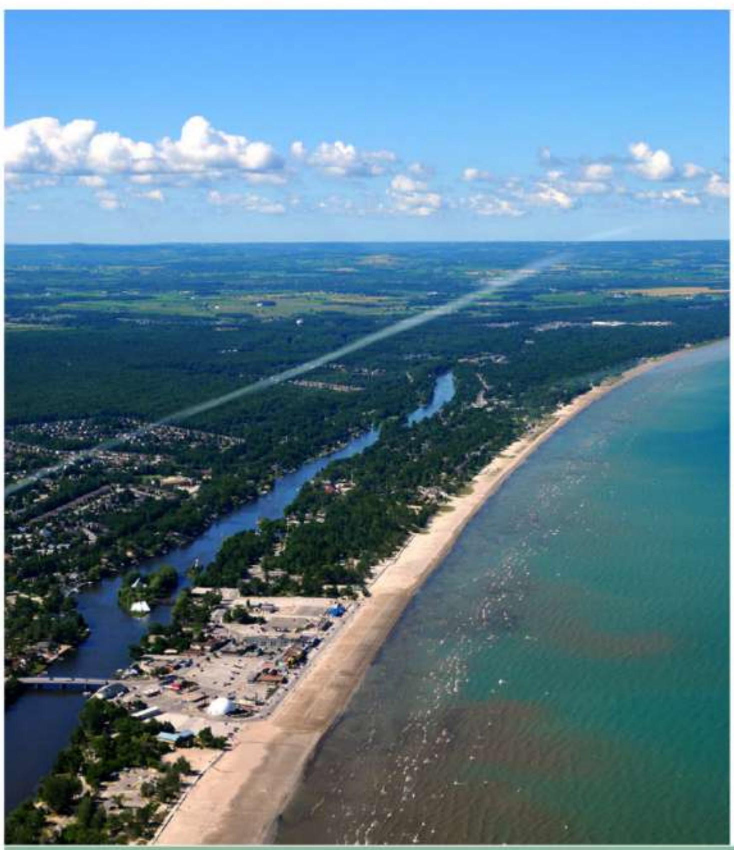
LAKE HURON

2022-2026 Lakewide Action and Management Plan



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Lake Huron Partnership 2022

- Bay Mills Indian Community (BMIC)
- Chippewa-Ottawa Resource Authority (CORA)
- Environment and Climate Change Canada (ECCC)
- Fisheries and Oceans Canada (DFO)
- Little Traverse Bay Band of Odawa Indians (LTBB)
- Little River Band of Ottawa Indians (LRBOI)
- Maitland Valley Conservation Authority (MVCA)
- Metis Nation of Ontario (MNO)
- Michigan Department of Environment, Great Lakes and Energy (EGLE)
- Michigan Department of Natural Resources (MDNR)
- Michigan Sea Grant
- National Oceanic and Atmospheric Administration (NOAA)
- Nottawasaga Valley Conservation Authority (NVCA)
- Ontario Ministry of Agriculture Food and Rural Affairs (OMAFRA)
- Ontario Ministry of Environment, Conservation and Parks (MECP)
- Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF)
- Parks Canada (PC)
- Saginaw Chippewa Indian Tribe of Michigan (SCIT)
- St. Clair Region Conservation Authority (SCRCA)
- Saugeen Ojibway Nation (SON)
- Sault St. Marie Tribe of Chippewa Indians
- Severn Sound Environmental Assocation (SSEA)
- U.S. Army Corps of Engineers (USACE)
- U.S. Bureau of Indian Affairs (BIA)
- U.S. Environmental Protection Agency (EPA)
- U.S. Fish and Wildlife Service (USFWS)
- U.S. Geological Survey (USGS)
- U.S. National Park Service (USNPS)
- USDA Forest Service (USDA-FS)
- USDA Natural Resources Conservation Service (USDA–NRCS)

LIST OF ACRONYMS AND ABBREVIATIONS

ANS	Aquatic Non-indigenous Species
ANS	Aquatic Nuisance Species
AOC	Area of Concern
AWQI	Adverse Water Quality Incidents
BIA	U.S. Bureau of Indian Affairs
BMIC	Bay Mills Indian Community
BMPs	Best Management Practices
BUIs	Beneficial Use Impartments
BWT	Boundary Waters Treaty
CCE	Calibrator Cell Equivalents
CECs	Contaminants of Emerging Concern
CEPA	Canadian Environmental Protection Act
CMCs	Chemicals of Mutual Concern
CMI-CWF	Clean Michigan Initiative-Clean Water Fund
COA	Canada-Ontario Agreement
CORA	Chippewa-Ottawa Resource Authority
CSMI	Cooperative Science and Monitoring Initiative
CSO	Combined Sewer Overflows
CWRM	Coastal Wetland Response Model
CZMA	Coastal Zone Management Act
DCC-CO	Declorane Plus
DCL	Deep Chlorophyl Levels
DDTs	Dichlorodiphenyltrichloroethanes
DFO	Fisheries and Oceans Canada
DWECD	Drinking Water and Environmental Compliance Division
DWSP	Drinking Water Surveillance Program
ECCC	Environmental and Climate Change Canada
EDDMapS	Early Detection and Distribution Mapping System
eDNA	Environmental DNA
EGLE	Michigan Department of Environment, Great Lakes and Energy

EPA	U.S. Environmental Protection Agency
FCM	Federation of Canadian Municipalities
GLANSIS	Great Lakes Aquatic Nonindigenous Species Information System
GLB	Great Lakes Basin
GLEAM	Great Lakes Environmental Assessment and Mapping Project
GLFC	Great Lakes Fishery Commission
GLRI	Great Lakes Restoration Initiative
GLWQA	Great Lakes Water Quality Agreement
HABs	Harmful Algal Blooms
HBCD	Hexabromocyclododecane
HCB	Hexachlorobenzene
HCBD	Hexachlorobutadiene
IADN	Integrated Atmospheric Deposition Network
IJC	International Joint Commission
ITCMI	Inter-Tribal Council of Michigan, Inc.
IUCN	International Union for Conservation of Nature
LAMP	Lakewide Action and Management Plan
LC-PFCAs	Long-Chain Perfluorocarboxylic Acids
LEL	Lowest Effect Levels
LHC	Lake Huron Committee
LRBOI	Little River Band of Ottawa Indians
LTBB	Little Traverse Bay Band of Odawa Indians
MCEP	Ontario Ministry of Environment, Conservation and Parks
MCMP	Michigan Coastal Management Program
MDHHS	Michigan Department of Health and Human Services
MDNR	Michigan Department of Natural Resources
MECP	Ontario Ministry of the Environment Conservation and Parks
MISIN	Midwest Invasive Species Network
MNO	Metis Nation of Ontario
MVCA	Maitland Valley Conservation Authority
NARS	National Aquatic Resource Surveys

NAS	Nonindigenous Aquatic Species
NASA	National Aeronautics and Space Administration
NAWQA	National Water-Quality Assessment
NCCA	National Coastal Condition Assessment
NDMNRF	Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry
NEL	No Effect Level
NOAA	National Oceanic and Atmospheric Administration
NVCA	Nottawasaga Valley Conservation Authority
OCFA	Orange County Fire Authority
OCPs	Organochlorine Pesticides
ODWQS	Ontario Drinking Water Quality Standards
OFAH	Ontario Federation of Anglers and Hunters
OMAFRA	Ontario Ministry of Agriculture Food and Rural Affairs
OMNDM	Ontario Ministry of Northern Development and Mines
OMNRF	Ontario Ministry of Natural Resources and Forestry
PBDEs	Polybrominated Diphenyl Ethers
PC	Parks Canada
PCBs	Polychlorinated Biphenyls
PEL	Probable Effect Levels
PFAAs	Perfluoroalkyl Acids
PFBA	Perfluorobutanoate
PFOA	Perfluprppctanoic Acid
PFOS	Perfluorooctane Sulfonate
PHCZs	Polyhalogenated Carbazoles
PIPES	Protecting our Infrastructure of Pipelines and Enhancing Safety
PWQMN	Provincial Water Quality Monitoring Network
SCCPs	Short-Chain Chlorinated Paraffins
SCIT	Saginaw Chippewa Indian Tribe of Michigan
SCRCA	St. Clair Region Conservation Authority
SDWIS	Safe Drinking Water Information System

SEL	Severe Effect Levels
SETAC	Society of Environmental Toxicology and Chemistry
SOGL	State of the Great Lakes
SON	Saugeen Ojibway Nation
SPARROW	Spatially Referenced Regression on Watershed
SRP	Soluble Reactive Phosphorus
SSEA	Severn Sound Environmental Association
SSO	Sanitary Sewer Overflows
TC	Transport Canada
TEQ	Toxicity Equivalent
TEK	Traditional Ecological Knowledge
TMDL	Total maximum Daily Load
TMDLS	Total Maximum Daily Loads
TRI	Toxics Release Inventory
U.S.	United States of America
UNESCO	United Nations Educational, Scientific and Cultural
USACE	Organization U.S. Army Corps of Engineers
USDA	United States Department of Agriculture
USDA-FS	USDA Forest Service
USDA-NRCS	USDA Natural Resources Conservation Service
USFWS	U.S. Fish and Wildlife Service
USGCRP	U.S. Global Change Research Program
USGS	U.S. Geological Survey
USNPS	U.S. National Park Service

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Lake Huron is the third largest Great Lake by volume and consists of four distinct, but interacting water bodies (Main Basin, North Channel, Georgian Bay, and Saginaw Bay). Its watershed, the second largest of the Great Lakes, contains rich boreal and mixed hardwood forests, vast coastal wetlands, productive agricultural lands, extensive recreational areas, and more than 30,000 islands. The lake is large enough to moderate local climate, and its powerful waves can shape shorelines. Its beauty attracts visitors from around the globe. The lake is a source of inspiration, rejuvenation, and discovery to its visitors and residents.

Indigenous peoples have called Lake Huron home for thousands of years. For the Ojibwe peoples, a long westerly migration ended when they found “the food that grows on the water” (Northern Wild Rice or “manoomin” [*Zizania palustris*]). The lake and its natural resources are also important to the local Indigenous Anishinaabe and Métis people: 35 First Nations and Tribal Nations, as well as 7 Métis Nation Councils who have established rights, are located in the Lake Huron basin, with many members of these communities harvesting natural resources for cultural, subsistence, spiritual, and/or livelihood purposes.

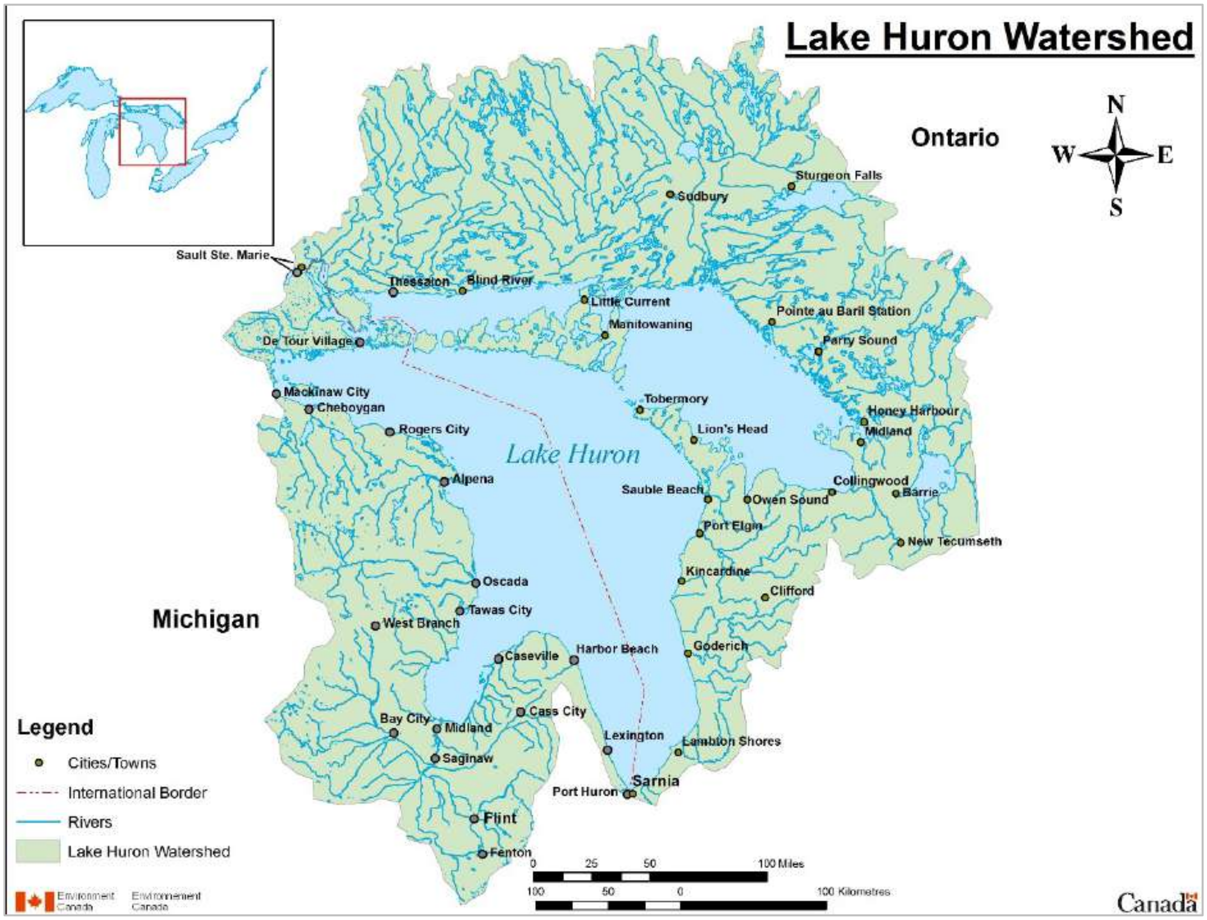


Figure 1: Lake Huron Watershed.

Through the *Great Lakes Water Quality Agreement* (the Agreement or *GLWQA*), the governments of Canada and the United States have committed to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes, including that of Lake Huron. This 2022-2026 *Lake Huron Lakewide Action and Management Plan* (*LAMP*) fulfills a United States and Canadian commitment of the Agreement to assess ecosystem condition, identify environmental threats, set priorities for research and monitoring, and identify further actions to be taken by governments and the public that address the key threats to the waters of Lake Huron and the St. Marys River.

Overall, Lake Huron is considered to be in ‘Good’ condition. Although the lake ecosystem is relatively healthy, Lake Huron is not in ‘Good’ condition in all aspects. Table 1 displays the condition of Lake Huron in relation to the General Objectives of the *GLWQA*. The majority of sub-indicators used to assess Lake Huron's condition are classified as 'Good' or 'Fair', but other sub-indicators are classified as 'Poor'. The major threats to Lake Huron include chemical contaminants, invasive species, nutrient pollution, and the degradation of habitat. In addition to these threats, significant impacts due to climate change are being observed in the Lake Huron ecosystem and are projected to continue in the future. To improve areas listed as 'Fair' and/or 'Poor' condition, restoration efforts are necessary in many degraded areas, but more importantly, protection and conservation actions are essential to maintain areas in 'Good' condition.


Cape Croker Lighthouse, Adobe Stock

Table 1: Status of Lake Huron in relation to the Great Lakes Water Quality Agreement General Objectives. Source: ECCC and EPA, 2022

				
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	Be a source of safe, high quality drinking water	Be free from the harmful impacts of contaminated groundwater
				
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 other substances, materials, or conditions that may negatively affect the Great Lakes	

Current status: Good Fair Poor

The *LAMP* was developed by members of the Lake Huron Partnership, a binational collaborative team of federal, Indigenous, state, provincial and local government agencies led by the federal governments of Canada and the United States. The Lake Huron Partnership agencies actively engage academic institutions, non-governmental organizations, other stakeholders and the public to help protect this unique and beautiful ecosystem which is of great ecological and economic importance. The restoration and protection actions identified in the *LAMP* respond to, and are categorized by, the major threats that are affecting one or more of the Agreement's General Objectives, specifically:

- chemical contaminant pollution;
- nutrient and bacterial pollution;
- invasive species;
- loss of habitat and native species; and,
- other threats including plastic pollution, climate change, risks from oil transport and cumulative impacts on the nearshore areas of the lake.

Over the next five years, members of the Lake Huron Partnership will undertake 52 actions to address priority environmental threats to water quality and the ecosystem health of Lake Huron. The actions are listed in Table 2 along with the contributing Partnership agencies. Coordination of all these efforts will be assisted by regular communication among the Partnership agencies. Tracking and reporting by the Partnership agencies will help to assess progress, determine success of implementation, support accountability, and provide feedback for future improvements.

There is a role for everyone in implementing the 2022-2026 Lake Huron *LAMP*. During *LAMP* implementation, agencies of the Partnership will regularly work with other organizations, academic institutions and communities to coordinate these on-the-ground actions. The public

Mackinac Bridge, Pixabay

especially plays an important role as advocates and implementers of local on-the-ground actions where feasible. For each major threat, the *LAMP* also includes some recommended actions that individuals can take to help protect Lake Huron. Together, collective action will reduce threats and support a prosperous and sustainable Lake Huron.

Table 2: Lake Huron LAMP 2022-2026 actions and contributing Lake Huron Partnership agencies

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	Actions to Prevent and Reduce Chemical Contamination	
1	Contribute to the implementation of actions identified in the Chemicals of Mutual Concern (CMCs) binational strategies within the Lake Huron basin.	MECP, ECCC, EPA
2	Advance remediation of contaminated sediment in Lake Huron's Areas of Concern: a. Spanish Harbour Area of Concern in Recovery (Canadian) o Conduct long-term sediment contaminant monitoring to track recovery. b. St. Marys River Area of Concern (binational AOC) o Continue to implement planned management actions on the Canadian side with focus on implementing the *Sediment Management Strategy* and associated *In-Water Works and Dredging Controls Guidance*. c. Saginaw Bay and River Area of Concern (U.S.) o Continue to implement the multi-year remediation efforts within the Tittabawassee River, Saginaw River and Saginaw Bay to address contaminated sediment.	MECP, EGLE, ECCC, EPA, NOAA, USGS, BMIC, SCIT
3	Undertake, support and/or promote innovative approaches and technologies to reduce releases of harmful chemicals.	ECCC
4	Continue to update and, where needed, develop fish consumption guidance.	LTBB, SCIT, MECP, MDHHS, ECCC, CORA, BMIC, PC
5	Continue long-term monitoring of CMCs and other contaminants in various media (air, water, sediment, fish and wildlife) to examine exposure, distribution and bioaccumulation trends. • Continue to investigate mercury sources and cycling using innovative approaches that help identify the relative importance of different pathways of mercury exposure (to fish and wildlife).	ECCC, EPA, USGS, NOAA, USFWS, Tribal Nations, EGLE

<table>
<tr><th>#</th><th>2022-2026 Lake Huron Partnership Management Actions</th><th>Agencies* Involved</th></tr>
<tr><td>6</td><td>Continue efforts to monitor and assess sources, fate, transport, distribution, and effects of contaminants of emerging concern (e.g., flame retardants, PAHs, pesticides, PFAS), legacy chemicals and trace metals in various media including groundwater with consideration to climate-pollutant interactions.</td><td>LTBB, ECCC, EGLE, EPA, USGS, NOAA, USFWS</td></tr>
<tr><td>7</td><td>Continue outreach and education to the public on impacts of chemical contaminants in fish with a focus on mercury, PCBs, PFAS and pesticides; the pathways into fish, wildlife and humans; and actions that can be taken to help reduce contaminants from entering the basin.</td><td>ECCC, EPA, USACE, USGS, EGLE, Tribal Nations</td></tr>
<tr><td>8</td><td>Continue outreach and education to the public on fish consumption guidance.</td><td>LTBB, SCIT, MDHHS, ECCC, BMIC, CORA, EGLE, EPA</td></tr>
<tr><td colspan="3">Actions to Prevent and Reduce Nutrient and Bacterial Pollution</td></tr>
<tr><td>9</td><td>Wastewater Treatment Plants and Stormwater Management Systems:
a. Support efforts to reduce and/or eliminate Combined Sewer Overflows (CSO) and Sanitary Sewer Overflows (SSO) in the Lake Huron watershed and ensure compliance with permitted discharges to ensure receiving waters meet Water Quality Standards.
b. Plan, undertake, and/or support low impact development, green infrastructure projects, and nature-based solutions that are suited to future extreme weather events and better protect species and habitat.</td><td>LTBB, SCIT, MECP, EGLE, ECCC, EPA, BMIC, CORA, Conservation Authorities, USDA-NRCS, USDA-FS, USACE, SSEA</td></tr>
<tr><td>10</td><td>Nutrient and Bacteria Control:
Build on existing integrated and systematic efforts to reduce overland runoff of nutrients, sediments, and bacteria, improve soil health, and maintain and restore natural heritage features.
• Reduce nuisance and harmful algae and promote safe and clean beaches in priority watersheds in Ontario through the Healthy Lake Huron Initiative (along the southeast shores) and in Michigan (i.e., Saginaw Bay), through the following actions:
o Support landowners’ adoption of agricultural Best Management Practices (BMPs) implementation.
o Conduct continuous flow and event-based water quality monitoring and edge-of-field monitoring and reporting in targeted watersheds to assess effectiveness of BMPs.
o Identify additional priority sub-watersheds, if necessary, in the Lake Huron watershed.</td><td>LTBB, SCIT, MECP, ECCC, EPA, EGLE, NOAA, USGS, USDA-NRCS, USDA-FS, Conservation Authorities, PC, SSEA, OMAFRA</td></tr>
</table>

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
11	**Watershed Management Planning and Implementation:** Develop and/or revise, as appropriate, integrated watershed management plans and implement coastal and nearshore management and other nutrient reduction actions at a community level: a. Support local initiatives to help communities develop and/or implement watershed plans and/or climate change adaptation plans including reforestation efforts. b. Implement the Tipping Points Planner in communities. c. Continue to implement management plans under Section 319 Nonpoint Source Management Program of the U.S. Clean Water Act. d. Continue surface water monitoring on lakes and wetlands under Tribal jurisdiction and in other areas.	LTBB, SCIT, MECP, Conservation Authorities, EGLE, EPA, NOAA, CORA, BMIC, OMAFRA, NDMNRF, USDA-NRCS, USDA-FS, SSEA
12	**Open Water:** Conduct open water nutrient and lower foodweb surveys.	EPA, ECCC, USGS, NOAA, EGLE, MECP, SSEA
13	**Streams:** Continue surface water quality monitoring and reporting of information from various stream and river locations: a. Continue the joint program between the province of Ontario and conservation authorities via the Provincial Water Quality Monitoring Network (PWQMN). b. Continue to assess stream water quality under Section 305(b) of the U.S. Clean Water Act.	LTBB, MECP, Conservation Authorities, EGLE, EPA, NOAA, USGS, SSEA
14	Saginaw Bay Water Quality Monitoring Initiative – Support efforts to implement a coordinated and comprehensive water quality monitoring program within the Saginaw Bay and Watershed. The goals of this initiative, include: a. Improve understanding of nutrient dynamics with the Saginaw Bay Watershed, Saginaw Bay, and the interactions with the offshore zone. b. Collect data to help support and calibrate nutrient models for Saginaw Bay. c. Collect data to evaluate and review the *GLWQA* nutrient targets for Saginaw Bay, and revise as necessary. d. Collect data to support removal of the Saginaw Bay Beneficial Use Impartments (BUIs), including tainting of fish flavor, eutrophication and others.	SCIT, EGLE, MDNR, EPA, NOAA, USGS
15	Continue to investigate how the food web responds to changes in nutrient inputs and cycling.	USGS-GLSI, USFWS, MDNR, EPA, NOAA

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
16	Investigate nutrient sources, sinks and recycling (e.g., release from sediments, decaying *Cladophora*, and dying mussels).	USGS, EGLE, NOAA, USFWS, MDNR
17	Improve understanding of lakewide physical and biological processes that translocate nutrients/energy from the nearshore to offshore and from the offshore to nearshore, with consideration of the influence of invasive species (e.g., dreissenid mussels).	USGS-GLSI, USFWS, MDNR, EGLE, NOAA
18	Characterize historical and current land use, nutrient sources and forms (soluble reactive vs total), and tributary phosphorus loadings with consideration of seasonality, climate change (e.g., increased frequency and intensity of storm event causing large nutrient pulses) and nearshore hydrodynamics and productivity (e.g., algal growth).	NOAA, USGS, EPA, EGLE, USDA-FS
19	Conduct outreach and education on local and regional scales to increase the understanding of water quality conditions and nutrient management challenges including nearshore and beach water quality, and implementation of best management practices (BMPs) and policies to control nutrient runoff.	LTBB, SCIT, MECP, Conservation Authorities, NOAA, USACE, EPA, EGLE, MDHHS, ECCC, BMIC, SSEA, USDA-FS, PC, OMAFRA
	Actions to Protect and Restore Habitat and Species	
20	Support climate change initiatives, projects and adaptation planning that increases the resilience of the Lake Huron ecosystem's habitats and native species.	LTBB, MECP, MDNR, ECCC, EPA, CORA, BMIC, SCIT, USFWS, PC, SSEA
21	**Aquatic Habitat Protection and Restoration:** Assess streams, estuaries, spawning reefs and shoals to determine aquatic habitat significance, stressors, and limitations to fish spawning and migration, and consult with local partners, stakeholders, and governments to identify protection and restoration priorities, including but not limited to: a. Assessment of Eastern Georgian Bay estuaries and Cheboygan River watershed; implementation of any subsequent protection and restoration actions. b. Assessment and restoration of aquatic habitat at Whitefish Island in the St. Marys River Area of Concern. c. Assessment and restoration of riparian habitats throughout the Lake Huron watershed through invasive species control, installation of large woody debris, and native plantings that control erosion and promote diversity, ecological function, and climate change resilience.	LTBB, SCIT, MDNR, EGLE, ECCC, NDMNRF, DFO, USFWS, EPA, CORA, BMIC, USGS, USDA-FS

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	d. Reef restoration efforts within Lake Huron including Saginaw Bay. e. Implementation of projects to restore a more natural flow regime in the St. Marys River.	
22	**Stream Connectivity:** Restore stream connectivity and function through dam removal, the construction of fish passage alternatives (e.g., ladders), and stream culvert improvements to increase accessible riverine habitat for migrating fish. a. Cold-water fishes and streams: Support the protection and enhancement of cold-water fishes. b. Create and enhance connectivity and cold-water refuges where appropriate to maintain appropriate habitat conditions for aquatic organisms.	LTBB, MDNR, EGLE, Conservation Authorities, USFWS, EPA, CORA, BMIC, USGS, NOAA, NDMNRF, USACE, USDA-NRCS, USDA-FS, SSEA
23	**Habitat and Native Species Conservation:** Implement recommendations in *The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron* through integrated conservation planning to identify areas of ecological significance and areas facing environmental threats and stressors: a. Update and share Canadian geospatial information on ecosystem classification. b. Engage stakeholders and the public. c. Facilitate information sharing. d. Develop regional conservation and stewardship plans (Ontario). e. Promote community-based conservation and stewardship. f. In appropriate areas as identified, restore and protect pollinator habitat and species. g. In appropriate areas as identified, restore and protect Lake Huron Islands, particularly unique habitats and globally rare and endemic species. h. Identify, inventory and map important native habitat sites in the Lake Huron basin. i. Protect and restore habitat for native species.	MDNR, EGLE, EPA, USFWS, CORA, BMIC, LRBOI, SCIT, USGS, MECP, ECCC, Conservation Authorities, PC, DFO, NDMNRF, USDA-NRCS, USDA-FS, SSEA
24	**Native Fish Species Restoration:** a. Walleye Restoration: Continue to implement a Walleye Management Plan for the Ontario waters of Lake Huron and track the effectiveness of harvest regulations throughout Lake Huron. b. Implement, monitor, and track the effectiveness of Arctic Grayling restoration.	LTBB, MDNR, BMIC, NDMNRF, USFWS, EGLE, LRBOI, CORA, USGS, NOAA, DFO

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	c. Implement, monitor, and track the effectiveness of Lake Sturgeon restoration. d. Continue to develop Lake Trout monitoring and restoration/rehabilitation plans. e. Continue Coregonid management, monitoring, and restoration.	
25	**Coastal Wetlands:** Monitor coastal wetlands to assess water quality, species diversity, impacts of human activities, and flora and fauna conditions; a. Promote protection, restoration, and enhancement efforts. b. Support nature-based solutions to improve the resilience of Great Lakes shorelines. c. Apply new decision support tools to help identify and prioritize coastal wetland restoration projects. d. Evaluate and support opportunities to convert agricultural land back to coastal and riparian wetlands.	SCIT, ECCC, BMIC, ECCC, EPA, EGLE, NOAA, USGS, USDA-FS, USFWS, NRCS, Conservation Authorities, NDMNRF, PC, USACE, SSEA
26	Protect and restore habitats including coastal wetlands, inland wetlands, riparian areas and other significant terrestrial habitats through conservation easements, land acquisitions and/or other means to strengthen ecosystem resilience.	MDNR, EGLE, ECCC, EPA, NOAA, USGS, USDA-FS, USFWS, NRCS, NDMNRF
27	**Manoomin (Wild Rice):** Restore and protect manoomin (wild rice) habitat including, but not limited to, the following areas: a. Cheboygan River watershed b. Tawas Lake c. Thunder Bay River watershed including Fletcher Pond d. St. Marys River e. Les Cheneaux Islands archipelago f. Eastern Georgian Bay g. North Channel and Manitoulin Island area	LTBB, SCIT, MDNR, EGLE, NOAA, BMIC, CORA, LRBOI
28	Improve quantification and biomass estimates of food web components (e.g., macroalgae, zooplankton, benthic macroinvertebrates, including dreissenid mussels) and fish production and distribution (including the Round Goby). Conduct broader spatial sampling of pelagic invertebrates (i.e., zooplankton) in the nearshore, inclusive of Georgian Bay, the North Channel, Saginaw Bay, and the nearshore areas of both the southern and northern main basins, including areas with rocky and other hard substrates. Also include winter ecology/under ice limnology in sampling.	MDNR, BMIC, NDMNRF, USGS, NOAA, USFWS, EPA, EGLE

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
29	Continue lakewide assessment of primary production, including seasonal and spatial distribution. a. Focus on spring bloom conditions. b. Consider possible implications for larval fish bottlenecks at locations throughout the Lake Huron basin.	MDNR, ECCC, NDMNRF, USGS, BMIC, EGLE, EPA, USGS
30	Characterize benthos population trends in the North Channel to better understand the decline in the benthic community.	ECCC, NDMNRF
31	Improve understanding of the physical, chemical, and biological processes in specific ecological zones (inshore, nearshore, and offshore), including the status of coastal wetlands, to guide management actions in the future.	ECCC, NDMNRF, EPA, EGLE, NOAA, USGS, USFWS
32	Engage with the public and landowners on the importance of the Lake Huron ecosystem's habitats and species including restoring degraded and protecting high-quality areas and mitigating the impacts of climate change. a. Support citizen science opportunities. b. Create "Important Habitat" map for outreach, engagement, protection, restoration, monitoring, and assessment efforts	BMIC, ECCC, EPA, EGLE, USACE, NOAA, USGS, USFWS, USDA-FS, SCIT, CORA, PC, NDMNRF, MDNR, LRBOI, LTBB, SSEA
	Actions to Prevent and Control Invasive Species	
33	**Ballast Water:** Implement programs and measures that protect the Great Lakes basin ecosystem from the discharge of AIS in ballast water, pursuant to commitments made by the Parties through Annex 5 of the *GLWQA*.	TC, EPA, USCG
34	**Early Detection and Rapid Response:** Maintain and enhance early detection, surveillance, and monitoring of non-native species (e.g., Invasive Carp) to find new invaders and prevent them from establishing self-sustaining populations.	DFO, BMIC, LTBB, MDNR, NDMNRF, EPA, USDA-FS, USFWS, SSEA
35	**Canals and Waterways:** Through the Invasive Carp Regional Coordinating Committee, prevent the establishment and spread of Bighead and Silver Carp in the Great Lakes.	EPA, USFWS, NOAA
36	**Sea Lamprey:** a. Control the larval Sea Lamprey population in the St. Marys River with selective lampricides. Continue operation and maintenance of existing barriers and the design of new barriers where appropriate. b. Design and construct Au Gres River sea lamprey trap in Arenac County, Michigan.	MDNR, PC, DFO, USACE, USFWS

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	c. Design and construct Au Sable River sea lamprey trap in Iosco County, Michigan. d. Support the GLFC's supplemental Sea Lamprey control program. e. Design and construct Sea Lamprey barriers with seasonal fish passage at the Trout and Tittabawassee rivers.	
37	**Improve understanding of invasive species impacts to inform management efforts:** a. Impacts of Round Goby on the Food web: Enhance assessment methods and technology to better understand Round Goby population density and distribution. b. Causes of Botulism Outbreaks: Improve understanding of links between mussels, Round Goby, and Botulism outbreaks in waterfowl. c. *Cladophora* growth: Maintain and/or continue to implement Lake Huron sentinel *Cladophora* monitoring sites to determine the role of mussels in nearshore algae growth and possible mitigation efforts.	USGS-GLSI, USFWS, MDNR, NOAA, NDMNRF
38	**Control of Terrestrial and Wetland Invasive Species:** • Maintain coastal and nearshore aquatic habitat diversity and function through appropriate control of *Phragmites* (i.e., *Phragmites australis, subsp. australis*) and other invasive species (e.g., Glossy Buckthorn, European Frog-bit, Purple Loosestrife, Japanese Knotweed, New Zealand Mud Snail) including monitoring, mapping, and control efforts guided by BMPs. • Coordinate *Phragmites* control efforts and share BMPs through the Ontario Phragmites Working Group and Great Lakes Phragmites Collaborative.	USDA-FS, SCIT, MDNR, EGLE, BMIC, NVCA, NDMNRF, PC, SCRCA, USDA-NRCS, EPA, USFWS, SSEA
39	Improve the understanding of the role and contribution of invasive species have on Lake Huron's food web/nutrient dynamics, including links between the benthic and pelagic, and the nearshore and offshore environments. a. Assess the contribution of invasive species to a-stressed system, consistent with bottom-up limitation. b. Improve the understanding of energy sources and the movement of energy within the Lake Huron food web, including consideration of stable isotopes or fatty acids and eDNA to determine diet composition.	EGLE, USGS, NOAA, EPA, BMIC, NDMNRF
40	Improve the understanding of how dreissenid mussels contribute to: 1) the movement of energy via the microbial loop	EGLE, USGS, NOAA, EPA

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	(i.e., dissolved organic material, bacteria, phytoplankton, protozoa, and other microbes); and 2) zooplankton productivity.	
41	Maintain an index time series that shows the impact of Sea Lamprey marking rates on Lake Trout population status in Michigan.	MDNR
42	Undertake aquatic invasive species prevention outreach and education, including discussions with recreational boaters and lake access site signage.	LTBB, SCIT, EGLE, BMIC, DFO, NDMNRF, SCRCA, USDA-FS, EPA, CORA, PC, SSEA
	Actions to Prevent and Address Other Threats	
43	**Watershed Resilience:** Continue efforts that engage landowners and the public in protecting and enhancing the proper functioning of watershed headwater features, streams, forests, and wetlands to maintain and enhance resilience to climate change impacts, including local climate change strategies and actions.	MECP, MDNR, BMIC, Conservation Authorities, USDA-NRCS, USDA-FS, PC, SSEA
44	Organize, participate, or support capture and clean-up projects to prevent and remove plastic pollution including “nurdles” from Lake Huron waterways and coastlines.	MECP, ECCC
45	Critical community infrastructure: Plan and implement Low Impact Development initiatives that are suited to future extreme weather events through projects that increase green space and green infrastructure.	SCIT, MECP, EGLE, Conservation Authorities, USDA-FS, EPA, ECCC
46	Assess on a lakewide basis, the cumulative effect of climate change on chemical contaminants, nutrients, invasive species and habitat and native species as it relates to the physical (e.g., substrate, bathymetry, sediment transport), chemical, and biological (e.g., food web) processes of Lake Huron.	ECCC, USGS, NOAA, EGLE, USFWS
47	Characterize the presence & distribution of microplastics in Lake Huron and analyze their effects on the physical, chemical, and biological (e.g., food web) processes of Lake Huron.	MECP, ECCC, USGS, NOAA
48	Improve understanding of the impacts of groundwater on the physical, chemical, and biological processes in specific ecological zones (inshore and nearshore) of Lake Huron to guide management actions in the future.	USGS, MECP
49	To the extent possible, quantify groundwater contribution to the water budget of Lake Huron in specific sub-basins.	USGS
50	Support outreach and engagement opportunities to stakeholders and the public on the impacts of climate change to	LTBB, Conservation Authorities, ECCC,

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	the Great Lakes and Lake Huron through fact sheets, newsletters, and other means.	NOAA, USDA-FS, EPA, USACE, PC, SSEA
51	Continue public outreach and engagement on the impacts of plastic waste pollution and ways to reduce the amount of plastic in the Lake Huron basin.	LTBB, SCIT, ECCC, EPA, USACE, PC
52	Increase the public's awareness of: the potential impacts associated with transporting oils and other hazardous materials by road, rail, ship, and pipeline; spill contingency plans already in place; and where to report spills of oils and other hazardous materials.	LTBB, BMIC, LRBOI, CORA, SCIT

**Acronyms for agencies not listed as Lake Huron Partnership agencies on page iv are: Michigan Department of Health and Human Services (MDHHS); Transport Canada (TC).*

Flowerpot Island, Don Wilkes

1.0 INTRODUCTION

The 2022-2026 Lake Huron Lakewide Action and Management Plan (*LAMP*) is an ecosystem-based strategy for restoring and protecting Lake Huron. It follows the successful implementation of the 2017-2021 *LAMP*, where Lake Huron Partnership agencies undertook actions in cooperation with 130 other organizations, businesses, communities, and academic institutions.

The Lake Huron *LAMP* fulfills a United States and Canadian commitment under the *2012 Great Lakes Water Quality Agreement* (the Agreement) to assess ecosystem conditions, identify environmental threats, set priorities for research and monitoring, and identify further actions to be taken by governments and the public to meet the objectives of the Agreement. This commitment includes integrating nearshore assessment information.

The *LAMP* is a world-recognized model for cooperation among binational and multi-jurisdictional governmental entities and their management agencies. The geographic scope of this *LAMP* includes activities in the waters of Lake Huron as well as tributaries and watersheds that impact the waters of Lake Huron. The *LAMP* is a resource for anyone interested in the

Lake Huron ecosystem, its water quality, and the actions that will help protect this unique and beautiful Great Lake.

1.1 Great Lakes Water Quality Agreement

Since 1972, the Agreement has guided U.S. and Canadian actions to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes. In 2012, the United States and Canada amended the Agreement, reaffirming their commitment to protect, restore, and enhance water quality and to prevent further degradation of the Great Lakes basin ecosystem.

In addition to having nine General Objectives (listed in Table 1), the Agreement commits the United States and Canada to address 10 priority issues through specific 'Annexes' as shown in (Table 3). The Lake Huron *LAMP* integrates information and management needs from each of these Annexes, with a focus on Lake Huron.

Table 3: GLWQA Annexes

1. Areas of Concern
2. Lakewide Management
3. Chemicals of Mutual Concern
4. Nutrients
5. Discharges from Vessels
6. Aquatic Invasive Species
7. Habitats and Species
8. Groundwater
9. Climate Change Impacts
10. Science

In Canada, many contributions to the Agreement and the Lake Huron *LAMP* are enabled through existing government programs such as the Great Lakes Protection Initiative, as well as the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health. Since 1971, a series of Canada-Ontario agreements have guided efforts to improve water quality and ecosystem health of the lakes and contribute to meeting Canada's obligations under the Canada-United States *Great Lakes Water Quality Agreement*.

In the U.S., many contributions to the Agreement and the Lake Huron *LAMP* are enabled through existing governmental programs and the Great Lakes Restoration Initiative (GLRI). The GLRI was launched in 2010 to accelerate efforts to protect and restore the largest system of fresh surface water in the world. Since 2010, the multi-agency GLRI has provided funding to 16 federal organizations (and indirectly, to their many state, tribal, and local partners) to strategically target the biggest threats to the Great Lakes ecosystem.

1.2 Lake Huron Partnership

The *LAMP* was developed by member agencies of the Lake Huron Partnership, a collaborative team of natural resources managers led by the governments of the United States and Canada, in cooperation and consultation with State and Provincial governments, Tribal governments, First Nations, Métis, Municipal governments and watershed management agencies. Current member agencies are listed in the Acknowledgements section.

Old Presque Isle Lighthouse, Adobe Stock

The Lake Huron Partnership aids in the implementation of the *LAMP* by helping member agencies share information, collaborate on assessing the state of the lake, set priorities, coordinate their actions and leverage funding. The Lake Huron Partnership consists of a Management Committee of senior-level representatives of government agencies with decision-making authority, and a Working Group that coordinates *LAMP* development, implementation, and reporting. The Working Group is supported by issue-specific subcommittees that bring together experts who contribute to project ideas, project implementation, coordination, tracking *LAMP* progress, and recommending priorities for science, monitoring and other actions.

The Lake Huron Partnership has set the priorities for science and monitoring for Lake Huron in the 2022-2026 timeframe. These science priorities include the continued need for information on chemical contaminant loading and cycling, nutrient loading and cycling, the status of habitat and native species, the impact and distribution of invasive species and other stressors such as groundwater flow, microplastics, and cumulative effects from climate change (e.g., intense storm events, variable ice cover, and fluctuating water levels). To understand the changing ecology and biological productivity of Lake Huron, consideration must be given to specific ecological zones (inshore, nearshore and offshore), and natural processes (physical, chemical, and biological). Focus on these priorities will allow the Lake Huron Partnership to better implement management actions identified in the *LAMP*. Refer to the Management Actions in Table 2 for a complete list of Lake Huron science priorities.


