan's habitats support a diverse array of plant and animal species and its waters continue to provide opportunities for swimming and recreational use. However, invasive species and other stressors continue to affect both water quality and the lake's food web – Lake Michigan is assessed as **Fair** and **Unchanging.**

Lake Huron remains healthy despite nearshore algal blooms and a reduction in offshore nutrients by invasive filter-feeding mussels – Lake Huron is assessed as **Good** and **Unchanging.**

Lake Erie supports a productive Walleye fishery, but elevated nutrient concentrations and algal blooms are persistent problems – Lake Erie is assessed as **Poor** and **Unchanging.**

Lake Ontario shows improvements with fewer beach closings and declines in contaminant concentrations in fish – Lake Ontario is assessed as **Fair** and **Unchanging to Improving.**

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 the largest freshwater ecosystem on Earth, supporting rare and globally unique species and ecosystems. They provide a source of drinking water to approximately 28 million 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. To the Indigenous communities around the basin, the Great Lakes waters, plants and wildlife provide a continuation of lifeways and a sense of identity. Indigenous communities recognize that the inherent value of the Great Lakes must be maintained through a relationship founded on respect and care.

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 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 waters of the Great Lakes, through sound management, use and enjoyment, will benefit present and future generations of Canadians and Americans. In fact, 2022 marks the 50th anniversary of the signing of the Agreement – 50 years over which the two countries and their many Agreement partners have worked together to protect this valuable resource.

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 directly linked to the General Objectives of the Great Lakes Water Quality Agreement and supported by 40 science-based sub-indicators. For this report, more than 110 government and non-government Great Lakes scientists and other experts analyzed available data (for most sub-indicators this includes data up to 2019 or 2020) and reached consensus on the assessments of each indicator in relation to both current status and trend over time. Statuses are described in terms of Good, Fair or Poor* conditions. Trends are described as being Improving, Unchanging, or Deteriorating* and are generally assessed over a 10-year period. Refer to the State of the Great Lakes 2022 Technical Report for all sub-indicator reports. *See page 39 for definitions.

How is the assessment of the Great Lakes used?

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

2022 assessment of the nine Great Lakes indicators of ecosystem health

Great Lakes Indicator	2022 Assessment: Status and Trend
Drinking Water	Status: Good; *Trend*: Unchanging
Beaches	Status: Good; *Trend*: Unchanging to Improving
Fish Consumption	Status: Fair; *Trend*: Improving
Toxic Chemicals	Status: Fair; *Trend*: Unchanging to Improving
Habitat and Species	Status: Fair; *Trend*: Unchanging
Nutrients and Algae	Status: Fair; *Trend*: Unchanging
Invasive Species	Prevention: Status: Good; *Trend*: Unchanging
	Impact: Status: Poor; *Trend*: Unchanging
Groundwater	Status: Good; *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*

Approximately 8.5 million Canadians and 19.5 million Americans get their drinking water from the surface waters of the Great Lakes.

* Trend based on Ontario data only

Drinking Water

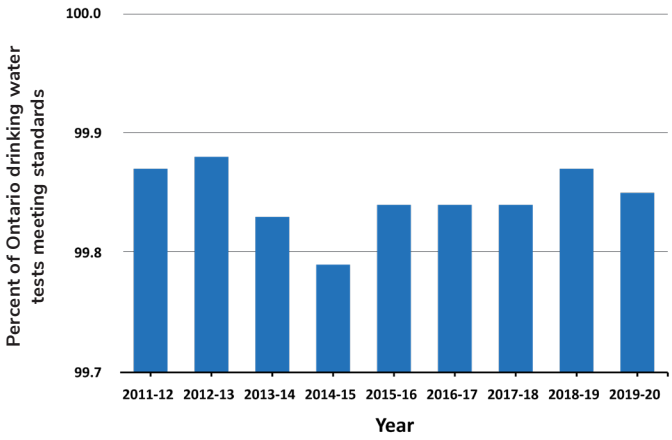
Assessment Highlights

The overall status of treated drinking water sourced from Great Lakes surface waters is **Good**. Based on Ontario data from 2011 to 2020, the trend is **Unchanging**. A 10-year trend was not established for U.S. treated water quality because a revised approach was used that more accurately aggregates Great Lakes-sourced treated drinking water data from Great Lakes states. While this improves the assessment, a trend cannot be determined because the current data are not directly comparable with data used in past reports. A U.S. treated water quality trend for Great Lakes-sourced drinking water will be assessed in future reports. The waters of the Great Lakes continue to be a source of high-quality drinking water. 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 monitoring protocols and reporting requirements regarding the quality of treated drinking water. Both countries compare microbial, radiological, and chemical parameters in treated drinking water to health-based standards. In the Province of Ontario, approximately 60% of the population is supplied with treated drinking water from the Great Lakes. In 2020, 99.8% of municipal residential treated drinking water quality tests met Ontario Drinking Water Quality Standards.

Of the 19.5 million U.S. residents served by the public water supplies that rely on the Great Lakes as their source water, 99.1% were serviced with drinking water that met all applicable health-based standards in 2020. While basin-wide treated drinking water is assessed as **Good**, localized exceedances of drinking water standards sometimes occur, impacting drinking water quality in those areas. Exceedances of drinking water standards can be caused by adverse source water quality, failure to treat properly, and inadequate water treatment and distribution infrastructure.

Over 99.7% of Ontario municipal residential treated drinking water quality tests met standards each year between 2011-2020



Sub-indicator supporting the Drinking Water assessment					
Sub-Indicator	**Lake Superior**	**Lake Michigan**	**Lake Huron**	**Lake Erie**	**Lake Ontario**
Treated Drinking Water	Good & Undetermined	Good & Undetermined	Good & Undetermined	Good & Undetermined	Good & Undetermined

This indicator and overall assessment are based on treated drinking water information from both Ontario and the U.S., however Ontario treated water data are not available for individual lake assessments. To assess individual lakes, U.S. treated drinking water data and Ontario source water data are used. There were insufficient data to determine a 10-year trend for individual lakes.

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 TO IMPROVING

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 including bacterial contamination (indicating pathogens).

Beaches

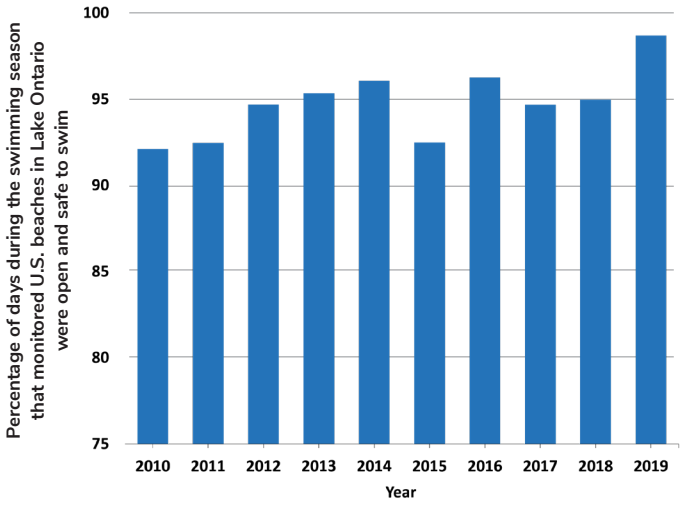
Assessment Highlights

The overall status of Beaches is **Good** and the trend is **Unchanging to Improving**. 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.

The U.S. and Canada use different *E. coli* criteria to determine when a beach is unsafe for swimming. Each year, over 700 beaches along the Great Lakes shoreline are monitored for *E. coli* as a measure of risk from fecal material contamination and these data are used in this assessment. Sources of *E. coli* can include overflow from wastewater treatment plants, runoff from the land, improperly working septic systems and even large flocks of waterbirds.

From 2018 to 2019, the percentage of days that monitored Canadian Great Lakes beaches met Ontario *E. coli* standards for swimming averaged 90% over this period. The U.S. Great Lakes beaches monitored from 2018 to 2019 were open and safe for swimming 94% of the time over this period. The status of monitored beaches was **Good** in all of the lakes other than Lake Erie. Lake Erie beaches in Canada and the U.S. were open and safe for swimming approximately 80% and 84% of the swimming season, respectively, resulting in a **Fair** assessment. The 10-year trend for Great Lakes U.S. beaches is **Unchanging** while the Canadian Great Lakes beaches are showing an **Improving** trend leading to an overall trend of **Unchanging** to **Improving**.

Monitored U.S. Lake Ontario beaches show improving 10-year trend



Sub-indicator supporting the Beaches assessment					
Sub-Indicator	**Lake Superior**	**Lake Michigan**	**Lake Huron**	**Lake Erie**	**Lake Ontario**
Beach Advisories	Good & Unchanging	Good & Unchanging	Good & Unchanging to Improving	Fair & Unchanging	Good & 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: IMPROVING

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

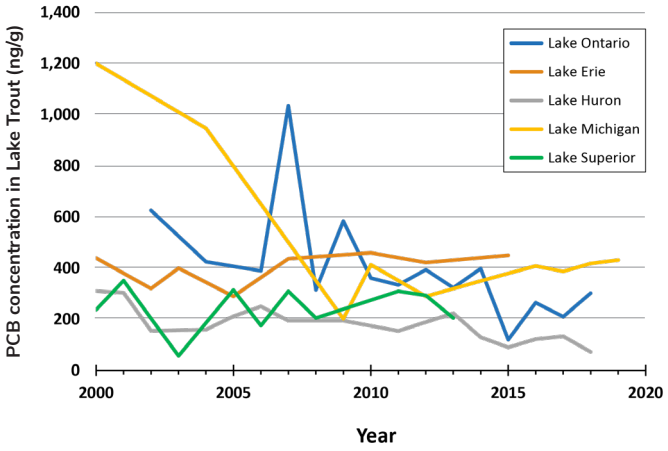
The Fish Consumption indicator is based on the analysis of the fish filet, the commonly consumed portion of fish, to determine the risks of chemicals to human health. Over the last 40-50 years, many contaminants in fish filets have declined dramatically in the Great Lakes although the current rate of decline has slowed. The status of contaminants in the filets is based on the analysis of five commonly eaten fish species and is assessed as **Fair** and the trend is **Improving**.

Fish consumption advisories for Great Lakes fish primarily result from elevated PCBs and mercury concentrations, with PCBs driving the majority of advisories in both the U.S. and Canada. PCB levels in fish filets have decreased by 90% for some fish species in some lakes since the 1970s, but concentrations remain above unrestricted consumption benchmarks. Mercury levels in fish filets have generally declined by half over the last four decades. Based on PCB and mercury concentrations conditions are considered **Fair** in all lakes except in Lake Huron where conditions are **Good**. These fish consumption advisories have a greater impact on communities that heavily rely on fish for food, and cultural, spiritual or economic purposes.

Over the past 10 years, PCB concentrations in fish filets have declined in most of the lakes while remaining stable in Lake Superior. During this same period, mercury levels have remained stable or decreased slightly. On this basis, the trend is assessed as **Improving**.

Other contaminants, such as per- and polyfluoroalkyl substances (PFAS), which have multiple uses including stain and water repellents, are now being more extensively monitored and have recently prompted issuance of fish consumption advisories for some areas of the Great Lakes.

PCBs in fish filets have declined substantially but have generally stabilized in the 2000s



Sub-indicator supporting the Fish Consumption assessment					
Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Contaminants in Edible Fish	Fair & Unchanging	Fair & Improving	Good & Unchanging to Improving	Fair & Improving	Fair & 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 concentrations of most toxic chemicals in the Great Lakes have decreased over the long term in water, air, sediment, fish and Herring Gull eggs. Overall, the status of Toxic Chemicals is **Fair** and the trend is **Unchanging to Improving**.

Many chemicals, including mercury and PCBs, have decreased significantly since the 1970s. Even with these long-term reductions, there are some instances of chemicals of mutual concern (CMCs), including polychlorinated biphenyls (PCBs), perfluorooctane sulfonate (PFOS), and polybrominated diphenyl ethers (PBDEs) exceeding ecosystem-based objectives in water, sediment, fish and Herring Gull eggs. Concentrations of other chemicals, including polycyclic aromatic hydrocarbons (PAHs), are higher in the waters of lakes Erie and Ontario than in other lakes.

The 10-year trend for most of the Toxic Chemical sub-indicators show **Unchanging** or **Improving** conditions. However, atmospheric deposition remains a significant pathway for mercury, PCBs, PBDEs, and other contaminants into the Great Lakes. In addition, localized areas of highly contaminated sediment in or adjacent to urban areas and in Areas of Concern (AOCs) continue to act as sources of contaminants to the lakes.

Sub-indicators supporting the Toxic Chemicals assessment

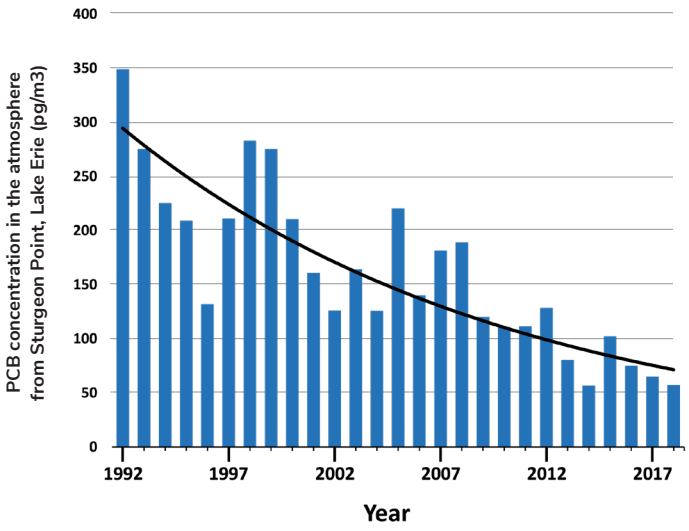
Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Toxic Chemicals in Sediment	Good & Unchanging	Fair & Unchanging	Good & Unchanging	Fair & Improving	Fair & Improving
Toxic Chemicals in Water	Fair & Improving	Fair & Undetermined	Good & Unchanging	Fair & Unchanging	Fair & Unchanging
Toxic Chemicals in Whole Fish	Fair & Unchanging	Fair & Unchanging	Fair & Unchanging	Fair & Unchanging	Fair & Unchanging
Toxic Chemicals in Herring Gull Eggs	Good & Improving	Good & Improving	Good & Improving	Good & Unchanging	Good & Improving
Toxic Chemicals in the Atmosphere	Fair & Improving (No lake-by-lake assessments were determined)				

STATUS

Good Fair Poor Undetermined

Toxic Chemicals

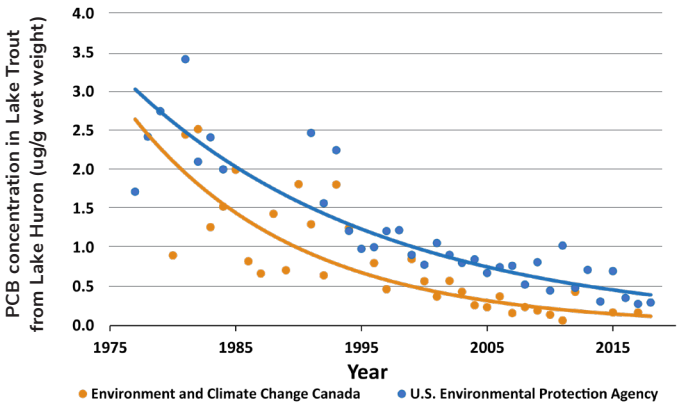
Air vapor concentrations of PCBs at Sturgeon Point in eastern Lake Erie have declined by about 50% every decade since the early 1990s



ASSESSING TOXIC CHEMICALS

The Toxic Chemicals sub-indicators help track progress on reducing inputs of chemicals into the Great Lakes. Status and trends of binationally designated CMCs (hexabromocyclododecane (HBCD), long-chain perfluorinated carboxylic acids (LC-PFCAs), mercury, perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), short-chain chlorinated paraffins (SCCPs)) as well as other toxic chemicals (e.g., PAHs, Dioxins) are assessed in Great Lakes water, sediment, fish, air and precipitation, and Herring Gull eggs. Herring Gull eggs are a standard medium for monitoring contaminant levels in wildlife in the Great Lakes; adult gulls feed on prey fish in surface waters and exposure to contaminants can be measured in their eggs.

PCBs in whole Lake Trout have decreased



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 ecologically diverse ecosystems, supporting rare and unique species and habitats not found anywhere else in the world. Great Lakes coastal wetlands capture, store, and process excess nutrients originating from upland habitats, protect shorelines and provide critical habitat for many species. The Great Lakes aquatic food web supports ecologically and culturally important fish populations that in turn support Indigenous, commercial, and recreational fisheries. However, urban and agricultural development, pollution, invasive species and other factors can impair 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, tributaries and components of the aquatic food web with an emphasis on native species. Coastal wetland and aquatic food web conditions are variable across the basin, ranging from **Good** to **Poor** and **Improving** to **Deteriorating**, depending on the lake, habitat and species of interest. The health of individual species as well as biological communities in the Great Lakes reflects the availability and condition of their habitats, which are influenced by stressors such as changing climate, land use changes, pollution, and invasive species. Overall, the Habitat and Species indicator is assessed as **Fair** and the trend is **Unchanging**.

Although coastal wetland restoration and protection efforts have improved some coastal wetlands, other wetlands remain degraded. Wetlands of Lake Superior and those along the northern shorelines of lakes Michigan and Huron are generally in better condition than wetlands in lakes Erie and Ontario. For example, most of the wetlands in lakes Erie and Ontario have degraded plant communities as a result of nutrient enrichment, sedimentation, invasive species, past water level regulation or combinations of these factors. These stressors can allow some plant species such as invasive cattails and non-native species like European Common Reed (also known as *Phragmites*), Frog-bit and Water Chestnut to thrive, reducing biodiversity and habitat quality for native flora and fauna.

Sub-indicators supporting the Habitat and Species assessment – Coastal Wetlands and Aquatic Habitat Connectivity

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Coastal Wetland Invertebrates	Fair & Undetermined	Fair & Undetermined	Fair & Unchanging	Undetermined	Undetermined
Coastal Wetland Fish	Fair & Unchanging	Fair & Undetermined	Fair & Unchanging	Poor & Undetermined	Fair & Unchanging
Coastal Wetland Amphibians	Fair & Undetermined	Fair & Undetermined	Good & Unchanging	Fair & Unchanging	Fair & Improving
Coastal Wetland Birds	Fair & Undetermined	Fair & Undetermined	Good & Unchanging	Fair & Unchanging	Fair & Improving
Coastal Wetland Plants	Good & Unchanging	Fair & Unchanging	Fair & Unchanging	Poor & Unchanging	Poor & Unchanging
Aquatic Habitat Connectivity	Fair & Improving	Poor & Improving	Fair & Improving	Fair & Improving	Fair & Improving

STATUS

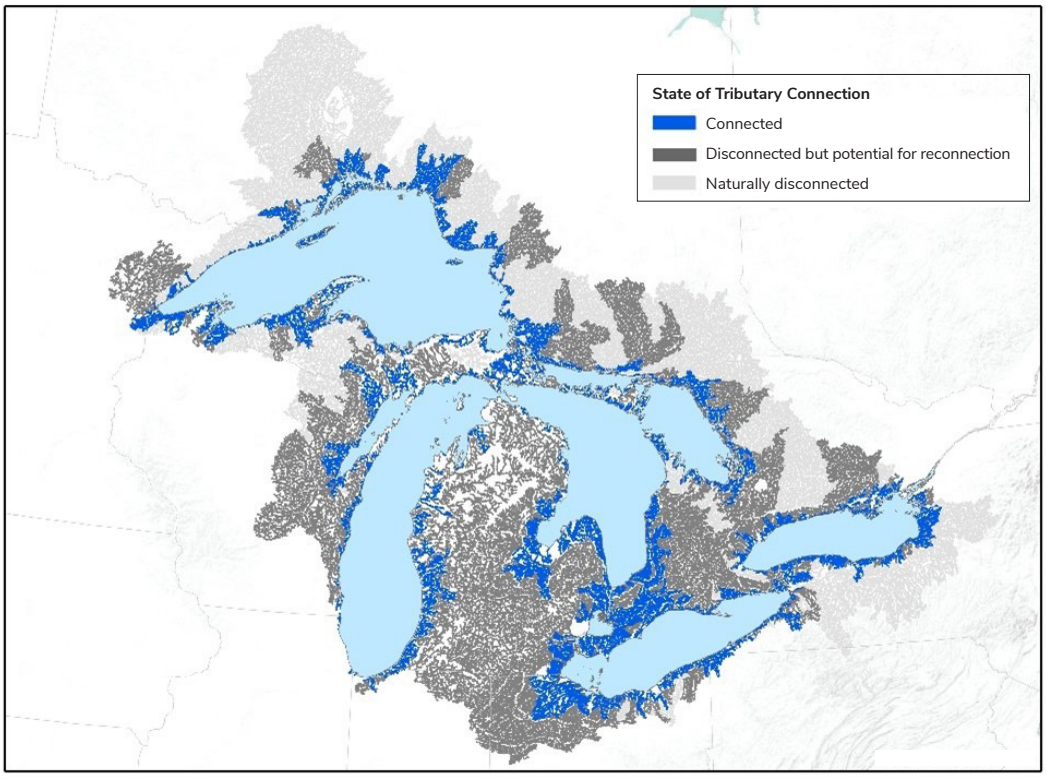
Good Fair Poor Undetermined

Habitat and Species

Amphibian, bird and fish communities in coastal wetlands tend to be healthiest where the footprint of human activity is the lowest. Coastal wetland amphibian and bird community health in each of the lakes are generally considered **Fair** to **Good** with **Unchanging** or **Improving** trends. However, species such as Western Chorus Frog and some marsh bird species have undergone long-term population declines. Coastal Wetland Fish communities are assessed as **Fair** in all lakes except Lake Erie where fish community health is assessed as **Poor.** This is due in part to Lake Erie coastal wetlands having higher average numbers of non-native fish species, which are more tolerant to disturbance.

Aquatic habitat connectivity assesses the percentage of tributary lengths that remain free of barriers impacting connection between the headwaters and the Great Lakes. The connectivity of tributaries is critical for migratory fish to reach spawning habitat and to maintain other ecological processes such as natural sediment transport. Tributary connectivity was reduced in each lake basin during the past century but is improving as a result of barrier removal and fish passage projects. These restoration efforts must also weigh the potential risk of creating spawning habitat for Sea Lamprey or allowing access of other non-native species into and out of the Great Lakes.

Only about one third of historically connected tributary lengths remain accessible to Great Lakes migratory fish



Habitat and Species

The Great Lakes aquatic food web is made up of many interacting species, from tiny algae (phytoplankton) and animals (zooplankton) to large fish. Changing nutrient conditions combined with the impacts of invasive species, especially dreissenid mussels (zebra and quagga mussels), are some of the most immediate stressors to Great Lakes food webs. Dreissenid mussels filter phytoplankton from the water column and alter the way nutrients are cycled through the lakes, resulting in reduced food for zooplankton, which impacts all other components of the aquatic food web including fish.