Bruce Peninsula, PC

1.3 Engagement in *LAMP* Development

Engagement, collaboration, and active participation by all levels of government, stakeholders, and the public is essential for the successful development and implementation of the *LAMP*. Local and regional organizations, academic institutions, and communities are among the most knowledgeable and effective champions to achieve environmental objectives in their area. For these reasons, member agencies of the Partnership funded, or collaborated with, over 130 communities, organizations, and institutions to implement the 2017- 2021 Lake Huron *LAMP*. The results of these engagements continuously inform the Lake Partnership member agencies and development of the *LAMP*. Twenty-three Lake Huron Partnership agencies have shared updates for 240 implementation highlights (i.e., largely distinct projects or programs) undertaken in the 2017 to 2021 timeframe.

Beyond engagements conducted by individual agencies, there are also coordinated lakewide public engagements. For the development of the 2022-2026 *LAMP* these included:

- **2019 State of Lake Huron Conference, hosted by the International Association for Great Lakes Research and Saginaw State University.**
  - Member agencies of the Lake Huron Partnership presented their latest science and monitoring program updates, including the 2017 Lake Huron Cooperative Science and Monitoring Initiative (CSMI) results.
  - The conference highlighted gaps in science and monitoring that need to be addressed to better achieve ecosystem objectives.

- 2019 Great Lakes Public Forum.
  - Held every three years in the U.S. or Canada, this Forum provides an opportunity for the United States and Canada to discuss and receive public comments on the state of the lakes, including Lake Huron, and binational priorities for science and action.
  - A State of the Great Lakes report is presented concurrent with the Forum.
- **2020 workshop to identify science and monitoring priorities.**
  - Held in October 2020, this workshop invited the public and stakeholders to provide input on future science and monitoring priorities
  - The workshop resulted in a report used in the development of the 2022-2026 *LAMP*.
- **Lake Huron Partnership public webinars.**
  - Held biannually, these webinars update the public on *LAMP* implementation and invite the public to share their insights and suggestions.
- **2022 draft *LAMP* public input period.**
  - All public input on a draft *LAMP* is considered and incorporated where applicable, in the final *LAMP*.
- **2021 workshop to identify First Nation priorities.**
  - Facilitated by the Union of Ontario Indians, the workshop was held over 2 days with participants representing various communities from Anishinabek Nation.

1.4 State of the Great Lakes Reporting

Pursuant to the *Agreement*, Canada and the United States have established a suite of nine indicators and 40 sub-indicators of ecosystem health to assess the State of the Great Lakes (SOGL). Indicators are updated every three years with support from over 200 scientists and experts using data from dozens of governmental and non-governmental organizations. These experts assess the current status of each indicator using a ‘Good’, ‘Fair’ or ‘Poor’ classification and assess the directional trend for each indicator using an ‘Improving’, ‘Unchanging’ or ‘Deteriorating’ classification. The latest SOGL report was released in 2022, and indicator-related information presented in the Lake Huron *LAMP* is referenced as “ECCC and EPA, 2022”.

Arch Rock Mackinac Island, Adobe Stock

2.0 INHERENT VALUE, USE, AND ENJOYMENT OF LAKE HURON

Lakewide management is guided by a shared vision of a healthy, prosperous, and sustainable Great Lakes region in which the waters of Lake Huron are used and enjoyed by present and future generations. The Lake Huron *LAMP* recognizes the inherent natural, social, spiritual, and economic value of the Lake Huron basin ecosystem. This includes the characteristics of the lake that are of global significance, the cultural significance of the area to Indigenous peoples, and the regional economic value the lake supports.

2.1 Global Significance

The Lake Huron watershed is currently home to three million people (~1.5 million Ontarians and ~1.5 million Michiganders) and has been used and enjoyed for thousands of years (Michigan Sea Grant, 2021). We continue to recognize the inherent natural, social, spiritual, and economic value of the Lake Huron basin ecosystem. Sustainable, sound, and strategic management, as well as protective measures, will ensure future generations can enjoy this beautiful resource.


Stream in the north shore of Georgian Bay, Emma Kirke

LAKE HURON PHYSICAL FACTS

Surface Area: 59,590 km^2 (23,007 mi^2)

Water Volume: 850 mi^3 (3,543 km^3)

Average depth: 59 m (195 ft)

Maximum depth: 229 m (750 ft)

Drainage basin: 64,497 km^2 (24,902 mi^2)

52% forested ● 1.4% water ● 22% agriculture ● 7.9% developed land ● 17% wetland

Sources: (EPA, 2020a; ECCC & EPA, 2021)

Lake Huron is the fifth largest freshwater lake in the world and contains the largest freshwater island in the world, Manitoulin Island, a sacred place for First Nations Peoples (LaRue, 2021; Global Great Lakes, n.d.; Wiikwemkoong Unceded Territory, 2021). Of the 35,000 islands in the Great Lakes, 30,000 of them are in Lake Huron, mostly in Georgian Bay. This abundance of islands gives Lake Huron the distinction of having the longest shoreline of all the Great Lakes (LaRue, 2021) (6,100 kilometres or 3,790 miles). These islands feature globally rare species and serve as stopover sites for migratory birds (Franks Taylor et al., 2010).

People have populated the Lake Huron watershed for thousands of years. During the Paleoindian and Archaic periods, an ancient land bridge, the Alpena-Amberley ridge, linked what is now Michigan and Ontario. This bridge was discovered to have contained a hunting blind dated at 9,000 years old. The site reveals much about how ancient peoples hunted caribou and is one of many archaeologically-significant sites around the watershed (O’Shea et al., 2014).

INDIGENOUS PEOPLES AROUND LAKE HURON

Indigenous peoples have called the Lake Huron basin home for 15,000 years. Their culture, traditions, and values are rooted in fishing, hunting, trapping and harvesting which bond communities to the land and water.

Seven treaties establish the sovereign rights of Indigenous peoples in the Lake Huron watershed. First nation communities, Métis, and U.S. federally recognized tribes call the Lake Huron basin home.

Map of Lake Huron Indigenous Communities, ATRIS

WHAT IS IN A NAME?

Lake Huron was named by the French after the Huron First Nation communities, also known as the Wyandot or Wendat, who resided on the shores of the lake. The Wyandot referred to the lake as the karegnondi, which has been translated as “Freshwater Sea” or “lake.” The Anishinabe referred to the lake as Naadowewi-gichigami, or Iroquois' Sea.

Great Lakes protection is a priority for Indigenous peoples. Water walker Josephine Mandamin was born on Lake Huron in the Wiikwemkoong Unceded Territory. She walked around Lake Huron in 2005 as a part of her activist work to protect the Great Lakes. Mandamin is known as the Grandmother Water Walker. She has since passed the legacy onto her great-niece Autumn Peltier, internationally recognized Anishinabe water warrior.

Successful Indigenous/Tribal Nation and Agency Collaboration

Coastal Wetland Monitoring – Completed

Detailed vegetation and elevation mapping at 8 coastal wetlands on Lake Huron in order to assess vulnerability to climate change and develop consensus-based adaption measures.

Wiikwemkoong Unceded Territory, ECCC, Parks Canada, ENGOs, local landowners, McMaster University, provincial government and municipalities.

Early Detection for New Non-Native Species – Ongoing

Conducting early detection for new non-native species at high-risk Lake Huron locations, including the Saginaw River and St. Marys River.

USFWS, Michigan DNR, Ontario Ministry of Natural Resources, USGS, Chippewa Ottawa Resources Authority, Sault Ste. Marie Tribes of Chippewa Indians, Grand Traverse Bay Band of Odawa and Chippewa Indians, Bay Mills Indian Community, Little River Band of Ottawa Indians.

2.2 Indigenous Peoples

Anishinaabeg people, including the Ojibwe, Odawa, Potawatomi, Algonquin, Saulteaux, Nipissing, and Mississauga of the Credit First Nations, as well as some Oji-Cree and Métis Nation, have called Gichiaazhoogami-gichigami Great Crosswater Sea and the St. Marys River (Gichigami-ziibe – Sea River) home for thousands of years. This is evident from their oral traditions as well as archeological evidence. Indigenous peoples continue to play an important role as stewards of the lake. According to Waganakising chief Assiginack, the original name for Lake Huron was "Ottawa Lake or Naadowe-gichigami" due to the strong presence of Odawa there. Along with the Ojibwe and Potawatomi, the Odawa had migrated from the east to the place where they found *manoomin* (wild rice), "the food that grows on the water." The Odawa remained in and around Lake Huron, establishing themselves at: Georgian Bay, Bruce Peninsula, Straits of Mackinac, Manitoulin Island, Drummond Island, and Thunder Bay. Many of the Odawa still live in their pre-contact villages, including those at Manitoulin Island. The Odawa have always been a water people, traversing the Great Lakes and many rivers that flow into it for trade, fishing, war, diplomacy, and attending cultural sites. The homelands of the *Anishinaabeg* bands in their entirety stretch from eastern Ontario to southeastern Manitoba and from southeastern Michigan to central Minnesota, with treaty-ceded territories located throughout the region and within the Lake Huron basin.

Today, there are at least 35 Tribal and First Nation communities located along the coast or within the Lake Huron basin. Figure 2 shows First Nations, Tribal Nations, and Treaty-defined territories within the Lake Huron basin. Additionally, there are seven regional, rights-bearing Métis communities within the Lake Huron basin. The Lake Huron historic Métis community developed from the inter-connected Métis populations at Historic Sault Ste Marie Métis Council, North Channel Métis Council, Sudbury Métis Council, North Bay Métis Council, Great Lakes Métis Council, Georgian Bay Métis Council, and Moon River Métis Council. These historic communities emerged prior to the Crown establishing legal and political control, having their own shared customs, traditions, and collective identities that are rooted in kinship. Today, these Métis communities are represented by the Métis Nation of Ontario. Reliance on the waters of Lake Huron and its basin for activities such as fishing, trapping, and harvesting are critical components of the history of these indigenous communities. To this day, these people continue to practice their right to harvest and rely on the waters of Lake Huron to sustain their way of life. Fishing and trapping remain vital to these communities, not only as valuable sources of nutrition, but also as cultural traditions.

The *nibi* (waters), *giigoonh* (fish), plants and wildlife in the Lake Huron basin continue to provide a sense of identity and continuity with traditional ways of life. All plant and animal life are culturally significant to Indigenous people. Some of the most well-known examples of animal beings are *migizi* (bald eagle), *ma'iingan* (wolf), *na' me* (Lake Sturgeon), *adikameg* (Whitefish), and *ogaa* (Walleye). Well-known examples of plant beings include *manoomin* (wild rice), *mashkiigobagwaaboo* (labrador tea), *wiigwassi-mitig* (paper birch), *baapaagimaak* (black ash), and *giizhik* (cedar). Indigenous peoples continue to rely on subsistence harvesting practices throughout the basin to sustain their communities and their culture.

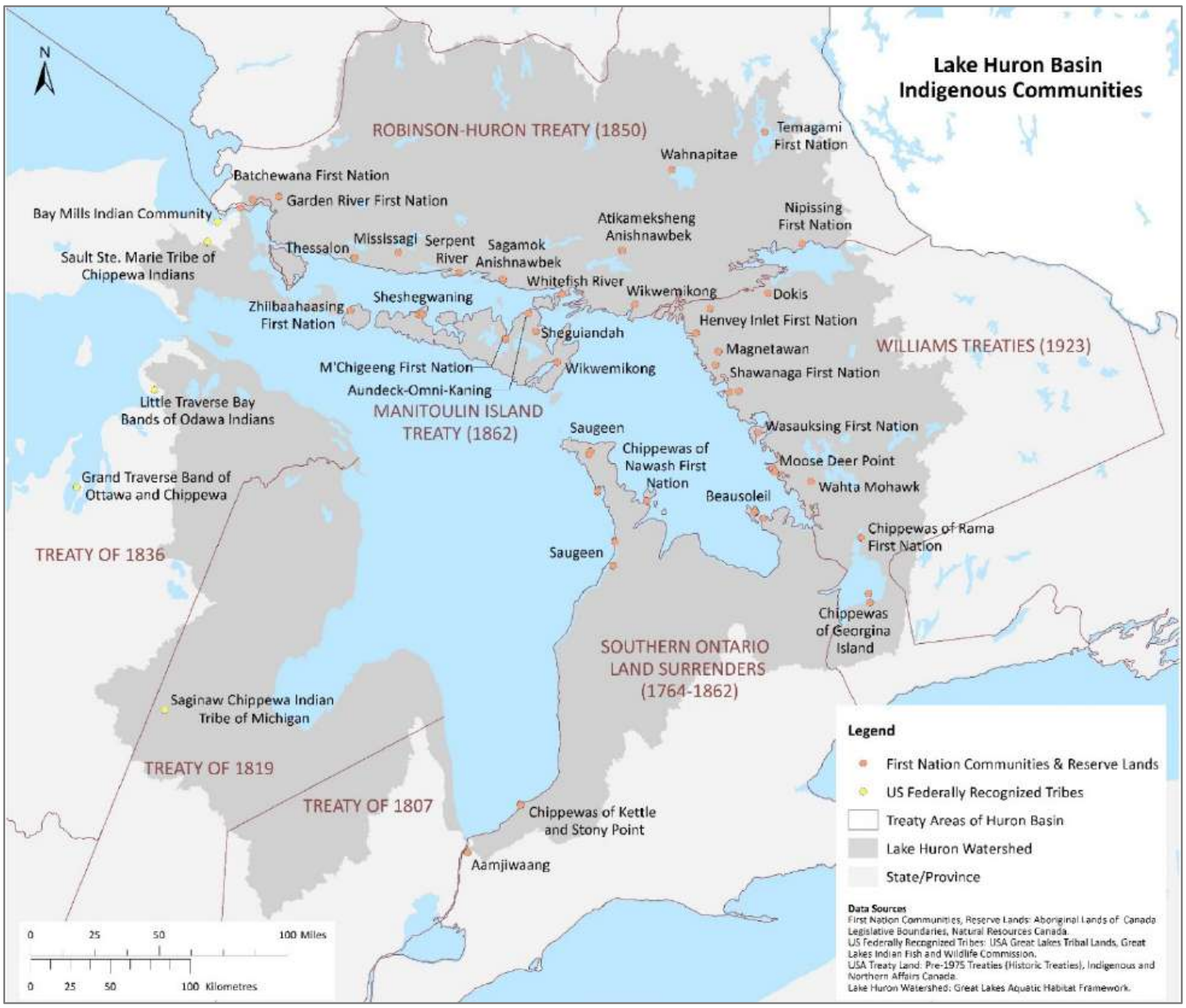


Figure 2: Lake Huron Basin First Nations, Tribal Nations, and Treaties (Source: ECCC).

Traditional Ecological Knowledge (TEK) is a term that encompasses an ecological element of Indigenous Knowledge. Indigenous knowledge encompasses environmental, socio-economic, cultural, and other elements of overall knowledge held by Indigenous peoples. TEK is the knowledge system of Indigenous people based upon generations of direct observations of the surrounding environment. Indigenous knowledge is passed down generation to generation and is used to explain their place within the complex and interdependent relationships of all creation. It is the kind of intimacy that comes from knowing a place profoundly, not just as scenery, but also as sustenance; knowledge is passed on with a sense of trust through generations. To continue this relationship, Indigenous people integrate modern and advanced science to ensure the health of the natural world. According to the *Anishinaabe* world view, Lake Huron and its connected lakes, rivers, and streams are not simply the sum of their constituent parts, or the property of a state, nation, or person. Instead, they are integral parts of the web of life that supports the continuation of *Anishinaabe* ways of life and provides life-giving benefits to all who now call the region home. One observation is that *nibi* (water) is life and the quality of water determines the quality of life. If water becomes sick, human beings become sick. Indigenous peoples can see their health in the health of the water. Another observation is that while non-human beings will survive, and even thrive, without the influence of humans, human beings cannot survive without the continuation of healthy and sustainable non-human beings. TEK enhances the understanding and appreciation of Lake Huron and is useful in local, regional, and lakewide management, including implementation of the *LAMP*. In 2021, the U.S. Caucus of the Traditional Ecological Knowledge Task Team Annex 10 Science Subcommittee released a document entitled "Guidance Document on Traditional Ecological Knowledge Pursuant to the Great Lakes Water Quality Agreement" (Koski et al., 2021). This Guidance Document on Traditional Ecological Knowledge ("Guidance Document") provides a starting point for understanding how TEK can be appropriately supported and engaged to contribute to the achievement of the objectives of the Great Lakes Water Quality Agreement ("Agreement"). This document seeks to provide a base from which a common understanding of TEK can grow. It provides an explanation of how TEK relates to and can enhance western science and priority-setting under the Agreement, and shares examples of how TEK can initiate and be integrated into interjurisdictional Great Lakes research and management activities. Lastly, it lays out possible next steps for future engagement with Indigenous nations and TEK under the Agreement.

2.3 Natural Resources and the Regional Economy

The abundant natural resources within Lake Huron and its watershed support a strong regional economy. Extensive water-based industries, commercial and recreational fishing, commercial shipping, forestry, agricultural operations, and tourism are major employers and contributors to the economy, as described below.

Water Use and Watershed Economy

Lake Huron provides 1.4 billion litres of freshwater per day (approximately 370 million gallons per day) to the public, agricultural, industrial, and thermoelectric power industries. Unlike the other Great Lakes, the majority of water in Lake Huron comes from two other Great Lakes, Lake Michigan and Lake Superior (Lake Huron-Georgian Bay Watershed, 2016). Over 2.3 million people get their drinking water from Lake Huron - including communities outside of the Lake Huron watershed such as parts of Detroit, Michigan and London, Ontario. Hydroelectric generation stations extract water from the St. Marys River to generate power. As an example, the Cloverland Electric Cooperative hydroelectric plant generates 225 million kilowatt-hours annually (International Upper Great Lakes Study, 2009).

Industries that are supported by the Lake Huron watershed include logging, commercial fishing, shipping, and agriculture. The southern portion of the watershed is more heavily developed due to rich soils for agriculture that led to the creation of urban centers. The northern part of the watershed (including Georgian Bay) is more rugged, with forestry and commercial fishing being the predominant industries (Lake Huron-Georgian Bay Watershed, 2016).

Cheboygan, Michigan, Adobe Stock

Commercial and Recreational Fishing

Lake Huron is the second major fish producing Great Lake (behind Lake Erie) with Whitefish, Walleye, Yellow Perch, Lake Trout, Channel Catfish, Carp, Pacific Salmon, and Chub comprising the foundation of the commercial fishery industry (Environmental Commissioner of Ontario, 2011; Malewitz, 2019). The 2020 harvest for Ontario exceeded 764 metric tons (842 tons) and a value of $3 million CAD ($2.75 million USD) (OCFA, 2020). Michigan's 2020 commercial harvest exceeded $1.9 million USD ($2.38 million CAD) (T. Goniea, personal communication, 2021). In Canada, direct recreational fishing expenditures are highest for Lake Huron relative to other Great Lakes, totaling over $92 million CAD ($73.4 million USD) (OMNRF, 2016). Saginaw Bay supports a world class recreational fishery valued in excess of $39 million USD ($48.9 million CAD) per year (Fielder et al., 2014; D. Fielder, personal communication, 2021).

There are 60 local commercial-licensed fisheries across Lake Huron, the North Channel, and Georgian Bay, including five Aboriginal commercial fishing agreements (Steiss, 2020). For recreational fishing opportunities, visitors can charter a fishing cruise, fish from the Lake Huron's extensive shorelines, go ice fishing, or boat or kayak fish in Lake Huron's calm waters. Top recreational fishing destinations include Saginaw Bay and Thunder Bay, and the towns of Linwood, Mackinaw City, and Rogers City in Michigan. Popular open water fisheries in Ontario include southern Georgian Bay, the south shore of Manitoulin Island, the east shore of the main basin as well as tributary fisheries like the Saugeen River (Fishing Booker, 2021). Eastern Georgian Bay and the North Channel also support popular fisheries for warm and cool-water fish species (OMNRF 2016).

Commercial Shipping

The St. Marys River is an industrial hub for manufacturing. The River and the Soo Locks provide U.S. and Canadian lakers and international salties access to Great Lakes ports. Approximately 79% of the iron ore mined in the United States (Kakela, 2013) is delivered via shipping through the St. Marys River. Shipping ports including Goderich, Sarnia, Port Huron, Mackinaw City and Saginaw, contribute over 90,000 jobs and $13.4 billion CAD ($10.7 billion USD) to both economies (Chamber of Marine Commerce, 2011). The primary industries supported by commercial shipping are grain, iron, and limestone (Great Lakes Guide, 2020).

Cargo that travels across Lake Huron includes bulk, containerized, break bulk, and project cargo. Project cargo includes items that are unusually heavy or awkward and cannot be carried by truck or rail. On Lake Huron, such items might include wind turbine blades, railroad locomotives, or steel pressure vessels for oil refining. Other goods shipped on Lake Huron include coal, limestone, farm products, and steel (American Great Lakes Ports Association, 2021).

Mining

Salt, limestone, and metal mines support many local economies in the watershed (OMNDM, 2011; GLEAM, 2014). The world's largest limestone and salt mines are located in Rogers City, Michigan, and Goderich, Ontario, respectively. The Goderich salt mine is located 549 metres (1,800 feet) under Lake Huron. Salt from this mine is used on roadways, and is packaged in bulk for applications in plastics, detergents, and disinfectants (Compass Minerals, 2021). The Michigan Limestone and Chemical Company has operated since 1910 and ships between 7 and 10.5 million tons of limestone each year. The limestone is crushed to make aggregate, is added to steel, or is used for building stone, soil enhancers, and lime (NASA, 2006).

Forestry

Lake Huron's northern watersheds abound with forest resources that have supported the establishment of communities. Logging began in the 1800s, with nearly all forests in the region having been logged at least once in the past 150 years. Currently, economic benefits from lumber sales in Ontario generate $230 million CAN ($183.5 million USD) annually, and the forestry and logging industries in Michigan as a whole generate over $5 billion USD ($6.3 billion


Alvars on Cabot Head, Hayley Austin

CAD) in direct economic output. In the Lake Huron basin, Oscoda County, Michigan alone generated over $4 million USD ($5 million CAD) in 2017 (Leefers et al., 2020). Carolinian forests (temperate deciduous forests common to the Eastern US) are found in the southernmost regions of the watershed, and northern mixed-wood forest can be found in the rest of the watershed (Domtar, 2020).

Agriculture

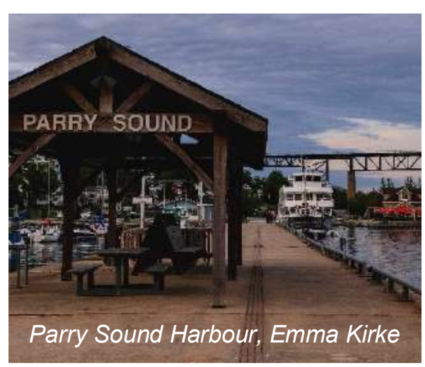
Agriculture is an important business sector in the Lake Huron watershed. The southern watersheds of Ontario and Michigan contain some of the most productive farmland in the basin. Approximately 800,000 hectares (1.98 million acres) of farmland are under production on 6,500 farms throughout Lambton, Huron, and Bruce counties of southwestern Ontario. In the Saginaw Bay and thumb region of Michigan, there are approximately 1.1 million hectares (2.8 million acres) under production on 10,000 farms with Bay, Genesee, Gratiot, Huron, Isabella, Lapeer, Saginaw, Sanilac, Shiawassee, and Tuscola counties totaling roughly $77 million USD ($96.5 million CAD) in farm-related income (USDA, 2019).

East-Central Michigan is the top producer in the US of black beans, cranberry beans, small red beans, and pickling cucumbers (Michigan Agritourism Association, n.d.; Freshwater Future, 2021). Other crops produced in East-Central Michigan include sugar beets, wheat, potatoes, and corn. Dairy and cattle farming is also prevalent in the area (Schaetzl, n.d.).

Because only 7% of Canada's land is suitable for agriculture, the warmer climate of southern Ontario is home to most of Ontario's agricultural production. Crops grown in the region include soybeans, sugar beets, fodder and grain corn, fruit, winter wheat, and potatoes (Morrison, 2015).

Aquaculture

Lake Huron has the only commercial fish farms operating on the Great Lakes. Parts of Manitoulin Island, the North Channel, and Georgian Bay support a number of cage aquaculture operations that predominantly raise Rainbow Trout in Ontario waters. The 2018 production statistics indicate that approximately 4,900 tonnes (5,401 tons) of Rainbow Trout were produced by aquaculture facilities (Moccia et. al., 2019).



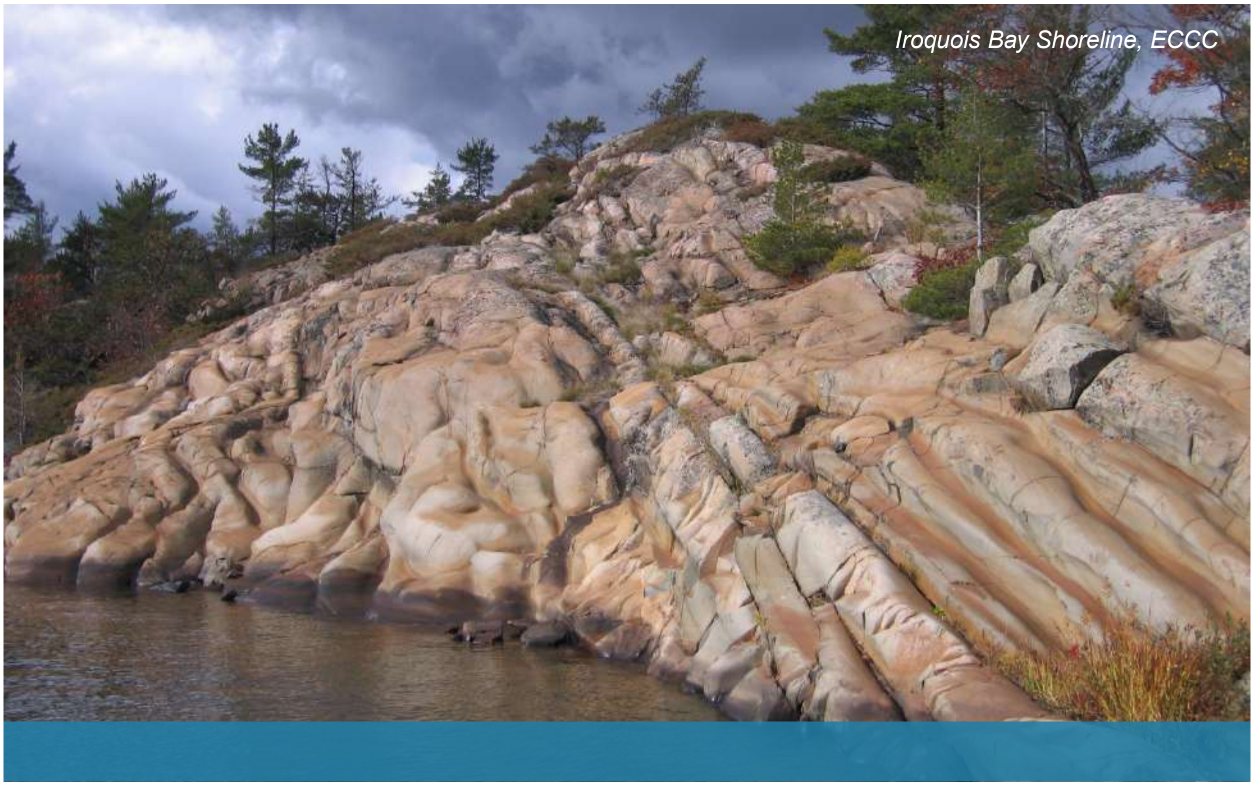
Parry Sound Harbour, Emma Kirke

Nature-based Tourism and Recreation

Lake Huron supports diverse recreational and tourism opportunities. It is a place to relax on the numerous public beaches and enjoy swimming, fishing, kayaking, scuba diving, or paddleboarding (Huron County Economic Development, 2020). Picturesque small communities line the shore, offering their own "sense of place", including invitation for fine dining and to experience the arts. Visitors can explore area lighthouses, shipwrecks, and museums that present Lake Huron's rich maritime heritage (Midwest Living, 2021). More remote parts of the Lake Huron watershed are excellent for stargazing and astronomy lovers (Michigan Economic Development Corporation, 2021). Most of the nearshore waters now have established routes, known as "water trails", that provide spectacular opportunities to explore the coastline with kayaks, canoes, and other small watercraft.

Round Island Lighthouse near Mackinac Island, Adobe Stock

Parks, wildlife refuges, marine parks, and conservation areas provide opportunities for tourism and recreation, while also fostering connections with the unique places within the watershed. Studies have repeatedly shown that people are happier, healthier, and more engaged when we connect to nature through these special places. These areas also strengthen the resiliency of the watershed and the extraordinarily diverse habitat and species found within it. Despite Lake Huron's significant coastal and nearshore ecosystem, almost 82% of the shoreline is not protected. This highlights the importance of existing parks and protected areas as refuges for fish and wildlife and for the protection of biodiversity (Scott Parker, Parks Canada, personal communication, 2016).



3.0 A HEALTHY WATERSHED, A HEALTHY LAKE

The Lake Huron watershed is the area of land that drains rain and snow into streams that flow into the lake. The water quality of Lake Huron depends on the health of its watershed. Indigenous peoples have long understood the connectedness of all living beings as demonstrated by their aim to live harmoniously with nature. An increasing number of western scientific studies echo the long-held *Anishinaabeg* knowledge that watersheds, rivers and lakes are parts of a single web of life. Scientific studies illuminate how the watershed and the lake send and receive nutrients and energy from one another. Terrestrial vegetation develops organic soil that enters water bodies and delivers nutrients to aquatic systems (Carpenter et al., 2005). Those nutrients are utilized by aquatic producers which form the base of the aquatic food web, sustaining populations of consumers and scavengers, including zooplankton and fish species. Some of this energy is returned to the land from the water through aquatic insect larvae hatches, which feed terrestrial consumers such as birds, bats, and spiders (Scharnweber et al., 2014; Soininen et al., 2015).

Protected and Conserved Areas

Parks, marine sanctuaries, conservation areas, nature reserves and other protected areas, comprise approximately 26% of the open water and 18.6% of the coastline of Lake Huron (Figure 3). These areas form the cornerstone of regional and national biodiversity conservation strategies and are valued as places for research, monitoring, and learning. In addition to International Union for Conservation of Nature (IUCN) categorized protected areas, there are also several fish refuges which have been key to Lake Trout recovery and conservation in Lake Huron. Two United Nations World Biosphere Reserves have been established in the Lake Huron basin and serve as models for sustainable development. More recently, the University of Michigan Biological Station Biosphere Reserve was expanded and renamed as the Obtawaing Biosphere Region, which touches on the Lake Huron, Lake Michigan and Lake Superior watersheds. To learn more about this Biosphere Reserve, visit umich.edu. Recognizing the importance of cooperation and collaboration, representatives from agencies across the lake have formed a Great Lakes Protected Areas Network, the intent of which is to improve communication, share capacity and advance protected area planning, management and establishment. With the growing global commitment to halt and reverse biodiversity loss, effectively managing these areas will be essential to meeting our conservation targets, such as protecting at least 30% of our lands and waters by 2030 (e.g., G7 2030 Nature Compact).


Turnip Rock, ECCC

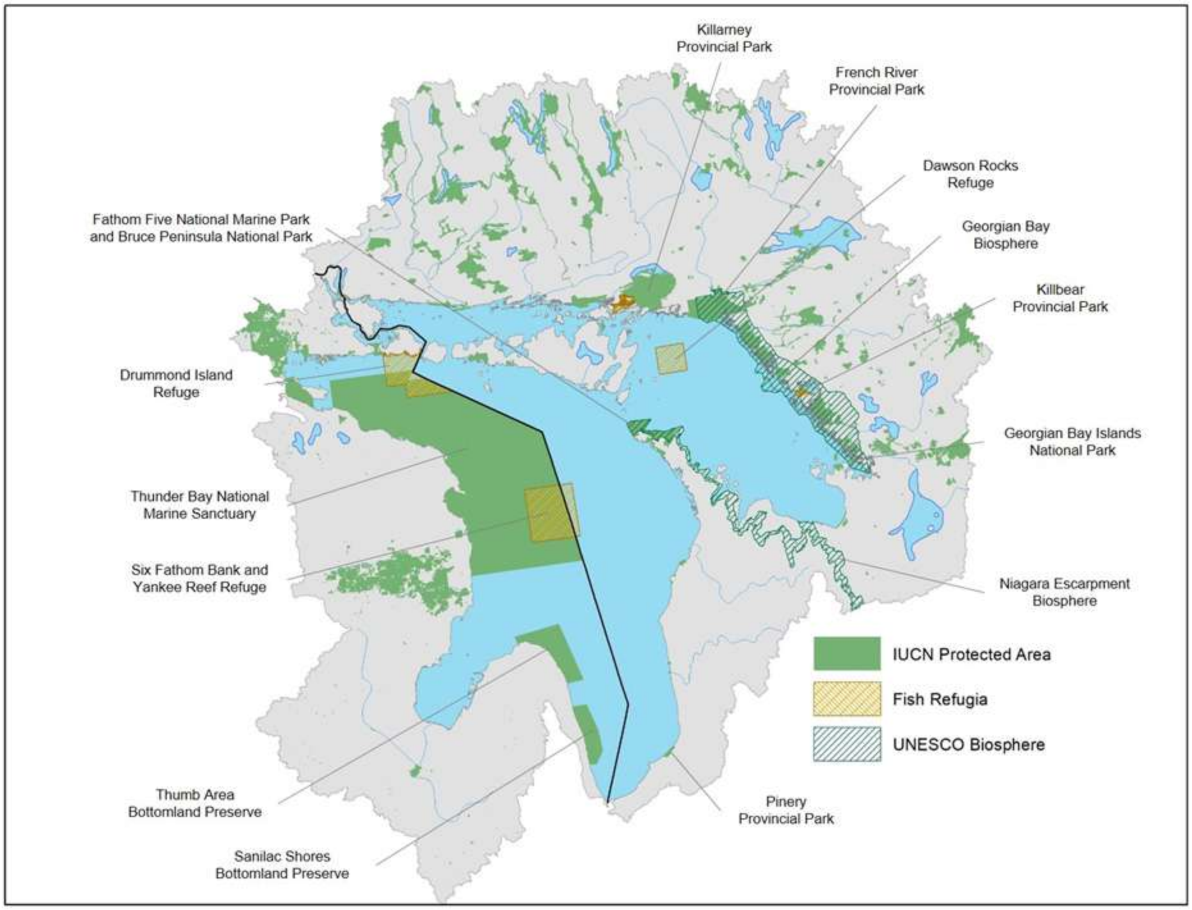


Figure 3: Protected and Conserved Areas in the Lake Huron basin, including International Union for Conservation of Nature (IUCN) categorized protected areas (Protected Planet, 2021), fish refugia (e.g., Lake Trout or Walleye sanctuaries), and UNESCO World Biospheres.

3.1 Lake Huron Water Sources and Flows

Lake Huron is downstream of Lakes Superior and Michigan and upstream of Lake Erie. On average, it holds about 3,540 km^3 (850 mi^3) of water, depending on the various flows into and out of the lake in a given year, as described below (EPA, 2020a).

Each hour, approximately 8 billion litres of water (~ 2 billion gallons) flow from Lake Superior through the St. Marys River. An additional 5.4 billion litres (~1.4 billion gallons) of water flow from Lake Michigan through the Straits of Mackinac. Lakes Michigan and Huron have the same surface elevation, hydrologically making them the same body of water (Lake Huron-Georgian Bay Watershed, 2021).

The watershed itself contributes about 10.4 billion litres of water (~2.7 billion gallons) per hour to the lake. About half of the input is from water flowing over the land and into streams that empty into the lake. Rain and snow falling directly on the surface of the lake and groundwater sources contribute the other half (Lake Huron-Georgian Bay Watershed, 2021).

Water leaves the lake through the various consumptive uses, evaporation and downstream flows. Every hour, about 4.3 billion litres (~1.1 billion gallons) of water evaporate from the lake into the atmosphere. An additional 19 billion litres (~5 billion gallons) of water per hour exit the lake through the St. Clair River and eventually flow into Lake Erie (Botts & Krushelnicki,1995).

3.2 Watershed and the Lake: An Important Connection

The Lake Huron watershed is comprised of a diverse collection of habitat types, each playing a critical role in maintaining water quality. The following sections describe some of the habitat types and distinct waterbodies in the basin and how a healthy watershed functions.

Watersheds

Lake Huron has the largest watershed area and the longest shoreline of all the Great Lakes. Lake Huron's watershed covers an area of approximately 59,590 km^2 (23,008 mi^2) (ECCC and EPA, 2022). Four interacting bodies of water make up Lake Huron: the North Channel, Georgian Bay, Main basin, and Saginaw Bay. Watersheds are the areas of land from which water flows to Lake Huron, and include headwaters, uplands, inland lakes and wetlands.

Headwaters include surface drainage features, groundwater seeps and springs that are the sources of water for streams and small watercourses. Headwaters intrinsically link to downstream water quality through their influence on the supply, transport, and fate of water and solutes in watersheds.

Well-functioning uplands allow water to infiltrate into the soil, which minimizes stormwater runoff, reduces the potential for extreme flooding, and recharges aquifers. Upland areas encompass the majority of the watershed land area and include both natural habitats and developed areas.

Tributaries

Forty-six percent of the water in Lake Huron comes from tributaries (Great Lakes Commission, 2003). Tributaries are vital habitat for fish, and some species only spawn in a few tributaries of Lake Huron. As such, protecting tributaries is vital to preserving the biodiversity of Lake Huron (Franks Taylor et al., 2010).

The 1,761 streams (1,334 in Canada, 427 in U.S.) throughout the watershed provide spawning habitat for one-third of Great Lakes fishes and allow movement between the headwaters and the lake (Liskauskas et al., 2007). In U.S. waters, over 10,000 kilometres (6213.7 miles) of stream habitat were at one time accessible to Lake Huron fish; an even greater amount of stream habitat was available in Canada. Refer to section 5.5.3 for more information about nearshore environments in Lake Huron. Dams and barriers fragment and degrade river habitat and prevent fish migration; however, many northern streams continue to sustain stocks of Walleye, Pike, threatened Lake Sturgeon, and a tremendous biomass of Suckers.

Cold-water streams, such as the Au Sable River in northern Michigan and the Saugeen River in Ontario, are known world-wide as outstanding trout streams. Warm-water streams like the Au Sable River in southwestern Ontario support as many as 26 species of native freshwater mussels, up to 85 species of fish and several species of rare and endangered turtles (DFO, 2018; Huron Pines, 2015).

Groundwater

Among tributaries that flow into Lake Huron, 40-75% of this water is derived from groundwater inflow (Kornelsen and Coulibaly, 2014). In periods of drought or low precipitation, groundwater seepage keeps freshwater flowing into streams, wetlands, and lakes. Often the groundwater seeping into these waterbodies occurs underwater and is invisible to observers (Grannemann & Van Stempvoort, 2015). Groundwater also feeds fens in Lake Huron and Georgian Bay, which are home to 40 provincially significant plants (Ontario Natural Heritage Information Centre, 2021; Wilcox,1995).

Additionally, Lake Huron contains submerged sinkholes and groundwater vents that form unique ecosystems. Life in these holes and vents is dependent on chemosynthesis, meaning chemosynthetic microbial communities get their energy from chemicals in the warmer, oxygen-poor and sulfur-rich water that is seeping from these submerged features (Biddanda et al., 2006; Ruberg et al., 2008).

Coastal Shorelines

Lake Huron's coastal shorelines are renowned for their inspiring beauty. They are the place of greatest human interaction with the lake through recreational activities. Natural coastal systems are also the last line of defense for the lake, trapping pollution in water runoff before it enters the lake.

The geology of the coast changes as you circle the lake. In the south, glacial deposits of sand, gravel and till predominate in coastal areas providing fine, white sand beaches. Limestone dominates much of the Bruce Peninsula, Manitoulin Island, the North Channel, and northern Michigan. Rocky shores associated with the Precambrian Shield extend across the eastern and northern shores of Georgian Bay and the North Channel. Natural shorelines provide protection against erosion while also supporting water quality and ecosystem health (Greer, 2019).

Coastal Wetlands

Lake Huron coastal wetlands represent 30% of those found in the Great Lakes. Wetlands link the open waters with the watershed. Coastal wetlands around the North Channel and Georgian Bay are rated among the most pristine of Great Lakes wetlands. Silver Creek in the Collingwood area is the largest coastal wetland on Georgian Bay in Ontario (Blue Mountain Watershed Trust, 2018). In Michigan, Saginaw Bay contains the largest freshwater coastal wetland system in the United States (Schroeder, 2013).

Coastal marshes of Lake Huron (the predominant wetland type at 30% of coastal wetlands) provide nesting, resting, and feeding places for hundreds of thousands of migratory and nesting birdlife, including at least 30 species of shorebirds, 27 species of ducks, geese and swans, and several species of terns and gulls (Schroeder & Ridgway, 2014).

Over 40 species of rare plants and five rare reptile species are found in the coastal wetlands of Lake Huron. Fifty-nine species of fish are found in coastal wetlands. About 80% of Lake Huron fish species depend on coastal wetlands for some portion of their life cycles (Fracz & Chow-Fraser, 2013; Midwood & Chow-Fraser, 2015). Fish such as Northern Pike, Perch, Muskellunge, and Bowfin spawn in coastal wetlands.