Phytoplankton communities are **Deteriorating** in all lakes except Ontario, but the reasons for this trend are variable. Lake Superior has maintained phytoplankton and zooplankton communities reflecting oligotrophic (low nutrient) conditions and is assessed as **Good** for phytoplankton and zooplankton, but gradual community shifts toward phytoplankton groups that thrive in warmer conditions may be occurring in response to climate change. In lakes Huron and Michigan, declines in the spring phytoplankton bloom resulted in decreased zooplankton biomass in past decades, but populations have stabilized in recent years. In Lake Erie, there has been a decrease in phytoplankton quality due to increases in the abundance of harmful cyanobacteria, but zooplankton communities are in **Good** condition due to high lake productivity.

Diporeia, a small bottom-dwelling invertebrate and an important food source for fish, severely declined in the 1990s and are in **Poor** status in all lakes except Lake Superior. The mechanisms causing these declines are complex and are not fully understood. However, dreissenid mussels have likely contributed to these trends by altering benthic habitat and reducing the amount of available food for other benthic organisms, such as *Diporeia*. In Lake Superior, *Diporeia* is assessed as **Good** and they remain a dominant component of some prey fish diets.

Sub-indicators supporting the Habitat and Species assessment – Aquatic Food Web

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Phytoplankton	Good & Deteriorating	Fair & Deteriorating	Fair & Deteriorating	Poor & Deteriorating	Good & Unchanging
Zooplankton	Good & Unchanging	Good & Unchanging	Fair & Unchanging	Good & Improving	Good & Unchanging
Benthos	Good & Unchanging	Good & Unchanging	Good & Unchanging	Poor & Unchanging	Fair & Unchanging
Diporeia	Good & Unchanging	Poor & Deteriorating	Poor & Deteriorating	Poor & Unchanging	Poor & Unchanging
Lake Sturgeon	Poor & Unchanging	Poor & Improving	Poor & Improving	Poor & Improving	Poor & Improving
Native Prey Fish Diversity	Good & Unchanging	Fair & Unchanging	Fair & Unchanging	Fair & Deteriorating	Fair & Improving
Lake Trout	Good & Improving	Fair & Improving	Fair & Improving	Fair & Improving	Fair & Improving
Walleye	Fair & Improving	Good & Unchanging	Good & Unchanging	Good & Improving	Good & Unchanging

STATUS

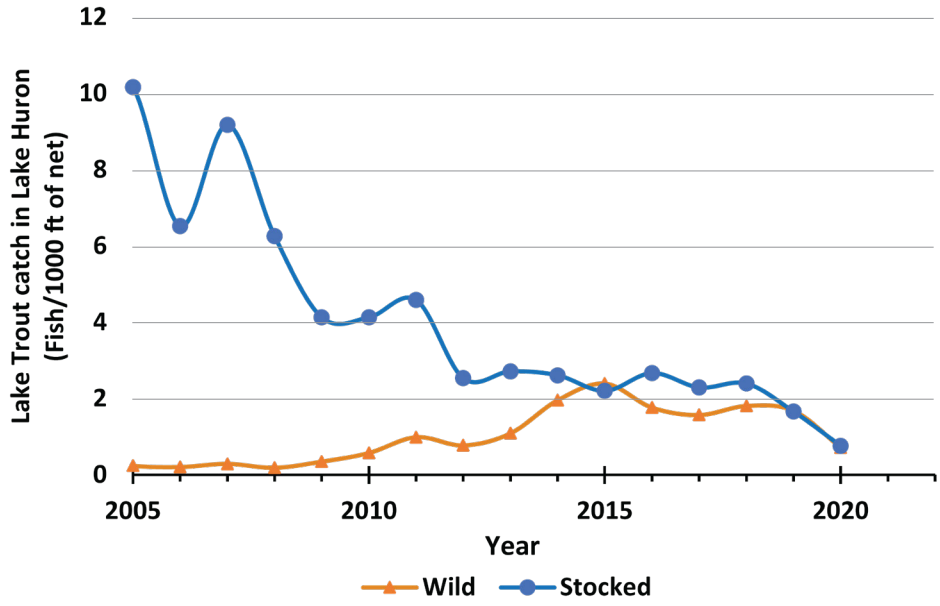
Good **Fair** **Poor** **Undetermined**

Habitat and Species

Phytoplankton, zooplankton, and benthic communities are important sources of food for prey fish and are essential to sustaining a healthy food web. The diversity of prey fish communities across the Great Lakes continues to change, although the direction and magnitude of those changes vary. The prey fish community is considered **Fair** overall based on the diversity and the proportion of native prey fish species in the Great Lakes. There have been fluctuations in the overall abundances of prey fish, which are influenced by both food availability and the number of top predator fish such as Lake Trout, Salmon, and Walleye. 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, ongoing Sea Lamprey control, improving water quality, population rehabilitation stocking, restoration of spawning habitat, and declines in Alewives (a non-native prey fish) have contributed to improving Walleye and Lake Trout populations and increased reproductive success for Lake Trout populations. Wild-born Lake Trout make up nearly half of total harvest in U.S. waters of Lake Huron and account for more than 75% of the total catch from Canadian waters of the Lake Huron main basin and North Channel. There has also been evidence of increased natural reproduction of Lake Sturgeon in tributaries throughout the Great Lakes basin due in part to habitat improvements, dam removals, and stocking efforts, although changes in Lake Sturgeon status will take a long time to manifest due to the long lifespan of the species.

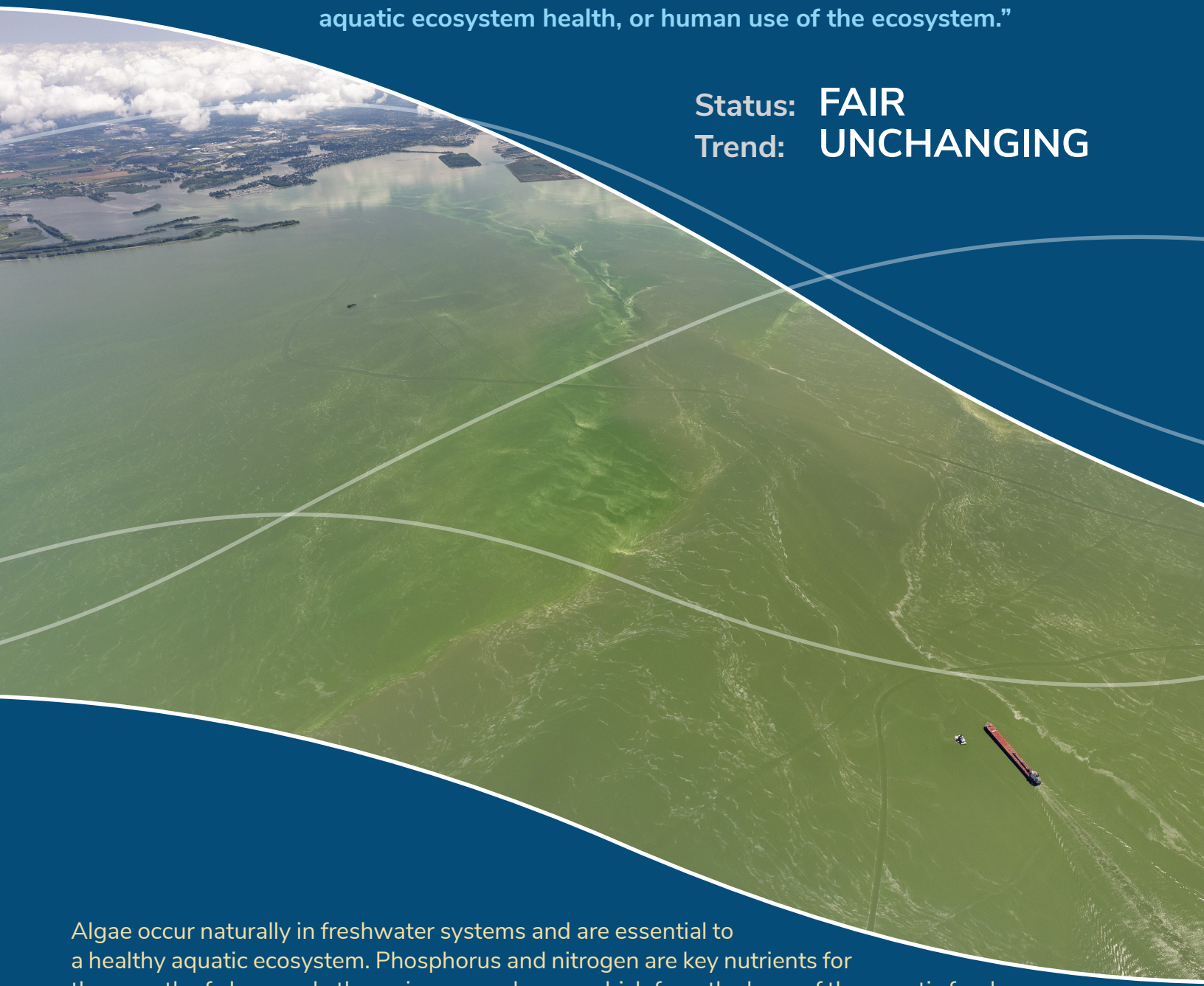
Populations of wild-born Lake Trout are increasing in Lake Huron and now occur at similar levels to hatchery-born fish, due to restoration efforts and increased reproductive success in recent years



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 and nitrogen are key nutrients for the growth of algae and other primary producers, which form the base of the aquatic food web. In the Great Lakes, 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 healthy Great Lakes food webs and 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 that were contributing to the formation of algal blooms, nuisance algae, and hypoxic (low oxygen) areas in the Great Lakes. There has been a resurgence of nutrient-related impairments due to impacts from invasive species, land use changes, climate change and other factors. Although nutrients and algal conditions for Lake Superior are generally **Good**, conditions remain **Poor** in Lake Erie and are **Fair** in lakes Michigan, Huron and Ontario. Overall, the Nutrients and Algae indicator is assessed as **Fair** and the trend is **Unchanging**.

Differing levels of nutrients are required to maintain each of the Great Lakes at their desired food web status. Only Lake Superior's offshore phosphorus concentrations are considered **Good**. The offshore waters of lakes Michigan, Huron and Ontario have phosphorus concentrations below objectives for nutrient concentrations and food web status. Phosphorus concentrations remain above objectives in Lake Erie's western and central basins and in some nearshore regions and embayments of each of the other lakes.