Islands

Of the 35,000 islands in the Great Lakes, 30,000 of these are in Lake Huron, the majority of which are in Georgian Bay. The most well-known islands in Lake Huron are Mackinac Island and Manitoulin Island. Mackinac Island is sacred ground for Native Americans and is the site of a battle from the War of 1812. No cars are allowed on the island, so tourists are transported via horse-drawn carriage (Cheung, 2017). Manitoulin Island is the largest freshwater island in the world and is home to many First Nations peoples (Briscoe, 2020). Additionally, the island itself contains over 100 lakes (Cheung, 2017). Islands in Lake Huron fall generally into one of three categories 1) limestone or dolostone islands surrounding the Bruce Peninsula, and Manitoulin and Drummond Islands; 2) archipelagos made of Precambrian Shield in Georgian Bay and the North Channel; and 3) groups of small islands in Saginaw Bay. These islands support colonial nesting birds (e.g., common terns, black-crowned night herons), migratory birds, and other endemic species (Audubon, n.d.). Threats to these islands include development and invasive species. Islands in the southern part of Lake Huron are less protected from threats than those in the northern region, and as such, warrant more conservation attention (Kraus, Henson, & Ewert, 2009).

Islands in northern and eastern Georgian Bay are the most ecologically distinct in Lake Huron. Globally rare snake species like the eastern foxsnake (*Elaphe gloydi*) and eastern massasauga (*Sistrurus catenatus*) can be found on these islands. Generally, warmer temperatures in southern Lake Huron allow higher numbers of species to thrive on these islands, which are considered more biodiverse than islands elsewhere in Lake Huron. The exception is islands in the North Channel, which are home to unique ecosystems with Great Lakes region endemic fauna like the dwarf lake iris (*Iris lacustris*), lakeside daisy (*Hymenoxys herbacea*) and Pitcher's thistle (*Cirsium pitcheri*). The ecology on these islands is associated with the limestone and dolostone bedrock, and communities such as Great Lakes alkaline cobble/gravel shore, limestone bedrock lakeshore, and wooded dune and swales can be found on these islands. The isolation of islands in the North Channel helps to protect their biodiversity (Kraus, Henson, & Ewert, 2009).

Low-lying islands and marshes in Saginaw Bay provide breeding ground, cover, and food for migratory birds and spawning areas for some fish species. Some of these islands also have unique prairie and savanna communities.

Forests

Remnants of Carolinian (i.e., Eastern temperate) forest still exist in the southernmost subwatersheds and support the most diverse flora and fauna assemblage of the basin (Carolinian Canada, 2004). Large tracts of Great Lakes-St. Lawrence mixed-wood forest are found in parts of Michigan, and in Ontario on the Bruce Peninsula, Georgian Bay, and in the northern watershed within the Canadian Shield. Approximately 52% of the land cover remains forested (ECCC and EPA, 2022). All Lake Huron forests and small woodlands provide habitat for wildlife, protection of source water, and important functions such as canopy shade that moderates stream temperature (Ecological Framework of Canada, n.d.).

Agricultural Lands

When responsibly farmed, agricultural lands use drainage systems that mimic natural conditions while still allowing for seedbed preparation and planting. The use of buffer strips, cover crops, grassed waterways, and two-stage ditches helps to minimize soil erosion and flooding (Union of Concerned Scientists, 2021).

Lake Plain Prairies

Much of the Great Lakes-St. Lawrence lake plain prairies and Midwest broadleaf forest in the Lake Huron basin have been converted to agriculture due to their rich soils. However, important vestiges of prairies are still found in the southern part of the watershed. The extensive root systems of trees, shrubs and plants of these natural plant communities bind soil particles together, helping to prevent soil erosion and water pollution. These sites also support a number of amphibian and reptile species as well as several species of grassland songbirds (Cohen et al., 2020).

Alvars

This globally rare habitat is found in areas dominated by limestone geology, including the Bruce Peninsula, Manitoulin Island, and Drummond Island. Alvars are flat, nearly treeless areas of exposed limestone bedrock and shallow soils. In spring, alvars collect water in shallow pools and bedrock pockets, and some areas remain flooded for weeks. By summer, the soils are dry. A number of endemic species have evolved to survive only in this environment (Reschke et al., 1999; Brownell and Riley, 2000).

Urban Centers

Population density, impervious surface area, and other aspects of urban centers can result in stormwater runoff, heat island effect, and other problems. Approximately 6% of the basin is developed (ECCC and EPA, 2021). Well-designed urban centers contain sufficient green space and green infrastructure to manage stormwater and minimize flooding. Green space refers to vegetated urban areas covered with grass or trees, such as parks, playing fields, community gardens, and cemeteries. Green infrastructure manages stormwater by utilizing, restoring, or mimicking the natural water cycle and includes features such as rain gardens, permeable pavement, green roofs, and other stormwater management techniques that soak up, store and slow water. Green infrastructure projects big and small contribute to improved water quality (Green City Times, 2021).

Inland Lakes and Wetlands

Inland lakes and wetlands act as reservoirs that help to moderate the quantity of water moving through the watershed and remove excess nutrients and sediments otherwise released by severe storms.

Inland lakes: Lakes of all sizes are found throughout the watershed. The biggest inland lakes include Lake Simcoe in Ontario and Burt Lake in Michigan. Water levels in lakes rise with input from precipitation and gradually fall due to evaporation, flows to rivers and groundwater, and periods of drought (Lake Simcoe Region Conservation Authority, 2016; Pure Michigan, 2021).

Inland wetlands: Swamps, marshes, acidic bogs, and alkaline fens are types of wetlands all found within the watershed. These wetlands filter and absorb nutrients like phosphorus and nitrogen that can potentially stimulate algal blooms. Wetlands provide critical habitat, help to maintain water quality, slow water movement and minimize the impacts of flooding and pollution.

The St. Marys River

The St. Marys River has a long and storied history as an important gathering place for Indigenous people, a center of French and British fur trading, and a 20th century hub for manufacturing. It also discharges a large volume of water (mean 2,140 m^3/s, 78,000 ft^3/s) through a relatively short river length (125 km, 78 mi) that drops 6.4 metres (21 feet) in elevation, creating rapids (Marsh, 2015).

The St. Marys River includes three sections: a 22.5-km (14 mi) Lake Superior outlet section; a 1.2-km (0.75 mi) rapids section with facilities and channels for navigation, hydropower, water regulation, and an 88.3-km (55 mi) lower river section largely at Lake Huron elevation (Tikkanen, 2013). Narrow channels, broad and wide lakes, four large islands, and many small islands are present (Waterway Guide, 2011). The St. Marys River supports a diverse fish community and active recreational, subsistence, and commercial fisheries.

North Channel

The North Channel is widely considered one of the best freshwater cruising destinations in the world known for its isolated, rugged beauty. Many Indigenous peoples live in the area surrounding the North Channel. Many boat-friendly towns and villages also dot the shores of the North Channel. The remote nature of the North Channel makes it a great spot to watch the Northern Lights or take in the night skies at Killarney Provincial Park Dark Sky Preserve (Jennings, 2021).

Georgian Bay

Georgian Bay, a northeastern arm of Lake Huron, was originally thought by explorers to be a separate lake because it is nearly enclosed by the Bruce Peninsula and Manitoulin Island. In fact, Georgian Bay is so large that it is one of the 20 largest freshwater bodies in the world (LaRue, 2021). Much of Georgian Bay is part of a United Nations Educational, Scientific and Cultural Organization (UNESCO) biosphere reserve, created to protect the unique ecology of the Bay (Georgian Bay Biosphere, 2021).

Visitors can explore the Bay’s 32 historic lighthouses via canoe, kayak, or on foot (Middleton, 2021). Another attraction in Georgian Bay is Fathom Five National Marine Park, which contains the iconic Flowerpot Island, named for two flowerpot-shaped limestones structures jutting out of the water. Many resort towns line the eastern shore of the Bay, and the southern shore is a popular apple growing region (Tikkanen, 2020).

Nearshore Waters

The shallow nearshore waters are a highly productive environment. Coastal wetlands provide spawning, nursery, or foraging habitat for 40-90% of Great Lakes fish species during some stage of their life cycle (Rutherford, 2008). As a result, the nearshore area hosts a high diversity of fish species (Liskauskas et al., 2007). The *GLWQA* recognizes that nearshore waters must be restored and protected because urban and rural communities rely on this area for safe drinking water, recreational activities such as swimming, fishing and boating, and water withdrawals for industry and power generation (IJC, 2012). The nearshore is the hydrological and ecological link between watersheds and the open waters.

Offshore Waters

When the open waters of Lake Huron are healthy, they support a robust and resilient fishery. Prior to the introduction of invasive species in the early 1900s, the deep waters of Lake Huron were dominated by Lake Trout, Lake Whitefish, and Burbot. The preyfish base was dominated by Cisco (or Lake Herring) and a number of other Deepwater Ciscos, including Bloater, with Sculpins, Lake Whitefish, and Round Whitefish contributing to a lesser extent (Lake Huron Binational Partnership, 2008).

Ongoing changes to the Lake Huron food web present new challenges for resource managers. Ecological changes that formerly occurred over decades have happened in just a few years. Many questions remain unanswered, and researchers continue to monitor Lake Huron in an effort to understand this dynamic system (ECCC and EPA, 2021). Because these changes are profound, developing management actions is a priority for member agencies of the Lake Huron Partnership. Current management goals involve maintaining a sustainable predator-prey balance with approaches that include monitoring fish community population trends, with consideration of the effects of several non-native fish species.

4.0 ROLE OF REGULATIONS AND ALIGNMENTS WITH OTHER INTERNATIONAL EFFORTS

This chapter explains how the Lake Huron Partnership agencies will implement the 2022-2026 *LAMP* within the context of existing laws and regulations. This chapter also describes how the Lake Huron Partnership agencies engage with the International Joint Commission, the Great Lakes St. Lawrence Governors and Premiers, the Great Lakes Fishery Commission, and the Great Lakes Commission.

4.1 Role of Regulations

The Lake Huron Partnership member agencies work within the context of laws and regulations to adopt common objectives, implement cooperative programs, and collaborate to address environmental threats to Lake Huron. Many existing federal, tribal, state, provincial and local environmental laws and regulations directly contribute to the restoration and protection of Lake Huron. These laws and regulations prohibit the manufacture and use of certain toxic chemicals (e.g., mercury, PCBs), protect species of conservation concern (e.g., Lake Sturgeon), enforce rules to stop the introduction of invasive species (e.g., ballast water management in vessels, cleaning of recreational boats, the movement of species listed as "injurious to wildlife"), and provide responsible oversight to major land developments (e.g., environmental impact assessments). A description of 35 pieces of existing legislation relevant to Lake Huron are listed in Appendix B, including the Canadian Environmental Protection Act (1999), and the U.S. Clean Water Act (1972).

4.2 Alignment with Other International Efforts

Actions identified in the *LAMP* are informed by, and complementary to, other international management efforts established under binational treaties, agreements, and programs, which are active within the Lake Huron ecosystem.

International Joint Commission

Great Lakes Oversight and Water Level Regulation

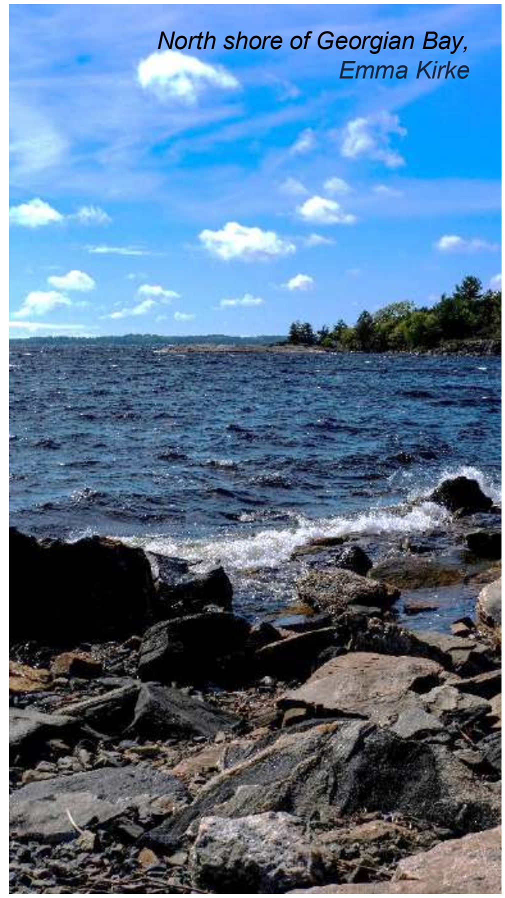
The 1909 Boundary Waters Treaty (BWT) provides principles for Canada and the United States to follow in using the waters they share. The International Joint Commission (IJC) is a binational organization established under the BWT that works to prevent and resolve boundary waters disputes between Canada and the United States. The IJC serves as an independent and objective advisor to the two governments and is an important mechanism for binational dialogue related to assessing the effectiveness of government programs to meet the Agreement's goals and objectives. The IJC is advised by more than 20 binational boards and task forces, including the Great Lakes Water Quality Board, which assists the IJC with the Agreement functions, powers, and responsibilities. The Great Lakes Science Advisory Board also advises the IJC and the Great Lakes Water Quality Board on scientific and research matters related to Great Lakes water quality. The IJC also provides oversight of efforts to regulate water levels and flows in some of the Great Lakes and connecting channels. The International Lake Superior Board of Control is responsible for regulating the outflow of Lake Superior into Lake Huron and managing the control works on the St. Marys River which flows into the North Channel of Lake Huron.

Plastic pollution at the north shore of Georgian Bay, Emma Kirke

Great Lakes St. Lawrence Governors & Premiers

Water Withdrawals Management and Other Initiatives

Signed by the Governors of the eight U.S. States and the Premiers of Ontario and Quebec in 2005, this interstate and inter-provincial agreement contains provisions for managing and protecting the water supplies in the Great Lakes basin. The agreement spawned legally binding legislation in the states and provinces and is most well-known for a commitment to prohibit water diversion proposals which pose a risk of unsustainable water withdrawals from the basin. The Great Lakes-St. Lawrence River Water Resources Regional Body was established through the agreement as a means for the Governors and Premiers to implement and coordinate their water resource management commitments. The Governors also created the Great Lakes Protection Fund, invested in combatting the introduction and spread of aquatic invasive species, and supported international trade, maritime transportation and tourism.


North shore of Georgian Bay, Emma Kirke

Great Lakes Fishery Commission

Fishery Management and Sea Lamprey Control

The Great Lakes Fishery Commission (GLFC) is responsible for developing coordinated fisheries research programs and for implementing a Sea Lamprey control program. GLFC also facilitates cross-border cooperation of state, provincial, tribal, and federal fishery management agencies for the improvement and preservation of the fisheries (GLFC, 2007). The Lake Huron Committee of the GLFC is comprised of senior officials from tribal, state, and provincial fishery management agencies. The Lake Huron Committee is tasked with sustainably and cooperatively managing Lake Huron's fisheries resources and the fish community by considering issues of common concern to the jurisdictions, developing and coordinating joint state/provincial/federal fisheries programs and research projects, and making recommendations on fisheries management issues.

Great Lakes Commission

Since it was established in 1955 by the Great Lakes Basin Compact, the Great Lakes Commission has worked with its member states and provinces to address issues of common concern, develop shared solutions and collectively advance an agenda to help protect and enhance the region's economic prosperity and environmental health. One of the strengths of the Great Lakes Commission lies in its creation and facilitation of well-respected regional forums to build consensus around shared goals. These forums include the Great Lakes Panel on Aquatic Nuisance Species, the Invasive Mussel Collaborative, the Great Lakes *Phragmites* Collaborative, and the Harmful Algal Bloom Collaborative.

Manitoulin Island, ECCC

Lake Huron, Pixabay

5.0 LAKE ACTION PLAN

This *LAMP,* developed by the member agencies of the Lake Huron Partnership, is an ecosystem-based strategy to improve and protect the water quality of Lake Huron. The actions included in the *LAMP* respond to, and are categorized by, the major threats that are affecting one or more of the Agreement's General Objectives, specifically: chemical contaminant pollution; nutrient and bacterial pollution; invasive species; loss of habitat and species; and other potential threats including plastics, risks from oil transport and mining, and cumulative impacts on the nearshore areas of the lake. Government agencies, Indigenous peoples, stakeholders, and the public all have an important role to play in implementing the actions identified in the *LAMP*.

5.1 Chemical Contaminant Pollution

This section summarizes the scientific information about Lake Huron's water quality related to chemical concentrations, current chemical contaminant threats, and corresponding actions to be taken by Lake Huron Partnership agencies in 2022-2026, as well as actions that everyone can take. The science is organized in response to the chemical-related General Objectives of the

Great Lakes Water Quality Agreement; specifically: drinking water, human consumption of fish and wildlife, pollutants that could harm people and wildlife, and impacts of contaminated groundwater.

Progress has been made at restoring Areas of Concern (AOCs), and remediating other contaminated sites continues to reduce chemical loadings to the lake. Long-term monitoring results of pollutant concentrations in environmental media (air, water, sediment, fish, and wildlife) show decreasing trends and the reproductive health of the fishery does not appear to be significantly impacted by chemical contaminant pollution. Chemicals of Mutual Concern (CMCs) and Contaminants of Emerging Concern (CECs) continue to warrant surveillance due to their wide distribution and persistence in the environment.

5.1.1 Objectives and Condition Overview

Four of nine General Objectives of the Agreement are addressed in this chapter. These objectives state that the Great Lakes should:

- Be a source of safe, high-quality drinking water;
- Allow for unrestricted human consumption of the fish and wildlife;
- Be free from pollutants that could harm people, wildlife or organisms; and
- Be free from the harmful impacts of contaminated groundwater

The status and trend of chemical contaminant sub-indicators for Lake Huron are displayed in Table 4. The chemical-related assessments for Lake Huron indicate that conditions are classified as being ‘Good’ with respect to concentrations of Chemicals of Mutual Concern (CMCs) and other chemical contaminants in drinking water, offshore water, sediment, fish-eating birds, edible fish (fillets), and groundwater; conditions are classified as ‘Fair’ in whole fish and atmospheric deposition. The majority of the chemical-related sub-indicators have been classified as having ‘Unchanging’ to ‘Improving’ trends (ECCC and EPA, 2022).

Lake Huron continues to be a good source of high-quality drinking water. Most legacy contaminants have decreased in Great Lakes air, water, sediment, fish and herring gull eggs. Although concentrations of toxic chemicals are much lower compared to the 1970s, fish consumption advisories continue to be in effect, primarily as a result of levels of PCBs and mercury which can bioaccumulate in fish tissues and may harm human health if consumption advisories are not followed. Atmospheric deposition of chemicals is an ongoing source to the lake (Gewurtz et al., 2019; Guo et al., 2018). Groundwater is in 'Good' condition with low chloride and nitrate levels in the areas assessed. The effects of climate change, and seasonal pulses on chemical cycling and accumulation in the food web are overarching considerations that may have ecosystem implications. Continued clean-up efforts in the Areas of Concern (AOCs) have resulted in improvements in Beneficial Use Impairments (BUIs) related to contaminants. However, wildlife health impairments related to elevated levels of PCBs remain in some areas (Grasman et al., 2020; Bush et al., 2020).

Trillium, Emma Kirke

The management of toxic chemicals is primarily regulatory and occurs through a variety of domestic programs driven by legislation at the federal, tribal, provincial, state, and local levels. The Agreement, although voluntary, provides another tool to coordinate efforts in identifying and reducing anthropogenic inputs of chemicals. Chemicals of Mutual Concern (CMCs) are those designated by the Parties of the Agreement that may require additional measures to protect against threats to human and environmental health resulting from their presence in the waters of the Great Lakes. To date, eight chemicals (or categories of chemicals) have been designated as CMCs:

- mercury;
- polychlorinated biphenyls (PCBs);
- hexabromocyclododecane (HBCD);
- polybrominated diphenyl ethers (PBDEs);
- perfluorooctane sulfonate (PFOS);
- perfluorooctanoic acid (PFOA);
- long-chain perfluorocarboxylic acids (LC-PFCAs);
- short-chain chlorinated paraffins (SCCPs).

The Parties have prepared strategies, which may include research, monitoring, surveillance and pollution prevention and control provisions, for the above Chemicals of Mutual Concern.

Table 4: Status and 10-year trends of chemical-related sub-indicators in the Lake Huron basin. Source: State of the Great Lakes report (ECCC and EPA, 2022)

Sub-Indicator	Status – Trend
Treated Drinking Water	Good – Undetermined
Contaminants in Edible Fish	Good – Unchanging to Improving
Toxic Chemicals in Sediment	Good – Unchanging
Toxic Chemicals in Water	Good – Unchanging
Toxic Chemicals in Whole Fish	Fair – Unchanging
Toxic Chemicals in Herring Gull Eggs	Good – Improving
Toxic Chemicals in the Atmosphere	Fair – Improving
Groundwater Quality	Good – Undetermined

5.1.2 Drinking Water

***GLWQA* General Objective:** The Waters of the Great Lakes should be a source of safe, high quality drinking water.

How is it monitored?

U.S. and Canadian treated drinking water is monitored for contaminants including inorganic (arsenic, cadmium, lead, nitrate/nitrite nitrogen), organic (benzene, perchloroethylene, nitrilotriacetic acids, certain pesticides and PCBs), microbial (bacteria), and radiological (tritium and other radiological compounds) parameters. A growing number of tests are now including polyfluoroalkyl substances (known as PFAS, such as PFOS and PFOA), which is a group of manufactured chemicals used in a variety of industries around the globe that do not break down in the environment and can accumulate over time.

PFAS are a group of over 4,700 fluorinated compounds that have been used in industrial and consumer applications since the 1950s. They are resistant to water, heat and oil, and used in adhesives, cosmetics, cleaning products, as well as fire-fighting foams. In recent years, the presence of PFAS in the Great Lakes basin has received increasing attention because PFAS do not break-down easily, can bioaccumulate and can cause a variety of harmful environmental and human health effects. Compared to the other Great Lakes, Lake Huron has lower concentrations of the suite of PFAS chemicals in various media (Remucal, C.K., 2019). High concentrations of PFAS in the leachate and air of landfill sites, in the wastewater influent/effluent, biosolids, and air at wastewater treatment plants, and in indoor air and dust highlight the waste sector and current-use products (used primarily indoors) as ongoing sources of PFAS to the environment (Gewurtz et al., 2013).

U.S. treated drinking water information for the Great Lakes is collected and reported by the Safe Drinking Water Information System (SDWIS). The data are assessed by calculating the percentage population served for a given year during which community water systems provide drinking water that meets all applicable health-based water standards (ECCC and EPA, 2022).

Information on source and treated drinking water in Ontario is provided by the Ontario Ministry of the Environment, Conservation and Parks' Drinking Water Surveillance Program (DWSP) and the Ministry's Drinking Water and Environmental Compliance Division (DWECD), respectively. The source water data are monitored from select municipal residential and First Nation drinking water systems. The treated water data is from all municipal residential drinking water systems. Both source and treated water data are from systems whose sources include not only the Great Lakes, but also inland lakes, rivers and groundwater. The data are compared to the Ontario Drinking Water Quality Standards (ODWQS), a set of health standards accounting for microbial, chemical, and radiological parameters in treated drinking water (ECCC and EPA, 2022).

What is the condition?

Lake Huron continues to be a good source of high-quality drinking water. The status of municipally treated drinking water is in 'Good' condition, but trend assessments are not available at this time (ECCC and EPA, 2022). Treated drinking water meets state and provincial standards the vast majority of the time. Source and treated water quality in Ontario rarely have contaminant levels above the Ontario drinking water quality standards (ODWQS) and no radiological parameters were found at levels above the ODWQS in source water. In the U.S., in the Great Lakes states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin, public water supplies provide drinking water that meets health-based drinking water standards.

What is the threat and other considerations for taking action?

Many contaminants including arsenic, uranium, lead, certain pesticides, microcystin, nitrate and radiological parameters such as tritium are regularly tested in drinking water systems. To lower the risk of source water contamination reaching the taps of consumers, continual efforts are made to decrease microbial, chemical and radioactive substances from contaminating source water. Potential threats include: over application of fertilizers, manure and pesticides that can enter groundwater and surface water; stormwater and wastewater sources, especially during and after extreme storm events; potential spills from nuclear power plants, faulty septic systems that leach pathogenic microorganisms and household chemicals; emerging chemicals of concern, chemical spills within the watershed and directly into Lake Huron, and toxic chemicals in the atmosphere that can influence chemical concentrations at drinking water intakes (ECCC and EPA, 2022). Continued progress toward addressing these issues will help to protect Lake Huron water quality and its use as a source of drinking water.

Climate change is expected to increase the amount of precipitation and the frequency of extreme weather events in the Lake Huron basin, which can lead to an increased amount, as well as seasonal pulses, of harmful chemicals and nutrients flowing into streams, rivers and the lake itself, which could threaten drinking water quality (Wuebbles et al., 2019).

5.1.3 Fish and Wildlife Consumption

***GLWQA* General Objective:** The Waters of the Great Lakes should allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants.

How is it monitored?

To determine potential risk to human health through fish consumption, Canadian and U.S. federal, tribal, state and provincial agencies monitor persistent, bioaccumulative and toxic substances such as CMCs and CECs in fish and wildlife. These monitoring programs focus on determining the safety of eating fish by monitoring chemical concentrations in the edible portions of fish (i.e., fillets). Consumption advice is issued in an effort to avoid the negative effects of harmful pollutants found in fish and wildlife. Such effects can include neurological and carcinogenic effects. For fish advisory information, visit:

- Great Lakes Indian Fish and Wildlife Commission: glifwc.org/mercury;
- Michigan: michigan.gov/eatsafefish; and
- Ontario: ontario.ca/fishguide.

What is the condition?

Lake Huron fish and wildlife are a nutritious food source but should be consumed in accordance with the appropriate consumption advisories. PCB and mercury levels in edible fish are considered ‘Good’ with a 10-year trend of ‘Unchanging to Improving’ and a long-term trend of ‘Improving’ for Lake Huron. There were substantial improvements in PCB and mercury levels in Lake Huron fish between the 1970s and 1990s. Since the 1990s, mercury concentrations have plateaued to low levels while PCBs, which are responsible for most of the fish consumption advisories in Lake Huron have continued to decline slowly in recent years (ECCC and EPA, 2022). In 2011-2012, the full range of traditional food across Ontario was sampled for contaminants as part of a First Nations food, nutrition and environment study. Results indicate that the ingestion of contaminants from traditional foods is not a concern, with the exception of mercury intake from fish in some locations (Chan et al., 2014).

What is the threat and other considerations for taking action?

Contaminant levels in Lake Huron fish vary not only by type of fish and age of fish, but also by geographic location (MOECC, 2017). This is due to the large size of the lake, the variety of fish populations and feeding habitats, and by local contaminant sources. Fish consumption advisories, in particular for PCBs and mercury, continue to be issued to protect human health.

The condition of the fish in Lake Huron are impacted by chemical contaminants that enter the ecosystem. Fish are exposed to contaminants in water and through sediment, which can be linked to the levels of chemicals found in the edible portion of fish. For example, fish can uptake chemicals from the water through their diet and gill uptake. Chemicals in the sediment can be acquired by lower trophic level species such as benthos that are in contact with contaminated sediment and can pass through the trophic levels in the food web.


North shore of Georgian Bay, Emma Kirke

Levels of contaminants in fish in Lake Huron may also be due to disturbances in the food web structure of the lake. Study results have shown that the introduction of invasive mussels changed contaminant cycling in the Great Lakes by redirecting dissolved and particulate bound contaminants through the food chain, causing biomagnification in higher trophic levels (Bruner et al., 1994). This process essentially allows contaminants to move up to higher trophic levels more quickly.

5.1.4 Chemical Contaminants in Ecosystem

***GLWQA* General Objective:** 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.

How is it monitored?

Long-term, lakewide monitoring and surveillance programs for chemical contaminants are conducted by the EPA and ECCC (EPA, 2021a). Chemical contaminants are monitored in a variety of media including water, air, sediments, whole fish, and fishing-eating birds (i.e., Herring Gull (*Larus argentatus*) eggs). Federal monitoring programs are augmented by tribal, state, provincial, and academic contaminant science and monitoring programs.

Contaminant monitoring efforts are also conducted as part of the Cooperative Science and Monitoring Initiative (CSMI) which is a binational effort instituted under the Science Annex of the 2012 Great Lakes Water Quality Agreement to coordinate science and monitoring activities in one of the five Great Lakes each year to generate data and information for environmental management agencies.

What is the condition?

The status of **chemicals in open (offshore) water** of Lake Huron is ‘Good’, with an overall ‘Unchanging’ trend over the past 10-years (ECCC and EPA, 2022). Compared to the other Great Lakes, Lake Huron has some of the lowest concentrations of many contaminants, with atmospheric deposition being the dominant source. Concentrations of mercury and legacy organochlorines in the offshore waters are largely showing declining trends over the long term. Increasing trends in some industrial by-products are observed, including hexachlorobenzene (HCB) and hexachlorobutadiene (HCBD), although the increasing trends are statistically significant only for HCB in Lake Huron. The ubiquity of flame retardants in the Great Lakes, such as PBDEs, reflects their widespread usage in commercial products. Higher PCB concentrations are seen in Saginaw Bay, relative to levels in Lake Huron. Increases of PAHs, which are largely driven by naphthalene and fluorene concentrations, are observed for Georgian Bay (although concentrations are below Canadian environmental quality guidelines) and may be due to urban runoff. Recent information on the radionuclide tritium indicates very low background concentrations in Lake Huron and Georgian Bay, with some locally elevated values near known sources to Lake Huron (Dove et al., 2021).

Atmospheric Deposition of Chemicals is considered 'Fair', with 10-year and long-term trends of 'Improving' for the entire Great Lakes airshed. The overall assessment is based on the evaluation of six Chemicals of Mutual Concern (CMCs) including PCBs, PBDEs, PFOS, PFOA, LC-PFCAs, and mercury. Available data for HBCD and SCCPs are not sufficient to establish a status or trend. Deposition of PCBs, PBDEs (polybrominated diphenyl ethers), mercury and other chemicals continue to be a concern due to legacy and on-going sources. However, the rate of deposition for PCBs, PBDEs and mercury is slightly decreasing. Atmospheric sources of mercury dominate in Lake Huron sediment (Lepak et al., 2015). Isotope signatures in predatory fish suggest that atmospherically derived mercury may be a more important source of methyl mercury to higher trophic levels than legacy sediments (Lepak et al., 2018). PFOS, PFOA and LC-PFCAs are water soluble; thus, it is appropriate to monitor them in precipitation. Time trends (2006-2018) for PFOA and PFOS in precipitation indicate a significant decrease over time. These overall decreasing trends were likely in response to North American phase outs and regulatory actions for PFOS, PFOA, and LC-PFCA (and their salts and precursors), which have been ongoing since the early 2000s (Gewurtz et al., 2019). In comparison, concentrations of shorter-chained perfluoroalkyl acids (PFAAs), which are not regulated in Canada or the U.S., have recently increased, which could be due to their use as replacements of the longer-chained PFAAs (such as PFOS and PFOA) that are being phased-out by industry (Gewurtz et al., 2019).

Although levels of toxic chemicals in air are generally low, the large surface area of the Great Lakes results in significant atmospheric inputs. For instance, results from the Integrated Atmospheric Deposition Network (IADN) precipitation station at Burnt Island suggest that atmospheric deposition is likely a major source of perfluorobutanoate (PFBA), a shorter-chained PFAA, to Lake Huron (Gewurtz et al., 2019). While concentrations of some toxic chemicals are considered low at rural sites, they are much higher in select locations, such as urban areas (ECCC and EPA, 2022). The IADN satellite station of Egbert, located between Lakes Ontario and Huron and surrounded by agricultural cropland, showed high concentrations of Organochlorine Pesticides (OCPs) such as dichlorodiphenyltrichloroethanes (DDTs), dieldrin, HCH (lindane), and endosulfan than more remote stations. These observations suggest that agricultural areas are a source of OCPs to the lakes (Shunthirasingham et al., 2016).

The status of **chemicals in sediment** in Lake Huron is considered ‘Good’ with a 10-year trend of ‘Unchanging’ and a long-term trend of ‘Improving’ (ECCC and EPA, 2022). Contaminant concentrations in sediment in Lake Huron are typically considered to be low, but local historical mining and industrial activity in some regions have resulted in higher levels of dioxins, furans (PCDD/Fs), nickel, and copper concentrations. Arsenic concentrations in sediment are above the Canadian sediment quality guidelines across a third of the lake (ECCC and EPA, 2022).

High surficial concentrations of total PBDE and BDE 209 have been observed in Lake Huron (especially Saginaw Bay and North Channel); however, recent core studies in Lake Huron levels indicate levels of PBDEs in surficial sediment have started to decline. Polyhalogenated carbazoles (PHCZs) are a group of bioaccumulative and toxic emerging contaminants that have been monitored in sediment samples in the upper Great Lakes including Lake Huron (Guo, 2017). Levels were below detection limits; however, PHCZs and their derivatives can be persistent and likely toxic (ECCC and EPA, 2017).

Based on a study between 2010-2012, concentrations of pesticides, such as atrazine and simazine, showed an increasing trend in Lake Huron sediment. Assessments of the occurrence and fate of these emerging contaminants are incorporated into sediment studies to support the development of environmental guidelines for emerging contaminants (Guo, 2016; ECCC and EPA, 2017).

Comparisons of surficial sediment contaminant concentrations indicate that concentrations of PCBs and mercury in Lake Huron have generally decreased by more than 9% and 11%, respectively, in the past four decades. Sediment burial is an important mechanism which aids in preventing contaminants from re-entering the water column (ECCC and EPA, 2019). However, very slow sedimentation rates, as seen in Lake Huron, can result in slow natural recovery of the lake from sediment contamination.

Chemicals in whole fish in Lake Huron are considered in ‘Fair’ status, with an overall ‘Improving’ long-term trend; however, the short-term trend is considered ‘Unchanging’.

Chemicals of Mutual Concern (CMCs) including mercury, TeBDE, HxBDE, and HBCD concentrations are below guidelines or targets while those of PCBs, PeBDE, and PFOS were above environmental guidelines or targets (ECCC and EPA, 2022) in whole fish from Lake Huron. Conditions have improved over time, largely due to declines in PCBs and TeBDE. Concentration trends for PFOS in Lake Huron top predator fish have been variable spatially across the basin and between the monitoring programs but remain above the Canadian Federal Environmental Quality guidelines or other published ecotoxicological thresholds (ECCC and EPA, 2022). However, individual analyte concentrations of PFAS (including PFOS) generally decreased in Great Lakes fish at US sites between 2005 and 2016 in top predator fish (Point et al., 2021).

PCBs in top predator fish declined significantly at all long-term U.S. monitoring stations since 1992 (U.S. EPA 2021). Similarly, concentrations of PBDEs have declined significantly since 2004, driven primarily by declines in BDE 47, but recently BDE 154 is increasing in many of the Great Lakes fish including Lake Huron (Zhou et al., 2019). These results indicate increasing fish uptake and bioaccumulation of higher brominated BDE congeners which may be related to the breakdown of BDE-209 to lower brominated BDE compounds in the Great Lakes environment or food web (Zhou et al., 2019). Total mercury concentrations in fish have declined over the last 30-40 years but have shown large variability across sites and species in recent years, likely due to the significant food web changes in Lake Huron and slower growth rates in fish. The increase of mercury in whole fish, without a concurrent increase of mercury in water, implies that changes in mercury cycling may be occurring in the Great Lakes environment. PHCZs were investigated in Lake Trout between 2004 and 2016. Concentrations of PHCZs in Great Lakes fish were highest in Lakes Michigan and Ontario, followed by Huron (ECCC and EPA, 2022). PHCZs were identified to be declining in concentration over time in most of the Great Lakes, however the high levels of bioaccumulation in the fish requires more research. The source of PHCZs in the Great Lakes is unknown and may originate from both natural and anthropogenic sources (ECCC and EPA, 2022; Guo et al., 2017).

The status of **chemicals in fish-eating birds** is considered to be in ‘Good’ condition with short-term and long-term trends of ‘Improving’ (ECCC and EPA, 2022). Chemicals in fish-eating birds are monitored through the long-standing Great Lakes Herring Gull Monitoring Program (ECCC), with complementary monitoring conducted through the Clean Michigan Initiative-Clean Water Fund (CMI-CWF; Michigan Department of Environment, Great Lakes, and Energy). The Herring Gull Monitoring Program, which began in 1974, provides the longest running continuous (annual) contaminants dataset for wildlife in the world. The data are assessed utilizing a wildlife contaminant index. Although there are Great Lakes wildlife species that are more sensitive to contaminants, Herring Gulls and other colonial nesting water bird species support accumulation tracking since many biological measures are correlated with contaminant levels in their eggs. Because their diet is primarily fish, they are an excellent terrestrial-nesting indicator species of the aquatic community. Monitoring of legacy contaminants, DDE, PCBs, TCDD, and mercury in the eggs has shown significant declines since the 1970s in Lake Huron (ECCC and EPA, 2022). However, immune, developmental, and reproductive impairments and elevated toxicity equivalents (TEQs) associated with PCBs continue to be observed in Herring Gulls and Caspian terns within Saginaw Bay (Grasman et al., 2020, Bush et al., 2020). Concentrations of Declorane Plus (DCC-CO), a flame retardant, in Herring Gull eggs have increased from 1982 to 2015 in some locations.

What are the threats and other considerations for taking action?

Non-point source pollution comes from many diffuse sources that are transported by means that do not have an easily and directly identifiable confined and discrete conveyance. These sources entering Lake Huron and the broader Great Lakes basin can be attributed to coal plants regionally and globally, agricultural and urban runoff, as well as activities such as mining. Atmospheric deposition is a primary non-point source of pollution entering the Lake Huron basin; additional sources include rainwater, rainfall runoff, snowmelt, and groundwater discharge. These pathways can have significant impacts on the lakes, and the sources of the pollution can be more difficult to control (ECCC and EPA, 2019). An example of atmospheric deposition includes many per- and poly-fluoroalkyl substances (PFAS) chemicals which were detected in wet deposition samples collected by the Great Lakes Basin Monitoring and Surveillance Program under the Chemicals Management Plan (CMP) (Gewurtz et al., 2019). The results demonstrate that contaminants can be delivered to large geographic areas through this means of non-point source pollution. An example of non-point source pollution in urban runoff includes PAHs from pavement that has been treated with coal tar sealant; this pathway has been identified as a primary source of PAHs in Great Lakes tributaries (Baldwin et al., 2020).

Contaminants of emerging concern, such as flame retardants, pharmaceuticals, personal care products, and endocrine disrupting substances are frequently being detected in the Great Lakes.

A variety of chloride salts, brines and additives are commonly used in road de-icing/anti-icing and dust suppression. Road salts enter the environment through losses at salt storage and snow disposal sites and through runoff and splash from roadways. When used in large concentrations, road salts can pose a risk to plants, animals and the aquatic environment. Long-term trends indicate increasing chloride concentrations in many North America streams including the Great Lakes basin (Kaushal et al., 2018; Corsi et al., 2016).

5.1.5 Contaminated Groundwater

***GLWQA* General Objective:** The Waters of the Great Lakes should be free from the harmful impact of contaminated groundwater.

How is it monitored?

Existing monitoring wells are usually in locations selected to address potential local groundwater issues (quantity or quality). Federal, provincial and state agencies in coordination with Conservation Authorities (in Ontario) and municipalities conduct groundwater-quality monitoring. The groundwater quality sub-indicator report assesses the concentrations of chloride and nitrate at monitoring locations/wells in the basin. Water quality measurements of various wells were used to report against the Canadian Council of Ministers of the Environment guidelines for the protection of aquatic life (ECCC and EPA, 2022).

What is the condition?

Groundwater quality in the Lake Huron basin is considered to be in ‘Good’ condition, with ‘Undetermined’ short and long-term trends. Water quality measurements of chloride and nitrate of various wells in the Lake Huron basin were collected, with 57% of the wells reporting good quality, 24% reporting fair quality, and 19% reporting poor quality (ECCC and EPA, 2022). There has not been enough data collected over time to determine water quality trends via this assessment approach. The USGS National Water-Quality Assessment (NAWQA) evaluations of chemical contaminants in groundwater identified an increasing trend in chloride in wells in the Lake Huron basin (Lindsey et al., 2016; ECCC and EPA, 2019).

What is the threat and other considerations for taking action?

Many of the threats to surface water quality also apply to water flowing through glacial deposits and bedrock units near the surface. Many of the streams, lakes and wetlands in the Lake Huron watershed are surface expressions of the water table and the aquifer beneath. Groundwater plays an important role as a reservoir of water that if contaminated, can become a continuous source of pollution into the Great Lakes. Groundwater quality is an important component of the Great Lakes ecosystem, and contamination can be a serious concern to the health of the basin. Groundwater quality has implications on treated drinking water and overall water quality in the basin. Groundwater can become contaminated with substances such as nutrients, salts, metals, pesticides, pharmaceuticals, PFAS, and other contaminants. Nitrate is introduced into groundwater primarily from agricultural practices, while chloride is primarily introduced through road salts, but can also be traced to landfills, fertilizers, and saline bedrock waters. Elevated concentrations of these chemicals have been shown to have detrimental effects on aquatic organisms and ecosystems, and human health (CCME, 2012; Health Canada, 2013). Other sources of contamination to groundwater may include precipitation amounts that can be linked to changes in the depth table and surface -groundwater interaction, and regional surface water quality issues (ECCC and EPA, 2022).

Groundwater is a major resource in the Lake Huron basin but the impact of groundwater on water quality is not well known. Groundwater may delay or accelerate water quality improvements in tributaries and the lake resulting from nutrient management actions on the landscape. Groundwater may also buffer or enhance changes in coastal wetlands and ecosystems in response to climate change and lake-level changes. There is a need to improve the understanding of groundwater flow to the Great Lakes and tributaries and groundwater/surface-water interactions to better determine where focused water management is needed.

Focused and coordinated assessments of groundwater dynamics and potential for non-point source contaminant transport in the Lake Huron basin would address several management questions. There is a need to consider the cumulative effects of existing stressors when developing lakewide management strategies. Groundwater is increasingly recognized as being important in the water budget of the Great Lakes and for maintaining chemical, physical, and biological integrity of the Great Lakes basin.

Indigenous Perspective and Other Vulnerable Populations

Contaminants in natural systems and species poses a threat to the traditional livelihoods of Indigenous and Tribal communities who rely on subsistence use of the land for food and cultural purposes. The presence of these contaminants is not only a source of potential harm to human health, but has an impact on the continuity of culture, for which no medicine will heal. Unrestricted consumption of Great Lakes fish is not yet possible, a fact that has a greater impact on communities that heavily rely on fish for food, cultural, economic, or spiritual purposes. For Indigenous peoples, there is no adequate cultural or nutritional substitute for fish, and consumption advisories are not an adequate solution to unhealthy levels of contaminants in fish.

Additionally, sensitive populations such as women of child-bearing age and young children are impacted by contaminants at lower levels than is the general population. It is important that these populations follow fish consumption recommendations.

5.1.6 Chemical Contaminant Pollution: Climate Change Impacts

Climate change poses significant risks to the health of Lake Huron and can have direct and indirect impacts on the ecosystem and water quality. Great Lakes water quality can be impacted by increases in precipitation and runoff as a result of climate change. Shifts in weather patterns may influence the pathways in which hazardous chemicals are capable of washing into Lake Huron (Adrian et al., 2009). Extreme weather and rain events can transport pollutants from the land to the lake, and increase the risk of infrastructure failure (e.g., mining, wastewater treatment facilities, and pipelines) (Pearce et al., 2011; Warren et al., 2014). Extreme changes in water level can expose formerly submerged toxic chemicals and sediments, or alternatively increase coastal erosion when water levels are high. The reintroduction and redistribution of chemicals during these events can pose a threat to aquatic habitats and water quality in the lake (Dempsey et al., 2008). Surface water temperature increases can result in changes to contaminant cycling and increases in some pollutants such as PCBs (Dempsey, D. et al., 2008). Increases in the intensity and frequency of storm events can exacerbate the amount of chemicals and toxics entering the lake, including contaminants resulting from increases in erosion due to wave action and flooding (Adrian R., et al., 2009).

The likelihood of wildfires in the region increases with climate-related changes, resulting in increases in the input of combustion related toxic substances, such as PAHs, to the lakes (Li et al., 2021).

Fish contaminant trends can also be affected by climate change, regardless of overall declines in active pools of contaminants in the system. Similarly, climate change can alter mercury deposition in the Great Lakes and accumulation in the food web (Krabbenhoft and Sunderland, 2013).

Climate change is also a stressor on groundwater quality through means of changes in precipitation, temperature, and impacts on the water flow cycle. Increases in precipitation are expected in the Great Lakes basin, which is estimated to result in increased groundwater uptake, and baseflow, accelerating the process by which groundwater interacts with surface water. Changes in the temperature of the surface water increases the potential for nutrient and chemical issues, such as algal blooms and increased uptake of atmospheric chemical deposition (Magnuson et al., 1997). Nutrients and chemicals can thereby be transferred into the groundwater through surface to groundwater interaction (Robinson, 2015).

5.1.7 Actions to Prevent and Reduce Chemical Contaminant Pollution

Regulatory actions taken by governments beginning in the 1970s, supported by past remediation projects and initiatives such as the Great Lakes Binational Toxics Strategy, have significantly reduced the impacts of many chemical releases into the environment.

Today, chemical contaminants continue to enter Lake Huron via number of different pathways, including through atmospheric deposition, point-sources (municipal/industrial wastewater discharges), non-point sources (stormwater/surface runoff), and release from existing contaminated bottom sediments. This section describes actions that will be taken to further reduce chemical contaminants in Lake Huron.

Since the 1970s, numerous environmental programs have been established over the last several decades to control the release of municipal and industrial chemicals into the environment and remediate contaminated sites. As a result, environmental concentrations of most chemicals measured in air, water, sediment, fish and wildlife samples are declining. The Lake Huron Partnership agencies will implement the 2022-2026 *LAMP* within the context of existing laws and regulations which contribute to the restoration and protection of Lake Huron.

Environmental legislation and corresponding regulations listed in Appendix B are contributing to the control of chemical releases from municipal and industrial discharges, remediating contaminated waste sites, addressing contaminated sediments, and overseeing the permitting and operations of mines and other developments. In addition, a number of national and regional plans and initiatives are underway that contribute to reducing chemical contaminants in Lake Huron.

Great Lakes wide, the Agreement's Chemicals of Mutual Concern (CMC) Annex calls for the governments of Canada and the U.S. to:

- Identify CMCs and potential candidate CMCs on an ongoing basis;
- Take specific actions for identified CMCs, including development of binational strategies, which may include pollution prevention, control and reduction efforts; and
- Ensure that research, science and monitoring and surveillance programs are responsive to CMC identification and management needs.

The Canada-United States Joint Inland Pollution Contingency Plan is in place, should there be a significant accidental and unauthorized release of pollutants along the Canada-U.S. border. The Canada-United States Joint Marine Pollution Contingency Plan is a mechanism for the two countries to coordinate the preparedness and response to spills in shared waters.

Remedial Action Plans are designed to restore impaired "beneficial uses" in defined degraded areas around the Great Lakes, known as Areas of Concern. Federal, provincial, and state agencies continue to work with local stakeholders to implement Remedial Action Plans for the Saginaw River and Bay AOC, the St. Marys River Binational AOC, and the Spanish Harbour AOC in Recovery (Canada, 2017). Appendix B describes AOCs in Lake Huron (Canada, 2020). Ongoing work within these AOCs is reducing the impact of contaminated sediments, and other site-specific remediation efforts will remove contaminant sources.

In the United States, communities are seeing success in reducing chemical contamination through federal funding for action on identified Superfund sites:

- The Dow Chemical Superfund site within the Tittabawassee and Saginaw rivers has undergone a multiyear effort to clean up dioxin-contaminated soil in the floodplain.
- The 5,223-acre former Wurtsmith Air Force Base is located on the northeastern part of Michigan's Lower Peninsula. Clean up, operation and maintenance activities are ongoing with some areas still under investigation, including U.S. federal and state efforts to address perfluorinated chemical contamination originating from the former Wurtsmith Air Force Base.

Over 3,900 substances on the Domestic Substances List have been assessed under Canada's Chemical Management Plan, and over 330 of these substances have been found to be harmful to the environment and/or human health. For these substances, over 200 risk management actions have been implemented, and additional risk management tools are in development.

The U.S. Toxics Release Inventory (TRI), developed under the Emergency Planning and Community Right-to-Know Act, is a resource for learning about toxic chemical releases and pollution prevention activities reported by industrial and federal facilities. TRI data support informed decision-making by communities, government agencies, companies, and others. The National Pollutant Release Inventory (NPRI) is a similar resource in Canada.

Other selected regional plans and initiatives include:

- Ontario's Source Water Protection Plans
- U.S. Great Lakes Restoration Initiative, administered by U.S. EPA. The GLRI also funds cleanup of AOCs in the U.S. and has been instrumental in funding efforts to delist Beneficial Use Impairments (BUIs). See Appendix A for more detailed information on AOCs in the Lake Huron basin.
- The U.S. Great Lakes Legacy Act provides federal funding to accelerate contaminated sediment remediation in Great Lakes AOCs. The Legacy Act was authorized in 2002 with the first appropriation in 2004. The Act was reauthorized in 2008. Sediment cleanups involve remediating such toxic chemicals as PCBs, mercury, and oil which settled into bottom sediments in rivers, harbors, and lakes.
- The U.S. Bipartisan Infrastructure Law contains provisions to help assure clean water and reduce contamination from lead pipes.
- Through the Great Lakes Protection Initiative, the Government of Canada takes action to address the most significant environmental challenges affecting Great Lakes water quality and ecosystem health by delivering on Canada's commitments under the *GLWQA*. It focuses on 8 priority areas for action including reducing releases of harmful chemicals.

Chemicals of Mutual Concern (CMCs) and Contaminants of Emerging Concern (CECs) continue to warrant surveillance due to their wide distribution and persistence in the environment. Data gaps do exist in monitoring for the various CMCs in media. Ensuring that all relevant CMCs, where relevant/warranted, are included in sampling of different media (water, air, sediment, fish, biota, groundwater) is important to track progress, fill gaps in available data, better understand impacts and inform environmental management and policy.

LAMP Actions

Actions will be taken in the Lake Huron basin to further reduce chemical contaminants and to track progress through science and monitoring as listed in Table 5.

Table 5: Actions to prevent and reduce chemical contaminant pollution

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	Actions to Prevent and Reduce Chemical Contamination	
1	Contribute to the implementation of actions identified in the Chemicals of Mutual Concern (CMCs) binational strategies within the Lake Huron basin.	MECP, ECCC, EPA
2	Advance remediation of contaminated sediment in Lake Huron's Areas of Concern: d. Spanish Harbour Area of Concern in Recovery (Canadian) o Conduct long-term sediment contaminant monitoring to track recovery. e. St. Marys River Area of Concern (binational AOC) o Continue to implement planned management actions on the Canadian side with focus on implementing the *Sediment Management Strategy* and associated *In-Water Works and Dredging Controls Guidance*. f. Saginaw Bay and River Area of Concern (U.S.) o Continue to implement the multi-year remediation efforts within the Tittabawassee River, Saginaw River and Saginaw Bay to address contaminated sediment.	MECP, EGLE, ECCC, EPA, NOAA, USGS, BMIC, SCIT
3	Undertake, support and/or promote innovative approaches and technologies to reduce releases of harmful chemicals.	ECCC
4	Continue to update and, where needed, develop fish consumption guidance.	LTBB, SCIT, MECP, MDHHS, ECCC, CORA, BMIC, PC

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
5	Continue long-term monitoring of CMCs and other contaminants in various media (air, water, sediment, fish and wildlife) to examine exposure, distribution and bioaccumulation trends. • Continue to investigate mercury sources and cycling using innovative approaches that help identify the relative importance of different pathways of mercury exposure (to fish and wildlife).	ECCC, EPA, USGS, NOAA, USFWS, Tribal Nations, EGLE
6	Continue efforts to monitor and assess sources, fate, transport, distribution, and effects of contaminants of emerging concern (e.g., flame retardants, PAHs, pesticides, PFAS), legacy chemicals and trace metals in various media including groundwater with consideration to climate-pollutant interactions.	LTBB, ECCC, EGLE, EPA, USGS, NOAA, USFWS
7	Continue outreach and education to the public on impacts of chemical contaminants in fish with a focus on mercury, PCBs, PFAS and pesticides; the pathways into fish, wildlife and humans; and actions that can be taken to help reduce contaminants from entering the basin.	ECCC, EPA, USACE, USGS, EGLE, Tribal Nations
8	Continue outreach and education to the public on fish consumption guidance.	LTBB, SCIT, MDHHS, ECCC, BMIC, CORA, EGLE, EPA

**Acronyms for agencies not listed as Lake Huron Partnership agencies on page iv are: Michigan Department of Health and Human Services (MDHHS); Transport Canada (TC).*

Actions Everyone Can Take

Here are some ways that you can do your part:

- Take household hazardous materials to hazardous waste collection depots.
- Don’t burn garbage in barrels, open pits, or outdoor fireplaces, to prevent the release of toxic compounds like dioxins, mercury and lead.
- Properly dispose of unwanted or expired medication through pharmaceutical take-back programs.
- Choose environmentally-friendly household cleaning and personal care products.
- Use sealant products which are not coal-tar based for sealing your driveway or parking lot because they have much lower PAH levels.
- Use natural non-toxic pest-control methods.

- Use energy wisely to minimize pollution (and save money too), such as changing to energy-efficient light bulbs, washing clothes in cold water, and further winterizing your home to prevent heat loss.
- Reduce your use of fluorinated consumer products such as non-stick cookware and stain-resistant treatments.

5.2 Nutrient and Bacterial Pollution

This chapter summarizes the scientific information about Lake Huron's nutrient and bacterial pollution, current threats, as well as corresponding actions to be taken by Lake Huron Partnership agencies in the 2022-2026 timeframe, and actions that everyone can take. The science is organized in response to the two related General Objectives of the *Great Lakes Water Quality Agreement*; specifically, that the waters are to be free from nutrients in amounts that promote growth of algae or cyanobacteria that interfere with aquatic ecosystem health or human use of the ecosystem, and for the waters to allow for unrestricted swimming and other recreational use.

Lake Huron's beaches and nearshore waters are most often clear and clean, offering unrestricted swimming and other recreation use. However, there are times that some beaches have a posted advisory or are closed due to a bacterial contamination, and some unsightly episodic algal blooms. Elevated nutrients in some areas of the nearshore contribute to excessive amounts of nuisance algae and cause episodic outbreaks of cyanobacteria blooms.

Nutrients are essential elements of the aquatic ecosystem food web. As a natural and essential part of aquatic ecosystems, nutrients play an important role in supporting the production of aquatic plants and algae which provide food and habitat for small organisms and fish. However, altered or reduced nutrient levels can decrease food web productivity, as observed in the offshore. Nutrient pollution caused by excess nitrogen and phosphorus, including the bioavailable soluble reactive phosphorus (SRP), is one of the lake's most challenging environmental problems. Excess nutrient pollution contributes to high levels of benthic macro-algae (e.g., *Cladophora, Chara* and periphyton) and harmful algal blooms (e.g., cyanobacteria). Maintaining the proper balance of nutrients is a significant challenge.

5.2.1 Objectives and Condition Overview

Two of nine General Objectives of the *Great Lakes Water Quality Agreement* are addressed in this chapter, i.e., the Great Lakes should:

- Be free from nutrients that promote unsightly algae or toxic blooms; and
- Allow for unrestricted swimming and other recreation use

The status and trends of the nutrient and bacterial pollution sub-indicators for Lake Huron is displayed in Table 6. Between the 1970s and 1990s, management actions helped reduce the amount of phosphorus discharged from point sources and wastewater treatment plants, and significantly reduced concentrations of phosphorus in the nearshore zone. However, offshore phosphorus concentrations have also significantly decreased and may be too low to support a healthy level of productivity needed to maintain a healthy food web. The water quality at Lake Huron's beaches continues to be in good condition and provides good opportunities for swimming and recreational use. The status of beaches along Lake Huron shores is 'Good,' with the 10-year trend of 'Unchanging to Improving,' and the long-term trend of 'Improving' (ECCC and EPA, 2022).

5.2.2 Nutrient Pollution

***GLWQA* General Objective:** The Waters of the Great Lakes should be free from excessive 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.

How is it monitored?

The condition of the Great Lakes with respect to nutrients in the offshore waters is assessed using total phosphorus data collected by ECCC and the EPA. Selected nearshore locations are monitored by a number of tribal, state, and provincial agencies, as well as academic institutions. In Canada, the Ontario Ministry of the Environment Conservation and Parks (MECP) oversees long-term water quality monitoring and science programs that provide information on nearshore water quality conditions. This is done through the ministry's Great Lakes Nearshore Index Station Network which provides information on where and how ambient water quality conditions are changing over time by periodically monitoring a suite of indicators at a network of 19 stations along the Lake Huron-Georgian Bay shoreline.

In the U.S., EPA's Office of Water in partnership with States and Tribal Nations conducts the National Coastal Condition Assessment (NCCA). This assessment is designed to yield unbiased estimates of the condition of the nearshore waters based on a random stratified survey and to assess changes over time. The NCCA measures sediment and water quality, and collects data for macroinvertebrate, habitat, and fish condition indices. The U.S. Geological Survey (USGS) conducts long-term monitoring on two tributaries to Lake Huron: Saginaw and Rifle Rivers. The USGS has estimated daily loads of phosphorus up to 2019 (Koltun, 2020) and other nutrients and sediment through 2013 (Robertson et al., 2018). The USGS is currently updating the nutrient loads on these tributaries through 2020.

What is the condition?

The status of Lake Huron's nutrient levels is considered 'Fair,' with an 'Unchanging' trend over the past 10-years and a 'Deteriorating' long-term trend (1970-2019) (ECCC and EPA, 2022). These assessments are based on offshore phosphorus concentrations which in Lake Huron have leveled off at concentrations well below the *GLWQA* objective of 5 micrograms per liter (ug/L), to levels that may be too low to support a healthy level of productivity (Figure 4). While offshore phosphorus concentrations are quite low, some nearshore areas and embayments (i.e., Saginaw Bay) have elevated nutrients that are contributing to nuisance algal conditions.

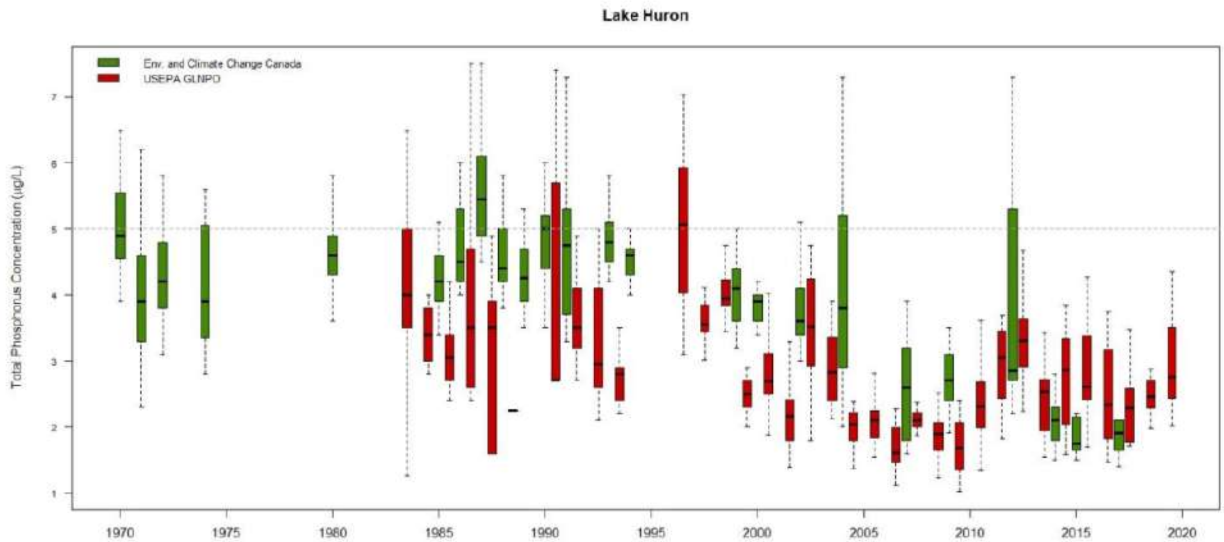


Figure 4: Phosphorus concentration levels that may be too low to support a healthy level of productivity based on the historic food web. Source: ECCC and EPA, 2022.

In Ontario, elevated phosphorus and nitrate concentrations occur along the southeast shores of Lake Huron (Dove, pers. comm., 2016). In fact, four of the top ten Canadian subwatersheds with the highest intensities of nitrogen and phosphorus production from livestock manure are located in this area (Statistics Canada, 2013). Models can be used to help understand pathways, conditions and potential solutions. Spatially Referenced Regression on Watershed attributes (SPARROW) models, developed for the Great Lakes basin (Robertson et al., 2019), enable the inputs and sources of phosphorus and nitrogen to be estimated to Lake Huron as a whole, and by individual tributaries, hydrologic units, and smaller catchments based on watershed management similar to the early 2000's. SPARROW results can be easily viewed with an online mapper (https://sparrow.wim.usgs.gov/midcontinent-2002/). Based on the SPARROW models, about 3,150 metric tonnes of phosphorus are delivered to Lake Huron per year from its direct watershed, with about 1,655 metric tonnes (1,824 tons) (52%) coming from the U.S. and 1,500 metric tonnes (1,653 tons) (48%) coming from the Canada (Robertson et al., 2019) (Figure 5). The largest contributors of phosphorus and nitrogen by tributary from Canada are the Maitland, Saugeen, Ausable, and Nottawasaga Rivers (approx. 60% of total Canadian input), whereas the largest contributor from the U.S. is the Saginaw River (50% of the total U.S. input).

Based on the SPARROW models, agricultural areas, with contributions from fertilizers, manure, and other nonpoint sources, are the largest overall source of phosphorus to Lake Huron (50%), followed by forested areas (26%), and urban areas (23%; wastewater treatment plants and urban areas) (Figure 5; Robertson et al., 2019a). The U.S. part of the watershed has relatively more urban inputs and less agricultural and forested inputs than the Canadian part of the watershed.

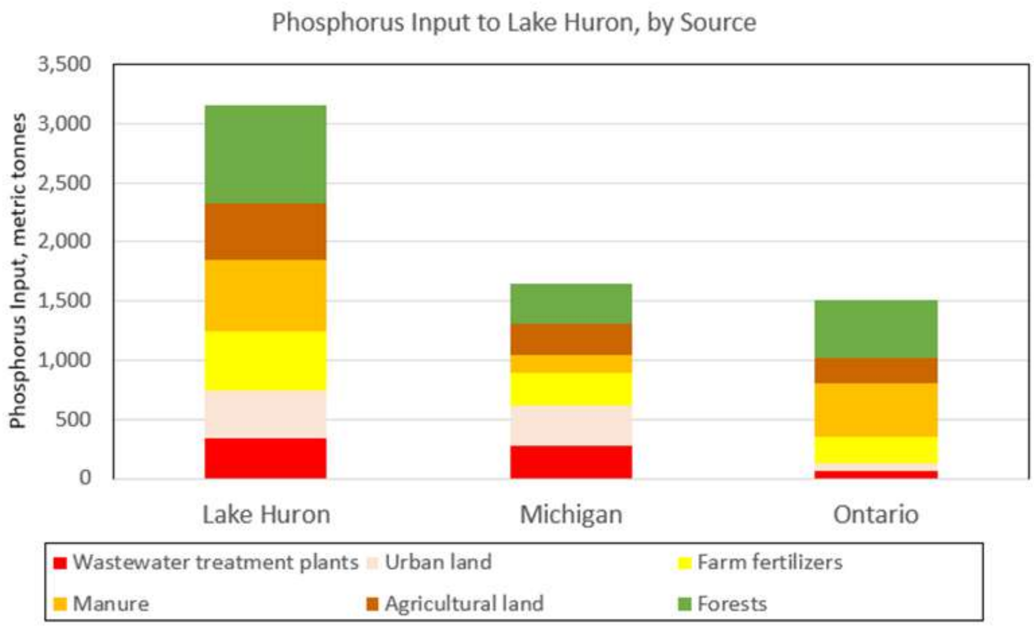


Figure 5: Average annual inputs of phosphorus to Lake Huron, by source based on SPARROW (Robertson et al., 2019).

Approximately 15% of the Lake Huron shoreline is impacted by excessive growth of submerged macroalgae, predominately *Cladophora* and *Chara*, found mostly near the mouths of drains and tributaries (Barton et al., 2013; Grimm et al., 2013). Excessive growth and accumulation of *Cladophora* occurs at some shoreline locations in shallow water up to 10 m in depth depending on water clarity and is associated with areas of local nutrient inputs; *Chara* fouling occurs at depths of 2-3 m, but the causes are unknown. Excessive growth of deep-water periphyton has been observed by divers and with video reconnaissance at depths of up to 20 m (Barton et al., 2013).

The current status of the *Cladophora* indicator for Lake Huron is 'Fair' with a 10-year and long-term trend of 'Undetermined' (ECCC and EPA, 2022). *Cladophora* levels are generally low in Lake Huron; however, some areas of the lake, such as along the southeast shore of the main basin, are prone to nuisance algae growth issues. *Cladophora* growth appears to be linked to point sources of nutrient inputs (Howell, 2015, unpublished data; ECCC and EPA, 2022).

Cladophora has been part of an assemblage of benthic macroalgae in Saginaw Bay linked to episodic beach fouling due to decaying organic matter (ECCC and EPA, 2022). Commercial fishers and Indigenous fishing communities report large amounts of plant material in their deep-water nets, suggesting the possibility that nearshore algae/plant growth may be transported offshore through hydrodynamic processes.

The current status of harmful algal blooms in Lake Huron (HABs) is 'Good' with an 'Unchanging' 10-year trend (ECCC and EPA, 2022). HABs are caused by cyanobacteria, which are microscopic, unicellular organisms that can grow as large, visible blooms and may be a nuisance, or even toxic. Algal biomass, especially for potentially toxic cyanobacterial species, remains mostly at low levels in Lake Huron. However, HABs can develop locally, such as the episodic summer blooms that occur in Saginaw Bay, select embayments in Georgian Bay (Sturgeon Bay and Deep Bay) and some areas of the southeast shore, and parts of the North Channel. Otherwise, the waters of Lake Huron are safe and substantially free from toxic and/or high abundances of harmful algae (ECCC and EPA, 2022). Since 2002, HABs have declined in Saginaw Bay.

What is the threat and other considerations for taking action?

Many human activities can increase nutrient inputs and promote nuisance and harmful algal growth. Loss of native forest and vegetative cover including from riparian areas, uplands, and loss of wetlands increases sediment and nutrients in stormwater runoff. Sources of excess nutrients from urban areas include stormwater runoff and sewer overflows. Nutrient levels are highest in nearshore waters near tributary mouths that drain urbanized or agricultural areas (e.g., Saginaw River). In rural areas, the handling of animal waste and fertilizers can contribute to excess nutrients. Cage aquaculture operations must be properly sited and managed to minimize enrichment of nearby waters. Faulty septic systems can leak nutrients (and bacterial pollution) into nearshore waters. The impacts of climate change are causing increased nutrient pollution due to severe rain events that increase stormwater runoff and soil erosion as well as warmer conditions that promote algal growth. In addition, changes in the food web brought about by invasive species such as dreissenids (i.e., zebra and quagga mussels) may also be a contributing factor. Invasive mussels are voracious filter feeders that rapidly remove phytoplankton from the water column, allowing for greater light penetration, and shunt nutrients to the benthic zone through their feces and pseudofeces. They sequester large quantities of phosphorus in their tissues. This combination of greater light penetration and increased nutrients in the benthic zone contributes to the proliferation of benthic and toxic cyanobacteria that may bloom late into the summer season (Stow et al., 2014).

On the Canadian shoreline, signs of nutrient enrichment occur from the outlet of Saugeen River south to Kettle Point near Sarnia, where the density of bottom-dwelling aquatic worms (indicators of organic pollution) increased 20-fold since the early 2000s (Nalepa et al., in prep).

Historically, nutrient inputs from tributaries contributed to spring phytoplankton blooms, abundant zooplankton and benthic invertebrate populations (especially *Diporeia* and *Mysis*), and ultimately to productive fisheries. However, long-term data illustrate that Lake Huron underwent major system-wide changes between 2003 and 2008. During that time, open water phosphorus concentrations decreased sharply, water transparency reached new record highs, the spring phytoplankton bloom largely disappeared, and zooplankton abundance drastically declined, as did the populations of prey fish. While spatial variations exist, both primary and secondary production have likely been spatially redistributed compared to historical conditions. These lower levels seem to have stabilized (Great Lakes Fisheries Commission, n.d). Low levels of total phosphorus in spring and chlorophyll *a* concentrations in the summer persist in the pelagic waters with ultra-oligotrophic conditions in parts of the basin. The dominant processes driving primary production may be changing, and the interactions and implications invite further investigation (e.g., the movement of nutrients from nearshore to offshore).

In the nearshore environment, nutrients are filtered by abundant dreissenid populations, are bound up as tissue/shells, and excreted or re-released as pseudofeces, which in turn are assimilated by algae and aquatic plants in the nearshore environment. While quagga populations have stabilized at shallower depths, they are increasing in deeper waters (>90 m). Their filter feeding activity in the deep, cold, offshore environment is believed to remove nutrients/plankton from the water that historically drove the springtime diatom bloom.

5.2.3 Bacterial Pollution

GLWQA* General Objective*: The Waters of the Great Lakes should allow for swimming and other recreational use, unrestricted by environmental quality concerns.

How is it monitored?

During the recreational season, Tribal Nations, First Nations, provincial, state and local governments test selected beaches and, in some cases, tributaries for *Escherichia coli (E. coli)*. The presence of *E. coli* is an indicator of the presence of human or animal fecal wastes in beach water. While most strains of *E. coli* are harmless, they are an indicator that other disease-causing (pathogenic) microbes may be present as well. People swimming in water contaminated with pathogens can contract diseases of the gastrointestinal tract, eyes, ears, skin and upper respiratory tract. When monitoring results reveal elevated levels of *E. coli*, state or local government/health units issue a beach advisory or closure notice until further sampling shows that the water quality meets the applicable water quality standards. A beach advisory (posting) functions as a warning against swimming at a particular beach but is not a closure. The province of Ontario and state of Michigan may also issue beach closures when health and safety thresholds are exceeded.

What is the condition?

The status and trends of nutrient and bacterial pollution sub-indicators for Lake Huron are displayed in Table 6. The status of Lake Huron's beaches is 'Good', with the 10-year trend of 'Unchanging to Improving'. Monitored U.S. Lake Huron beaches were open and safe for swimming for an average of 97% percent of the swimming season, and monitored Canadian Lake Huron beaches were open and safe for swimming for an average of 93% of the swimming season based on the respective acceptable *E. coli* concentrations (ECCC and EPA, 2022). The 10-year trend was assessed as 'Unchanging to Improving' due to a slight improvement in beach conditions in Canadian waters of Lake Huron over the past 10 years.

Table 6: Status and 10-year trends of nutrient and bacterial pollution sub-indicators in the Lake Huron basin. Source: State of the Great Lakes report (ECCC and EPA, 2022)

Sub-Indicator	Status – Trend
Nutrients in Lakes	Fair – Unchanging
Harmful Algal Blooms	Fair – Unchanging
Cladophora	Fair – Undetermined
Beach Advisories	Good – Unchanging to Improving

What is the threat and other considerations for taking action?

In rural areas, failing septic systems and agricultural runoff from lands treated with manure can be sources of *E. coli* to the lake. In urban settings, inputs from sanitary and combined (sanitary/stormwater) sewer overflows and stormwater runoff from roads, roofs, construction sites and parking lots can carry bacterial contamination to local beaches. Local wildlife (i.e., gulls and geese) may also be a direct source of *E. coli* at beaches.

In addition, algal mats and decaying vegetation washed nearshore may harbor *E. coli* and other pathogens and contribute to elevated concentration in beach sands and water.

5.2.4 Nutrient and Bacterial Pollution: Climate Change Impacts

Climate change impacts include more frequent and intense rain events, resulting in heavy runoff that can carry biological contaminants such as harmful bacteria from sewers and other polluted areas from the watershed to the beach (IJC and GLWQB, 2003). Precipitation, for example, has increased by 9.7% between 1948 and 2012 in Ontario resulting in increased flooding and large fluctuations in water levels (Bush et al., 2018). These are confounding factors in the loading, cycling and algal uptake of nutrients in the lakes which can lead to increased frequency, distribution, and severity of HABs, hypoxic zones, and *Cladophora* (ECCC and EPA, 2022).

Increased disturbances and terrestrial species range-shifts due to a changing climate may increase colonization of terrestrial invasive species, which can in turn alter nutrient dynamics, and may increase erosion and nutrient loading to waterways. Lake level changes, high winds and waves, and extreme storm events may cause erosion and disturb sediments, potentially releasing stored nutrients. The impacts that climate change has on nutrient and bacterial pollution is not adequately understood; however, climate change is likely to complicate nutrient and bacterial pollution mitigation efforts in the watershed.

5.2.5 Actions to Prevent and Reduce Nutrient and Bacterial Pollution

This section describes actions that will be taken to further reduce and prevent nutrient and bacterial pollution in Lake Huron. The Lake Huron Partnership agencies will implement the 2022-2026 *LAMP* within the context of existing laws and regulations which contribute to the restoration and protection of Lake Huron. Federal, state and provincial legislation that address nutrient and bacterial pollution are listed in Appendix B. This legislation includes the Canadian

Environmental Protection Act (1999), the U.S. Clean Water Act (1972), and Ontario's Nutrient Management Act (2002).

In addition, a number of national and regional plans and initiatives, such as the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health (COA), Ontario's 12 point plan and the U.S. Great Lakes Restoration Initiative administered by EPA, are contributing to the prevention of nutrient and bacterial pollution.

Article 4 and the Nutrients Annex (Annex 4) of the 2012 *GLWQA* commits both countries to implement programs for pollution abatement and enforcement for municipal sources (including urban drainage), industrial sources, agriculture, and forestry. The Annex 4 subcommittee is co-chaired by ECCC and EPA. Efforts under this Annex include developing the scientific information and modeling techniques required to evaluate nutrient targets for the Great Lakes. The Annex 4 subcommittee is currently focused on addressing the nutrients issue in Lake Erie and is reviewing nutrient targets and objectives for Lake Ontario. Lessons learned from these lakes, including the approaches taken for monitoring and modeling algal blooms and *Cladophora* growth could be applied to Lake Huron in the future. Ideally, there should be enough nutrients in the water to support a productive fishery, while minimizing harmful and nuisance algal growth and beach fouling.

LAMP Actions

Actions will be taken in the Lake Huron basin to further prevent excessive nutrients and bacterial pollution and to track progress through science and monitoring as listed in Table 7.

Table 7: Actions to prevent and reduce nutrient and bacterial pollution

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	Actions to Prevent and Reduce Nutrient and Bacterial Pollution	
9	**Wastewater Treatment Plants and Stormwater Management Systems**: a. Support efforts to reduce and/or eliminate Combined Sewer Overflows (CSO) and Sanitary Sewer Overflows (SSO) in the Lake Huron watershed and ensure compliance with permitted discharges to ensure receiving waters meet Water Quality Standards.	LTBB, SCIT, MECP, EGLE, ECCC, EPA, BMIC, CORA, Conservation Authorities, USDA-NRCS, USDA-FS, USACE, SSEA

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	b. Plan, undertake, and/or support low impact development, green infrastructure projects, and nature-based solutions that are suited to future extreme weather events and better protect species and habitat.	
10	**Nutrient and Bacteria Control:** Build on existing integrated and systematic efforts to reduce overland runoff of nutrients, sediments, and bacteria, improve soil health, and maintain and restore natural heritage features. • Reduce nuisance and harmful algae and promote safe and clean beaches in priority watersheds in Ontario through the Healthy Lake Huron Initiative (along the southeast shores) and in Michigan (i.e., Saginaw Bay), through the following actions: o Support landowners' adoption of agricultural Best Management Practices (BMPs) implementation. o Conduct continuous flow and event-based water quality monitoring and edge-of-field monitoring and reporting in targeted watersheds to assess effectiveness of BMPs. o Identify additional priority sub-watersheds, if necessary, in the Lake Huron watershed.	LTBB, SCIT, MECP, ECCC, EPA, EGLE, NOAA, USGS, USDA-NRCS, USDA-FS, Conservation Authorities, PC, SSEA, OMAFRA
11	**Watershed Management Planning and Implementation:** Develop and/or revise, as appropriate, integrated watershed management plans and implement coastal and nearshore management and other nutrient reduction actions at a community level: a. Support local initiatives to help communities develop and/or implement watershed plans and/or climate change adaptation plans including reforestation efforts. b. Implement the Tipping Points Planner in communities. c. Continue to implement management plans under Section 319 Nonpoint Source Management Program of the U.S. Clean Water Act. d. Continue surface water monitoring on lakes and wetlands under Tribal jurisdiction and in other areas.	LTBB, SCIT, MECP, Conservation Authorities, EGLE, EPA, NOAA, CORA, BMIC, OMAFRA, NDMNRF, USDA-NRCS, USDA-FS, SSEA
12	**Open Water:** Conduct open water nutrient and lower foodweb surveys.	EPA, ECCC, USGS, NOAA, EGLE, MECP, SSEA
13	**Streams:** Continue surface water quality monitoring and reporting of information from various stream and river locations: a. Continue the joint program between the province of Ontario and conservation authorities via the Provincial Water Quality Monitoring Network (PWQMN).	LTBB, MECP, Conservation Authorities, EGLE, EPA, NOAA, USGS, SSEA

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	b. Continue to assess stream water quality under Section 305(b) of the U.S. Clean Water Act.	
14	Saginaw Bay Water Quality Monitoring Initiative – Support efforts to implement a coordinated and comprehensive water quality monitoring program within the Saginaw Bay and Watershed. The goals of this initiative, include: a. Improve understanding of nutrient dynamics with the Saginaw Bay Watershed, Saginaw Bay, and the interactions with the offshore zone. b. Collect data to help support and calibrate nutrient models for Saginaw Bay. c. Collect data to evaluate and review the *GLWQA* nutrient targets for Saginaw Bay, and revise as necessary. d. Collect data to support removal of the Saginaw Bay Beneficial Use Impartments (BUIs), including tainting of fish flavor, eutrophication and others.	SCIT, EGLE, MDNR, EPA, NOAA, USGS
15	Continue to investigate how the food web responds to changes in nutrient inputs and cycling.	USGS-GLSI, USFWS, MDNR, EPA, NOAA
16	Investigate nutrient sources, sinks and recycling (e.g., release from sediments, decaying *Cladophora*, and dying mussels).	USGS, EGLE, NOAA, USFWS, MDNR
17	Improve understanding of lakewide physical and biological processes that translocate nutrients/energy from the nearshore to offshore and from the offshore to nearshore, with consideration of the influence of invasive species (e.g., dreissenid mussels).	USGS-GLSI, USFWS, MDNR, EGLE, NOAA
18	Characterize historical and current land use, nutrient sources and forms (soluble reactive vs total), and tributary phosphorus loadings with consideration of seasonality, climate change (e.g., increased frequency and intensity of storm event causing large nutrient pulses) and nearshore hydrodynamics and productivity (e.g., algal growth).	NOAA, USGS, EPA, EGLE, USDA-FS
19	Conduct outreach and education on local and regional scales to increase the understanding of water quality conditions and nutrient management challenges including nearshore and beach water quality, and implementation of best management practices (BMPs) and policies to control nutrient runoff.	LTBB, SCIT, MECP, Conservation Authorities, NOAA, USACE, EPA, EGLE, MDHHS, ECCC, BMIC, USDA-FS, PC, SSEA, OMAFRA

**Acronyms for agencies not listed as Lake Huron Partnership agencies on page iv are: Michigan Department of Health and Human Services (MDHHS); Transport Canada (TC).*

Actions Everyone Can Take

Landowners and the public are encouraged to do their part to prevent nutrient and bacterial pollutants from entering groundwater, streams, lakes, wetlands, and Lake Huron by undertaking the following actions:

- Avoid using lawn fertilizers containing phosphorus.
- Always pick up pet waste.
- Choose phosphate-free dishwashing detergents, soaps, and cleaners.
- Install a rain barrel to slow the fast flush of water during a storm and reuse the water for beneficial purposes, such as watering a lawn or garden.
- Plant a rain garden with native trees, shrubs, and herbaceous plants and direct rainwater to this area so that the water can soak into the ground and be used by the vegetation.
- Keep organic matter like leaves and woody debris out of storm drains.
- Inspect and pump out your septic system every 3 to 5 years, or as otherwise required.
- Implement improved septic technologies or removal, including conversion of septic systems to municipal or communal sewage systems, where available.
- In Ontario, report potential blue-green algal blooms at 1-866-MOE-TIPS (663-8477) so samples can be collected and preventative measures can be taken.
- Participate in Bloomwatch.

5.3 Loss of Habitat and Species

Lake Huron's water quality depends on the health of the basin's ecosystem, including the interacting components of air, land, water and living organisms. This section summarizes the scientific information about Lake Huron's habitat and species, current threats, and corresponding actions to be taken by Lake Huron Partnership agencies in the 2022-2026 timeframe, as well as actions that everyone can take. The science is organized in response to the habitat and species General Objective of the *Great Lakes Water Quality Agreement.*

Lake Huron's geology provides for a high level of diversity in its natural environment, including: the southern glacial till (deposits of clay, sand and gravel); the Niagara Escarpment, or 'Great Arc' of limestone extending through the Bruce Peninsula, Manitoulin Island and Michigan's Upper Peninsula; and the northern Precambrian Shield. The open lake ecosystem, coastal wetlands, islands, rocky shorelines, sand and cobble beaches, dunes, alvars, and the hundreds of interconnected tributaries and their watersheds provide the essential habitat for a multitude of species.

5.3.1 Objectives and Condition Overview

One of the nine General Objectives of the Agreement is addressed in this section:

- Support healthy and productive wetlands and other habitats to sustain resilient populations of native species

The status and trend of habitat and species sub-indicators for Lake Huron are displayed in Table 8. The overall condition of Lake Huron's habitats and species (its **biological diversity**) is 'Fair' with a 10-year trend of 'Unchanging' and long-term trend of 'Undetermined' (ECCC and EPA, 2022). Although in fair condition, Lake Huron's habitat and species are under stress. Lake Huron has a relatively cold climate and simple food-web making the ecosystem susceptible to climate change (e.g., warming temperature) and to the impact of new invasive species and land-use changes. While restoration work is needed in degraded areas, protection and conservation actions are required to maintain and improve Lake Huron's habitat and species 'Fair' condition.

Table 8: Status and trends of habitat and species sub-indicators in the Lake Huron basin. Source: State of the Great Lakes report (ECCC and EPA, 2022)

Sub-Indicator	Status – Trend
Aquatic Habitat Connectivity	Fair – Improving
Coastal Wetland Invertebrates	Fair – Unchanging
Coastal Wetland Fish	Fair – Unchanging
Coastal Wetland Amphibians	Good – Unchanging
Coastal Wetland Birds	Good – Unchanging
Coastal Wetland Plants	Fair – Unchanging
Benthos	Good – Unchanging
Phytoplankton	Fair – Deteriorating
Zooplankton	Fair – Unchanging
Diporeia	Poor – deteriorating
Prey Fish	Fair – Unchanging
Lake Sturgeon	Poor – Improving
Walleye	Good – Unchanging
Lake Trout	Fair – Improving
Forest Cover	Fair – Unchanging
Land Cover	Fair – Unchanging
Hardened Shorelines	Good – Deteriorating
Ice cover	Decreasing
Water Levels	Unchanging
Water Quality in Tributaries	Fair – Unchanging
Precipitation amount	Increasing
Surface water temperature	Increasing

5.3.2 Loss of Habitat and Species

***GLWQA* General Objective:** The Waters of the Great Lakes should support healthy and productive wetlands and other habitats to sustain resilient populations of native species.