Elevated nutrient concentrations may lead to the formation of harmful algal blooms (HABs). HABs are made up of cyanobacteria, which sometimes produce toxins such as microcystin. These toxins can impact drinking water safety and may be harmful to people, wildlife and pets when present at high levels. Decomposition of large amounts of algae can also lead to hypoxic zones (such as in the central basin of Lake Erie), which can suffocate aquatic organisms and degrade habitat. The western basin of Lake Erie experiences the most consistent and widespread HABs in the Great Lakes and conditions are highly variable from year-to-year. However, the percent of Lake Erie nearshore area (areas less than 16 meters in depth) experiencing blooms declined between 2012 and 2020. In other areas of the Great Lakes such as Green Bay (Lake Michigan), Saginaw Bay (Lake Huron), Lake St. Clair, and in embayments such as Hamilton Harbour and the Bay of Quinte in Lake Ontario, HABs have also adversely impacted ecosystem health and recreational activities. Localized, short-lived blooms have also been observed in Lake Superior in recent years, but these blooms have been primarily confined to the immediate nearshore. Based on the geographical extent of blooms, conditions are considered **Poor** for Lake Erie, while nearshore

Sub-indicators supporting the Nutrients and Algae assessment

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Nutrients in Lakes	Good & Unchanging	Fair & Unchanging	Fair & Unchanging	Poor & Unchanging	Fair & Unchanging
Harmful Algal Blooms: nearshore & embayments	Good & Undetermined	Fair & Unchanging	Fair & Unchanging	Poor & Improving	Good & Unchanging
Cladophora	Good & Unchanging	Poor & Unchanging	Fair & Undetermined	Poor & Unchanging	Poor & Undetermined

STATUS

Good Fair Poor Undetermined

Nutrients and Algae

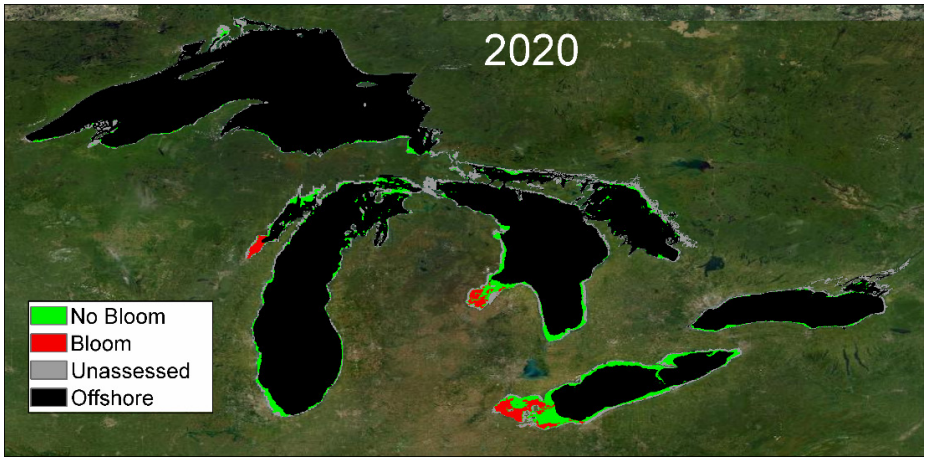
conditions are considered **Fair** in lakes Michigan and Huron, and **Good** in lakes Superior and Ontario.

Cladophora is a native alga that provides food and shelter for invertebrates and small fish but that sometimes reaches nuisance levels over broad areas in the nearshore regions of lakes Erie, Ontario, and Michigan. conditions in those lakes are considered **Poor**. 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. The introduction of invasive dreissenid mussels has changed nutrient dynamics and contributed to increased water clarity in many areas of the Great Lakes, promoting increased *Cladophora* growth. However, it 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*.

CONCERNS AND EMERGING THREATS

Nutrients and algae levels are influenced by the timing and magnitude of nutrient inputs, effects of invasive species on nutrient cycling, weather, and climate change. A change to one or more of these influences has resulted in certain areas of the Great Lakes experiencing nuisance algal growth, HABs and hypoxia. Actions are being taken to address excess inputs of nutrients and to prevent further introductions and spread of invasive species. However, in some geographic areas of the Great Lakes, regular and routine monitoring does not occur, which limits our ability to determine the extent of the problem and track changes over time. Climate change in the form of warming water temperatures and increased frequency of extreme storm events may cause nuisance algae and HABs to form in areas where they have not typically occurred, such as western Lake Superior.

Harmful Algal Blooms are frequently observed in Western Lake Erie, Green Bay, and Saginaw Bay but bloom extents are variable from year to year

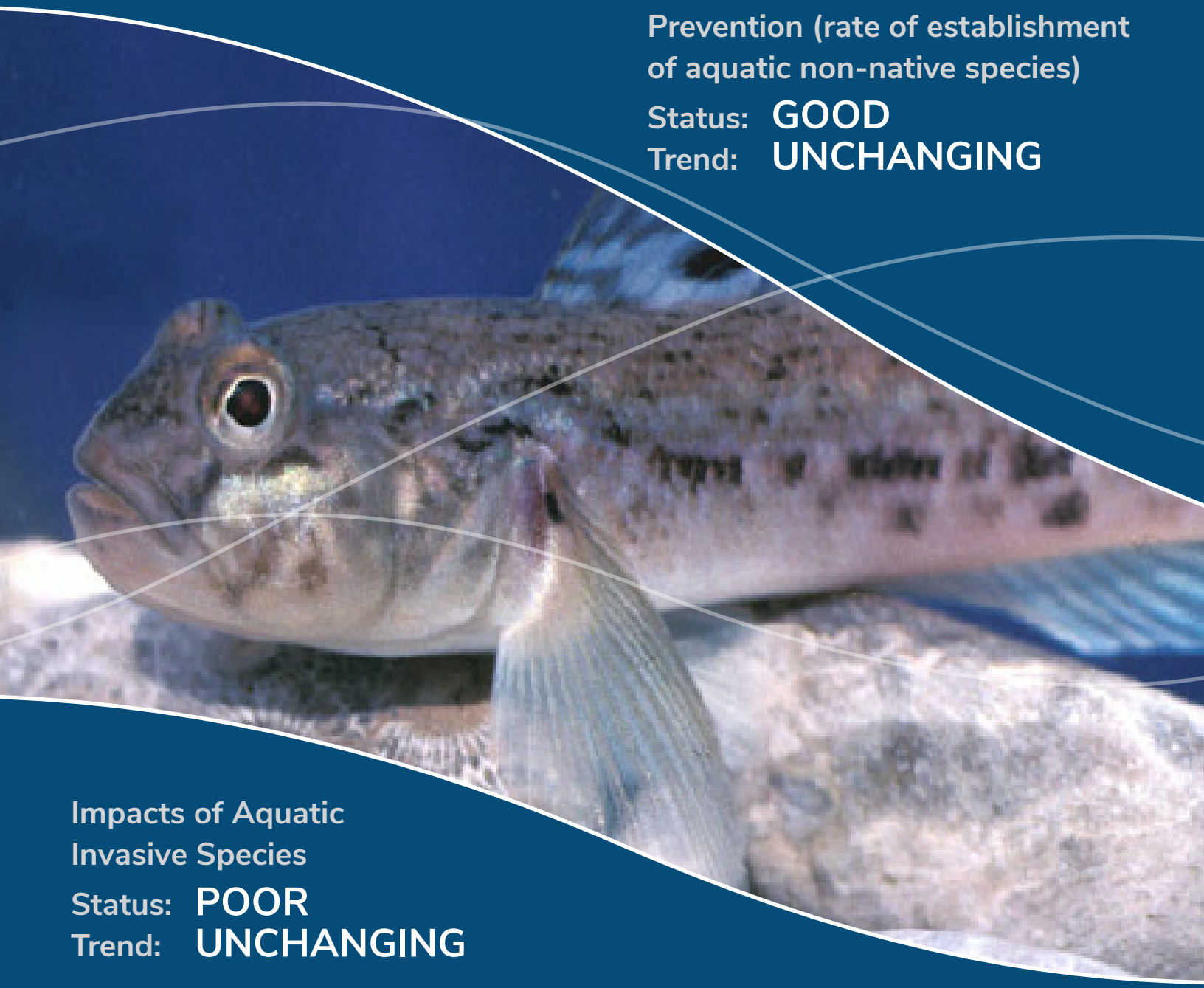


INVASIVE SPECIES

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."

Prevention (rate of establishment of aquatic non-native species)

Status: GOOD
Trend: UNCHANGING



Impacts of Aquatic Invasive Species

Status: POOR
Trend: UNCHANGING

The number of new non-native species entering the Great Lakes has been significantly reduced, largely through improved ballast water management by transoceanic ships. However, invasive species already in the Great Lakes such as zebra and quagga mussels and *Phragmites* continue to spread and cause substantial ecological and economic impacts.

Invasive Species

Assessment Highlights

The assessment for this indicator is based on two components: Prevention, measured as rate of establishment of new aquatic non-native species in the Great Lakes (assessed as **Good** with a trend of **Unchanging**), and Impacts of Aquatic Invasive Species (AIS) (assessed as **Poor** with a trend of **Unchanging**). The assessments for these two components highlight that there has been success with the prevention of establishment of aquatic non-native species (species that are not native to the Great Lakes basin that may or may not have known negative environmental and/or socioeconomic impacts); however, already established AIS (species that have known negative environmental and/or socioeconomic impacts) continue to expand their ranges.

To date, 188 aquatic non-native species have been reported as established in the Great Lakes, of which 64 are considered invasive. However, there has been tremendous success in reducing establishments in recent decades. This is largely due to the implementation of regulations on ballast water from transoceanic ships and implementation of the joint inspection program to confirm that these ships are managing ballast. No new aquatic non-native species confirmed to be introduced through ballast water have become established in the Great Lakes since 2006. Various efforts, such as the Great Lakes Aquatic Non-indigenous Species Information System Risk Assessment Clearinghouse, which incorporates binational data, have been important in supporting the prevention of establishment of new aquatic non-native species.

Sub-indicators supporting the Invasive Species assessment					
Sub-Indicator	**Lake Superior**	**Lake Michigan**	**Lake Huron**	**Lake Erie**	**Lake Ontario**
Rate of New Aquatic Non-indigenous Species Establishment in the Great Lakes	Great Lakes Basin assessment is Good & Unchanging				
Impacts of Aquatic Invasive Species	Poor & Undetermined	Poor & Undetermined	Poor & Undetermined	Poor & Deteriorating	Poor & Deteriorating

The overall trend for the Impacts of Aquatic Invasive Species sub-indicator is not an averaging of the lake assessments, but is based on separate calculations using basin-wide data.

STATUS

Good | Fair | Poor | Undetermined

Invasive Species

From 2011 to 2020, four new aquatic non-native species (all zooplankton) established overwintering and reproducing populations in the Great Lakes (*Thermocyclops crassus*, *Mesocyclops pehpeiensis*, *Salmincola californiensis*, and *Diaphanosoma fluviatile*). The entry route for these four species is uncertain. Despite establishment of these four species, there has been a significant slowdown in establishments of aquatic non-native species compared with the previous two decades.

Populations of AIS can spread within and between the lakes, including by hitching rides on boats, trailers, and gear used by anglers, boaters, and other recreationists. Stopping the spread of invasive species is essential for protecting Great Lakes native species and habitats.

The Sea Lamprey is a prominent invasive species and a lethal parasite of many Great Lakes fish species such as Lake Trout. Annual control activities in the Great Lakes have successfully suppressed Sea Lamprey populations by approximately 90% since pre-control efforts and Sea Lamprey populations have declined in most lakes. Currently, adult Sea Lamprey indices are meeting targets in lakes Michigan, Erie and Ontario, but are above targets in lakes Superior and Huron.

Sub-indicators provided for background information, but not included in the Invasive Species assessment

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Rate of New Aquatic Non-Indigenous Species Establishment into Each Lake Basin	Poor & Improving	Fair & Improving	Poor & Undetermined	Fair & Undetermined	Fair & Unchanging
Sea Lamprey	Poor & Deteriorating	Good & Improving	Fair & Improving	Good & Improving	Good & Improving
Dreissenid Mussels	Good & Unchanging	Poor & Deteriorating	Poor & Deteriorating	Fair & Unchanging	Poor & Deteriorating
Terrestrial Invasive Species	The methodology used to assess this sub-indicator is being updated. This sub-indicator is currently assessed as Undetermined.				