How is it monitored?

This chapter is based on several summaries of monitoring and research surveys and compiled habitat and species assessments for one or more ecosystems in Lake Huron. Long-term, basin-wide monitoring programs for habitats and species are undertaken by federal, tribal, state and provincial agencies and their partners. Coordinated lakewide monitoring efforts include surveillance and research on the lower food-web, fish species, and important habitats such as coastal wetlands. Monitoring in the watershed and tributaries is undertaken by multiple agencies at various scales.

Numerous reports and documents have been developed to assess the current condition of habitats and species. The Lake Huron Biodiversity Conservation Strategy used seven conservation features that represent a baseline assessment of the lake's biological health (Franks Taylor et al., 2010). The *Environmental Objectives for Lake Huron* (Liskauskas et al., 2007) provided a critical review by the Great Lakes Fisheries Commission of environmental impediments and important habitat features essential in achieving Fish Community Objectives (Desjardin et al., 1998) for Lake Huron. The Lake Huron Binational Partnership prepared a coastal wetland science synthesis which compiles several information sources to provide a comprehensive assessment for Lake Huron (Ciborowski et al., 2015). Findings include the fact that environmental stresses and biological conditions vary across Lake Huron; stresses and biota differ greatly between granitic northern and sedimentary southern ecoprovinces; and water quality stress categories are 'Good' or 'Excellent' in most subregions but only 'Fair' in Saginaw Bay. The State of the Great Lakes (SOGL) Ecosystem indicator reports were updated and revised in 2022 and provide the most recent information on status and trends (ECCC and EPA, 2022). The most recent comprehensive summary of the status of fish communities in Lake Huron (Riley and Ebener, 2020) covering the period of 2011-17 provided additional insights on impediments and emerging issues affecting the achievement of Fish Community Objectives as directed by the Great Lakes Fishery Commission (GLFC, 2007). The 2022 Canadian Baseline Habitat Survey for Lake Huron will provide quantitative and qualitative measures of the landscape within the Lake Huron coastal margin (shoreline up to 2 kilometres inland). By reviewing the syntheses above, communication and data sharing, basinwide assessments can be made for a number of indicators of ecosystem health, including land-use trends, forest cover and aquatic habitat connectivity.

What is the condition?

The most comprehensive and complete set of habitat and species condition indicators are found in the SOGL report (as summarized in Table 8). Supplemental indictors are supplied by some of the other surveys and reports outlined in the section above. In the SOGL report, the majority of habitat and species sub-indicators are classified as being ‘Fair’; however, they range from ‘Poor’ to ‘Good’, with trends varying from ‘Deteriorating’ to ‘Improving’ (ECCC and EPA, 2022). Many specific habitat and species sub-indicator results are summarized below, supplemented by lake-specific studies and input from members of the Lake Huron Partnership and the Lake Huron Technical Committee of the Great Lakes Fishery Commission.

The following sections of this chapter include habitats and species of particular interest as identified by experts in the field. These include ecosystem components used as sub-indicators in the SOGL reporting, as well as some additional subjects that are important for describing the condition of the Lake Huron basin, including wild rice, Grayling, and nearshore areas.

Watersheds and Tributaries – Forest cover in riparian areas and land use status within the basin are both ‘Fair’ with an ‘Unchanging’ 10-year trend (ECCC and EPA, 2022). Natural vegetation and forest cover in riparian areas impact both terrestrial and aquatic habitat and are more intact in the northern portion of the basin. Agriculture and urban land uses, dominant in the southern portion of the basin, limit habitat for terrestrial wildlife in the basin due to habitat fragmentation and pose a higher risk of degrading aquatic habitat due to their impacts on water quality and hydrology. Riparian areas that support natural vegetation can provide connectivity of terrestrial habitat and protect water quality and ecosystem integrity of Lake Huron tributaries (Foley et al., 2005; ECCC and EPA, 2021; ECCC and EPA, 2022). Invasive species such as emerald ash borer, discussed in the Invasive Species subsection, can impact and degrade habitat despite natural vegetation or forest cover. Efforts to repair damage to watersheds from extensive logging, resource extraction and improper land use have been undertaken by several government agencies, conservation authorities, and Non-Government Organizations in Ontario waters such as the Manitoulin Streams Improvement Association and the Eastern Georgian Bay Stewardship Council. Restoration and repair efforts, such as restoration of important habitat, has resulted in improvements to spawning habitat and access for both native and naturalized species (Liskauskas et al., 2020).

***Aquatic habitat connectivity* –** is considered ‘Fair’ and the 10-year and long-term trend is ‘Improving’ (ECCC and EPA, 2022). The role of dams in the watershed continues to have positive and negative impacts. While dams notoriously impede the migration of native and naturalized aquatic species, they continue to prevent invasive Sea Lamprey and potentially other invaders from expanding their ranges. Approximately 30% of tributary habitat in the Lake Huron basin is connected to the lake, with Georgian Bay tributaries offering ample access to spawning sites for migratory fish while Saginaw Bay tributaries are considerably obstructed (ECCC and EPA, 2022). There continues to be increased interest and action for removing dams while concurrently implementing new strategies for mitigating the populations and effects of invasive species. Progress on fish passage and dam removal was highlighted in the most recent *The State of Lake Huron in 2018* (Liskauskas et al., 2020) where several successful mitigation projects improved flow conditions and access for fish (St. Marys River rapids and Little Rapids, several Manitoulin Island streams) as well as improving spawning habitat features (several eastern Georgian Bay tributaries). In general, access to first order watersheds in Lake Huron was not substantially improved over the most recent reporting period ending in 2020 (Liskauskas et al., 2020).

***Coastal terrestrial habitat* –** Sandy beaches and dunes make up only 2-3% of Lake Huron’s shoreline, but they are critical habitat for endangered species such as the Piping Plover and for erosion protection (Lake Huron CCC, 2021). Some of the biggest stressors on the health of these ecosystems are invasive species, increased development, recreational activities, and vehicular use that crushes eggs, young birds, and vegetation (Lake Huron CCC, 2021).

Bluffs along the shoreline of Lake Huron erode and feed beaches and shorelines downstream, which create healthy coastal environments (Lake Huron CCC, 2021). The stability of these bluffs is reliant on vegetation roots and foliage that hold the soil together, especially woody vegetation (Lake Huron CCC, 2021). Some stressors include vegetation removal and infrastructure development adjacent to the edge (Lake Huron CCC, 2021). Coastal woodlands are remnants of large forests which now act as filters to absorb nutrients and pollutants from runoff (Lake Huron CCC, 2021). Habitat destruction and forest fragmentation are among the many threats to these ecosystems and the services they provide (Lake Huron CCC, 2021).

Coastal Wetlands **–** Lake Huron coastal wetlands account for roughly 64,641 hectares (~160,000 acres), almost 30% of the total wetland area for all five Great Lakes (Chow-Fraser, 2008). More than 3700 coastal wetlands (17,350 hectares; ~43,000 acres) are found along the eastern Georgian Bay coast and the St. Marys River contains approximately 10,790 hectares (~26,600 acres) (Fracz and Chow-Fraser, 2013). Additional efforts aimed at monitoring wetlands add to the body of information on water quality, invasive species, and diversity (Harrison et al., 2020; Ilison et al., 2020; Thomas et al., 2018). These studies indicate that reducing nutrient loading from human activities on the landscape (e.g., agriculture and urbanization) is critical for improving water quality (Harrison et al., 2020).

A synthesis of 157 wetlands sampled in 30 watersheds across the U.S. and Canadian portions of the Lake Huron basin and the St. Marys River provides a comprehensive analysis of wetland condition (Darwin, 2016; Ciborowski, 2015; Harrison et al., 2020). Index scores for water-quality data and the presence of wetland vegetation and fishes are presented (Figure 6). All three indices indicate a ‘Very good’ to ‘Excellent’ condition for coastal wetlands along the Canadian shoreline, especially those in eastern and northern Georgian Bay. However, wetlands assessed as ‘Fair’ or ‘Good’ condition are found near towns and marinas of southern Georgian Bay. Some coastal wetlands of the Bruce Peninsula were rated as ‘Fair’ or ‘Poor’ condition. Results are more variable for Michigan wetlands with most being in ‘Poor’ or ‘Fair’ condition. These patterns are consistent with the increased level of anthropogenic stressors, such as urban development, that are common in U.S. coastal wetlands but are largely absent in undisturbed watersheds in eastern and northern Georgian Bay (Ciborowski et al., 2015; Host et al., 2019). Coastal wetlands are also crucial habitat for plants, fish, amphibians, birds, and especially aerial migrants, as described below.

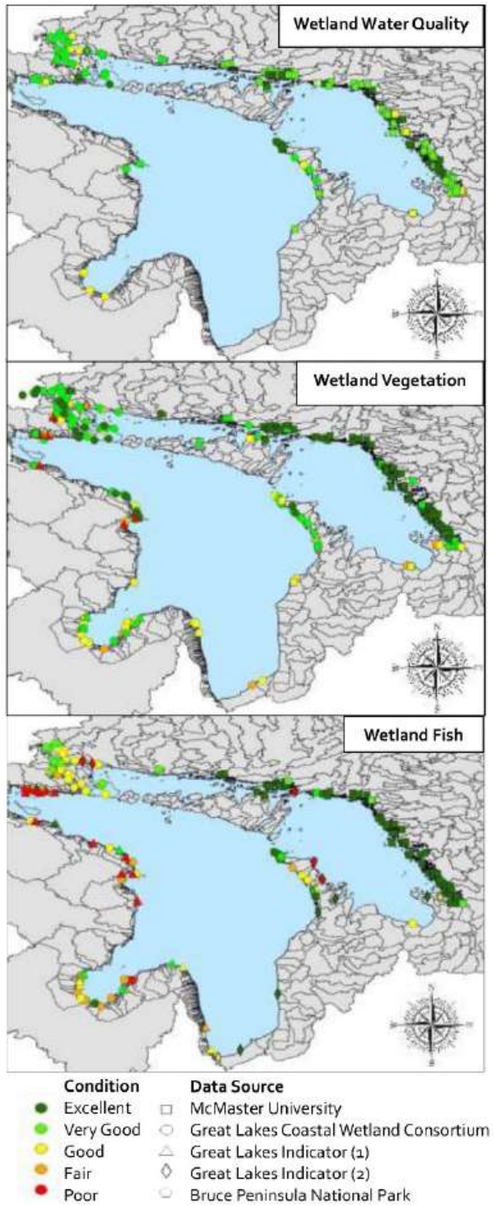


Figure 6: Index scores for water-quality data and the presence of wetland vegetation and fishes.

Nearshore Ecosystem and Reefs – The nearshore region consists of shallow coastal areas of the lake, shallow areas around islands, drowned river mouths, and the St. Marys River, all in waters less than 30 m deep (Edsall and Charlton, 1997). The nearshore-zone surface area is roughly 18,000 km^2 (6,950 mi^2) and represents 31% of the total lake surface area (Fielder et al., 2020). These relatively warmer, shallow areas contain a high level of habitat diversity as well as warmer temperatures which results in greater species richness compared to colder, more open waters (Fetzer et al., 2017). In shallow nearshore waters of Ontario, there is a high level of diversity of small fishes (>60 species), the majority of which are native to Lake Huron (Mohr et al., 2013). In Michigan waters the diversity of the nearshore fish community has decreased following the spread of invasive species mussels and Round Goby (Loughner, unpublished data). Changes to nutrient cycling in the nearshore area have caused nuisance filamentous algae growth, beach fouling, and harmful algae blooms, also contributing to negative impacts on fish and wildlife. Despite these stressors, some native species have increased in abundance in certain areas: Walleye abundance has increased in Saginaw Bay (Fielder et al., 2010), and Smallmouth Bass has increased in eastern Georgian Bay (Fielder et al., 2013).

Open Water Ecosystem and Reefs – In general, the open water ecosystem is in 'Fair' condition (Franks Taylor et al., 2010). The trends are variable across sub-indicators, and continued monitoring is needed to improve our understanding of drivers of change in lake productivity, the composition and abundance of lower food web organisms, and the population trends of fishes. Many fish species (e.g., Lake Trout and Lake Whitefish) in Lake Huron depend on clean, unobstructed reef habitats to spawn successfully. Future trends in the offshore food web may depend in part upon trends in dreissenid mussel populations, which affect both food availability and benthic habitat available for spawning.

Coastal Wetland Invertebrates – Lake Huron coastal wetland invertebrates exhibit a wide range of conditions, and the majority of Lake Huron coastal wetland invertebrate communities are not considered degraded. In fact, Lake Huron wetlands had the highest maximum invertebrate species richness of the Great Lakes. The status and 10-year trend are 'Fair' and 'Unchanging', respectively, based on macroinvertebrate surveys (ECCC and EPA, 2022).

Coastal Wetland Amphibians – The status is 'Good' and 'Unchanging.' Despite considerable development and agricultural stressors, Lake Huron encompasses some of the highest quality coastal wetlands with respect to anurans in the Great Lakes (ECCC and EPA, 2022).

Coastal Wetland Fish – As of 2019, the majority of sampled Lake Huron coastal wetlands were not degraded, with 28.2% of the Lake Huron wetlands assessed as degraded based on fish community metrics over the 9-year period. Based on fish community surveys, the status is 'Fair' and 'Unchanging.' Year to year changes in water levels do not appear to affect overall habitat for coastal wetland fish (ECCC and EPA, 2022). However, prolonged or rapid changes in water levels have the potential to affect fish species, particularly obligate wetland spawners such as Northern Pike and Muskellunge. Both of these species are prominent nearshore predators and their reproductive success is influenced by lake levels that if too low can reduce access to wetland areas and produce less than ideal incubating conditions for fertilized eggs (Midwood and Chow-Fraser, 2012).

Coastal wetland birds – The status of coastal wetland birds in Lake Huron is 'Good' and 'Unchanging' based on a low degree of disturbance and high availability of nesting habitat on islands, as well as bird population size and structure, which tend to range from 'Good' to 'Very good' in the northern basin and 'Fair' to 'Good' in the south (Franks Taylor et al., 2010; ECCC and EPA, 2022).

Coastal wetlands are crucial habitat for aerial migrants (birds, bats, and insects) that have high fidelity to Lake Huron, and for which migratory corridors associated with the lake are crucial to their survival. Lake Huron, western Lake Erie, and the St. Clair and Detroit Rivers are an important flyway for many species of migrating birds, and the shorelines of Lake Huron provide stopover sites for millions of birds, especially landbirds. There are globally or nationally important concentrations of Red-necked Grebes in northern Lake Huron, Tundra Swans in Saginaw Bay, and landbirds along a number of shorelines and peninsulas of Lake Huron, such as Tawas Point (MI), the tip of the Bruce Peninsula (ON), and much of the northern shore of Lake Huron in both the U.S. and Canada (Franks Taylor et al*.,* 2010). Places where migrants concentrate are important refueling sites and provide shelter for birds, bats, and insects. The large number of Islands in Lake Huron likely provides critical refugia for landbird migrants. Important Bird Areas for migrating birds have been identified in Canada and the United States (Figure 7). Studies are critically needed to identify where and when bats migrate around Lake Huron (Gehring, 2011). Similarly, the distribution of migrating insects, such as some odonates and monarchs, requires further investigation (Smith et al., 2007).

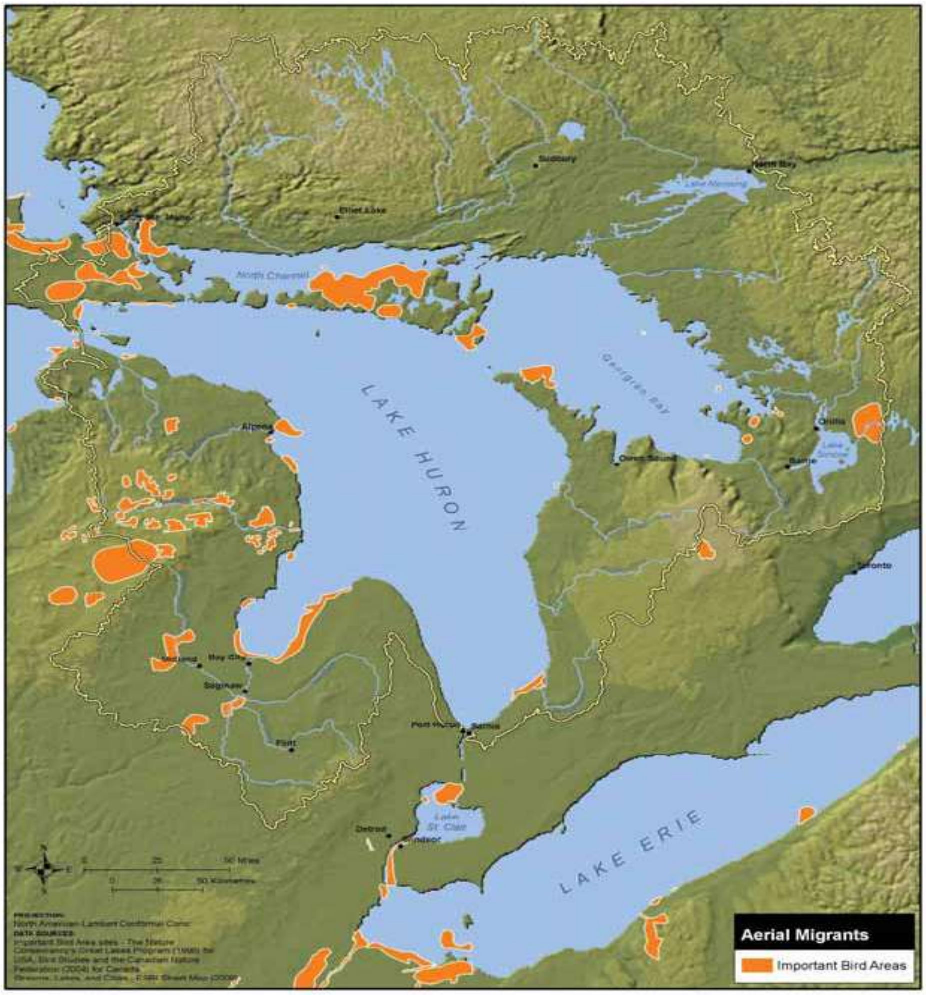


Figure 7: Map of migratory land bird stopover habitat (modeled). Biodiversity Conservation Strategy for Lake Huron.

Colonial Nesting Waterbirds – Populations of Double-crested Cormorants, Great Egrets and Black-crowned Night Herons have increased since 1976. Over the same time period, populations of Great Blue Herons, Herring Gulls, Ring-Billed Gulls, Common Terns and Caspian Terns declined, consistent with trends across the Great Lakes. The observed declines in Caspian Terns on Lake Huron are in contrast to increases on the other Great Lakes. Great Lakes breeding colonies of black terns have plummeted since the 1960s, due in large part to habitat loss and degradation. Black terns are now listed as endangered or “of special concern” in most Great Lakes states. Herring Gull egg size and development, as well as and possible population-level effects, have been linked to the decline of prey fish abundance (Hebert et al., 2008, 2009; Hebert et al., 2000). In 2015, nesting White Pelicans were first observed and documented in Saginaw Bay.

Coastal Wetland Plants – Status is 'Fair' and 'Unchanging' due to a wide range of coastal wetland plant community conditions (ECCC and EPA, 2022). Wetland sites in the northern and eastern areas of the lake tend to be of higher quality due to surrounding forest cover while wetland sites in other areas of the lake suffer due to human interactions and invasive species (ECCC and EPA, 2021; ECCC and EPA, 2022). Low-water periods permit the expansion of *Phragmities australis* and the cattail hybrid *Typha x glauca* as well as the loss of native emergent vegetation although recent high-water levels may erode the invasive plant beds (ECCC and EPA, 2022). Conversely, high water periods have also propagated the increase of European frogbit (*Hydrocharis morsus-ranae*) in Saginaw Bay and St. Marys River (Monks et al., 2019 as cited in ECCC and EPA, 2022).

Wild Rice – Manoomin (*Zizania palustris and Zizania aquatica),* also known as wild rice, is a culturally and ecologically important native species to the Great Lakes basin. This plant plays a central role in Indigenous people's migration stories where the Creator instructed the people to "go to where the food grows on water." Historically, manoomin was utilized as a significant portion of Indigenous people's diet and also served as a food source for migratory birds, aquatic mammals and provided habitat for fish. Manoomin, an emergent vegetation that grows in shallow waters and slow-moving streams, has suffered from habitat loss, degraded water quality and other factors (Michigan Sea Grant, 2014). Historic logging practices, navigation practices, and land use have destroyed many wild rice beds over the last few hundred years; only one large rice bed remains in the state of Michigan. There are growing efforts, such as the Michigan Wild Rice Initiative, amongst U.S. Tribal Nations and other agencies to restore this uniquely important species.

Phytoplankton – Abundance and community composition in the open water reflect a system in 'Fair' condition with a 'Deteriorating' trend. The lake has a phytoplankton assemblage reflective of oligotrophic conditions. However, average phytoplankton abundance declined 88% between 1971 and 2013 and the fair and deteriorating conditions were assigned because this reduction in phytoplankton is likely causing food web stress (ECCC and EPA, 2022). Further evidence of decreasing phytoplankton abundance is evident in declining Deep Chlorophyl Levels (DCL) (Scofield et al., 2020; Rudstam et al., 2020). The DCL in oligotrophic lakes can contribute significantly to total lake production during the stratified season and is thus another important indicator of food web condition (Scofield et al., 2020; Rudstam et al., 2020).

Zooplankton – Zooplankton is in ‘Fair’ condition with and an ‘Unchanging’ 10-year trend and ‘Deteriorating’ long term trend. Zooplankton declined significantly between 1998 and 2006 (Barbiero et al., 2009, 2012), which was driven by a 95% decline in the abundance of herbivorous crustaceans like cladocerans (Bunnell et al., 2012). Other forms of crustaceans (calanoid copepods) now dominate Lake Huron and Saginaw Bay (Pothoven et al., 2013). Declines are attributed to changes in the fish community and the non-native predatory Spiny Water Flea (*Bythotrephes longimanus)*, as well as decreased nutrient availability perpetrated by the proliferation of dreissenid mussels, which altered the composition of essential food web relationships (ECCC and EPA, 2019). Refer to Rudstam et al. (2020) and the Great Lakes Biological Monitoring Program Technical Reports (EPA, 2020b; EPA, 2021b) for further details on recent Zooplankton abundance and diversity throughout the lake.

Diporeia spp. (a freshwater bottom-dwelling crustacean) is an important prey species among Great Lakes fishes. Historically, populations native to Lake Huron, including Whitefish, Lake Trout, and Walleye, were supported by abundant *Diporeia* spp. However, the abundance of *Diporeia* has drastically declined throughout the Great Lakes, including Lake Huron (Nalepa et al., 2007; Barbiero et al., 2011; Rudstam et al., 2020). The deterioration of *Diporeia* populations may be due to complex factors beyond a reduction in available food. While more evidence is necessary, hypotheses suggest the decrease of *Diporeia* may be related to a combination of factors including: decreased quality and quantity of food resulting from increased filtering activity of the mussels, increased exposure to contaminants, and increased exposure to disease and/or parasites due to accumulation of dead mussel biomass (ECCC and EPA, 2019; Rudstam et al., 2020). The status of *Diporeia* is ‘Poor’ with a ‘Deteriorating’ trend. The 2017 lake-wide survey showed further Diporeia abundance declines, compared to a similar survey in 2012 (ECCC and EPA, 2022; Rudstam et al., 2020).

Prey fish – Between the 1970s and the early 2000s, the prey fish community was dominated by non-native Alewife and Rainbow Smelt. Over the last two decades, Alewife populations have declined significantly (Riley et al., 2008; Roseman and Riley, 2009; Riley et al., 2020), and Rainbow Smelt and native Sculpin populations have reached record lows (O’Brien et al., 2009; O’Brien et al., 2014; Roseman et al., 2015; Riley et al., 2020). Due to their cryptic nature and occupancy of complex habitats, Round Gobies are difficult to sample with bottom trawls, which are one of the primary means of long-term monitoring of prey fish populations in the lake (Riley et al, 2020). They have become an important prey item for many predator fish species in the lake and their abundance and distribution is underrepresented in USGS lake-wide prey-fish biomass estimates (Riley et al., 2020). Phosphorus-poor conditions and the decades-long management practice of stocking piscivorous fish, both native and non-native, have contributed to the decline of prey fish biomass (ECCC and EPA, 2019). The result is a preyfish community that is lower in abundance and diversity. Its status is 'Fair' with a 10-year trend of 'Unchanging' (ECCC and EPA, 2022).

Cisco – Cisco is a term used to describe seven Coregonid fish species found in Lake Huron during the early 20th century and in the same genus as the commercially important Lake Whitefish. Today, only two species remain, *Coregonus artedi* ("Cisco", previously known as "Lake Herring") and *C. hoyi* ("Bloater"), and their taxonomy is debated. *C. artedi* mainly occur in the North Channel and in the northern part of the main basin, but *C. artedi* are much less abundant than in the early 20th century. *C. hoyi* occur throughout the basin, and their abundance has approached near record-high levels over the past five years. Nonetheless, the commercial harvest of these two Coregonid species remains a fraction of historic levels (B. Bunnell, pers. comm., 2016).

In 2016, USFWS along with several other federal, state, and tribal partners began a program to rehabilitate Cisco populations in the main basin of Lake Huron. This program established lines of broodstock from the extant populations in northern Lake Huron and used these lines to stock Cisco into Saginaw Bay. Cisco historically moved from the main basin of the lake into Saginaw Bay to spawn, which is why Saginaw Bay was identified as an ideal location for these reintroduction efforts (Goodyear et al., 1982). An estimated 1 million Cisco fingerlings are planned to be stocked in Saginaw Bay annually from 2017-2027. Evaluations are currently underway to assess the success of this program and to determine if these stocked fish will develop a self-sustaining population with the ability to move into the main basin.

Lake Whitefish – Although Lake Whitefish continue to be the dominant species harvested by the commercial fishery, their abundance has declined almost continuously since reaching a peak in the early 2000s (Cottrill et al., 2020). The decline has largely been attributed to substantial reductions in recruitment, survival, and growth, driven by broad-scale ecological phenomena such as reduced offshore nutrients caused by the proliferation of dreissenid mussels and concurrent loss of the native benthic prey *Diporeia* (Pothoven and Madenjian, 2008; Rennie et al., 2009; Fera et al., 2015; Gobin et al., 2015). Lake Whitefish have also undergone shifts in distribution, diet, and density dependence that have contributed to the gradual and sustained decline in abundance (Pothoven and Madenjian, 2008; Riley and Adams, 2010; Pothoven and Madenjian, 2013; Rennie et al., 2015; Gobin et al., 2016; Fera et al., 2017). Although the specific mechanisms responsible for the lower recruitment levels have not been identified, several agencies (USFWS, USGS, NDMNRF, MDNR) have begun to develop monitoring programs to document where recruitment is or is not occurring.

Lake Trout – The status of Lake Trout in Lake Huron is 'Fair' and the trend is 'Improving' according to recent assessments (ECCC and EPA, 2022). Other than Lake Superior, Lake Trout recovery is the most pronounced in Lake Huron, where substantial progress toward Lake Trout rehabilitation is evident in the main basin and North Channel (Lenart et al., 2020). The abundance of wild Lake Trout continues to increase, while recruitment to fisheries and overall abundance of hatchery Lake Trout has continued to decline (ECCC and EPA, 2022). Rehabilitation of Lake Trout continues to lag in Georgian Bay compared to other parts of the lake. Improvements in the status of Lake Trout are the culmination of numerous factors ranging from changes in management approaches to broad ecological changes in Lake Huron. Sea Lamprey induced mortality has declined (Madenjian et al., 2008; He et al., 2012) in response to enhanced Sea Lamprey control on the St. Marys River (Morse et al., 2003). The effect of Lake Trout strain stocked has emerged as an important determinant of survival to adulthood and subsequent natural reproduction. The Seneca Lake strain, originating from outside of the Great Lakes, has outperformed a suite of native Great Lakes strains of Lake Trout (Scribner et al., 2018). The observation that the survival rate of stocked Lake Trout of all strains continues to decline (He et al., 2012) has also prompted management agencies to reduce stocking rates and rely on naturally recruited Lake Trout to support rehabilitation efforts. The ongoing and consistent levels of natural reproduction may also be partially due to the lack of Alewife in the lake and the increase in thiamine levels in Lake Trout eggs (Riley et al., 2011). The distribution of favorable spawning habitat may also be influencing the occurrence of successful natural reproduction with most reproduction occurring in the northern part of the main basin where there is a large concentration of favorable spawning habitat (Riley et al., 2014). Signs of rehabilitation are encouraging but are tempered by the observation that progress is not occurring throughout the lake. Continued restoration and monitoring efforts are required particularly as it relates to issues such as maintaining exploitation levels at sustainable levels and recognizing that reduced productivity in offshore waters may mean that composition and abundance of prey will influence Lake Trout growth and recruitment, so continued monitoring of predator-prey dynamics should remain a priority (Lenart et al., 2020).

Lake Trout populations in the Northern Main basin tend to consist of smaller, younger, wild origin fish compared to the populations in the Southern Main basin. The dynamics of fish movement and recruitment between the Northern and Southern Main basins are not well understood despite implications for the lakewide management of the species. Less progress toward rehabilitation has been observed in Georgian Bay, and populations there remain largely dependent on stocking to maintain current levels (GLFC, 2013; SORR, 2010).

Lake Sturgeon – Lake Sturgeon are a culturally significant native species to Indigenous people of the Great Lakes region and were once abundant. Initially, European settlers found lake sturgeon to be a nuisance species but eventually utilized the fish as a commercial resource (ECCC and EPA, 2019). The practice of over-harvesting in combination with dam construction, preventing them from reaching their spawning grounds, led to the impacts, including population declines, on Lake Sturgeon. The status in Lake Huron is considered 'Poor' and the 10-year trend is 'Improving' (ECCC and EPA, 2022). The population structure of Lake Sturgeon is rated as 'Poor' (natural reproduction is being observed in only 8 of 33 Lake Huron tributaries where spawning historically occurred) except where consistent spawning occurs in three streams of the North Channel, the Nottawasaga River, and the mouth of the St. Clair River (Franks Taylor et al., 2010; Chiotti et al., 2013). The trend is improving as a result of stocking programs in areas like the Saginaw River watershed, and increased encounters are being reported in both the fishery and fishery-independent surveys there. Similarly, an increase in catch per unit effort of juvenile Lake Sturgeon from fishery independent survey gear in the St. Marys River, and improved river connectivity have contributed to the increasing trend in Lake Sturgeon. Spawning activity has been observed in new locations in recent years, including the Moon and Musquash Rivers in eastern Georgian Bay and the Manitou River on Manitoulin Island. Stream-side hatcheries and stocking have been initiated to help restore Sturgeon populations in the U.S.

Walleye – Walleye populations are in 'Good' condition with a 10-year trend of 'Unchanging' (ECCC and EPA, 2022). This assessment is primarily restricted to Saginaw Bay, where recovery targets were met in 2009, and to the southern main basin of the lake, as opposed to a majority of populations in Ontario waters where the status is more variable (Fielder et al., 2020). Saginaw Bay contains the largest Walleye stock in Lake Huron (ECCC and EPA, 2022). Its recovery was aided by stocking and ecosystem changes that led to the decline of non-native prey fish such as Alewife. Reef construction in Saginaw Bay and tributaries draining into eastern Georgian Bay are expected to also benefit this species.

Grayling – Arctic Grayling historically occupied most cold-water streams throughout Michigan's Lower Peninsula and a small number of streams in the western Upper Peninsula. The now extirpated species was also predominant within Michigan's Lake Huron tributaries (Hubs and Lagler, 1985, as cited in Roseman et al., 2009). Efforts to restore this species have begun under a large collaboration of governmental and non-governmental entities, primarily Michigan DNR, Little River Band of Ottawa Indians, Michigan Tech University, and many others. This collaboration has been dubbed "Michigan's Arctic Grayling Initiative," and most of these efforts are focused in the Lake Michigan basin. However, the Little Traverse Bay Bands of Odawa Indians has already undertaken habitat and fish community surveys in the Maple River of Lake Huron's upper watershed in 2020 with the intention to re-introduce Grayling into the Lake Huron basin.

What is the threat and other considerations for taking action?

Protective actions are necessary to maintain good quality habitats in the Lake Huron ecosystem. The Great Lakes Fishery Commission's Environmental Objectives for Lake Huron (Liskauskas et al. 2007) and the Lake Huron Biodiversity Conservation Strategy (Franks Taylor et al., 2010) identified chemical contaminants, disrupted nutrient cycle, loss and degradation of habitat and native species, non-native invasive species, and climate change as critical threats to biological diversity. Examples of how some of these threats are being addressed can be found in the most recent GLFC *State of Lake Huron* report (Liskauskas et al., 2020). These threats impede the full achievement of the General Objective to "support healthy and productive wetlands and other habitat to sustain resilient populations of native species". The GLFC supported the development of environmental priorities for each of the Great Lakes including Lake Huron to address aquatic habitat impediments to achieving Fish Community Objectives. The Lake Huron Committee recently approved environmental priorities for Lake Huron that focused on habitat features including dams, reefs, coastal wetlands and streams (http://www.glfc.org/pubs/lake_committees/huron/Lake%20Huron%20Committee%20Environmental%20Priorities%202021.pdf). Further details on threats that include *Chemical Contaminant Pollution*, *Nutrient and Bacterial Pollution*, and *Invasive Species* are covered in other "state of" chapters in this document.

Shoreline development as well as dams and barriers are two additional management challenges. Shoreline development, hardening, and the construction of groynes, dredging and infilling are widespread. These practices have destroyed or degraded coastal wetlands and other nearshore habitat negatively impacting native fish species (Dodd and Smith, 2003; Franks Taylor et al., 2010; Leblanc et al., 2014). Dams and hydropower facilities and other barriers have reduced stream connectivity and altered in-stream flow, temperature, and stream habitat (Gebhardt et al., 2005; Franks Taylor et al., 2010). As a result of these dams and barriers, only 30% of the naturally unobstructed stream habitat remains connected to Lake Huron. (unpublished data, The Nature Conservancy et al., 2017).

Protection is necessary – Protective actions are necessary to maintain good quality habitats in the Lake Huron ecosystem. Lake Huron islands, coastal wetlands and coastal terrestrial systems are in good condition, owing primarily to the comparatively intact nature of these ecosystems in northern Lake Huron but also to the persistence of these ecosystems (even in a degraded condition) in many parts of southern Lake Huron. (Franks Taylor et al*.,* 2010). At the same time, the overall threat rank for Lake Huron is 'Very high'. The high-quality habitats of the Lake Huron basin should remain so given the need for representative, functional habitats that can act as refugia from changing land use and climate. However, protective habitat management should be balanced with habitat restoration as part of integrated resource management programs. The implications of failing to protect the health and sustainability of Lake Huron ecosystems are substantial, as witnessed by the multi-generational efforts and investments being made to restore beneficial uses in the Great Lakes Areas of Concern and other degraded areas.

Significance to Indigenous Peoples – The *nibi* (waters), *giigoonh* (fish), plants and wildlife in the Lake Huron basin continue to provide a sense of identity and continuity with traditional ways of life. All plant and animal life are culturally significant to Indigenous people. Some of the most well-known examples of animal beings are migizi (bald eagle), *ma'iingan* (wolf), *na'me* (Lake Sturgeon), and *ogaa* (Walleye). Well-known examples of plant beings include manoomin (wild rice), *mashkiigobagwaaboo* (labrador tea), *wiigwassi-mitig* (paper birch), *baapaagimaak* (black ash) and *giizhik* (cedar). Indigenous peoples continue to rely on subsistence harvesting practices throughout the basin to sustain their communities and their culture. Management decisions regarding native species and habitats benefit from indigenous values, traditional ecological knowledge, and respecting treaty resources. Refer to Chapter 2.2, Indigenous peoples, for the more information.

Regional considerations — Degradation and loss of habitat in tributaries, near shore areas, and coastal wetlands are major stressors throughout Lake Huron; however, the Lake Huron basin still exhibits a high level of biological and geophysical diversity that supports productive aquatic habitat and native species.

Large scale wetland loss has not occurred in the North Channel and eastern Georgian Bay to the extent of southern regions, mostly due to sparse human population and the irregular and, in some cases, remote shoreline of the northern coast. Wetland loss and degradation continue to occur in developed areas, adjacent to high road density and near cottage development. Invasive species continue to spread northward. The table below describes the varying challenges across different regions on Lake Huron.

Table 9: Habitat and species related issues in the regions of Lake Huron

Lake Huron Regions	Habitat and Species Related Issues
Main Basin	• Non-native invasive dreissenid mussels in the nearshore and offshore are taking nutrients from the water column and moving them to the benthic zone of the lake • Low nutrient levels in the offshore waters impacting food web dynamics • Enriched nutrient levels in nearshore waters (associated with tributary discharges) impacting food web dynamics • The abundance of *Diporeia* has drastically declined in offshore waters. The cause is unknown • Barriers to tributary habitats
St. Marys River	• Shoreline development and alteration • Altered flow regime of the St. Marys River and watershed streams due to agriculture, deforestation, urban development, drainage, channelization, dams and barriers • Erosion and water turbulence from shipping traffic • Historic loss of rapids habitat due to navigational structures requires remedial action (additional project planned for Canadian waters of the river) • Historic wetland loss, including wild rice habitat.
North Channel / Manitoulin Island	• *Phragmites* continues to spread northward to the North Channel and Manitoulin Island • Non-point sources of sediment and excess nutrients cause algal blooms degrading habitat • Stream habitat fragmentation and altered hydrological flow due to dams and barriers

Lake Huron Regions	Habitat and Species Related Issues
	• Historic wetland loss, including wild rice habitat.
Georgian Bay	• Stream habitat fragmentation and altered hydrological flow due to dams and barriers • Parry Sound, Severn Sound, Nottawasaga Bay experience population growth, shoreline development pressure, intense recreational use, historic and present industrial activities with wetland and island habitat impacts • Shoreline development and alteration (including shoreline hardening) • Eastern and southern Georgian Bay vulnerable to shoreline alteration under sustained low water levels; ranging from rock blasting to extensive nearshore dredging (> 30 cuts/km) • Southern Georgian Bay: non-point sources of pollution mostly in the agricultural south • *Phragmites* spread to coastal wetlands and river mouths of southern and eastern Georgian Bay
Ontario's Southeastern Shores	• Stream and nearshore water quality impacts on aquatic habitat due to non-point source pollution from dense agricultural sector • Stream habitat fragmentation due to dams and barriers • Shoreline development and alteration (including shoreline hardening) • Continued loss and degradation of coastal wetlands • Dense stands of *Phragmites* continue to spread northward
Saginaw Bay	• Stormwater runoff from urban areas and dense agricultural activity with impacts to stream and nearshore habitats • Wetland loss and degradation; areas of native wetland have been replaced by *Phragmites* • Stream habitat fragmentation due to dams and barriers • Loss of offshore reef spawning habitat
Michigan's Western Shores	• Wetland loss and degradation • Non-point sources of pollution • Shoreline development and alteration (including shoreline hardening) • Stream habitat fragmentation due to dams and barriers • Loss of offshore reef spawning habitat

5.3.3 Loss of Habitat and Species: Climate Change Impacts

Climate change impacts are expected to alter the physical, chemical, and biological integrity of Lake Huron. For the period 1985-2016 relative to 1901-1960, annually averaged temperature in the Great Lakes basin increased 1.6 degrees Fahrenheit (0.9 degrees Celsius) (Wuebbles et al., 2019). Average annual ice coverage on the Great Lakes declined 72% between 1973 and 2010, and the average number of snow days decreased more than 15 days since 1975. Figure 8 shows historic annual ice cover on Lake Huron. These trends are expected to continue along with changes in the frequency of intense storms, extreme flow and discharge rates in Great Lakes tributaries, extended droughts and heat waves, and fluctuating lake water levels. The effects of climate change will impact aquatic habitat and species in multiple ways including shifts in spawning locations and times, northern migration of boreal plant species and cold-water species, changes in the thermocline depth and timing that results in temporal shifts in nutrient cycling and spring blooms, and changes to plant phenology. Ongoing study of the effects of climate change on Great Lakes aquatic ecosystems is essential to allow for development of adaptation and mitigation strategies to protect vulnerable habitat and species.

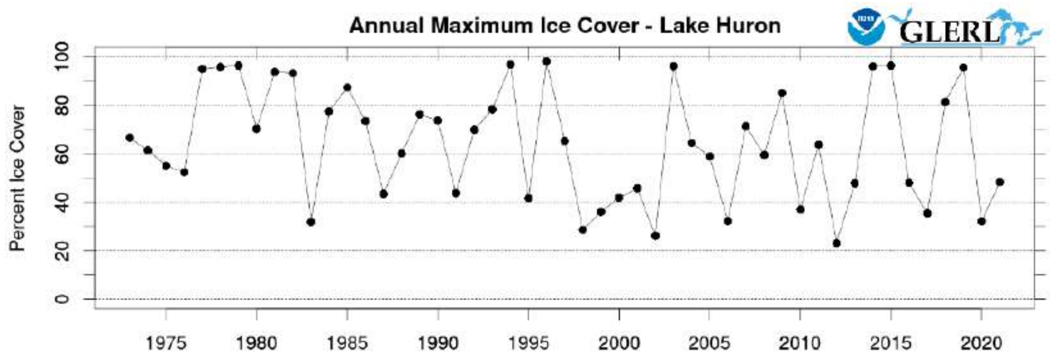


Figure 8: Annual maximum ice cover on Lake Huron, 1975-2020 (NOAA, 2022).

An aquatic-riparian vulnerability assessment conducted by USGS for the Midwest found that a number of watersheds in southeast Michigan are likely the most vulnerable to climate change, of those on the U.S. side of the Lake Huron basin (Delaney, et al., 2021). In 2016, a climate change vulnerability assessment of specific resources was completed by the Inter-Tribal Council of Michigan, including over 100 tribally-important species across jurisdictional boundaries to benefit Tribal Nations in Michigan as they face a changing climate. According to this assessment, Lake Sturgeon are highly vulnerable to climate change, as are black ash and both wild rice species (ITCMI, 2016). Perch, bass, and smelt, however, scored low vulnerability to climate change. Refer to Appendix C for the vulnerability rankings of all the assessed species.

Through the Great Lakes Protection Initiative, an ECCC project, entitled *Assessing and Enhancing the Resilience of Great Lakes Coastal Wetlands* (2017 – 2022) used spatially explicit models to predict the effect of climate change on future wetland availability. The results from ECCC's climate modelling will be used to forecast the exposure of coastal wetlands to the changes in regional hydro-climatic variables including wind, waves and water levels. Section 5.7 of a recent Environmental Law and Policy Center's 2019 report, titled "An Assessment of the Impacts of Climate Change on the Great Lakes," discusses the anticipated impacts on Lake Huron's coastal processes. Hard rock shorelines, such as those within the Niagara Escarpment in northern Lake Huron, will be minimally impacted by climate change over the next 100 years, whereas many shoreline types along southern Lake Huron, including soft rock bluffs, clay, glacial till, sandy beach, and dune coasts, may be greatly damaged through greater changes in wave action and water levels (ELPC 2019). The influence these changes may have on the structure and function of coastal wetlands will be examined by integrating georeferenced physical and ecological data into a modelling platform (see Figure 9). Annual predictions on the size and composition of twenty coastal wetlands across the Great Lakes Region will then be generated, including seven locations in Lake Huron and the St. Marys River.

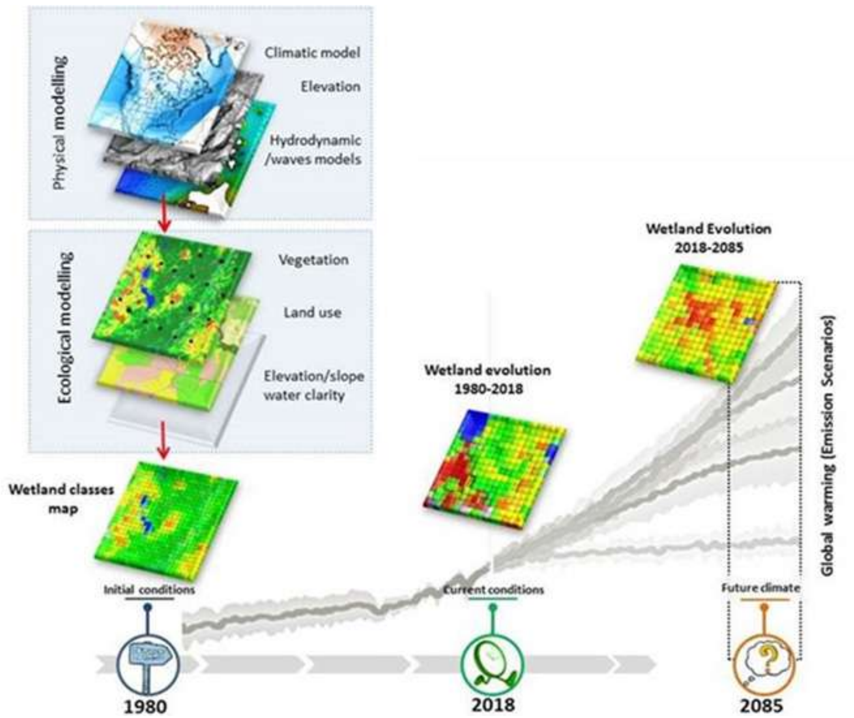


Figure 9: ECCC's Coastal Wetland Response Model (CWRM) integrates physical and ecological into a continuous data platform, which will be used to forecast the composition of Great Lakes coastal wetlands when exposed to changes in hydro-climatic variables.

5.3.4 Actions to Protect and Restore Habitat and Species

The Lake Huron Partnership agencies will implement the 2022-2026 *LAMP* within the context of existing laws and regulations which contribute to the restoration and protection of Lake Huron. Federal, state, and provincial legislation that protect and restore habitat and species are listed in Appendix B. This legislation includes the Canada National Marine Conservation Areas Act (2002) and the U.S. Endangered Species Act (1973).

Other contributing national and regional plans and initiatives are described below.

In 2010, the former Lake Huron Binational Partnership built on numerous strategies to complete *The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron* (Franks Taylor et al., 2010). This involved a two-year consultation period with more than 300 individuals representing approximately 100 agencies, Tribal, First Nations and Métis governments, conservation authorities, non-government organizations and universities. The Strategy discusses ecological condition, identifies key threats to biodiversity, prioritizes conservation action sites, and recommends 21 conservation strategies for Lake Huron. For more information, go to: https://www.conservationgateway.org.

Numerous other binational, regional, and place-based plans and ecological assessments have been developed or are ongoing to identify threats, recommend conservation action, and implement restoration projects. Some examples include the following:

- The Great Lakes Fishery Commission's Lake Huron Technical Committee works across borders to implement fisheries management plans, report on the fishery, and develop Fish Community Goals and Environmental Objectives (Liskauskas et al., 2007; Riley and Ebener, 2020). More recently, the commission has been compiling a list of "Functional Habitats" for Lake Huron and scoring their condition and status to help guide protection and restoration;
- GLFC lake committee environmental priorities are completed and they are posted here;
- The State of the Lakes Ecosystem Conference 1998 Biodiversity Investment Areas for Aquatic Ecosystems (Koonce et al., 1999);
- Michigan Department of Natural Resources Watershed Assessment Reports;
- Ontario Conservation Authorities Watershed Assessment Reports; and
- Conservation Authority Watershed Report Cards

Since the last Lake Huron CSMI year in 2017, efforts have focused on describing the current spatial configuration, extent and understanding of the ecological processes of the habitats found in the Lake Huron basin. The identification of functional habitats (dynamic systems of hydraulically connected areas that support requirements of desired fish species for sustained production) is critical to identifying where environmental improvement can be enhanced (GLFC, 2016). Finer scale resolution of energy and nutrient flow pathways are needed, especially in areas identified as priority functional habitats for fish (GLFC, 2016; SOLH, 2018; Riley and Ebener, 2020).

The current status of the Lake Huron native fish community highlights a need for more information regarding large-scale fish movements, prey fish biomass estimates, and the early life history of Coregonids. Fish movements and habitat use at lake-wide spatial scales are unknown for many commercially- and ecologically-important fish species. Documenting and evaluating fish movements within the lake would allow managers to make better informed decisions regarding harvest and other population restoration activities.

Coastal wetlands in the Lake Huron basin have been characterized as some of the most abundant and highest quality in all the Great Lakes, but gauging the health of these wetlands is challenging, especially during substantial changes in lake levels observed over the past decade. Wetlands are dynamic systems, and high-water levels may shrink their overall spatial extent due to increased water depths and gradients found near shorelines. Monitoring of coastal wetlands is needed to assess coastal wetland water quality, species diversity, and the impacts of human activities.

Lake Whitefish support the largest and most economically-valuable fishery in Lake Huron, but Whitefish abundance and harvest have declined significantly over the past decade. Declining abundance has been linked to poor recruitment from the larval to the juvenile stage, but studies of recruitment dynamics within individual populations have yet to show that larval growth and survival are consistently related to specific physical and biological conditions. Comparison of the ecology and survival of Whitefish larvae among multiple sites with varying physical and biological conditions could help fishery managers better understand potential recruitment bottlenecks for Lake Whitefish.

Existing Initiatives

Environmental legislation and corresponding regulations listed in Appendix B are contributing to the protection of habitat and species. Other contributing national and regional plans and initiatives include are described below.

A Joint Strategic Plan for Management of Great Lakes Fisheries (GLFC, 2007) provides a framework for common fishery management and mandates the development of lakewide Fish Community Objectives.

The GLFC Environmental Principles for Sustainable Fisheries in the Great Lakes Basin (GLFC, 2016) and subsequent Environmental Priorities for Lake Huron approved by the Lake Huron Committee (GLFC, 2021) provide clear actions and commitments to improve habitat conditions for fish populations.

Protected areas including those displayed in Figure 3 in Chapter 3 (protected and conserved areas) form the cornerstone of habitat and species conservation, but also conserve ecosystem services and provide “natural solutions” by:

- Sequestering and storing vast amounts of carbon in forests, wetlands and other natural ecosystems;
- Serving as a safe haven for species as climatic conditions shift. Networks of protected areas can facilitate species movement and connectivity, increasing ecosystem resilience and adaptive capacity;
- Helping to clean water, mitigate floods and prevent erosion through harbouring intact natural ecosystems, such as wetlands and forested riparian areas
- Preventing biodiversity loss; and
- Serving as a benchmark for research and monitoring, and demonstrating evidence-based planning and management.

The Nature Conservancy of Canada has purchased most of Cockburn Island east of Manitoulin Island and Vidal Bay (7,284 hectares or 18,000 acres) on Manitoulin Island. These areas have become permanently protected wilderness and are one of the most significant transfers of Canadian private land for conservation in decades. The Canada Nature Fund and the Georgian Bay Land Trust agreed to a conservation easement agreement to protect 2185 hectares (5,400 acres) of wilderness on the eastern coast of Georgian Bay. The Tadenac Conservation Initiative preserves a regional biodiversity hotspot. The eastern Georgian Bay region is globally recognized for its unique habitat, which supports the largest diversity of reptile and amphibian species in Canada. Also as part of The Canada Nature Fund, the Georgian Bay Biosphere was nominated as a community priority place for species at risk. The Biosphere Reserve and co-applicants, including Shawanaga First Nation, Magnetawan First Nation and Georgian Bay Land Trust, received funds to work with partners to gather data and plan and implement actions to address threats to biodiversity, such as roads and railroads, invasive plants and climate change. The project will benefit 46 listed species at risk, including the Blanding’s Turtle and the Massasauga Rattlesnake, as well as six species not yet listed. The project will cover 347,000 hectares (857,456 acres) in the Eastern Georgian Bay region of Ontario, which runs along the eastern coast of Georgian Bay from Severn Sound to the French River.

Climate change adaptation resources include:

- Canada’s Federal Adaptation Policy Framework for climate change
- Environment and Climate Change Canada. 2021. Adapting to Climate Change: Solutions to Enhance Great Lakes Coastal Wetland Resilience. Mayne, G., Hazen, S., Milner, G., Rivers, P., MacMillan, K., Zuzek, P. and Mortsch, L. 144 p.
- Dibaginjigaadeg Anishinaabe Ezhitwaad: A Tribal Climate Menu
- Climate Change Response Framework Adaptation Strategies and Approaches
    - Forests
    - Forested watersheds
    - Non-forested wetlands
    - Coastal ecosystem
- Federation of Canadian Municipalities (FCM)’s Municipalities for Climate Innovation Program
- Pan-Canadian Framework on Clean Growth and Climate Change

Additional habitat and species strategies relevant to the Lake Huron basin include the following:

- Canada's Nature Fund
- Canada's Climate Action and Awareness Fund
- Canadian Species at Risk strategies and plans
- Ontario Species at Risk recovery strategies
- A Made-in-Ontario Environment Plan
- Michigan's Wildlife Action Plan
- Great Lakes Basin Fish Habitat Partnership Strategic Plan
- U.S. Endangered Species recovery plans
- U.S. Great Lakes Restoration Initiative
- USFWS's Great Lakes Coastal Program

LAMP Actions

Actions will be taken in the Lake Huron basin to further protect and restore habitats and species and to track process through science and monitoring as listed in Table 10.

Table 10: Actions to Protect and Restore Habitat and Species

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	Actions to Protect and Restore Habitat and Species	
20	Support climate change initiatives, projects and adaptation planning that increases the resilience of the Lake Huron ecosystem's habitats and native species.	LTBB, MECP, MDNR, ECCC, EPA, CORA, BMIC, SCIT, USFWS, PC, SSEA
21	**Aquatic Habitat Protection and Restoration:** Assess streams, estuaries, spawning reefs and shoals to determine aquatic habitat significance, stressors, and limitations to fish spawning and migration, and consult with local partners, stakeholders, and governments to identify protection and restoration priorities, including but not limited to: a. Assessment of Eastern Georgian Bay estuaries and Cheboygan River watershed; implementation of any subsequent protection and restoration actions. b. Assessment and restoration of aquatic habitat at Whitefish Island in the St. Marys River Area of Concern. c. Assessment and restoration of riparian habitats throughout the Lake Huron watershed through invasive species control, installation of large woody debris, and native plantings that control erosion and promote diversity, ecological function, and climate change resilience. d. Reef restoration efforts within Lake Huron including Saginaw Bay. e. Implementation of projects to restore a more natural flow regime in the St. Marys River.	LTBB, SCIT, MDNR, EGLE, ECCC, NDMNRF, DFO, USFWS, EPA, CORA, BMIC, USGS, USDA-FS
22	**Stream Connectivity:** Restore stream connectivity and function through dam removal, the construction of fish passage alternatives (e.g., ladders), and stream culvert improvements to increase accessible riverine habitat for migrating fish. a. Cold-water fishes and streams: Support the protection and enhancement of cold-water fishes. b. Create and enhance connectivity and cold-water refuges where appropriate to maintain appropriate habitat conditions for aquatic organisms.	LTBB, MDNR, EGLE, Conservation Authorities, USFWS, EPA, CORA, BMIC, USGS, NOAA, NDMNRF, USACE, USDA-NRCS, USDA-FS, SSEA
23	**Habitat and Native Species Conservation:** Implement recommendations in *The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron* through integrated conservation planning to identify areas of ecological significance and areas facing environmental threats and stressors:	MDNR, EGLE, EPA, USFWS, CORA, BMIC, LRBOI, SCIT, USGS, MECP, ECCC, Conservation Authorities, PC,

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	a. Update and share Canadian geospatial information on ecosystem classification. b. Engage stakeholders and the public. c. Facilitate information sharing. d. Develop regional conservation and stewardship plans (Ontario). e. Promote community-based conservation and stewardship. f. In appropriate areas as identified, restore and protect pollinator habitat and species. g. In appropriate areas as identified, restore and protect Lake Huron Islands, particularly unique habitats and globally rare and endemic species. h. Identify, inventory and map important native habitat sites in the Lake Huron basin. i. Protect and restore habitat for native species.	DFO, NDMNRF, USDA-NRCS, USDA-FS, SSEA
24	**Native Fish Species Restoration:** a. Walleye Restoration: Continue to implement a Walleye Management Plan for the Ontario waters of Lake Huron and track the effectiveness of harvest regulations throughout Lake Huron. b. Implement, monitor, and track the effectiveness of Arctic Grayling restoration. c. Implement, monitor, and track the effectiveness of Lake Sturgeon restoration. d. Continue to develop Lake Trout monitoring and restoration/rehabilitation plans. e. Continue Coregonid management, monitoring, and restoration.	LTBB, MDNR, BMIC, NDMNRF, USFWS, EGLE, LRBOI, CORA, USGS, NOAA, DFO
25	**Coastal Wetlands:** Monitor coastal wetlands to assess water quality, species diversity, impacts of human activities, and flora and fauna conditions; a. Promote protection, restoration, and enhancement efforts. b. Support nature-based solutions to improve the resilience of Great Lakes shorelines. c. Apply new decision support tools to help identify and prioritize coastal wetland restoration projects. d. Evaluate and support opportunities to convert agricultural land back to coastal and riparian wetlands.	SCIT, ECCC, BMIC, ECCC, EPA, EGLE, NOAA, USGS, USDA-FS, USFWS, NRCS, Conservation Authorities, NDMNRF, PC, USACE, SSEA
26	Protect and restore habitats including coastal wetlands, inland wetlands, riparian areas and other significant terrestrial habitats	MDNR, EGLE, ECCC, EPA, NOAA, USGS, USDA-FS,

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	through conservation easements, land acquisitions and/or other means to strengthen ecosystem resilience.	USFWS, NRCS, NDMNRF
27	**Manoomin (Wild Rice):** Restore and protect manoomin (wild rice) habitat including, but not limited to, the following areas: a. Cheboygan River watershed b. Tawas Lake c. Thunder Bay River watershed including Fletcher Pond d. St. Marys River e. Les Cheneaux Islands archipelago f. Eastern Georgian Bay g. North Channel and Manitoulin Island area	LTBB, SCIT, MDNR, EGLE, NOAA, BMIC, CORA, LRBOI
28	Improve quantification and biomass estimates of food web components (e.g., macroalgae, zooplankton, benthic macroinvertebrates, including dreissenid mussels) and fish production and distribution (including the Round Goby). Conduct broader spatial sampling of pelagic invertebrates (i.e., zooplankton) in the nearshore, inclusive of Georgian Bay, the North Channel, Saginaw Bay, and the nearshore areas of both the southern and northern main basins, including areas with rocky and other hard substrates. Also include winter ecology/under ice limnology in sampling.	MDNR, BMIC, NDMNRF, USGS, NOAA, USFWS, EPA, EGLE
29	Continue lakewide assessment of primary production, including seasonal and spatial distribution. a. Focus on spring bloom conditions. b. Consider possible implications for larval fish bottlenecks at locations throughout the Lake Huron basin.	MDNR, ECCC, NDMNRF, USGS, BMIC, EGLE, EPA, USGS
30	Characterize benthos population trends in the North Channel to better understand the decline in the benthic community.	ECCC, NDMNRF
31	Improve understanding of the physical, chemical, and biological processes in specific ecological zones (inshore, nearshore, and offshore), including the status of coastal wetlands, to guide management actions in the future.	ECCC, NDMNRF, EPA, EGLE, NOAA, USGS, USFWS
32	Engage with the public and landowners on the importance of the Lake Huron ecosystem's habitats and species including restoring degraded and protecting high-quality areas and mitigating the impacts of climate change. a. Support citizen science opportunities.	BMIC, ECCC, EPA, EGLE, USACE, NOAA, USGS, USFWS, USDA-FS, SCIT, CORA, PC, NDMNRF, MDNR, LRBOI, LTBB, SSEA

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	b. Create “Important Habitat” map for outreach, engagement, protection, restoration, monitoring, and assessment efforts	

**Acronyms for agencies not listed as Lake Huron Partnership agencies on page iv are: Michigan Department of Health and Human Services (MDHHS); Transport Canada (TC).*

Actions Everyone Can Take

Here are some ways that you can do your part:

- Maintain natural vegetation along the coast and streams.
- Resist the urge to “tidy up” the beach; natural vegetation and debris serve as habitat.
- Plant native trees and shrubs on your property.
- Get involved with shoreline clean up events.
- Consider working with neighbours, not-for-profit organizations and municipalities to restore beach-dune health by installing sand fencing and planting dune grasses.
- Stay on constructed beach and dune paths and avoid trampling the sparse and fragile vegetation in these areas.
- Support and/or volunteer with local conservation authorities, stewardship councils and non-governmental environmental organizations.
- Access shoreline stewardship guides for advice, see https://www.lakehuron.ca/stewardship-plans-and-guides.
- Share your knowledge with your friends, neighbours, cottage renters or even strangers, about the rarity and ecological importance of each of the special shoreline types.

5.4 Invasive Species

This section summarizes the scientific information about Lake Huron’s invasive species, current threats, and corresponding actions to be taken by Lake Huron Partnership agencies in the 2022-2026 timeframe, as well as actions that everyone can take. The science is organized in response to one invasive species-related General Objective of the *Great Lakes Water Quality Agreement.*

5.4.1 Objectives and Condition Overview

One of nine General Objectives of the Agreement is addressed in this section:

- Be free from adverse impacts of aquatic and terrestrial invasive species

For the purposes of this chapter, “invasive species” refers to a subset of non-native species that are known to be causing adverse impacts to the ecosystem, recreation, and/or the economy. In addition, information on non-native species is also presented in this chapter because the potential adverse impacts of some non-native species are not currently known. Lake Huron has experienced aquatic flora and fauna invasions since at least the time of European settlement. The rate of introductions increased during the 19th and 20th centuries but has slowed in recent decades.

Please note that not everyone defines species as “native, non-native and invasive”. Some people, including many Anishinaabe recognize that living beings move and migrate, and these migrations are not inherently good or bad (Reo and Ogden, 2018). From this perspective, and recognizing that all creation has purpose, the species described in this chapter would be defined either as non-local beings or Zhaagoojichigaadeng Meyagi-bimaadiziimagak, translated to ‘being overtaken by foreign living things’. Individuals with this perspective seek to learn about non-local beings, and how they could possibly co-exist to achieve a healthy and sustainable environment.

The status and trends of sub-indicators for the invasive species General Objective in relation to Lake Huron are displayed in Table 11.

Aquatic invasive species, such as Zebra and Quagga Mussels, Round Gobies, and Sea Lamprey as well as terrestrial invasive species, such as Emerald Ash Borer and Garlic Mustard, continue to impact water quality, nutrient cycling and limit the productivity of Lake Huron. They restructure the food web and habitat resulting in limited production of some portions of the fishery that are recreationally and commercially important. Aquatic and terrestrial invasive species impact Lake Huron water quality by disrupting chemical, physical and biological processes in the ecosystem including upstream terrestrial watersheds. They also directly compete with native species for food and habitat.

5.4.2 Invasive Species

***GLWQA* General Objective:** *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.

How are they monitored?

Newly introduced, established, and potentially invasive species are monitored by a variety of organizations including local, state, provincial and federal agencies, First Nations, Tribal Nations, non-governmental organizations, industries, and academic institutions. The public is also playing an increasingly important role in invasive species surveillance. Monitoring and assessing the impacts of invasive species is challenging due to the size of Lake Huron and its watershed. With the exception of a few species, comprehensive lakewide assessments of invasive species do not exist.

Aquatic Invasive Species: Targeted early detection monitoring programs for novel species are conducted by the Fisheries and Oceans Canada (DFO), Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF), and U. S. Fish and Wildlife Service (USFWS). There are ongoing targeted monitoring programs for existing species including Sea Lamprey and Zebra and Quagga mussels (or dreissenid mussels). Adult Sea Lamprey status is measured annually by the Sea Lamprey Control Program of the Great Lakes Fishery Commission and is conducted by the USFWS, DFO, and cooperative partners. The population size of invasive dreissenid mussels is estimated on a five-year cycle through a multi-agency sampling effort. The binational “Early Detection and Rapid Response Initiative”, established by experts working under Annex 6 of the Agreement, is now monitoring additional locations in Lake Huron that are potential points of invasion by new aquatic invasive species. This effort is conducted by DFO and USFWS through partnerships with Sault Ste. Marie Tribe of Chippewa Indians and NDMNRF. This monitoring includes environmental DNA (eDNA), a surveillance tool used to monitor for the genetic signature of an aquatic species in the ecosystem. New AIS reports and existing AIS distributions are tracked in several ways, including the regional GLANSIS database which is a regional node of the National USGS Nonindigenous Aquatic Species database, EDDMaps Midwest formerly the Great Lakes Early Detection Network, and the Midwest Invasive Species Information Network. Data and information are shared among these systems.

Lake Huron agency representatives participate in multi-agency, binational coordination meetings including the Great Lakes Panel on Aquatic Nuisance Species (ANS) and AIS early detection rapid response and surveillance. Invasive sightings can be reported online in the U.S. at the USGS Nonindigenous Aquatic Species (NAS) website (https://nas.er.usgs.gov/) or in Canada at http://www.invadingspecies.com/. Information about aquatic invasive species is available at the Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS, https://www.glerl.noaa.gov/glansis/).

Terrestrial Invasive Species: Due to the variety of different governmental jurisdictions and the mix of public and private land ownership, there is no single method for assessing the location and spread of terrestrial invasive species in the Lake Huron watershed. Some plants classified as terrestrial in this *LAMP*, such as *Phragmites* and Purple Loosestrife (*Lythrum salicaria)*, also occur in wetland areas and are classified as aquatic plants in some databases.

Land managers and the public can voluntarily report sightings and share information on terrestrial invasive species distributions via the Midwest Invasive Species Network (MISIN) and the Early Detection and Distribution Mapping System (EDDMapS) hotline maintained by the Ontario Federation of Anglers and Hunters (OFAH) and Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF). Reporting can also be done online or via a phone app. MISIN and EDDMapS provide spatial data that helps track the spread of terrestrial invasive species, including Emerald Ash Borer (*Agrilus planipennis*), Asian Longhorned Beetle (*Anoplophora glabripennis*), European Buckthorn (*Rhamnus cathartica*), Garlic Mustard (*Alliaria petiolate*), *Phragmites*, invasive knotweeds and Purple Loosestrife.

Additionally, there are a number of species-specific efforts underway, including the United States Department of Agriculture Forest Service and Michigan State University's Emerald Ash Borer Information Network website, which includes monthly updates on the confirmed locations for this species in the U.S. and Canada. The USDA Forest Service and Michigan State University maintain the Emerald Ash Borer Information Network website, which includes monthly updates on the confirmed locations for this species in the U.S. and Canada: http://www.emeraldashborer.info/about-eab.php

What is the condition?

There are now over 187 non-indigenous species that have become established within Lake Huron (ECCC and EPA, 2022). Several of these are causing both direct and indirect impacts to the ecology and water quality. Limited information is available on the impact of terrestrial invasive species, but land managers are concerned by the presence of species in the watershed that are known to cause water quality impacts. The status and trend of invasive species sub-indicators for Lake Huron are displayed in Table 11.

Table 11: Status and trends of invasive species sub-indicators in the Lake Huron basin. Source: State of the Great Lakes report (ECCC and EPA, 2022)

Sub-Indicator	Status - Trend
Rate of New Aquatic Non-indigenous Species (ANS) Establishment in the Great Lakes	Poor - Undetermined
Establishment of Aquatic Non-Indigenous Species from Outside of the Great Lakes basin	Good - Undetermined
Interbasin spread into Lake Huron basin	Poor - Undetermined
Impacts of Aquatic Invasive Species	Poor – Undetermined
Sea Lamprey	Fair – Improving
Dreissenid Mussels	Poor – Deteriorating
Terrestrial Invasive Species	Undetermined

Aquatic Invasive Species: Lake Huron is significantly impacted by invasive species. The 2022 SOGL report assesses the issue of invasive species in terms of the rate of new introductions to the Great Lakes basin, the rate of introductions between the Great Lakes (inter-basin spread), and the impact of invasive species.

At least 114 non-indigenous species are overwintering and reproducing in Lake Huron (including the St. Marys River), with 52 of these aquatic invasive species (46%) exhibiting notable environmental or socioeconomic impact. Thirty-eight (38) of these invasive species entered Lake Huron after 1950 and 6 of those in the last decade. The lake-specific cumulative impact index for U.S. waters of Lake Huron has increased more than 10-fold since 1950. Species including Sea Lamprey (*Petromyzon marinus*), dreissenid mussels (Quagga Mussels, *Dreissena rostriformis bugensis;* and Zebra Mussels, *Dreissena polymorpha*), Round Goby

(*Neogobius melanostomus*), European frog-bit (*Hydrocharis morsus-ranae*), starry stonewort (*Nitellopsis obtusa*), and others are problematic. The expansion of European frog-bit in Lake Huron and the St. Marys River, and rediscovery of starry stonewort in Saginaw Bay were noted as disturbing in the coastal wetland plants sub-indicator (ECCC and EPA, 2022). There is concern about the invasive characteristics of Didymo (*Didymosphenia geminata)*, a diatom that is currently problematic in the St. Marys River due to impacts the thick stalked mats are having on the habitat and ecology of the upper river (A. Moerke, LSSU).

It is also important to note that a large-scale decline and virtual disappearance of invasive Alewives and invasive Rainbow Smelt has had a negative effect on the popular Pacific salmon fisheries in Lake Huron but has removed an obstacle to Walleye recovery and Lake Trout recovery (Fielder and Baker, 2019). The loss of these primary prey species has resulted in declines in fitness, survival, and abundance of naturalized Chinook salmon and consequently a decline in angler catch rates and size of fish caught. The reduced predation on Alewife by native Walleye and Lake Trout has had a positive impact on early life stages of both Walleye and Lake Trout with the added benefit for Lake Trout being improved reproductive capabilities as a result of improved egg thiamin levels from consuming prey other than Alewife.

Invasive species pose a detriment to many Lake Huron Fish Community Objectives and have negative impacts on salmonids, coregonids, percids, esocids, and other indigenous fish species through predation, impacts to early development success, direct competition for food resources, displacement, degradation of spawning, nursery, and feeding habitats, and altered energy transfer between trophic levels (Liskauskas et al., 2007). Overall, the impact of invasive species on the Lake Huron is ‘Poor’ with a 10-year trend of ‘Undetermined’ and a longer-term trend of ‘Deteriorating’ (ECCC and EPA, 2022). This reflects the number of invasive species that have become established since 1950 and the range of those species within the lake.

The rate of invasion by new non-indigenous species from 2011-2020 (0.8 species per year) trended substantially lower than the previous 2 decades; however, it is still significantly higher than the pre-1950 level (0.2 species per year) (Figure 10; ECCC and EPA, 2022). Sea Lamprey control has successfully suppressed Sea Lamprey populations in the St. Marys River to all-time lows, and the adult Sea Lamprey populations in Lake Huron are near target levels. However, spread to Lake Huron of species previously established in the other Great Lakes has resulted in the establishment of 8 additional species in the Lake Huron basin in the last decade (ECCC and EPA, 2022). For this reason, Lake Huron is assessed as being in ‘Good’ condition for rate of new introductions of non-native species from outside of the Great Lakes basin, but is in ‘Poor’ condition for rate of introductions of non-native species from other Great Lakes.

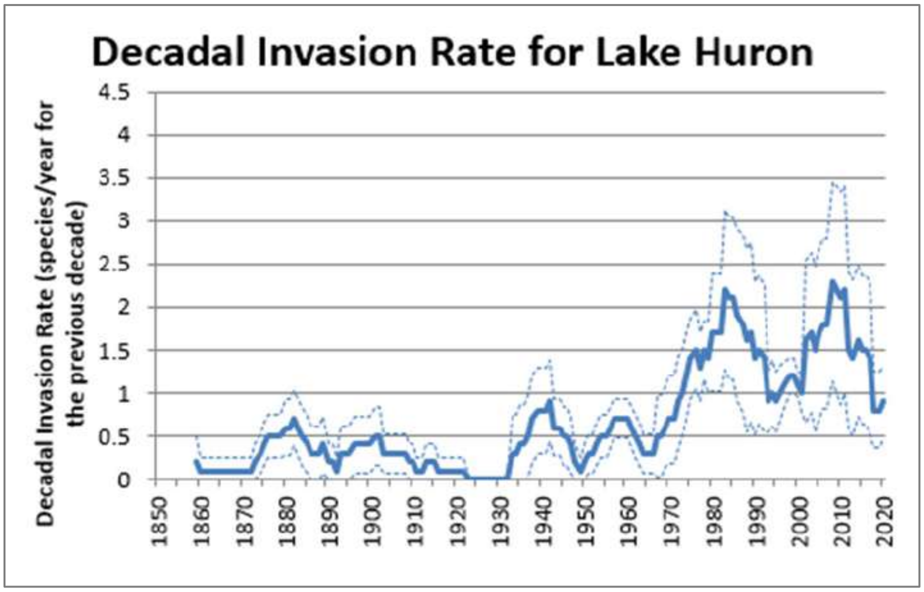


Figure 10: Decadal invasion rate of new non-indigenous species for Lake Huron. The invasion rate has trended lower for the last decade (ECCC and EPA, 2022).

Sea Lamprey: The status is considered ‘Fair’ and a 10-year and long-term trend of ‘Improving’ (ECCC and EPA, 2022). Unlike most other aquatic invasive species, there are management tools available for controlling Sea Lamprey. Using barriers, chemical lampricides, and other supplemental control methods, Sea Lamprey populations have been reduced to about 10% of their historic levels due to effective control. Adult abundance has remained steady and is in ‘Fair’ condition (Barber and Steeves, 2021). In 2015, the Lake Huron population control target was achieved for the first time in 30 years (Figure 11) (Barber and Steeves, 2021). However, adult Sea Lamprey abundance has increased since then and marking rates on Lake Trout still exceed the lakewide target of 5 marks per 100 fish greater than 533 mm in length (Nowicki et al., 2021).

Most of the adult Sea Lamprey population comes from production in the St. Marys, Garden, and Mississagi rivers; however, there are many other streams with suitable spawning habitat that are currently inaccessible due to dams blocking upstream spawning Sea Lamprey migration. As discussed in section 5.4, the removal of any dams to improve habitat connectivity must consider the potential for Sea Lamprey to access additional spawning habitat and the resulting increases in parasitism of Lake Huron fish.

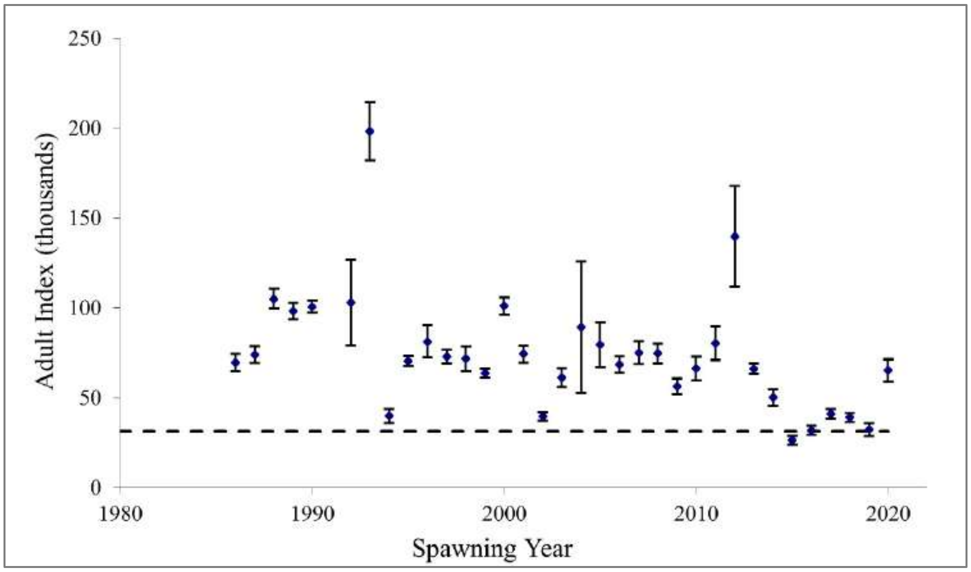


Figure 11: Index estimates with 95% confidence intervals of adult Sea Lampreys in Lake Huron. The index target of 31,274 adults is represented by the horizontal dotted line. The index target was estimated as 0.25 times the mean of indices between 1989 and 1993 (Barber and Steeves, 2021).

Dreissenid mussels: The overall status of dreissenid mussels is ‘Poor,’ and the long-term trend is ‘Deteriorating’ (ECCC and EPA, 2022). Invasive mussel populations continue to expand in Lake Huron at depths >50 m (ECCC and EPA, 2021; Figure 12). These filter-feeding organisms remove algae and small zooplankton from the water, reducing the food available for young fish and some native invertebrates. This filter-feeding activity has resulted in greater water transparency and relocated food resources from the pelagic to the benthic environment. Increased light availability and more nutrients near bottom have contributed to excess Cladophora growth – even in areas which do not have significant land-based sources of nutrient pollution. This increased algal growth contributes to the formation of sloughed algae mats that provide the perfect micro-habitat for *Clostridium botulinum* (Wijesinghe et al., 2015), the bacteria that produces the neurotoxin that causes avian botulism. The gene that produces the botulinum toxin was found in 83% of algal samples collected during summer 2012 at Bay City State Recreation Area beach on Saginaw Bay, and concentrations at this location were the highest of 150 algal samples collected from 10 Great Lakes beaches (Wijesinghe et al., 2015). The Clostridium botulinum gene is abundant in the Great Lakes, but the link between invasive species and botulism outbreaks in waterfowl is not well-understood.

The filter-feeding activity of Quagga Mussels in the deep, offshore environment is believed to remove nutrients and plankton that historically drove the springtime diatom bloom and is considered a contributing factor to the low nutrients in the offshore zone. A 2021 study revealed that the tissues and shells of Quagga Mussels now contain nearly as much phosphorus as the entire water column, and the cycling of phosphorus in Lake Huron is now regulated by the dynamics of mussel populations while the role of the external inputs of phosphorus is suppressed (Li et al., 2021). Quagga Mussels have broadly displaced Zebra Mussels, with few Zebra Mussels found in the Lake Huron main basin since 2003 (Nalepa et al., 2007; Bunnell et al., 2014; Nalepa et al., 2018; Karatayev et al., 2020) (Figure 13). In 2017, Quagga Mussels were most abundant in the main basin, less common in Georgian Bay, and almost absent in North Channel. Between 2012 and 2017, *Dreissena* density in the main basin in the shallowest (less than 30 m) depth zone studied declined by a factor of eight, declined at 31-50 m, increased at 51-90 m, and more than doubled at depths greater than 90 m. As a result, the bulk of the population is now found deeper than 50 m (Karatayev et al., 2020, 2021; Rudstam et al., 2020; ECCC and EPA, 2022). Densities in Georgian Bay at 31-90 m decreased two-fold from 2007-2012 and changed little from 2012-2017; a few dreissenid mussels were observed in 2017 in the North Channel – a basin where mussels had not been found in previous years (Figure 13). In Saginaw Bay, Quagga and Zebra Mussels coexist and the combined dreissenid mussel density remains much lower than the peaks reported in the 1990's (Karatayev et al., 2021).

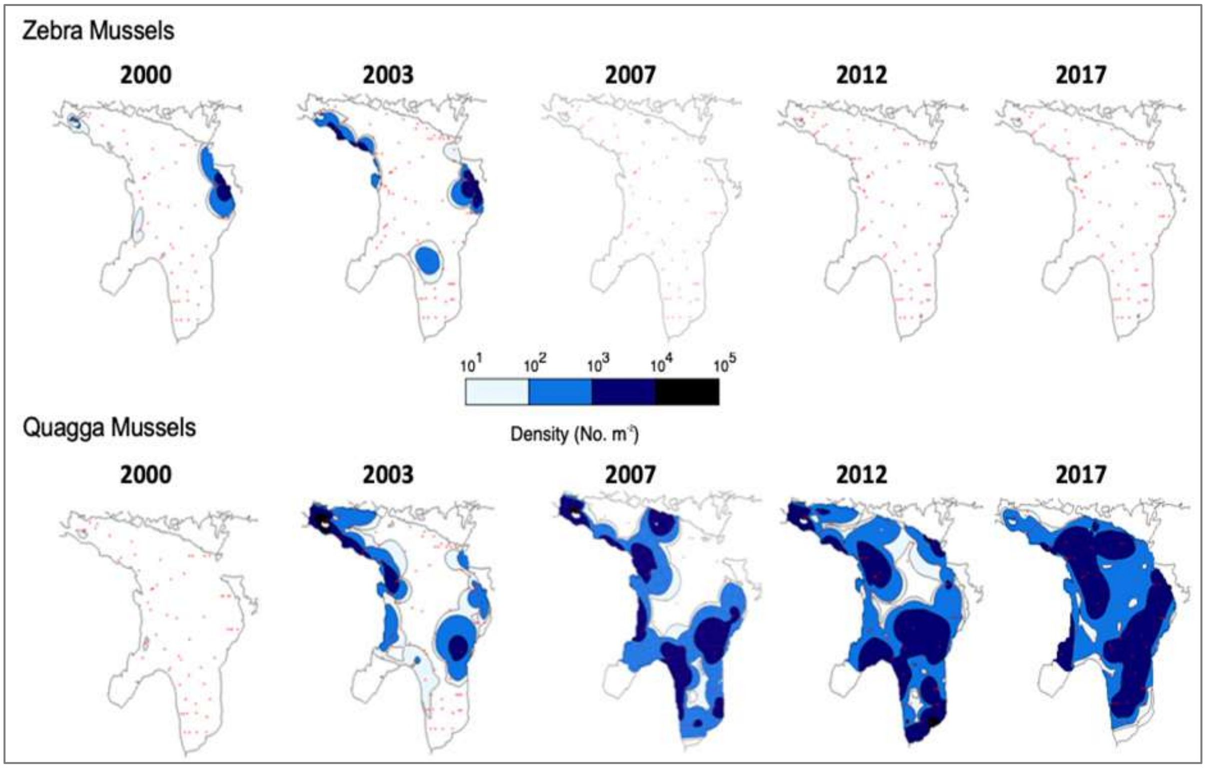


Figure 12: Comparison of densities (m2) of Zebra and Quagga Mussels in the main basin of Lake Huron, 2000-2017 (Nalepa et al., 2018; Karatayev et al., 2020; ECCC and EPA 2021).