The overall assessment for the Rate of New Aquatic Non-indigenous Species Establishment in the Great Lakes sub-indicator is solely based on new establishments in the Great Lakes; the lake-to-lake spread component is provided here for additional information. Sea Lamprey and dreissenid mussels are among the species already included in the Rate and Impacts assessments. Their separate sub-indicator assessments provide more detailed information.

STATUS

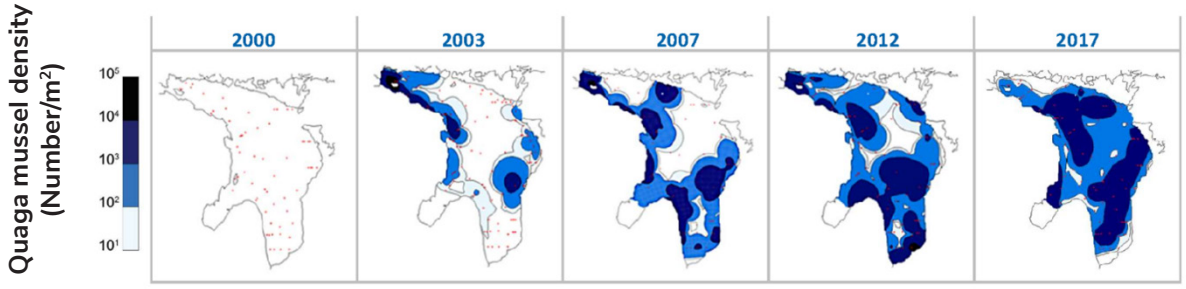
Good | Fair | Poor | Undetermined

Invasive Species

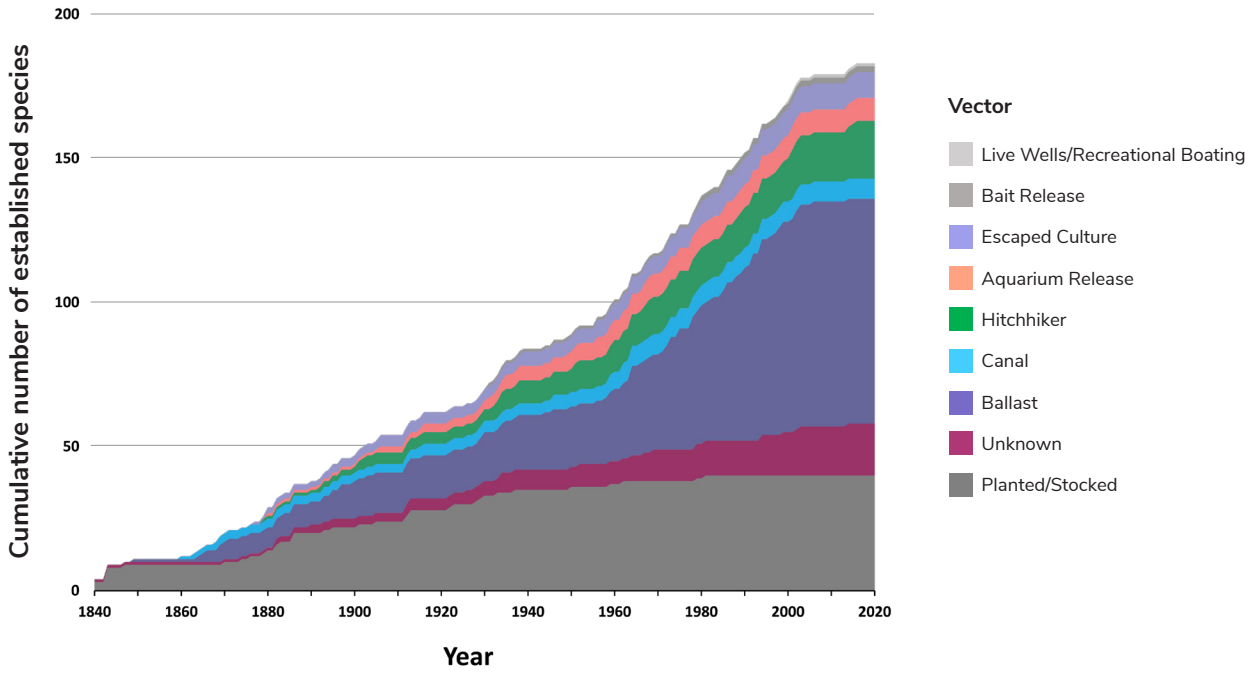
Dreissenid mussels (zebra and quagga mussels) are aquatic invasive species in the Great Lakes. Their impacts include altering nutrient cycling, increasing water clarity and modifying zooplankton and phytoplankton communities. In lakes Michigan, Huron and Ontario, populations in the shallow and mid-depth regions appear to be stable or declining, however, in the deep zone, populations of quagga mussels continue to increase. In Lake Erie, overall dreissenid mussel densities are much lower than the peak levels of the 1990s; but there is variability across the lake.

Terrestrial invasive species such as emerald ash borer, mute swan and garlic mustard, are widely distributed in the Great Lakes basin and have detrimental impacts to the ecosystem. Participatory science (community science) data collection systems are valuable sources of information for terrestrial invasive species distribution and are used to inform the sub-indicator.

Quagga mussels are continuing to expand in the deep zones of Lake Huron



Cumulative discovery of established aquatic non-native species in the Great Lakes basin for all known vector pathways has leveled off in recent decades



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: GOOD
Trend: UNDETERMINED

Groundwater can influence the surface water quality of lakes and rivers by providing base flows of cool, clean water. Activities that occur on land, such as application of fertilizers, pesticides or road salt, can cause contaminants to seep through the ground and impact underground aquifers and surrounding wells. Groundwater can also be a pathway for transmitting contaminants and nutrients to the Great Lakes.

Groundwater

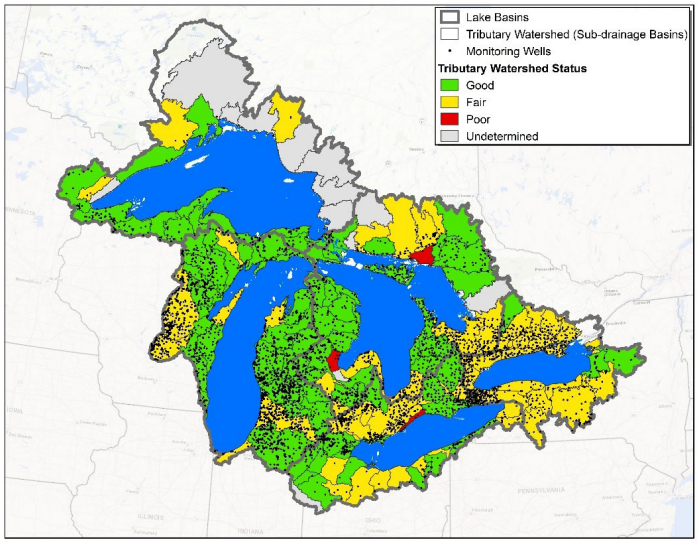
Assessment Highlights

The Groundwater indicator status is assessed as **Good** based on chloride and nitrate data, however, the trend is **Undetermined** due to insufficient long-term data. The concentrations of nitrate in groundwater are primarily from agricultural practices. Chloride is mainly from the urban use of road de-icing salt. Elevated concentrations of both of these constituents in water can have detrimental impacts to ground- and surface water quality, aquatic ecosystems, and human health. Groundwater plays an important role as a reservoir of water that, if contaminated, has the potential to become a source of contamination to the Great Lakes.

The assessment is based on data obtained from over 6,550 shallow wells throughout the Great Lakes basin. These data were used to assess the status of tributary watersheds which are incorporated into each lake assessment and an overall Great Lakes assessment.

Groundwater quality is assessed as **Good** in all individual Great Lake basins except Lake Ontario where it is assessed as **Fair**. Monitoring results indicate that chloride concentrations are generally highest in developed areas, while nitrate concentrations are generally highest in areas with intense agricultural land use. Sites with groundwater contamination do exist within the Great Lakes basin and these locations are being actively investigated and remediated by environmental agencies. Currently trends are **Undetermined** due to a lack of ongoing and consistent monitoring. A better understanding of the concentrations and fluxes of various contaminants (including, but not limited to nitrate and chloride) in groundwater discharging to nearshore areas, and their impacts on aquatic life, is also important.

Tributary watershed assessments based on shallow well data indicate that groundwater quality is overall Good in all lake basins, except Lake Ontario (Fair)



Sub-indicator supporting the Groundwater assessment					
Sub-Indicator	**Lake Superior**	**Lake Michigan**	**Lake Huron**	**Lake Erie**	**Lake Ontario**
Groundwater Quality	Good & Undetermined	Good & Undetermined	Good & Undetermined	Good & Undetermined	Fair & 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 26% since the 1970s, resulting in significant changes to watershed land use. Climate trends are also shifting across the Great Lakes basin, including warming temperatures, changing precipitation patterns, decreased ice cover and wide 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

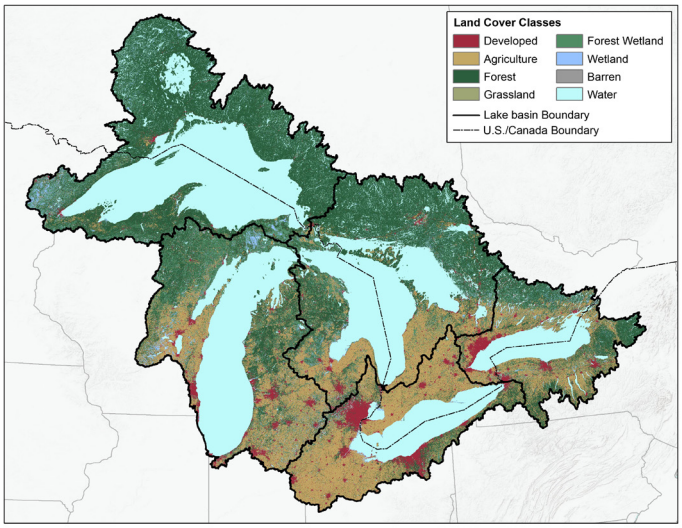
Land-based stressors which can affect water quality are assessed as **Fair** with an **Unchanging** trend. Status is not currently assessed for the Climate Trend sub-indicators; however long-term trends are presented.

Watershed Impacts

The northern portion of the Great Lakes basin remains largely undeveloped and dominated by natural cover. The southern portion is more populated with less natural cover. 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 at higher risk of impairment.

Most of the lake basins experienced an overall increase in population over the current 10-year period that census data are available (2010-2020 for U.S. and 2011-2021 for Canada), with the greatest population growth occurring in the Lake Ontario basin, especially in Canada. In fact, it is expected that the Lake Ontario basin's population will continue to increase rapidly, particularly in the Greater Toronto Area, further impacting the basin.

Natural land cover is more prominent in the northern regions of the Great Lakes basin



Sub-indicators supporting the Watershed Impacts assessment					
Sub-Indicator	**Lake Superior**	**Lake Michigan**	**Lake Huron**	**Lake Erie**	**Lake Ontario**
Forest Cover	Good & Improving	Fair & Unchanging	Fair & Unchanging	Poor & Unchanging	Fair & Unchanging
Land Cover	Good & Unchanging	Fair & Unchanging	Fair & Unchanging	Poor & Deteriorating	Fair & Deteriorating
Hardened Shorelines	Good & Undetermined	Good & Deteriorating	Good & Deteriorating	Poor & Deteriorating	Poor & Deteriorating
Water Quality in Tributaries	Undetermined	Not Assessed	Fair & Unchanging	Poor & Unchanging	Fair & Unchanging
Human Population	Unchanging	Increasing	Increasing	Increasing	Increasing

STATUS

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

Watershed Impacts and Climate Trends

Based on 2015 data, overall Great Lakes basin land cover is classified as approximately 66% natural land cover. There is a high degree of variability in the percentage of land cover type between the lake basins. For example, Lake Superior has a high amount of natural land cover (97%), compared to the Lake Erie basin (21%). From 2000 to 2015, there was an estimated net increase in developed land of 2,893 km^2 in the Great Lakes basin. Various other land cover types changed in overall extent over this period, including an estimated net decrease in forest land of 2,900 km^2 and in wetlands of 583 km^2.

Research has shown that Great Lakes water quality benefits from forest cover within a riparian zone (i.e., land along a lake, river or stream). Forested riparian zones provide essential ecosystem services such as decreasing runoff and erosion and regulating water temperatures.

The amount of Great Lakes shoreline that has been hardened (any placement of material used to armor the shoreline to offer protection from waves and water level changes) has increased. Shoreline hardening can cause changes in habitats and sediment transport. Currently almost one quarter of the assessed Great Lakes shoreline is either moderately or highly hardened.

Tributaries play an important role in transporting surface water, however, watershed land use and stressors directly impact water quality in receiving tributaries. Water quality data from 72 Canadian Great Lakes tributaries were evaluated using an index based on ammonia, chloride, copper, iron, nitrate, nitrite, phosphorus and zinc. The results of the index scores confirm that overall tributary water quality is influenced by land use with poorer scores typically being seen in more urbanized or agricultural watersheds.

Historical Climate Trends

Long-term climate data generally show basin-wide increases in precipitation, increases in summer surface water temperatures and a reduction in Great Lakes ice cover. Studies have shown that Lake Superior is one of the fastest warming large lakes in the world. Lake Superior also has the greatest long-term decline in ice cover in the Great Lakes, experiencing a 35% decrease in maximum ice cover from 1973 to 2020.

Sub-indicators supporting the Climate Trends assessment

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Precipitation Amounts (1950-2020)	Unchanging	Increasing		Increasing	Increasing
Water Levels (1918-2020)	Unchanging	Unchanging		Increasing	Unchanging
Surface Water Temperature (1980-2020)	Increasing	Increasing	Increasing	Increasing	Increasing
Ice Cover (1973-2020)	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing

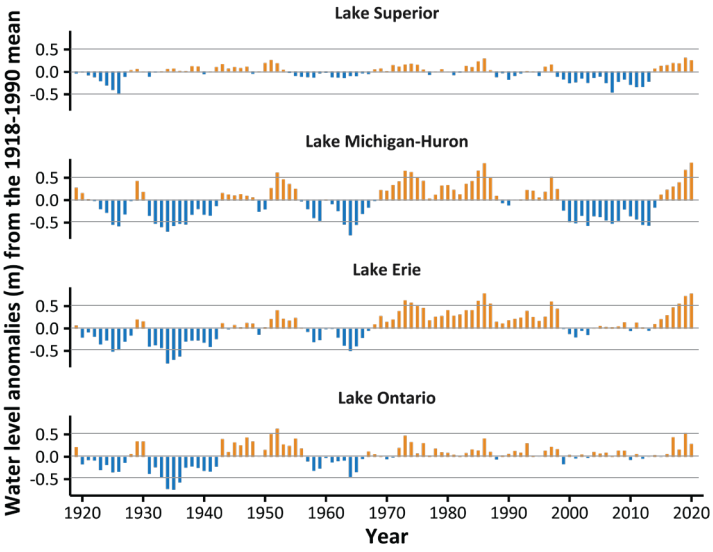
Climate information is not assessed in the same manner as other indicators in this report, as thresholds for Good, Fair or Poor have not been established at this time. Therefore, climate trends are simply assessed as Increasing, Unchanging or Decreasing. Note that the datasets used to calculate these trends span different time periods and are therefore not directly comparable.

Watershed Impacts and Climate Trends

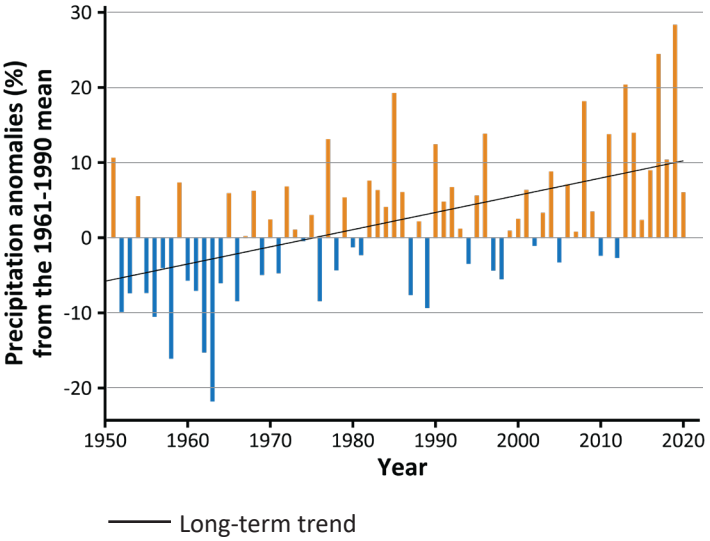
In general, water levels in lakes Superior, Michigan, Huron and Ontario show no significant overall average change over the last 100 years, while Lake Erie has seen increasing water levels. However, short-term trends are quite variable. For example, water levels in all the Great Lakes have increased over the past 10 years and Lake Ontario experienced its highest monthly mean levels in over 100 years during June of 2019. 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. However, the recent increasing water levels align with the very high precipitation amounts experienced over the most recent ten-year period. In fact, the total precipitation amounts measured from 2011 to 2020 in the Great Lakes basin were higher than any other ten-year period since 1950.

Shifts in climate can affect Great Lakes habitats, including impacting spawning areas 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 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 increases in runoff, changes to contaminant and nutrient cycling and increases in algal blooms.

Water levels increased on all lakes over the 2010-2020 period

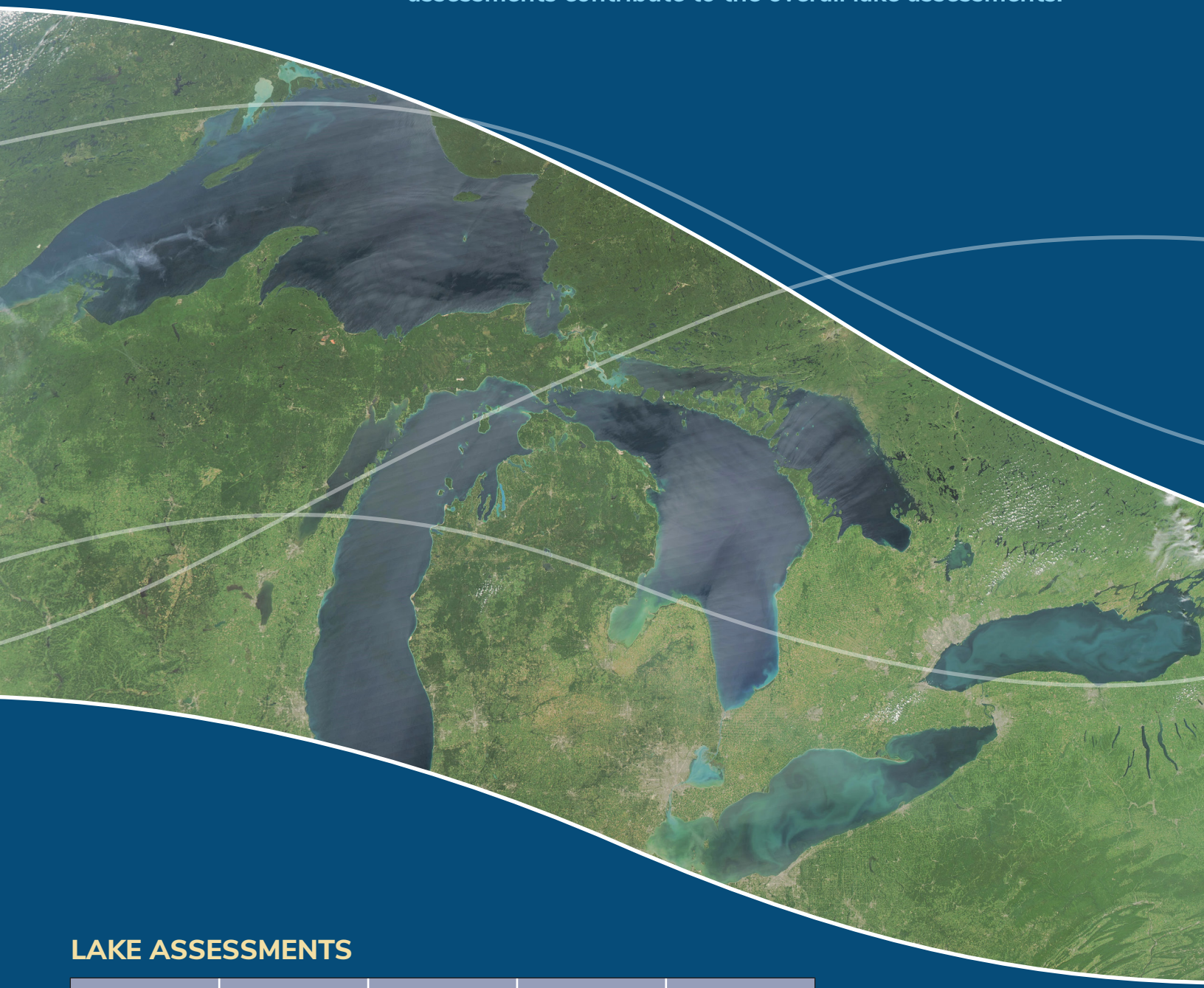


Great Lakes basin total annual precipitation has increased since 1950



LAKE ASSESSMENTS

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 assessments contribute to the overall lake assessments.



LAKE ASSESSMENTS

LAKE SUPERIOR	LAKE MICHIGAN	LAKE HURON	LAKE ERIE	LAKE ONTARIO
Good & Unchanging	Fair & Unchanging	Good & Unchanging	Poor & Unchanging	Fair & Unchanging to Improving

Lake Superior

Lake Superior's forested watershed and coastal wetlands help maintain water quality and a healthy aquatic ecosystem.

Lake Superior continues to be a good source of high-quality drinking water. Most toxic chemicals monitored in Lake Superior are low compared to other Great Lakes and long-term trends indicate that concentrations are declining. Lake Superior fish continue to be a nutritious food source and contaminant concentrations in fish filets are currently stable. However, fish consumption advisories continue to be in effect for some species. Overall, beaches and nearshore waters in Lake Superior are clear and clean and provide good opportunities for swimming and recreational use, with only occasional closures or advisories.