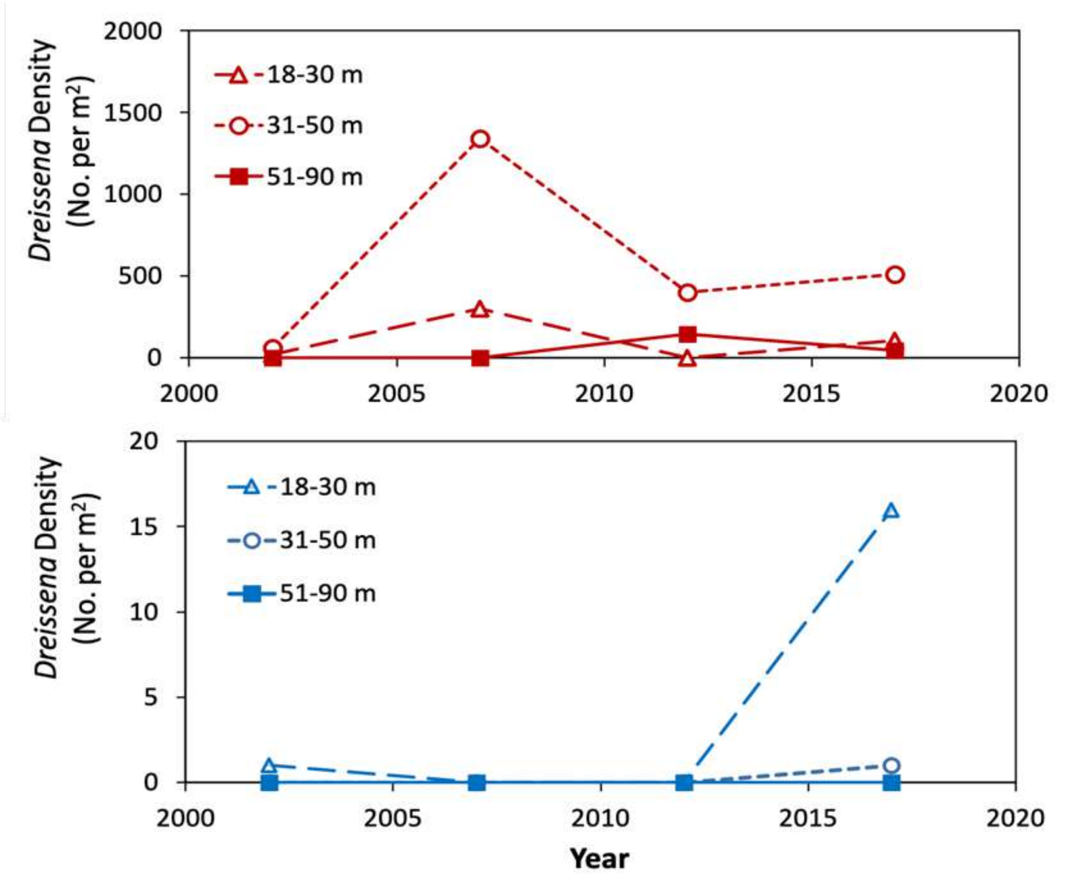


Figure 13: Comparison of densities (m2) of dreissenid mussels in Georgian Bay (upper panel, in red) and North Channel (lower panel, in blue), 2002-2017 (data from Nalepa et al., 2018; Karatayev et al., 2020).

Round Goby: Invasive Round Goby are aggressive benthic fish that compete with native species for prey, habitat and are known to consume native fish eggs. They also consume dreissenid mussels. They have become a prey item for fish in many areas of Lake Huron, but information is needed about how Round Gobies contribute to the diet of predators and their role in the link between trophic transfer of the benthic and pelagic food webs. Round gobies prefer rocky substrate, habitat that is difficult to sample. The USGS and NDMNRF have initiated studies to better estimate Round Goby abundance using deepwater electrofishing and images from autonomous vehicles with computer learning, but more information is needed about what percentage of the population is being detected.

Terrestrial Invasive Species: In the 2022 SOGL, the status of Terrestrial Invasive Species in the Lake Huron basin was 'Undetermined' for both the status and trend (ECCC and EPA, 2022). Three new species were included in this sub-indicator report for the 2022 SOGL cycle: mute swan, Japanese knotweed, and common buckthorn. *Phragmites* and purple loosestrife were already assessed in the other sub-indicator reports, and therefore were removed from the Terrestrial Invasive Species sub-indicator to avoid double counting of the impacts and spread of species.

While the SOGL 2022 report rated the status and trend of terrestrial invasive species as 'Undetermined' for Lake Huron due to changes in the species assessed and the overall assessment approach, Emerald ash borer (*Agrilus planipennis*), garlic mustard (*Alliaria petiolata*), *Phragmites* (European Common Reed, *Phragmites australis subsp. australis*), and purple loosestrife (*Lythrum salicaria*) negatively impact biodiversity, habitat, chemical loads, nutrient cycling, and hydrology of ecosystems within the Lake Huron watershed (ECCC and EPA, 2022). Despite ongoing management efforts, these species and other terrestrial invasive species associated with water quality impacts, continue to spread within the Lake Huron basin. Climate change is expected to expand the ranges of many terrestrial invaders as temperatures rise and growing seasons are extended (Clements and DiTommaso, 2012). Real-time, web-based mapping platforms, such as Early Detection and Distribution Mapping System (EDDMapS) (http://www.eddmaps.org/ontario/), have improved the tracking of invasive species and public engagement. This has enabled land managers to detect and respond to an invasion before a species become established (ECCC and EPA, 2021).

Emerald Ash Borer: The emerald ash borer was first discovered in North America in the Detroit-Windsor area in the early 2000s and quickly spread throughout Michigan and southern Ontario. This insect feeds on green, red, white, black and blue ash trees. High mortality rates are typical once an infestation occurs; after 6 years of initial infestation, roughly 99% of ash trees are killed in the woodlot (NRCAN, 2016). Deforestation in natural areas can increase erosion, runoff, and water temperature in previously shaded streams. In urban centers, the loss of ash trees can increase the amount of stormwater runoff and exacerbate the urban heat island effect (Wisconsin Department of Natural Resources, n.d.). The increased runoff and erosion are particularly concerning because of the potential for increased pollutant and nutrient loading which can have additional impacts on the water quality and native species.

Garlic Mustard: Garlic mustard was likely introduced in the late 19th century from Europe, and can control the nutrient supply in the soil, making it difficult for tree seedlings to germinate (Rodgers et al., 2008) altering understory growth and forest composition. It impacts native wildlife by changing habitat and food availability on the forest floor (Anderson, 2012) and has contributed to the decline of rare native flora (i.e., wood poppy and white wood aster) (Lake Huron Centre for Coastal Conservation, 2000). It is also toxic to the larvae of some butterflies, which results in a reduction of plant pollination (Lake Huron Centre for Coastal Conservation, 2000).

Purple Loosestrife: Purple loosestrife directly degrade inland and coastal wetlands by altering their structure and function and reducing plant species diversity. Purple loosestrife weaves thick mats of roots that cover vast areas, impacting the quality of habitat for birds, insects and other plants (Warne, 2016). Furthermore, purple loosestrife threatens wetland ecosystems by altering water levels and reducing food sources for both aquatic and terrestrial native species (Thompson et al., 1987). Since arriving in the early 19th century the plant now occurs along the shorelines of all the Great Lakes. Efforts to manage this species by introducing its natural predators, *Neogalerucella spp.* beetles, have been successful in the Lake Huron basin (Warne, 2016); however, this method of biocontrol will not completely eradicate a population but can reduce it to a more manageable level.

Phragmites australis subsp. australis: *Phragmites* is considered to be the most aggressive, invasive species of marsh ecosystems in North America and Canada's worst invasive plant (Nichols, 2020). This aggressively spreading invasive plant often out-competes all native vegetation and expands into massive monoculture stands. *Phragmites australis subsp. australis* can hybridize with the native form, *Phragmites australis subsp. americanus,* which inherit traits that confer invasiveness (i.e., beneficial reproductive, genetic and morphological characteristics) from both parental lineages (Williams et al. 2019). The loss of native plant diversity and habitat complexity directly impacts wildlife by reducing suitable habitat. *Phragmites* also negatively impact tourism and local economies due to loss of shoreline views, reduced recreational use and access, fire risks, declining property values, and plugged roadside and agricultural drainage ditches (Kowalski et al., 2015; ECCC and EPA 2017). No natural controls exist to regulate invasive *Phragmites* populations, underscoring the need for human intervention and often requiring multiple control methods for eradication (Nichols, 2020). Invasive *Phragmites* is now found extensively throughout the Lake Huron basin with over 10,000 hectares (24,710 acres) of dense stands mapped using radar imagery on the U.S. side of the basin (ECCC and EPA, 2022). The rise in Lake Huron's water level during 2019 and 2020 resulted in some *Phragmites* drowning and being unable to migrate; however, it is unclear how future lake level fluctuations will impact this and other species. There is concern that future prolonged periods of low-water will result in localized expansion of wetland invasive plants (ECCC and EPA, 2022).

What is the threat and other considerations for taking action?

Invasive species have been introduced to Lake Huron through a variety of means. Past shipping practices had been a significant pathway for invasive species present in the Great Lakes, primarily via the discharge of ballast water (Ricciardi, 2006). The invasion rate attributed to this pathway declined since the late 1980s after a series of ballast management practices and regulations were implemented. River systems, canals, waterways and lakes connected to Lake Huron are also potential pathways for invasive species to spread through modes such as swimming/transport and seed dispersal. At the consumer level, at least 12 species were introduced into the Great Lakes through the aquarium and horticultural industry since the late 1800’s (Funnell et al., 2009). Other potential sources of introductory pathways for invasive species include recreational boating, and live fishing bait (Johnson et al., 2001), as well as construction and vehicle transportation. Once established, there is a danger the species will spread.

***Habitat impacts*:** Dense colonies of invasive species have had impacts on a variety of habitats in Lake Huron. Stands of invasive *Phragmites* have impacted the nearshore terrestrial habitat; floating mats of European frog-bit shade aquatic submergent vegetation; and dreissenid mussels, Round Gobies, and rusty crayfish impact the physical structure and function of reef spawning habitat. The Lake Huron Committee identified environmental priorities including the need to remove and control aquatic invasive species that are impacting the physical and biological structure of priority reefs within Lake Huron, continue invasive *Phragmites* control in coastal wetland habitats, and restore fish passage but continue to minimize invasive species impacts (LHC, 2021).

***Food web impacts*:** Dreissenid mussels, spiny water flea and Round Goby are the three most important invasive species that have become widespread in Lake Huron and which have associated food web impacts. Zebra mussels are implicated in a ‘nearshore phosphorus shunt’ and ‘benthification’ resulting in a shift of nutrients towards the nearshore zones and lake bottom. As ‘ecosystem engineers’, they alter the physical habitat of the benthos resulting in shifts in community composition. Round Goby take advantage of these changes (and dreissenid mussels as a food source), resulting in even further changes to community composition, and alter energy flow patterns. Spiny water fleas may be exacerbating this – pelagic zooplankton populations are shifting to larger species, diurnal zooplankton migratory patterns have shifted, and fish diets (particularly for smaller and larval fishes) have also shifted.

***Invasive spread*:** Changes in water quantity and quality, climate change impacts, land use changes, alterations to the nearshore and shoreline, as well as the presence of existing invasive species, make the Lake Huron basin more hospitable for new invasive species and contribute to the spread of existing invasive species. Potential pathways for the spread of invasive species include canals and waterways, boating and shipping, internet trade, illegal trade, the release of aquarium species, live bait, and live food markets. Plant species purchased through nurseries, internet sales and water garden trade can also be vectors of spread. Private sector activities related to aquaria, garden ponds, baitfish and live food fish markets are additional potential vectors. Silver Carp and Bighead Carp escapees from southern U.S. fish farms have developed into large populations that have spread upstream in the Mississippi River system. These species have been captured in the Illinois River and Des Plaines River, threatening the Great Lakes.

***Invasive carp*:** Invasive carp including Bighead Carp, Silver Carp, Black Carp, and Grass Carp are not known to be established within Lake Huron. However, risk assessments show that the right conditions exist in Lake Huron to support the establishment of Grass, Bighead and Silver carp (Cudmore et al., 2012, 2017) and that they could cause significant impacts should they become established. Grass Carp individuals have been captured in Lake Huron (USGS, 2022). If any of these species become established, it would have significant ecological consequences including impacts to submerged vegetation communities reducing the habitat quality for native species and increased competition affecting native species growth, recruitment and abundance (Cudmore et al., 2012, 2017). The hydrological connection with the Mississippi River drainage via the Chicago Sanitary and Ship Canal represents a potential pathway for invasive species to enter the Great Lakes. The MDNR, NDMNRF, DFO, and USFWS have developed strategies to address invasive carps (Clapp et al., 2012; ACRCC, 2021) and agencies are using traditional sampling gears and eDNA for early detection of invasive carps in Lake Huron. The USFWS Lacey Act prohibits importation or possession of species designated as injurious wildlife, including Bighead Carp, Silver Carp, and Black Carp. Information about invasive carp is available online at http://www.invasivecarp.us/ and https://www.asiancarp.ca/.

5.4.3 Invasive Species: Climate Change Impacts

Managers and researchers are considering the impacts of climate change and how they may affect the threat posed by invasive species and the effectiveness of current management efforts. The changing conditions will facilitate the spread and impacts of some invaders, while others may be hindered. Lennox et al., 2020 addressed potential impacts of climate change on invasive Sea Lamprey in the Great Lakes, and how climate change may require changes to management of Sea Lamprey. Beyond species spread and abundance, secondary impacts from invasive species may be exacerbated as well (e.g., improved conditions for avian botulism, Princé et al., 2018). Indigenous communities are also considering Great Lakes climate change and how this may provide opportunities for non-local beings to spread and suggest best practices to prevent their establishment (Tribal Adaptation Menu Team, 2019).

5.4.4 Actions to Prevent and Control Invasive Species

This section describes actions that will be taken to further address invasive species in Lake Huron.

The Lake Huron Partnership agencies will implement the 2022-2026 *LAMP* within the context of existing laws and regulations which actively contribute to the restoration and protection of Lake Huron. Federal, state and provincial legislation that address invasive species are listed in Appendix B. This legislation includes the U.S. National Invasive Species Act (1996) and the Canada Shipping Act (2001).

Other contributing national and regional plans and initiatives are described below.

The *GLWQA* Invasive Species Annex is co-led by Fisheries and Oceans Canada (DFO) and the United States Fish and Wildlife Service (USFWS). Efforts under this annex are to identify and take actions to minimize the risk of invasive carp and other species invading the Great Lakes using a risk assessment approach. Through efforts of federal, state, and provincial agencies, Canada and the United States have developed and implemented an Early Detection and Rapid Response Initiative with the goal of finding new invaders and preventing them from establishing self-sustaining populations.

The Great Lakes Fishery Commission in collaboration with all levels of government have been implementing the invasive Sea Lamprey Control Program since the late 1950s.

The Great Lakes and St. Lawrence Governors' and Premiers' Aquatic Invasive Species Task Force works to stop the introduction and spread of aquatic invasive species. This includes the implementation of a Mutual Aid Agreement that empowers the States and Provinces to work together by sharing staff, expertise, and resources. The Governors and Premiers have a list of 21 "least wanted" aquatic invasive species that present a serious threat to the Great Lakes - St. Lawrence Basin.

Other initiatives active in basin include:

- Ontario's Invasive Species Strategic Plan
- State of Michigan Aquatic Invasive Species Plan
- Phragmites Adaptive Management Framework
- U.S. Great Lakes Restoration Initiative, administered by EPA

Through efforts of federal, state, and provincial agencies, Canada and the United States have developed and implemented an early detection and rapid response initiative under the *GLWQA* with the goal of finding new invaders and preventing them from establishing self-sustaining populations.

Key components of the Early Detection and Rapid Response Initiative include:

- Development of a "species watch list" of those species of the highest priority and likelihood of risk of invading the Great Lakes;
- Identification of priority locations to undertake surveillance on the "species watch list";
- Development and implementation of protocols for systematically conducting monitoring and surveillance methodologies and sampling;
- The sharing of relevant information amongst the responsible departments and agencies to ensure prompt detection of invaders and prompt coordinated actions; and
- The coordination of plans and preparations for any response actions necessary to prevent the establishment of newly detected aquatic invasive species.

Environmental legislation and corresponding regulations listed in Table B-1 in Appendix B are contributing to prevention and establishment of invasive species. Other contributing national and regional plans and initiatives are described below.

LAMP Actions

Actions will be taken in the Lake Huron basin to further prevent invasive species from entry into the Great Lakes basin and provide early detection to prevent their establishment. Efforts will be tracked via monitoring as listed in Table 12.

Table 12: Actions to Prevent and Control Invasive Species

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	Actions to Prevent and Control Invasive Species	
33	**Ballast Water:** Implement programs and measures that protect the Great Lakes basin ecosystem from the discharge of AIS in ballast water, pursuant to commitments made by the Parties through Annex 5 of the *GLWQA*.	TC, EPA, USCG
34	**Early Detection and Rapid Response:** Maintain and enhance early detection, surveillance, and monitoring of non-native species (e.g., Invasive Carp) to find new invaders and prevent them from establishing self-sustaining populations.	DFO, BMIC, LTBB, MDNR, NDMNRF, EPA, USDA-FS, USFWS, SSEA
35	**Canals and Waterways:** Through the Invasive Carp Regional Coordinating Committee, prevent the establishment and spread of Bighead and Silver Carp in the Great Lakes.	EPA, USFWS, NOAA
36	**Sea Lamprey:** a. Control the larval Sea Lamprey population in the St. Marys River with selective lampricides. Continue operation and maintenance of existing barriers and the design of new barriers where appropriate. b. Design and construct Au Gres River sea lamprey trap in Arenac County, Michigan. c. Design and construct Au Sable River sea lamprey trap in Iosco County, Michigan. d. Support the GLFC's supplemental Sea Lamprey control program. e. Design and construct Sea Lamprey barriers with seasonal fish passage at the Trout and Tittabawassee rivers.	MDNR, PC, DFO, USACE, USFWS
37	**Improve understanding of invasive species impacts to inform management efforts:** a. Impacts of Round Goby on the Food web: Enhance assessment methods and technology to better understand Round Goby population density and distribution.	USGS-GLSI, USFWS, MDNR, NOAA, NDMNRF

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	b. Causes of Botulism Outbreaks: Improve understanding of links between mussels, Round Goby, and Botulism outbreaks in waterfowl. c. *Cladophora* growth: Maintain and/or continue to implement Lake Huron sentinel *Cladophora* monitoring sites to determine the role of mussels in nearshore algae growth and possible mitigation efforts.	
38	**Control of Terrestrial and Wetland Invasive Species:** • Maintain coastal and nearshore aquatic habitat diversity and function through appropriate control of *Phragmites* (i.e., *Phragmites australis, subsp. australis*) and other invasive species (e.g., Glossy Buckthorn, European Frog-bit, Purple Loosestrife, Japanese Knotweed, New Zealand Mud Snail) including monitoring, mapping, and control efforts guided by BMPs. • Coordinate *Phragmites* control efforts and share BMPs through the Ontario Phragmites Working Group and Great Lakes Phragmites Collaborative.	USDA-FS, SCIT, MDNR, EGLE, BMIC, NVCA, NDMNRF, PC, SCRCA, USDA-NRCS, EPA, USFWS, SSEA
39	Improve the understanding of the role and contribution of invasive species have on Lake Huron's food web/nutrient dynamics, including links between the benthic and pelagic, and the nearshore and offshore environments. a. Assess the contribution of invasive species to a-stressed system, consistent with bottom-up limitation. b. Improve the understanding of energy sources and the movement of energy within the Lake Huron food web, including consideration of stable isotopes or fatty acids and eDNA to determine diet composition.	EGLE, USGS, NOAA, EPA, BMIC, NDMNRF
40	Improve the understanding of how dreissenid mussels contribute to: 1) the movement of energy via the microbial loop (i.e., dissolved organic material, bacteria, phytoplankton, protozoa, and other microbes); and 2) zooplankton productivity.	EGLE, USGS, NOAA, EPA
41	Maintain an index time series that shows the impact of Sea Lamprey marking rates on Lake Trout population status in Michigan.	MDNR
42	Undertake aquatic invasive species prevention outreach and education, including discussions with recreational boaters and lake access site signage.	LTBB, SCIT, EGLE, BMIC, DFO, NDMNRF, SCRCA, USDA-FS, EPA, CORA, PC, SSEA

**Acronyms for agencies not listed as Lake Huron Partnership agencies on page iv are: Michigan Department of Health and Human Services (MDHHS); Transport Canada (TC).*

Actions Everyone Can Take

Here are some ways you can do your part to prevent the introduction and spread of invasive species:

- Learn how to identify, report, and stop the spread of invasive *Phragmites* and invasive carp.
- Use non-invasive plants for your yard or garden.
- Clean your boots before you hike in a new area to prevent the spread of weeds, seeds and pathogens.
- Drain and clean your boat before using it on a different body of water.
- Do not move firewood that can harbor forest pests.
- Do not release aquarium fish and plants, live bait or other exotic animals into the wild.
- Volunteer at a local park to help remove invasive species. Help educate others about the threat of invasive species.

5.5 Other Threats: Plastics, Risks from Oil Transport and Cumulative Impacts to Nearshore Areas

This section summarizes the scientific information about other threats specific to Lake Huron and corresponding actions to be taken by Lake Huron Partnership agencies in the 2022-2026 timeframe, as well as actions that everyone can take. This section responds to the other substances, materials or conditions-related General Objective of the *Great Lakes Water Quality Agreement*.

5.5.1 Objectives and Condition Overview

One of nine General Objectives of the Agreement is addressed in this chapter:

- Be free from other substances, materials or conditions that may negatively affect the Great Lakes.

In response to this objective, the following issues have been identified by multiple Lake Huron Partnership agencies: plastics, risks associated with oil transport, and cumulative impacts to the nearshore areas including groundwater.

5.5.2 Other Threats

***GLWQA* General Objective:** 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.

Most threats to Lake Huron are being addressed through ongoing environmental programs. Other issues of public concern may impact ecosystem health and impede progress to achieve this *GLWQA* General Objective. Understanding these threats will help inform the public and guide management decisions and priority actions.

Microplastics

Defined as plastic particles generally less than 5 millimeters (0.2 inches) in size, microplastics are non-biodegradable, synthetic organic polymers such as polyethylene, polypropylene, and polystyrene. Microplastics are characterized based on shape or morphology into five common categories, fiber/line, fragment, film, pellet/bead, and foam. Microplastics originate from primary and secondary sources; primary sources fulfill a specific need or function (e.g., microbeads used in personal care products, abrasive cleaning particles, and pre-production resin pellets), and secondary sources result from degradation, wear and tear, or fragmentation of larger debris. Secondary sources include litter fragments (e.g., plastic bags, bottles, wrappers, polystyrene containers, cigarette filters), synthetic fibers from textiles, and tire wear particles (GESAMP, 2019). Pathways for microplastics to enter the aquatic environment can include stormwater runoff (e.g. litter and tire wear particles); domestic, industrial, and commercial wastewater treatment plant effluent; treated sewage sludge and illicit wastewater treatment plant discharges (e.g., plastic shavings and dust, microbeads, and synthetic fibers); organic fertilizers from biowaste fermentation and composting (e.g., litter fragments, synthetic fibers, and microbeads); and atmospheric deposition (e.g., synthetic fibers) (Weithmann et al., 2018, Wagner et al., 2018, Mason et al., 2016, Zubris et al., 2005, Dris et al., 2016). For example, a load of laundry can contain up to 700,000 microfibers depending on the composition of the clothing and could be a significant source of microfibers entering treatment plants. A recent study showed that the addition of after-market washing machine filters is highly effective at reducing microfibers that detach from clothes during laundering, resulting in reduced microfibers in washing machine discharge water. Most washing machines in households today do not have these types of filters installed. Although wastewater treatment plants capture some of these substances, removal of microplastic fibers is not 100% efficient (Erdle et al., 2021). Studies on the biological effects of microplastics on freshwater fish are still in their early stages, but as additional research occurs experts agree microplastics (and fibers in particular) may be a growing threat to water quality and wildlife as the number of organisms with microplastics in their digestive systems continues to be observed. The consequences for ingestion of microplastics are not well understood, although potential negative effects on organisms have been documented and include obstruction of the digestive system, clogging of feeding appendages, reduced food consumption and predator performance, nutritional deprivation, reduced immune response, substantial energy reduction, and impaired reproduction and survival (Watts et al., 2015, Sussarellu et al., 2016, Wright et al., 2013, Foley et al., 2018, Pedá et al., 2016, de Sá et al., 2015, Rochman et al., 2013). A systematic review of the literature on plastic pollution in the Laurentian Great Lakes and its effects on freshwater biota provides information to guide and support management strategies (Earn et al., 2020). This review showed that Lake Huron had the smallest concentrations of surface water plastic pollution when compared to lakes Erie, Michigan and Superior. Microplastics collected from beaches in Lake Huron showed a strong influence of industry due to the high presence of “nurdle pellets” (small resin pellets used in manufacturing) observed in beach microplastic litter in Lake Huron (Ellison, 2022).

In 2020, the Government of Canada released a Science Assessment of Plastic Pollution. This assessment presents a thorough scientific review of the occurrence and potential impacts of plastic pollution on human health and the environment. The Science Assessment recommends pursuing actions to reduce macroplastics (plastic particles >5 mm) and microplastics that are released to and accumulate in the environment in accordance with the precautionary principle. In order to take action as recommended in the Science Assessment, in May 2021 “plastic manufactured items” was added to Schedule 1 of the Canadian Environmental Protection Act (CEPA). This will allow the Canadian Government to enact regulations that target sources of plastic pollution and change behaviour at key stages in the lifecycle of plastic products in order to reduce pollution and create conditions for achieving a circular plastics economy.

The U.S. government signed into law H.R. 1321, the Microbead-Free Waters Act of 2015 on December 28, 2015. The bipartisan legislation began the phase out of plastic microbeads from personal care products on July 1, 2017. In 2017, the Government of Canada implemented the Microbeads in Toiletries Regulations (Appendix B) which prohibit the manufacture, import and sale of certain toiletries including non-prescription drugs and natural health products that contain plastic microbeads.

The ban on the use of microbeads in personal care products was an important first step in reducing the flow of microplastics into the Great Lakes, but other, more abundant and concerning sources and pathways for microplastics to contaminate the environment remain. In 2020, the Government of Canada announced the banning of harmful single-use plastics to further protect the environment from plastic pollution and reduce waste. In June 2022, the Government of Canada published the *Single-use Plastics Regulations* in the Canada Gazette, Part II. The regulations prohibit the manufacture, import, sale, and eventually export of six categories of single-use plastic items.

Researchers from the U.S. Geological Survey examined plastic pollution in water surface samples from 29 tributaries of the Great Lakes and found that 98% of plastics collected were microplastics; 71% of these were plastic fibers (Baldwin et al., 2016). An offshore survey of lakes Superior, Huron, and Erie showed that microplastic concentrations from water surface samples increased from Lake Superior to Lake Erie, consistent with increasing urban population size, while plastic fibers only made up less than 0.5% of the total microplastics collected (Table 2 in Eriksen et al., 2013). More recently, additional research from the Great Lakes region suggests that synthetic fibers are suspended in the water column of rivers due to turbulent flows, but as these rivers flow into the more quiescent coastal environments of the Great Lakes the fibers, and other negatively buoyant microplastics, begin to settle through the water column and are deposited in benthic sediment (Lenaker et al., 2019, Lenaker et al., 2021).

Lake Huron has the fewest published studies related to microplastics of all the Great Lakes. The research that has been performed to date has investigated shoreline and beach contamination and the water surface from the offshore lake environment with additional information needed for fibers. Additionally, the water surface of the Saginaw River, Michigan was sampled four times in 2014 and represents the only information on microplastics in U.S. and Canadian Lake Huron tributaries. Recent research indicates that microplastics have been found in the water surface, water column, and benthic sediment, which suggests water surface samples previously collected from the tributaries and offshore Lake Huron environment represent underestimates of the actual concentration (Lenaker et al., 2019, Lenaker et al., 2021, Belontz et al., 2022). In addition, low-density microplastic particles have been shown to decrease from the water surface through the water column to the sediment while high-density microplastic particles have shown the opposite trend (Lenaker et al., 2019, Lenaker et al., 2021). The lack of information on particle types and the polymers that make up microplastics below the water surface suggests the need for studies on microplastics content in the water column to understand the types of plastics that fish eat. Without this information, making conclusions or designing studies to understand the potential biological effects of microplastics on fish, algae, invertebrates, and benthic organisms would be highly speculative and may not represent existing conditions occurring within and across the Great Lakes.

Risk from Oil Transport

Most oil transported on or near water in the Great Lakes basin is moved by pipeline, followed by rail (Marty and Nicoll, 2017). No crude oil is currently transported on the Great Lakes by marine shipping, but the industry does utilize refined petroleum products. Figure 14 presents a map of crude oil pipelines. As experienced in locations where oil spills have occurred (e.g., Exxon Valdez and Deepwater Horizon spills), there is potential for far-reaching impacts (e.g., disruptions to the food web) which could, for example, result in new fishing restrictions (Murray et al., 2018). In addition to a potential oil spill, other impacts include oil spill response activities that can negatively impact waterways, wetlands, and air quality. Traditional mechanical clean up methods can be damaging to fragile wetlands and other habitats (Owens et al., 1993) or may disturb bird and fish migrations. The USCG has investigated the use of *in situ* burning as a potential oil clean up method for the Great Lakes Region (Murphy et al., 2021). The use of *in situ* oil burning during a large-scale oil spill event may have both long term and short-term environmental and human health impacts for the Lake Huron basin. Research has shown that when spilled on land, oil can enter the groundwater system and adversely impact biological activity, and the oil can remain in the aquifer for decades (Bekins et al., 2016). The risks associated with petroleum product transport include altered hydrology and potential accidental releases, particularly where a pipeline or railway crosses a river or stream. The potential negative effects of a crude oil spill are not only ecological but social and cultural as well, as numerous verified and unverified archaeological sites are found along the shores and on the bed of the Great Lakes including a high density of these resources in the Straits of Mackinac.

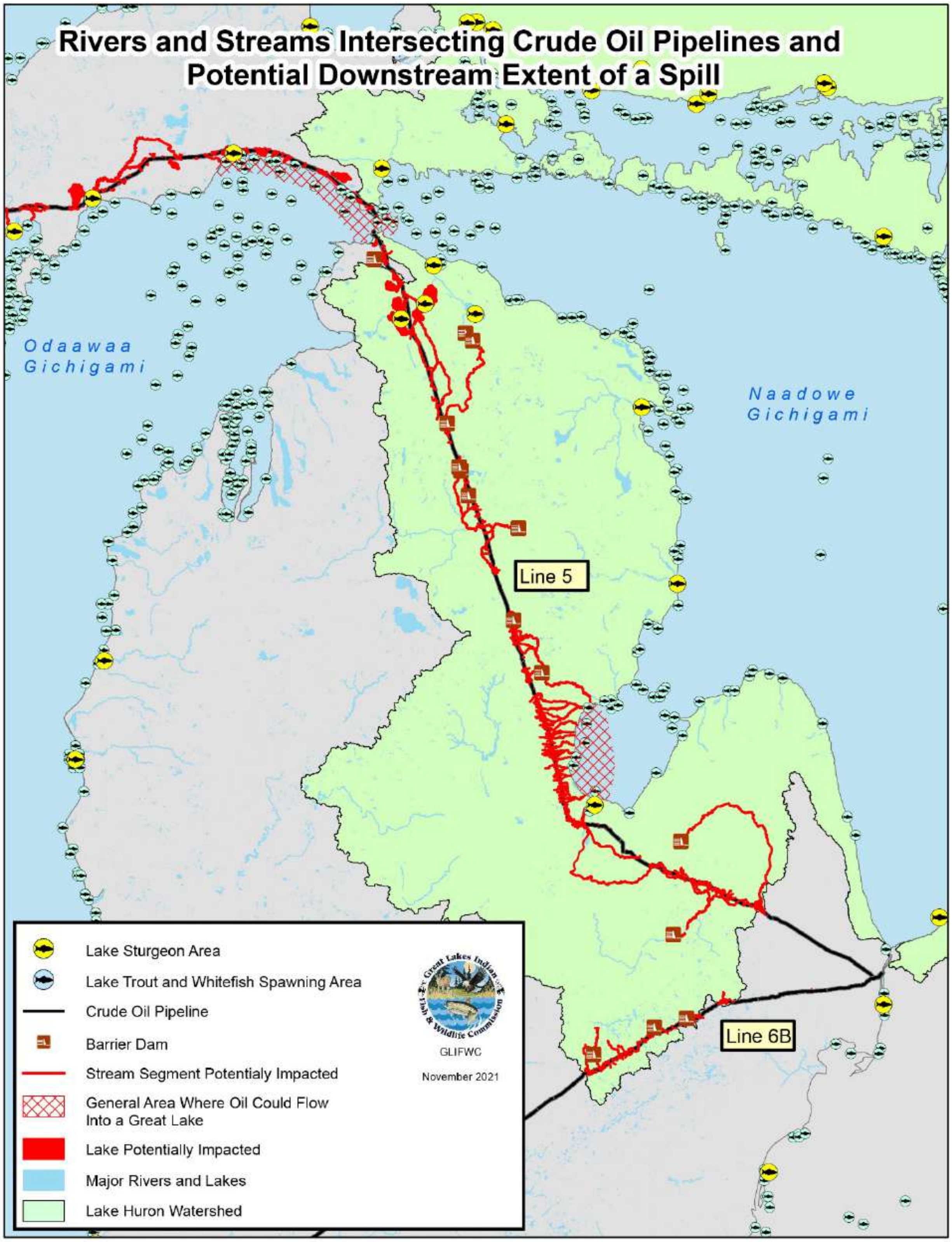


Figure 14: Rivers and Streams Intersecting Crude Oil Pipelines and Potential Downstream Extent of a Spill.

5.5.3 Nearshore Framework

The Great Lakes nearshore areas are a key priority for restoration and protection because they are the source of drinking water for most communities with the basin, are the areas of the lakes where most human recreation (e.g., swimming, boating, fishing, wildlife viewing) occurs, and are the critical ecological link between watersheds and the open waters of the Great Lakes.

The Nearshore Framework is a systematic, integrated and collective approach for assessing nearshore health and identifying and communicating cumulative impacts and stresses. It was developed by Canada and the United States in 2015 under the Lakewide Management Annex of the Agreement to inform and promote action to restore and protect the ecological health of Great Lakes nearshore areas.

5.5.3.1 Canadian Nearshore Waters

Canadian Nearshore Framework

Canada is implementing a Nearshore Framework to provide a cumulative effects assessment of nearshore waters; share the information from the assessment; identify areas that would benefit from protection, restoration or prevention activities; and identify causes of impairment and threats. Data used in the assessment came from existing monitoring programs from a range of partners, and varied in type, format and resolution. Key considerations in the selection of data were the spatial and temporal resolution, availability of the data and amount of processing required. Using a weight of evidence approach, disparate data that is typically evaluated separately has been integrated into the first cumulative assessment of the Canadian nearshore waters in Lake Huron. The approach has three phases:

- **Phase 1:** Delineate the nearshore into distinct Regional Units using physical characteristics such as bathymetry (up to 30 meter depth), bottom substrate type, wave energy and littoral cells.
- **Phase 2:** The assessment consists of 11 individual measures grouped into four categories developed with consideration of the *GLWQA* General Objectives. Each measure was assigned low, moderate or high stress based on documented ecological thresholds or best professional judgement, and then grouped into an overall cumulative assessment for each Regional Unit. A special status was assigned to Regional Units where there is concern to human and ecosystem health due to cyanobacteria.

- **Phase 3:** Integrate additional information related to areas of High Ecological Value to assist in establishing priorities for nearshore restoration and protection based on consideration of nearshore and whole-lake factors.

The Canadian nearshore waters of Lake Huron include the St. Marys River, the North Channel, Georgian Bay and main basin from Cape Hurd to the St. Clair River. Twenty-three distinct Regional Units were delineated in the first phase of the assessment. Due to the unique geomorphology of Lake Huron, the size and shape of the Regional Units vary drastically. Western Georgian Bay is characterized by a steep nearshore and the Regional Units from Owen Sound to Burnt Point are very narrow, while Regional Units in the North Channel are much larger and, in some areas, bounded by two shorelines (mainland and Manitoulin Island) due to a much shallower nearshore.

Overall, nearshore waters in Lake Huron are under low to moderate cumulative stress. In one Regional Unit – South Manitoulin Island – all four categories were assessed as low stress, and the Regional Unit overall cumulative stress is very low. Eight Regional Units (Cockburn Island, Christian Island, Collingwood to Meaford, Owen Sound, Colpoy's Bay, Cape Croker to Cabot Head, Fathom Five and Cape Hurd to Chiefs Point) are under low cumulative stress and no Regional Units are under high stress. A summary of the low, moderate and high stress thresholds is provided in Table 13. The key findings from each of the four categories are presented in Figures 15 – 18 and the Overall Results are shown in Figure 19. Further details are available in the 2021 Lake Huron Canadian Nearshore Assessment report (ECCC, in prep).

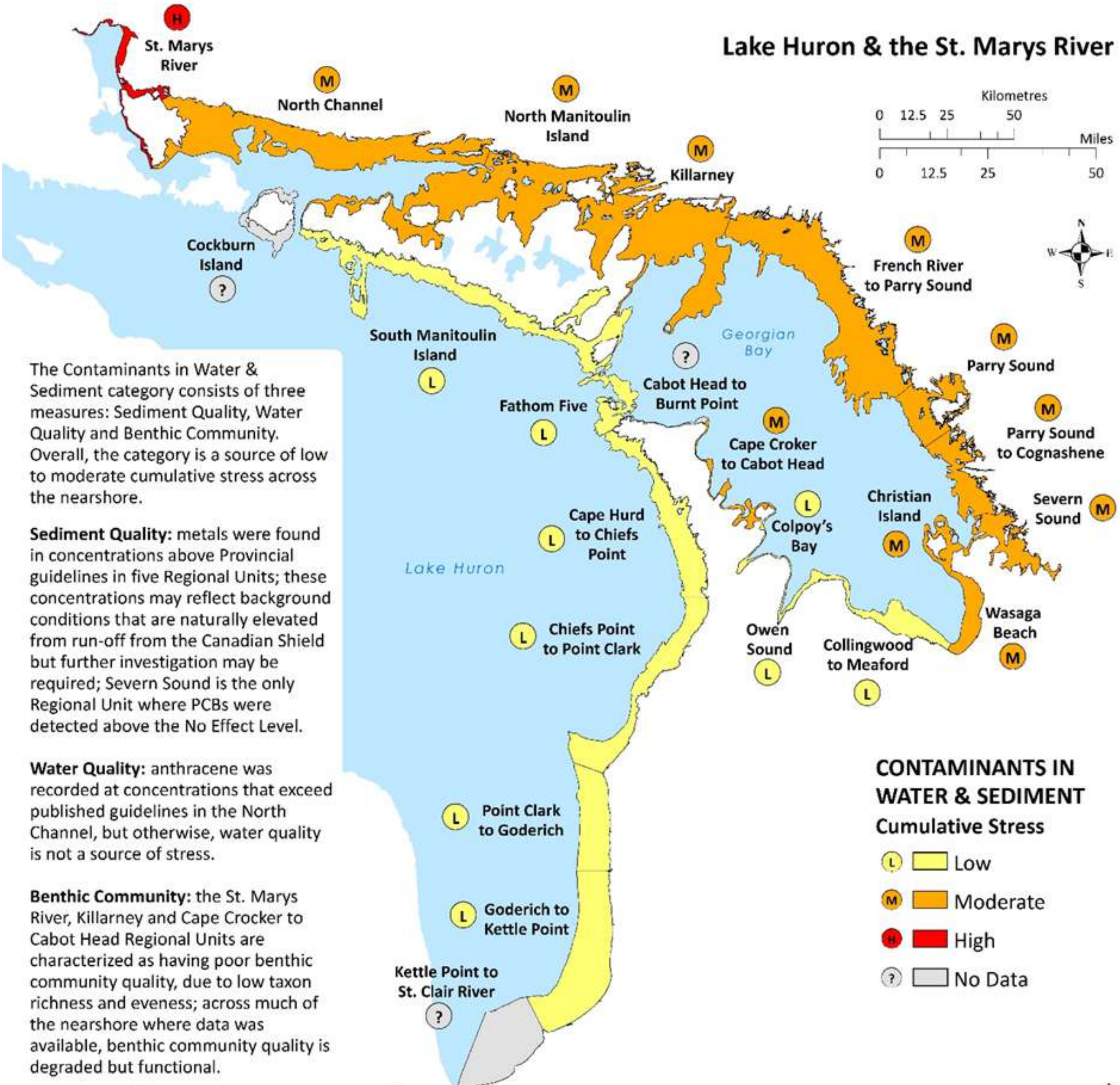
Table 13: Description of Low, Moderate and High Stress thresholds for each measure in the assessment, as well as the weight it carries in the overall assessment

Category	Measure	Weight	Low Stress	Moderate Stress	High Stress
Coastal Processes	Shoreline Hardening	+	<25% shoreline hardening	25-50% shoreline hardening	>50% shoreline hardening
	Littoral Barriers	+	0 littoral barriers	1 littoral barrier	>1 littoral barrier
	Tributary Connectivity	+	>75% tributary connectivity	25-75% tributary connectivity	<25% tributary connectivity
Contaminants in Water & Sediment	Water Quality	+	0 exceedances	1-2 exceedances	>2 exceedances
	Benthic Community	++	Functional, high quality	Degraded, but functional	Severely degraded, not functional
	Sediment Quality	++	PCBS < No Effect Level (NEL), Organochlorine pesticides & PAHs < Lowest Effect Levels (LEL), Metals < Probable (PEL) or Severe Effect Levels (SEL)	PCBs > No Effect Level OR, Organochlorine pesticides & PAHs > Lowest Effect Levels but < Severe Effect Levels OR, Metals > Probable Effect Level but < Severe Effect Levels	Any contaminant > Severe Effect Level
Nuisance & Harmful Algae	Cyanobacteria	++	<2% coverage	N/A	>2% coverage
	Cladophora	+	<20% SAV extent	20-35% SAV extent	>35% SAV extent
Human Use	Beach Postings	+	<5% of days	5-20% of days	>20% of days
	Fish Consumption	+	>8 meals per month	Between 1 and 7 meals per month	Less than 1 meal per month
	Treated Drinking Water	+	No Adverse Water Quality Incidents (AWQI)	N/A	Adverse Water Quality Incidents

(N/A: not applicable)

See Table 1 for description of low, moderate and high stress thresholds	St. Marys River	North Channel	North Manitoulin Island	Cockburn Island	South Manitoulin Island	Killarney	French River to Parry Sound	Parry Sound	Parry Sound to Cognashene	Severn Sound	Christian Island	Wasaga Beach	Collingwood to Meaford	Owen Sound	Colpoy's Bay	Cape Croker to Cabot Head	Cabot Head to Burnt Point	Fathom Five	Cape Hurd to Chiefs Point	Chiefs Point to Point Clark	Point Clark to Goderich	Goderich to Kettle Point	Kettle Point to St. Clair River
Tributary Connectivity	75%	7%	70%	100%	79%	58%	36%	51%	59%	9%	100%	26%	45%	89%	100%	100%	100%	100%	100%	15%	36%	90%	84%
Shoreline Hardening	16%	6%	1%	<1%	<1%	<1%	<1%	4%	<1%	32%	12%	24%	45%	35%	25%	6%	<1%	4%	4%	17%	15%	28%	56%
Littoral Barriers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	1	3	1

Figure 15: Cumulative Stress on Canadian Nearshore Waters – Coastal Processes (N/A: measure is not applicable in the Regional Unit: for Littoral Barriers, because littoral drift is not a significant process in the Regional Unit).