Naturally lower water temperatures promote resilience to nutrient and bacterial pollution and current nutrient levels remain similar to historic values. However, impacts of climate change include increasing lake water temperatures which may threaten this natural resiliency. Some short-lived, non-toxic blooms of cyanobacteria occur primarily in the area between Duluth Harbor and the Apostle Islands. Overall, Lake Superior has the best habitat and species conditions of all the Great Lakes. Overall, coastal wetlands in the Lake Superior basin are in **Fair** condition. While 62% of surveyed wetland sites have plant communities that are assessed as **Good**, there are numerous wetlands that are degraded. The health of the lake is dependent on the health of the watersheds and the tributaries that connect them. Lack of habitat connectivity has affected some native fish species such as Lake Sturgeon, but conditions are **Improving**. Lake Trout are in **Good** condition, 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. The Lake Superior prey fish community is dominated by native species, a condition not found in other Great Lakes. Invasive species, particularly Sea Lamprey, are still causing harm to predatory fish such as Lake Trout. Adult Sea Lamprey populations are above target levels. Groundwater quality is assessed as **Good** based on nitrate and chloride, however there are limited data in northern parts of the basin. The Lake Superior basin has a high percentage of natural land cover, which is at low risk of habitat and water quality degradation. Still, the lake is experiencing changes such as warming waters and decreasing ice cover due to long-term climate shifts. **Based on the assessments of the nine State of the Great Lakes indicators, the overall status of the Lake Superior basin ecosystem is Good and the trend is Unchanging.**

BE A SOURCE OF SAFE, HIGH QUALITY DRINKING WATER

ALLOW FOR UNRESTRICTED SWIMMING AND OTHER RECREATIONAL USE

ALLOW FOR UNRESTRICTED HUMAN CONSUMPTION OF THE FISH AND WILDLIFE

BE FREE FROM POLLUTANTS THAT COULD HARM PEOPLE, WILDLIFE OR ORGANISMS

SUPPORT HEALTHY AND PRODUCTIVE HABITATS TO SUSTAIN OUR NATIVE SPECIES

BE FREE FROM NUTRIENTS THAT PROMOTE UNSIGHTLY OR TOXIC BLOOMS

BE FREE FROM AQUATIC AND TERRESTRIAL INVASIVE SPECIES

BE FREE FROM THE HARMFUL IMPACTS OF CONTAMINATED GROUNDWATER

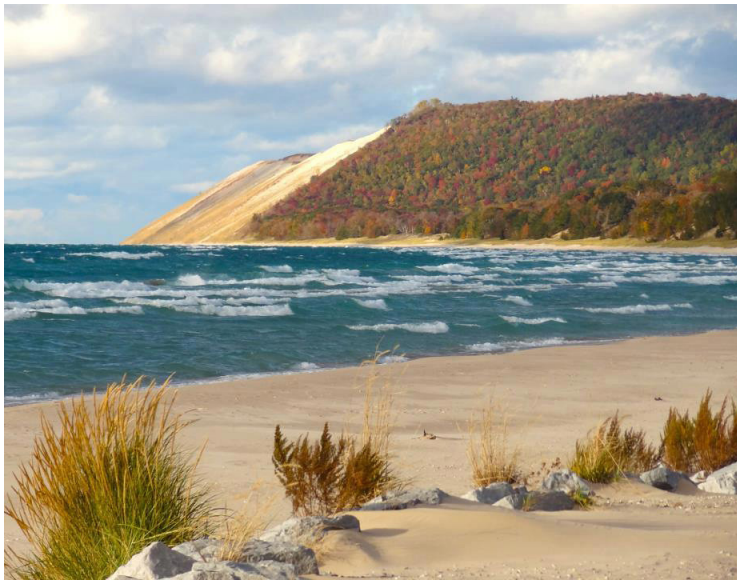
BE FREE FROM OTHER SUBSTANCES, MATERIALS, OR CONDITIONS THAT MAY NEGATIVELY AFFECT THE GREAT LAKES

Good Fair Poor

Lake Michigan

Lake Michigan's habitats support a diverse array of plant and animal species and its waters continue to provide opportunities for swimming and recreational use. However, invasive species and other stressors continue to affect both water quality and the lake's food web.

Lake Michigan continues to be a good source of high-quality drinking water and provides good opportunities for swimming and recreation. Most toxic chemicals continue to decline in the environment, however, restrictions on fish consumption continue to be advised in certain areas. Overall, coastal wetlands are in **Fair** condition, due to a combination of wetlands with degraded plant and animal communities and healthy wetlands with some of the highest amphibian and bird species richness observed in the Great Lakes. In some nearshore areas, there is excessive growth of the nuisance algae *Cladophora* and toxic blooms of cyanobacteria occur in Green Bay. Aquatic habitat connectivity is considered **Poor** with over 80% of tributary habitat no longer accessible to migratory fish, however, projects implemented over the past decade to remove barriers or improve fish passage have increased connectivity, with more tributary habitat accessible for native fish like Lake Sturgeon. Offshore, invasive filter-feeding mussels have contributed to overall lower phosphorus levels and less phytoplankton biomass. In the mid-2000s, zooplankton biomass rapidly declined and has since stabilized at reduced levels. This long-term decline of zooplankton, along with the decline in *Diporeia*, has contributed to a lower overall abundance of prey fish. Despite these challenges, increased natural reproduction of Lake Trout is evident, due in part to the successful control of invasive Sea Lamprey. Lake Trout is an important species that contributes to the multi-million dollar Lake Michigan sport fishery. Groundwater quality is assessed as **Good** based on nitrate and chloride concentrations. Land-based stressors continue to impact the Lake Michigan basin. Shifts in long-term climate trends, such as increasing water temperatures and decreasing ice cover, are expected to have ecosystem implications. **Based on the assessments of the nine State of the Great Lakes indicators, the overall status of the Lake Michigan basin ecosystem is Fair and the trend is Unchanging.**



BE A SOURCE OF SAFE, HIGH QUALITY DRINKING WATER

ALLOW FOR UNRESTRICTED SWIMMING AND OTHER RECREATIONAL USE

ALLOW FOR UNRESTRICTED HUMAN CONSUMPTION OF THE FISH AND WILDLIFE

BE FREE FROM POLLUTANTS THAT COULD HARM PEOPLE, WILDLIFE OR ORGANISMS

SUPPORT HEALTHY AND PRODUCTIVE HABITATS TO SUSTAIN OUR NATIVE SPECIES

BE FREE FROM NUTRIENTS THAT PROMOTE UNSIGHTLY OR TOXIC BLOOMS

BE FREE FROM AQUATIC AND TERRESTRIAL INVASIVE SPECIES

BE FREE FROM THE HARMFUL IMPACTS OF CONTAMINATED GROUNDWATER

BE FREE FROM OTHER SUBSTANCES, MATERIALS, OR CONDITIONS THAT MAY NEGATIVELY AFFECT THE GREAT LAKES

Good **Fair** **Poor**

Lake Huron

Lake Huron remains healthy despite nearshore algal blooms and a reduction in offshore nutrients by invasive filter-feeding mussels.

Lake Huron continues to be a good source of high-quality drinking water. Toxic chemicals monitored in Lake Huron are assessed as **Good** and long-term trends indicate that concentrations are declining. Contaminant concentrations in fish filets also continue to decline or are remaining stable. Lake Huron fish continue to be a nutritious food source, although restrictions on consumption of certain species of fish continue to be advised. Lake Huron's beaches and nearshore waters are most often clear, clean and provide good opportunities for swimming and other recreational use. Nutrient concentrations are considered to be **Fair** with a **Deteriorating** trend over the long-term due to reduced offshore phosphorus levels. *Cladophora* levels are generally low in Lake Huron, although some areas of the lake are prone to nuisance algal growth issues such as the southern end of Georgian Bay and Saginaw Bay. The current status of harmful algal blooms in Lake Huron is **Fair** with an **Unchanging** trend, with most impairments occurring in Saginaw Bay. Lake Huron coastal wetlands account for approximately 30% of the total wetland area for all five Great Lakes. Coastal wetland conditions range from **Fair** to **Good**, with those in the northern regions generally in better condition. Agricultural and land use stressors, such as run-off from farms and urban areas, are more common in the southern part of the basin and contribute to coastal wetland degradation. Populations of fish as well as lower food web organisms such as *Diporeia* have remained low in the offshore waters since the mid-2000s. These populations continue to decline. Fish populations in the nearshore waters, including Walleye, have not been significantly impacted by the changes in the lower food web. Walleye populations are assessed as **Good** and **Unchanging**. Lake Trout are in **Fair** condition and the trend is **Improving** with increasing natural recruitment. The impacts of aquatic invasive species, specifically the filter feeding quagga mussel, are generally assessed as **Poor**. Invasive species are the main cause of lower productivity in offshore waters and nuisance algae growth in some nearshore waters. The status of invasive Sea Lamprey is **Fair** with adult Sea Lamprey populations above target but **Improving**. Between-lake spread of aquatic non-native species is assessed as **Poor**, as eight new non-native species have spread into Lake Huron from other basins over the last decade. Groundwater quality is assessed as **Good** based on nitrate and chloride concentrations. Land-based stressors, such as changing land cover from natural lands to developed or agricultural lands, continue to impact the Lake Huron basin. Shifts in long-term climate trends, such as increasing water temperatures and decreasing ice cover, may have ecosystem implications. **Based on the assessments of the nine State of the Great Lakes indicators, the overall status of the Lake Huron basin ecosystem is Good and the trend is Unchanging.**

BE A SOURCE OF SAFE, HIGH QUALITY DRINKING WATER

ALLOW FOR UNRESTRICTED SWIMMING AND OTHER RECREATIONAL USE

ALLOW FOR UNRESTRICTED HUMAN CONSUMPTION OF THE FISH AND WILDLIFE

BE FREE FROM POLLUTANTS THAT COULD HARM PEOPLE, WILDLIFE OR ORGANISMS

SUPPORT HEALTHY AND PRODUCTIVE HABITATS TO SUSTAIN OUR NATIVE SPECIES

BE FREE FROM NUTRIENTS THAT PROMOTE UNSIGHTLY OR TOXIC BLOOMS

BE FREE FROM AQUATIC AND TERRESTRIAL INVASIVE SPECIES

BE FREE FROM THE HARMFUL IMPACTS OF CONTAMINATED GROUNDWATER

BE FREE FROM OTHER SUBSTANCES, MATERIALS, OR CONDITIONS THAT MAY NEGATIVELY AFFECT THE GREAT LAKES

Good Fair Poor

Lake Erie

Lake Erie supports a productive Walleye fishery, but elevated nutrient concentrations and algal blooms are persistent problems.

Lake Erie continues to be a good source of high-quality drinking water. Toxic chemicals monitored in Lake Erie are assessed as **Fair**; while overall long-term trends indicate that concentrations are **Unchanging**, declines in contaminant concentrations in fish filets are being observed. Lake Erie fish continue to be a nutritious food source, however, restrictions on consumption of certain species of fish continue to be advised in certain areas. Lake Erie's beaches and nearshore waters provide **Fair** opportunities for swimming and other recreational use for the majority of the swimming season. Nutrients and algae continue to be a significant issue and are assessed as **Poor**. Harmful algal blooms resulting from high concentrations of nutrients occur regularly in the western basin of Lake Erie during the summer months. These blooms can produce toxins, which are harmful to humans and wildlife. Excessive growth of *Cladophora* continues to be a problem in the eastern basin of the lake which can cause fouling of beaches and shorelines, clog municipal water intakes, and impact tourism and recreational fishing. Coastal wetland conditions range from **Fair** to **Poor** as a result of several factors, including the impacts of invasive species like *Phragmites* and Hybrid Cattail. The lower food web is generally in **Poor** condition. However, zooplankton are in **Good** condition, helping to support abundant prey and predator fish. 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. Lake Trout populations in Lake Erie have been entirely supported by stocking for many decades, however, several wild Lake Trout hatchlings were captured in the New York waters of Lake Erie in 2021 providing the first evidence of natural reproduction of Lake Trout in the lake in over 60 years. 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 and prey fish populations in the lake. The status of invasive Sea Lamprey is **Good** with the number of adult Sea Lamprey being maintained below the target, and the trend is **Improving**. Invasive mussels are impacting nutrient cycling by retaining and recycling nutrients in nearshore and bottom areas of the lake through their filtering and excretion activities. Lake Erie has the highest number of aquatic non-native species as the warmer, highly productive waters provide a more hospitable environment for these species. Groundwater quality is assessed as **Good** based on nitrate and chloride concentrations. Land-based stressors continue to impact Lake Erie. Shifts in climate trends such as earlier onset of stratification and decreasing ice cover, may also have ecosystem implications. **Based on the assessments of the nine State of the Great Lakes indicators, the overall status of the Lake Erie basin ecosystem is Poor and the trend is Unchanging.**

BE A SOURCE OF SAFE, HIGH QUALITY DRINKING WATER

ALLOW FOR UNRESTRICTED SWIMMING AND OTHER RECREATIONAL USE

ALLOW FOR UNRESTRICTED HUMAN CONSUMPTION OF THE FISH AND WILDLIFE

BE FREE FROM POLLUTANTS THAT COULD HARM PEOPLE, WILDLIFE OR ORGANISMS

SUPPORT HEALTHY AND PRODUCTIVE HABITATS TO SUSTAIN OUR NATIVE SPECIES

BE FREE FROM NUTRIENTS THAT PROMOTE UNSIGHTLY OR TOXIC BLOOMS

BE FREE FROM AQUATIC AND TERRESTRIAL INVASIVE SPECIES

BE FREE FROM THE HARMFUL IMPACTS OF CONTAMINATED GROUNDWATER

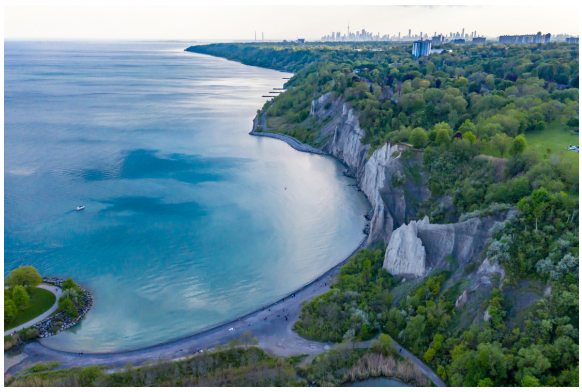
BE FREE FROM OTHER SUBSTANCES, MATERIALS, OR CONDITIONS THAT MAY NEGATIVELY AFFECT THE GREAT LAKES

Good **Fair** **Poor**

Lake Ontario

Lake Ontario shows improvements with fewer beach closings and declines in contaminant concentrations in fish.

Lake Ontario continues to be a good source of high-quality drinking water. Toxic chemicals monitored in Lake Ontario are assessed as **Fair** and long-term trends indicate that concentrations are declining, including declines in contaminant concentrations in fish filets.



Lake Ontario fish continue to be a nutritious food source. While consumption advisories for certain species of fish remain in effect, some have recently become less restrictive due to several decades of clean-up efforts. Lake Ontario beaches and nearshore waters provide good opportunities for swimming and other recreational use. Over the past 10 years, the percentage of days during the swimming season that Lake Ontario monitored beaches are open and safe for swimming has increased. Excessive growth of *Cladophora* is problematic in some nearshore areas due in part to nutrient loading and increased water clarity caused by the filtering effects of invasive mussels. The current status of harmful algal blooms in Lake Ontario is **Good** with an **Unchanging** trend, although there are localized impaired zones in some embayments. Nutrient concentrations are considered to be **Fair** due to offshore phosphorus levels that are below objectives. Further work is underway to ascertain the impact of current phosphorus concentrations on offshore lake productivity, including impacts on fish populations. Coastal wetlands have been impacted by development, past water level regulation and invasive species such as *Phragmites* and Hybrid Cattail, however, coastal wetland amphibians and birds are showing **Improving** trends. Habitat connectivity between the tributaries and the lake is **Fair** and the trend is **Improving**. Lake Trout populations are **Improving**, due in part to successful Sea Lamprey control. Prey fish are in **Fair** condition; 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 recovery with spawning occurring in a few tributaries. Phytoplankton and zooplankton communities are assessed as **Good**. However, *Diporeia*, an important food source for prey fish, is now rarely found during regular sampling. Invasive species, including Sea Lamprey, invasive mussels and Phragmites, have significantly altered habitat and the food web in Lake Ontario. Groundwater quality is assessed as **Fair** with elevated chloride levels due to road salt being an issue. Land-based stressors continue to impact Lake Ontario including the rapid urban population growth in the western part of the Canadian side of the basin. Human population in the Lake Ontario basin has increased by more than 60% over the past 50 years which is the highest of all the Great Lakes basins. Shifts in climate trends such as increasing surface water temperatures and decreasing ice cover may have ecosystem implications. **Based on the assessments of the nine State of the Great Lakes indicators, the overall status of the Lake Ontario basin ecosystem is Fair and the trend is Unchanging to Improving.**

BE A SOURCE OF SAFE, HIGH QUALITY DRINKING WATER

ALLOW FOR UNRESTRICTED SWIMMING AND OTHER RECREATIONAL USE

ALLOW FOR UNRESTRICTED HUMAN CONSUMPTION OF THE FISH AND WILDLIFE

BE FREE FROM POLLUTANTS THAT COULD HARM PEOPLE, WILDLIFE OR ORGANISMS

SUPPORT HEALTHY AND PRODUCTIVE HABITATS TO SUSTAIN OUR NATIVE SPECIES

BE FREE FROM NUTRIENTS THAT PROMOTE UNSIGHTLY OR TOXIC BLOOMS

BE FREE FROM AQUATIC AND TERRESTRIAL INVASIVE SPECIES

BE FREE FROM THE HARMFUL IMPACTS OF CONTAMINATED GROUNDWATER

BE FREE FROM OTHER SUBSTANCES, MATERIALS, OR CONDITIONS THAT MAY NEGATIVELY AFFECT THE GREAT LAKES

Good **Fair** **Poor**

Participating Organizations

Many people have been involved with the development of the State of the Great Lakes 2022 Report. Thank you to the authors and advisory committee members, as represented by the organizations listed below, for their hard work and continued support.

Agriculture and Agri-foods Canada

Bird Studies Canada

Central Michigan University

Conservation Ontario

Cornell University

Environment and Climate Change Canada

Fisheries and Oceans Canada

General Dynamics Information Technology

Great Lakes Fishery Commission

Great Lakes Indian Fish & Wildlife Commission

Illinois-Indiana Sea Grant

Indiana Department of Environmental Management

Indiana University

International Joint Commission

LimnoTech

Little Traverse Bay Bands of Odawa Indians

Michigan Department of Environment, Great Lakes and Energy

Michigan Department of Natural Resources

Michigan Technological Research Institute

National Oceanic and Atmospheric Administration

Natural Resources Canada

Nature Conservancy Canada

New York Department of Environmental Conservation

Ohio Lake Erie Commission

Ontario Ministry of Northern Development, Mines, Natural Resources, and Forestry

Ontario Ministry of the Environment, Conservation and Parks

Oregon State University

SUNY Brockport

SUNY Buffalo State

U.S. Army Corps of Engineers

U.S. Department of Agriculture Forest Service

U.S. Environmental Protection Agency

U.S. Fish and Wildlife Service

U.S. Geological Survey

University of Minnesota Duluth, Natural Resource Research Institute

University of Minnesota Duluth, Large Lakes Observatory

University of Wisconsin, Green Bay

University of Wisconsin, Milwaukee

University of Wisconsin, Superior

Wildlife Conservation Society Canada

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:

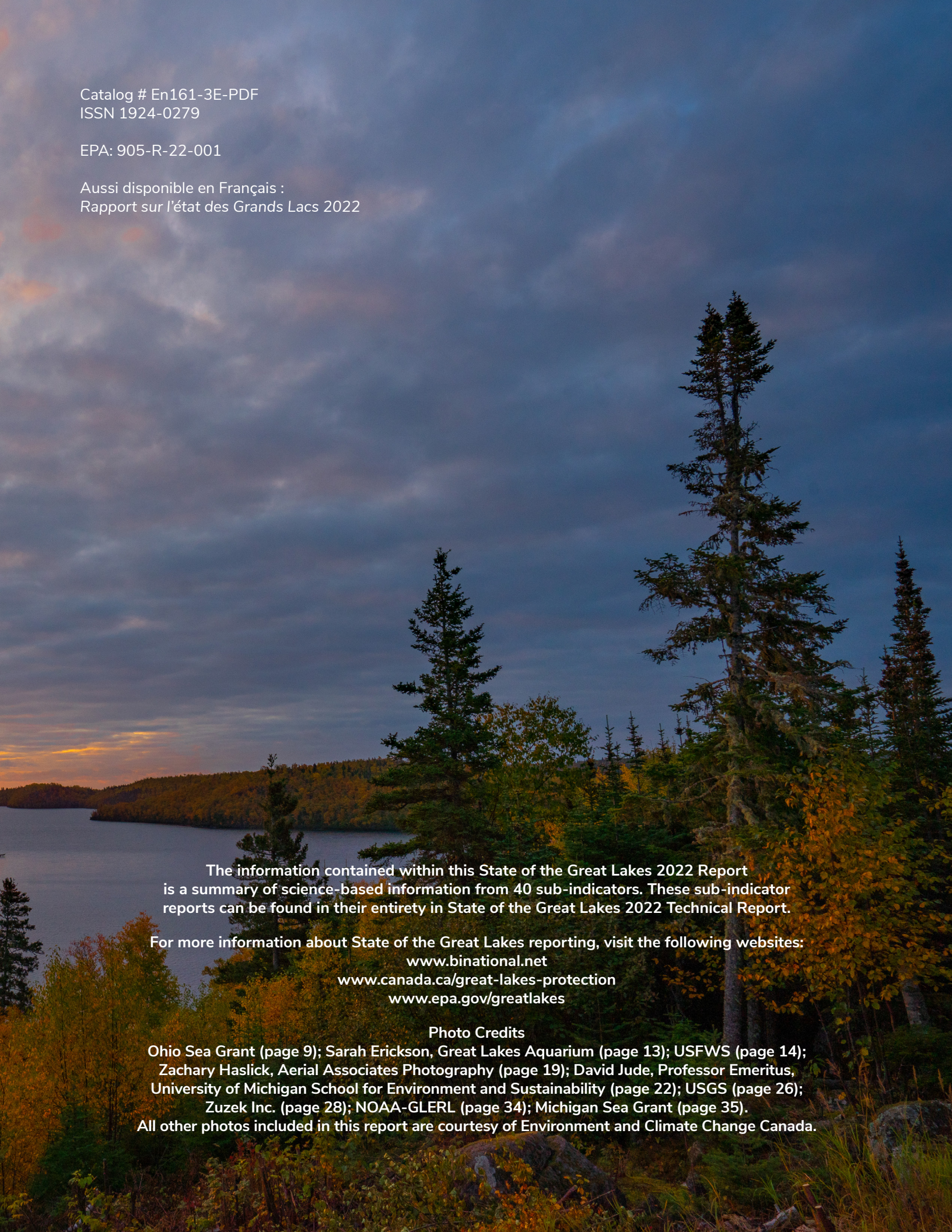
Improving: Metrics show a change toward more acceptable conditions.

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 information contained within this State of the Great Lakes 2022 Report is a summary of science-based information from 40 sub-indicators. These sub-indicator reports can be found in their entirety in State of the Great Lakes 2022 Technical Report.

For more information about 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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