The Contaminants in Water & Sediment category consists of three measures: Sediment Quality, Water Quality and Benthic Community. Overall, the category is a source of low to moderate cumulative stress across the nearshore.

Sediment Quality: metals were found in concentrations above Provincial guidelines in five Regional Units; these concentrations may reflect background conditions that are naturally elevated from run-off from the Canadian Shield but further investigation may be required; Severn Sound is the only Regional Unit where PCBs were detected above the No Effect Level.

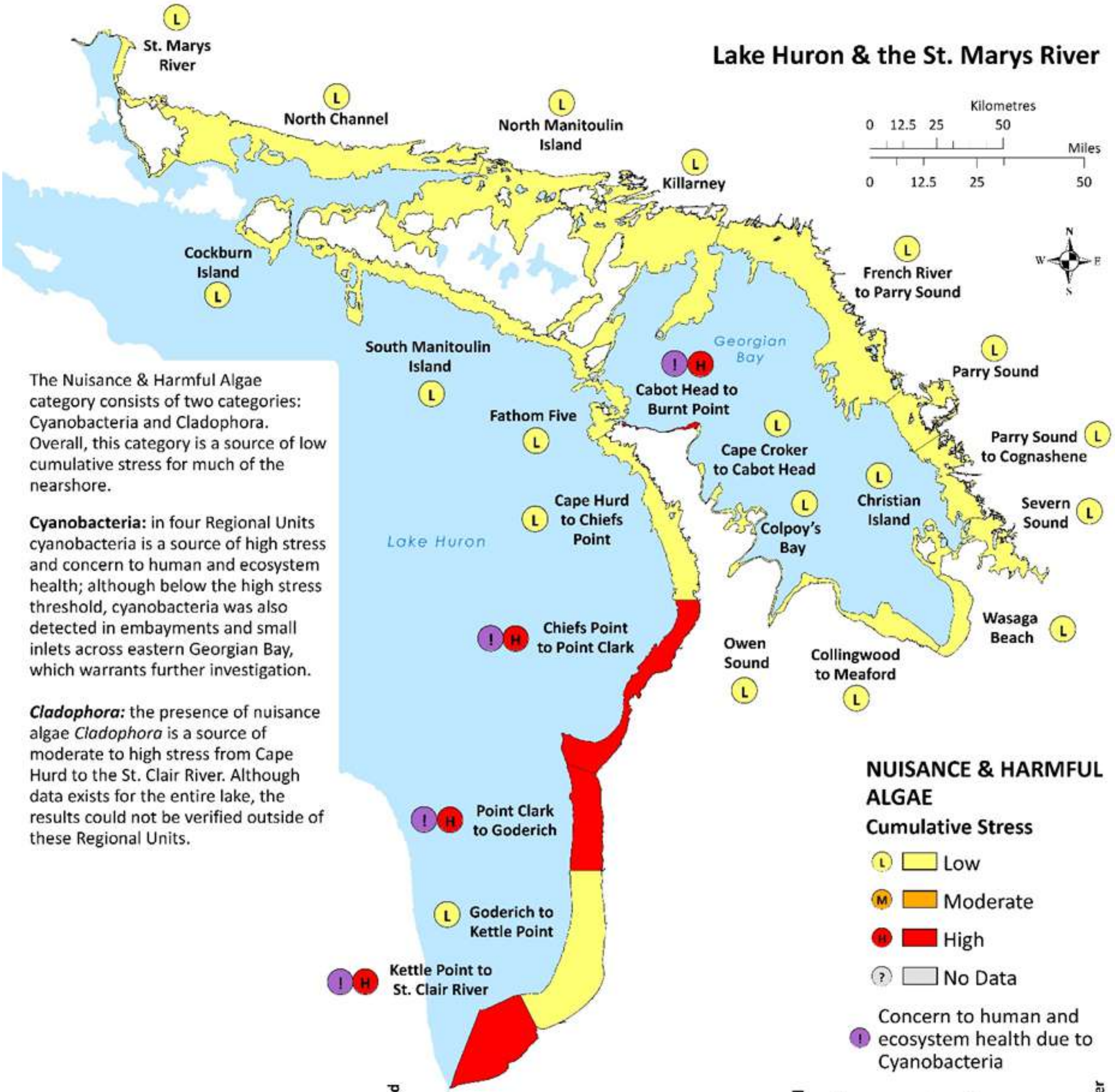
Water Quality: anthracene was recorded at concentrations that exceed published guidelines in the North Channel, but otherwise, water quality is not a source of stress.

Benthic Community: the St. Marys River, Killarney and Cape Crocker to Cabot Head Regional Units are characterized as having poor benthic community quality, due to low taxon richness and eveness; across much of the nearshore where data was available, benthic community quality is degraded but functional.

See Table 1 for description of low, moderate and high stress thresholds	St. Marys River	North Channel	North Manitoulin Island	Cockburn Island	South Manitoulin Island	Killarney	French River to Parry Sound	Parry Sound	Parry Sound to Cognashene	Severn Sound	Christian Island
Sediment Quality	No Data	Ni > SEL; 5 metals > LEL	Ni > SEL; 7 metals > LEL	No Data	0 exc.	No Data	Ni > SEL; 8 metals > LEL	Mn > SEL; Pb > PEL; 8 metals > LEL	Pb > PEL; 2 PAHs > LEL; 7 metals > LEL	Mn & Fe > SEL; PCBs > NEL; 8 metals > LEL	No Data
Water Quality	No Data	1 exc.	0 exc.	0 exc.	0 exc.	0 exc.	0 exc.	0 exc.	No Data	0 exc.	0 exc.
Benthic Community	Poor Quality	Mod. Quality	Mod. Quality	No Data	No Data	Poor Quality	Mod. Quality	Good Quality	Mod. Quality	Mod. Quality	Mod. Quality

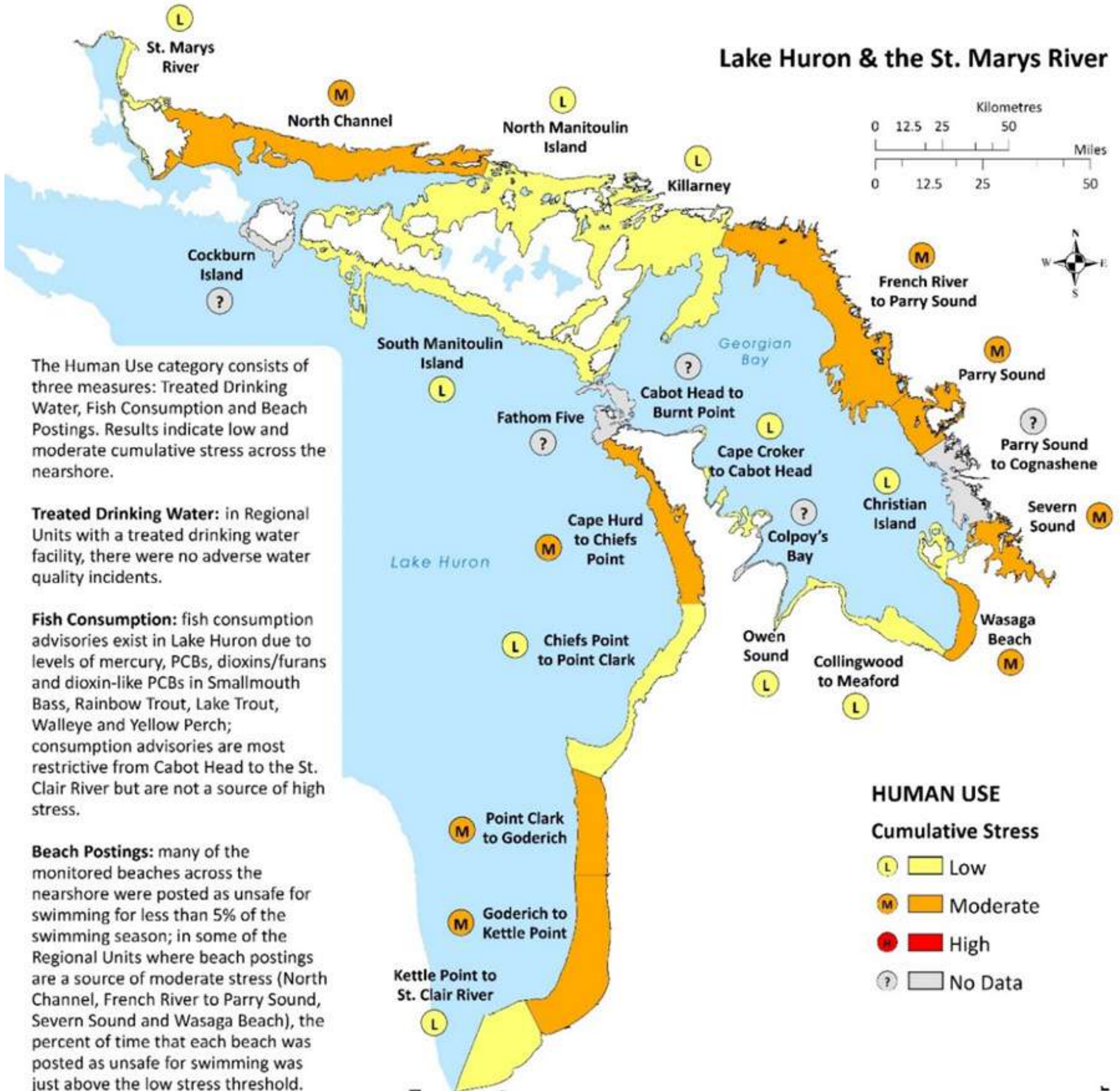
	Wasaga Beach	Collingwood to Meaford	Owen Sound	Colpoy's Bay	Cape Croker to Cabot Head	Cabot Head to Burnt Point	Fathom Five	Cape Hurd to Chiefs Point	Chiefs Point to Point Clark	Point Clark to Goderich	Goderich to Kettle Point	Kettle Point to St. Clair River
Sediment Quality	0 exc.	0 exc.	5 metals > LEL	1 metal > LEL	No Data	No Data	1 metal > LEL	2 metals > LEL	0 exc.	0 exc.	1 metal > LEL	No Data
Water Quality	No Data	0 exc.	0 exc.	No Data	0 exc.	0 exc.	0 exc.	0 exc.	0 exc.	0 exc.	0 exc.	No Data
Benthic Community	Mod. Quality	No Data	Mod. Quality	Good Quality	Poor Quality	No Data	No Data	Mod. Quality	No Data	No Data	Mod. Quality	No Data

Figure 16: Cumulative Stress on Canadian Nearshore Waters – Contaminants in Water & Sediment.



	St. Marys River	North Channel	North Manitoulin Island	Cockburn Island	South Manitoulin Island	Killarney	French River to Parry Sound	Parry Sound	Parry Sound to Cognashene	Severn Sound	Christian Island	Wasaga Beach	Collingwood to Meaford	Owen Sound	Colpoy's Bay	Cape Croker to Cabot Head	Cabot Head to Burnt Point	Fathom Five	Cape Hurd to Chiefs Point	Chiefs Point to Point Clark	Point Clark to Goderich	Goderich to Kettle Point	Kettle Point to St. Clair River
Cyanobacteria	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	3%	<2%	<2%	4%	4%	<2%	5%
Cladophora	N/A	unable able to verify	unable able to verify	unable able to verify	unable able to verify	unable able to verify	unable able to verify	unable able to verify	unable able to verify	N/A	unable able to verify	unable able to verify	unable able to verify	unable able to verify	unable able to verify	unable able to verify	unable able to verify	unable able to verify	28%	24%	26%	34%	38%

Figure 17: Cumulative Stress on Canadian Nearshore Waters – Nuisance & Harmful Algae (N/A: measure is not applicable in the Regional Unit: for Cladophora, because the habitat conditions are not conducive for growth in the Regional Unit).



See Table 1 for description of low, moderate and high stress thresholds	St. Marys River	North Channel	North Manitoulin Island	Cockburn Island	South Manitoulin Island	Killarney	French River to Parry Sound	Parry Sound	Parry Sound to Cognashene	Severn Sound	Christian Island	Wasaga Beach	Collingwood to Meaford	Owen Sound	Colpoy's Bay	Cape Croker to Cabot Head	Cabot Head to Burnt Point	Fathom Five	Cape Hurd to Chiefs Point	Chiefs Point to Point Clark	Point Clark to Goderich	Goderich to Kettle Point	Kettle Point to St. Clair River
Treated Drinking Water	0 AWQI	0 AWQI	0 AWQI	N/A	0 AWQI	0 AWQI	N/A	N/A	N/A	0 AWQI	N/A	N/A	0 AWQI	0 AWQI	N/A	0 AWQI	N/A	N/A	N/A	0 AWQI	N/A	0 AWQI	0 AWQI
Fish Consumption	8	6	7	9	8	7	7	7	8	7	9	9	9	9	9	9	5	3	6	6	7	6	5
Beach Postings	13%	5%	1%	N/A	2%	0%	6%	<1%	N/A	7%	1%	7%	13%	N/A	N/A	19%	N/A	N/A	0%	4%	14%	11%	3%

Figure 18: Cumulative Stress on Canadian Nearshore Waters – Human Use (N/A: measure is not applicable in the Regional Unit: for Treated Drinking Water, because there are no treated drinking water plants in the Regional Unit and for Beach Postings, because there are no publicly monitored beaches).

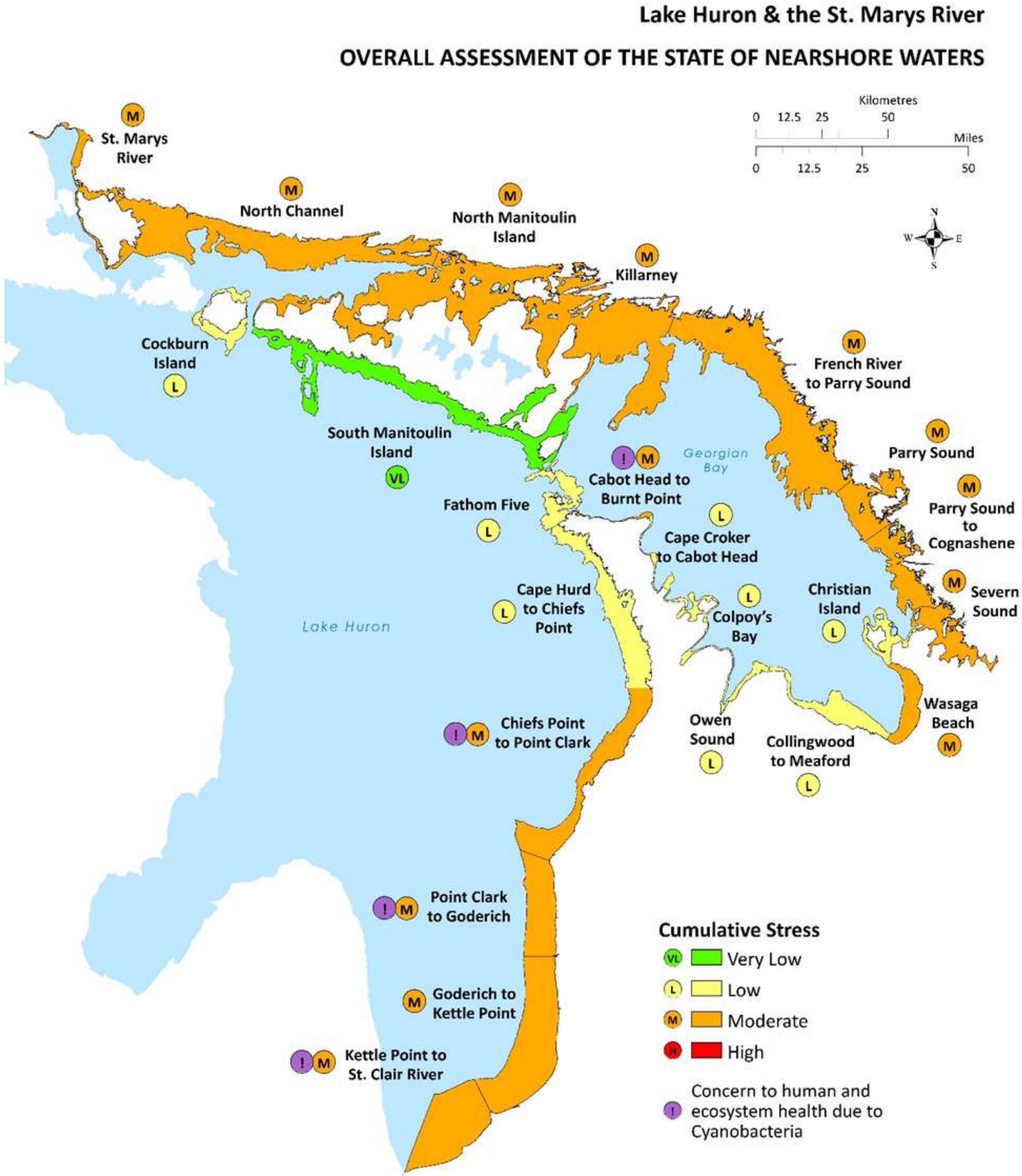


Figure 19: Cumulative Stress on Canadian Nearshore Waters – Overall Results.

5.5.3.2 U.S. Nearshore Waters

The United States uses a system of long-standing collaborative programs between EPA, states, and Tribal Nations under the Clean Water Act to assess the quality of watersheds and nearshore waters in the Great Lakes. Achievement of the U.S. Clean Water Act's primary goal – to restore and maintain the integrity of the nation's waters – is dependent on having good information about watershed condition, as the health of receiving waters is heavily influenced by the condition of their surrounding watersheds.

The Impaired Waters and Total Maximum Daily Load (TMDL) Program is an important component of the Clean Water Act's framework to restore and protect U.S. waters. The program is comprised primarily of a two-part process. First, states and Tribal Nations identify waters that are impaired or in danger of becoming impaired (threatened) and second, for these waters, states and Tribal Nations determine pollutant reduction levels, called Total Maximum Daily Loads (TMDLs), or in some cases alternative restoration approaches for these waterbodies necessary to meet approved water quality standards. TMDLs establish the maximum amount of a pollutant allowed in a waterbody and serve as the starting point or planning tool for restoring water quality.

Every two years, States are required to develop Integrated Water Quality Monitoring and Assessment Reports (also called Integrated Reports) that indicate the general condition of the State's waters and identify waters that are not meeting water quality goals. The Integrated Report satisfies the Clean Water Act requirements for both Section 305(b) for biennial reports on the condition of the State's waters and Section 303(d) for a prioritized list of impaired waters. To find impaired waters in your state using the Assessment and TMDL Tracking System (ATTAINS) visit https://ofmpub.epa.gov/waters10/attains_index.home. Because of differences in state assessment methods, the information in this site should not be used to compare water quality conditions between States or to determine water quality trends.

Under the Clean Water Act, the EPA is also required to periodically report on the condition of the nation's water resources by summarizing water quality information provided by the States. However, approaches to collecting and evaluating data vary from state to state, making it difficult to compare the information across states, on a nationwide basis, or over time. To enable this reporting, the EPA uses the National Aquatic Resource Surveys (NARS), which are statistical surveys designed to assess the status of and changes in quality of the nation's coastal waters, lakes and reservoirs, rivers and streams, and wetlands. Using sample sites selected at random, these surveys provide a snapshot of the overall condition of the nation's waters. Because the surveys use standardized field and lab methods, results from different parts of the country and between years can be compared. EPA works with State, tribal, and federal partners to design and implement the NARS program. These surveys provide critical, nationally consistent water quality information. Additionally, the national surveys are helping to build stronger water quality monitoring programs across the country by fostering collaboration on new methods, new indicators and new research.

The National Coastal Condition Assessment (NCCA) is a national coastal monitoring program with rigorous quality assurance protocols and standardized sampling procedures designed and used by NARS to produce unbiased national and regional estimates of coastal condition and to assess change over time (Nord, et al., 2016). The sample design is based on a random, stratified survey, where each site sampled represents a known amount of area of the nearshore system. NCCA surveys are conducted every 5 years and the data collected are used to evaluate four primary indices of condition: water quality (which is a composite of chlorophyll a, water clarity, dissolved oxygen, and total phosphorus conditions), sediment quality (which is a composite of sediment toxicity and sediment contaminant conditions), benthic community condition, and fish tissue contaminants – to evaluate the ecological condition and recreational potential of nearshore areas of the Great Lakes. Results for each index of condition are categorized as good, fair, and poor based on set thresholds (Gregor and Rast, 1979; PMSTF, 1980). Details about the methods used for data collection and indicators are available here. The EPA and state partners conducted surveys of all the Great Lakes under NCCA during the summer and fall of 2020 and 2021, but data from these surveys are currently under review.

Critical coastal monitoring also occurs via implementation of the U.S. Coastal Zone Management Program. The program is a voluntary partnership between the federal government and U.S. coastal and Great Lakes states and territories, authorized by the Coastal Zone Management Act (CZMA) of 1972 to address national coastal issues. The program is administered by NOAA. The Coastal Zone Enhancement Program was established in 1990 under Section 309 of the Coastal Zone Management Act to encourage improvements to state and territory coastal management programs. The focus is on nine enhancement areas: wetlands, coastal hazards, public access, marine debris, cumulative and secondary impacts, special area management plans, ocean and Great Lakes resources, energy and government facility siting, and aquaculture.

In support of the Coastal Zone Management Program, the Michigan Coastal Management Program (MCMP) provides technical assistance and grant funding to coastal communities to assist in their efforts to mitigate coastal hazards, create healthy habitats, support coastal eco-tourism opportunities, and support resilient and sustainable coastal economies. The program boasts more than 40 years of existence and accomplishments. In Lake Huron, the program has provided technical and financial support to projects that assess storm water issues and management.

The MCMP is overseen by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) Office of the Great Lakes. EGLE is involved in a variety of other Great Lakes nearshore monitoring and protection efforts. For example, EGLE provides funds and resources to local managers to monitor beach safety and contamination on public beaches of the Great Lakes and compiles these data to report on water quality. EGLE is also a partner in AOC monitoring and clean-up efforts on Lake Huron (as well as the St. Marys, St. Clair, and Detroit Rivers) and provides funding and support for shoreline protection projects.

NEARSHORE STATUS AND SUPPORTING DATA

Lake Huron NCCA results (2015)

During 2015, 67 sites were sampled to assess 3,289 km^2 of Lake Huron's nearshore area (Figure 20). Much of the nearshore area of Lake Huron was in good condition based on the four primary indicators. Based on the water quality index (an indicator of eutrophication), 47±10% of Lake Huron's combined nearshore area was classified as being in good condition, 36±11% was in fair condition, and 17±5% was in poor condition. Of the water quality index components, chlorophyll a and dissolved oxygen conditions were good in 59±7% and 100% of the nearshore area, respectively. Total phosphorus and clarity conditions were both good in approximately 43±9% of the Lake Huron nearshore area.

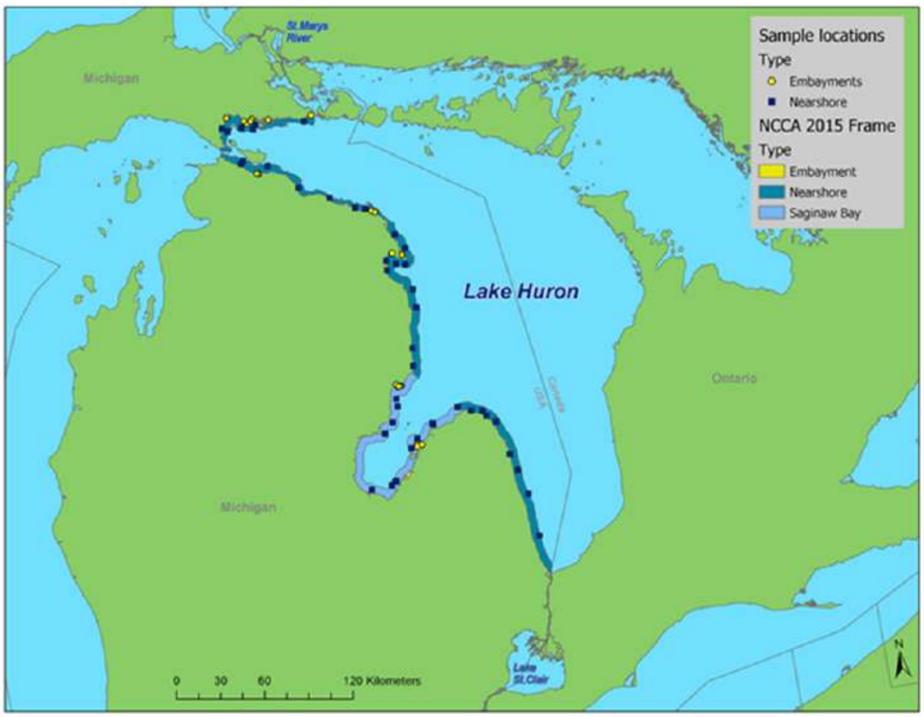


Figure 20: Sample locations in Lake Huron for the 2015 NCCA. Source: EPA

Conditions based on cyanobacteria cell counts were good in 34±8% of the Lake Huron nearshore area and were fair and poor in 43% and 25% (respectively) in the remaining nearshore area of the lake. Microcystin concentrations at 100% of the nearshore area assessed in Lake Huron had good conditions based on the threshold of 8 µg/L for low risk to recreational users. Microcystin was detected at only 18 of the 67 sites in Lake Huron and concentrations ranged from 0.11-4.23 µg/L. No sites exceeded the EPA recreational threshold of 1,280 calibrator cell equivalents (CCE)/100 mL for enterococci in Lake Huron in 2015.

Sediment quality conditions in Lake Huron were good in more than 60% of the area in the nearshore because sediment contaminant and sediment toxicity conditions were also generally good (Figure 21).

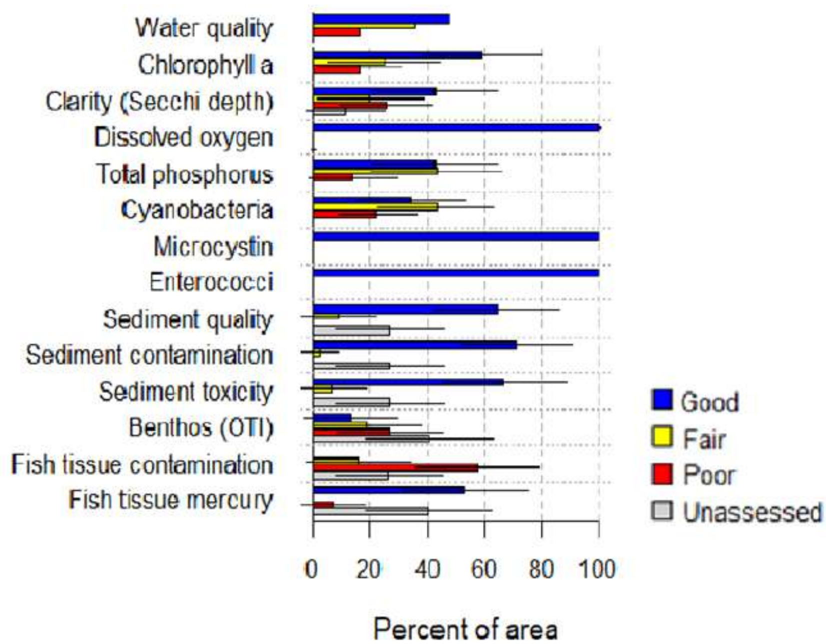


Figure 21: Sediment quality conditions in Lake Huron. Source: Pawlowski, et al., 2019.

Benthos conditions could not be assessed in 41% of the Lake Huron nearshore area. Of the unassessed area, 27% was due to PONARs not being collected and 14% was due to PONAR samples not containing the tolerance-classified oligochaetes necessary to calculate the OTI. Benthos conditions in the assessed area of the nearshore were 13±11% good, 35% fair, and 17% poor. Efforts are being made to utilize more of the benthic organisms, not just oligochaetes, for benthic assessments. This will eventually increase the amount of area that can be assessed.

Fish tissue mercury conditions in Lake Huron were good in about 53±7% of the nearshore area. About 7% of the area of the nearshore was found to have poor fish tissue mercury conditions and the remaining 40% went unassessed due to lack of sufficient amounts of fish caught.

Based on underwater video, round gobies were present for an estimated 4% of the nearshore area in Lake Huron, with an additional 2% of the area with possible goby presence. However, 18% of the area went unassessed due to poor video quality. Dreissenid mussels were estimated to be present across 46% of Lake Huron's nearshore area. Figure 22 summarizes conditions in the Lake Huron nearshore.

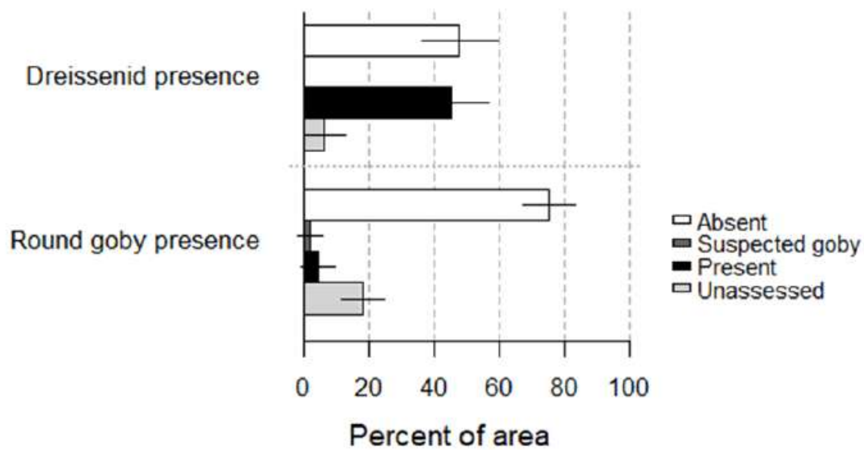


Figure 22: Dreissenid and Round Goby presence in Lake Huron Nearshore (U.S.). Source: Pawlowski, et al., 2019.

Pilot studies to assess the St. Marys River were done during 2015 and 2016. In the St. Marys River, 94 total sites in the US and Canada were assessed. Water quality conditions in this system were compared to conditions in the Great Lakes nearshore in Wick et al., 2019. Fish tissue contaminant and mercury conditions in the St. Marys River had slightly more area assessed as good than in Lake Huron, but also had less unassessed area. Benthos conditions in St. Marys River had considerably higher amounts of area in good condition compared to Lake Huron. This Connecting River study was intended to give system-wide context in places where known, localized contamination and degradation have occurred. Figure 23 presents conditions in the St. Marys River.

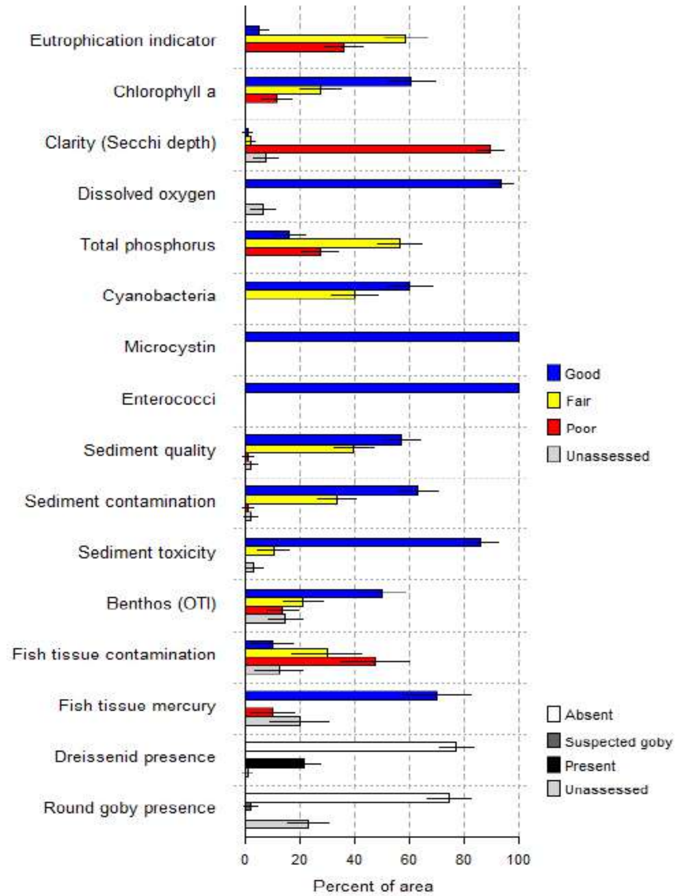


Figure 23: Water quality conditions in the St. Marys River (2015-2016). Source: Pawlowski, et al., 2019.

THREATS

Threats to Lake Huron's nearshore areas include impacts to habitats and/or water quality due to shoreline hardening; loss of tributary connectivity and coastal wetlands; invasive species; nuisance algae; harmful algal blooms; and contaminants and bacteria.

IMPACTED NEARSHORE AREAS

Michigan: For its state integrated reporting, Michigan monitors beach conditions on the shores of Lake Huron, and also assists other agencies with coastal wetlands monitoring and the EPA with the NCCA program.

Michigan's integrated reports provide links to the beach monitoring efforts of the Michigan Department of Environmental Quality. Beaches along Lake Huron periodically reach bacterial levels of *E. coli* that exceed safety guidelines for recreation. The report also notes that there are consumption advisories for Lake Huron fish due to PFOS. Lastly, the report also describes the status of Saginaw Bay, especially as it relates to BUIs like fish consumption and nuisance algae.

5.5.4 Other Threats: Climate Change Impacts

Climate change is amplifying variability in a system naturally predisposed to fluctuations in temperature, water quantity, and weather events and interacts with all other ecosystem stressors in complex ways. Nearshore areas may be more vulnerable to the effects of climate change because more intense rainfall events can result in shoreline erosion, non-point source run-off, and high wave action. This could potentially result in loss of biodiversity of aquatic and terrestrial species and changes to shoreline and wetland structure and function.

In recent years, increasing Great Lakes surface water temperatures have been driven by increasing ambient air temperatures during the spring and summer months and declining ice-cover in the winter months. Combined, these factors have contributed to lower water levels by increasing rates of evaporation and causing lake ice to form later than usual and break up earlier in the spring, which extends the evaporation season (Austin and Colman, 2007; Gronewold et al., 2013; USGCRP, 2018). However, the past few years (2017-2022) have shown the opposite trend with water level increases at the high end of the historical range corresponding with long-term water level trends that have fluctuated since 1918 (USACE, 2022). Even so, with current high-water levels, the number of days per winter with lake ice coverage has declined since the start of recordkeeping in 1973 (Mason et al., 2016). Interestingly, ice cover has decreased the most in the north (i.e., Lake Superior and Northern Lake Michigan and Lake Huron) and in coastal areas. Great Lakes ice cover is expected to continue to decrease in the future; however, these decreasing ice cover trends are expected to be interspersed with cold air outbreaks and high ice-covered winters (NOAA, 2021). Reductions in ice cover will result in more winter lake-effect precipitation and increased winter wave activity (Wang et al., 2012). These shorter winters and earlier spring open lake waters will allow the lakes to become stratified earlier, allowing the lakes a longer period to warm and amplifying the effects of warmer summer air temperatures (Austin and Colman, 2007). Significant changes to the physical properties of the lakes (i.e., ice cover, water temperature, and evaporation) have important implications for the climate of the Great Lakes region. Most prominently, the formation of lake-effect precipitation requires open water on the lakes. Declining ice cover, or longer periods of the year with open lake water, combined with warmer surface temperatures, will lead to increased lake-effect precipitation in the future. In the near term this may mean increased lake-effect snow, but as air temperatures rise lake-effect snow could transition to lake-effect rain.

5.5.5 Actions to Prevent and Address Other Threats

The Lake Huron Partnership agencies will implement the 2022-2026 *LAMP* within the context of existing laws and regulations which actively contribute to the restoration and protection of Lake Huron. Federal, state and provincial legislation that address invasive species are listed in Appendix B. These include Canada's Impact Assessment Act (2019) and the United States' Protecting our Infrastructure of Pipelines and Enhancing Safety Act (2016). Spill prevention and contingency plans are in place for Ontario, and Michigan.

In addition, the Canada-United States Joint Inland Pollution Contingency Plan is in place, should there be a significant accidental and unauthorized release of pollutants along the Canada-U.S. border. The Canada-United States Joint Marine Pollution Contingency Plan is a mechanism for the two countries to coordinate preparedness and response to spills in shared waters. This plan covers all potential sources of marine pollution in contiguous waters (i.e., ships, offshore platforms, mystery spills).

Other national and regional plans and initiatives that address other threats include, but are not limited to:

- 2020 Great Lakes Marine Debris Action Plan
- Measures initiated in 2020 by Transport Canada to enhance Canadian railway safety and the safe transportation of dangerous goods
- Canadian 2018 ban of the manufacture and import of all toiletries that contain plastic microbeads
- U.S. 2017-2019 ban on the manufacturing, packaging, and distribution of rinse-off cosmetics containing plastic microbeads
- U.S. Great Lakes Restoration Initiative

LAMP Actions

Actions will be taken in the Lake Huron basin to further reduce other threats and to track progress through science and monitoring as listed in Table 14.

Table 14: Actions to prevent and address other threats

#	2022-2026 Lake Huron Partnership Management Actions	Agencies* Involved
	Actions to Prevent and Address Other Threats	
43	**Watershed Resilience:** Continue efforts that engage landowners and the public in protecting and enhancing the proper functioning of watershed headwater features, streams, forests, and wetlands to maintain and enhance resilience to climate change impacts, including local climate change strategies and actions.	MECP, MDNR, BMIC, Conservation Authorities, USDA-NRCS, USDA-FS, PC, SSEA
44	Organize, participate, or support capture and clean-up projects to prevent and remove plastic pollution including “nurdles” from Lake Huron waterways and coastlines.	MECP, ECCC
45	Critical community infrastructure: Plan and implement Low Impact Development initiatives that are suited to future extreme weather events through projects that increase green space and green infrastructure.	SCIT, MECP, EGLE, Conservation Authorities, USDA-FS, EPA, ECCC
46	Assess on a lakewide basis, the cumulative effect of climate change on chemical contaminants, nutrients, invasive species and habitat and native species as it relates to the physical (e.g., substrate, bathymetry, sediment transport), chemical, and biological (e.g., food web) processes of Lake Huron.	ECCC, USGS, NOAA, EGLE, USFWS
47	Characterize the presence & distribution of microplastics in Lake Huron and analyze their effects on the physical, chemical, and biological (e.g., food web) processes of Lake Huron.	MECP, ECCC, USGS, NOAA
48	Improve understanding of the impacts of groundwater on the physical, chemical, and biological processes in specific ecological zones (inshore and nearshore) of Lake Huron to guide management actions in the future.	USGS, MECP
49	To the extent possible, quantify groundwater contribution to the water budget of Lake Huron in specific sub-basins.	USGS
50	Support outreach and engagement opportunities to stakeholders and the public on the impacts of climate change to the Great Lakes and Lake Huron through fact sheets, newsletters, and other means.	LTBB, Conservation Authorities, ECCC, NOAA, USDA-FS, EPA, USACE, PC, SSEA
51	Continue public outreach and engagement on the impacts of plastic waste pollution and ways to reduce the amount of plastic in the Lake Huron basin.	LTBB, SCIT, ECCC, EPA, USACE, PC
52	Increase the public's awareness of: the potential impacts associated with transporting oils and other hazardous materials by road, rail, ship, and pipeline; spill contingency plans already in place; and where to report spills of oils and other hazardous materials.	LTBB, BMIC, LRBOI, CORA, SCIT

**Acronyms for agencies not listed as Lake Huron Partnership agencies on page iv are: Michigan Department of Health and Human Services (MDHHS); Transport Canada (TC).*

Actions Everyone Can Take

- Report an oil or hazardous materials spill:
    - Ontario's pollution reporting hotline at 1-866-MOE-TIPS (663-8477)
    - Michigan's pollution emergency alerting system at 1-800-292-4706
- Participate in public input opportunities for major land development proposals.
- Purchase clothing made of natural materials like cotton or wool, and/or install a synthetic fibers capture trap on your washing machine to reduce the release of plastic fibers from materials like polyester, nylon and acrylic.
- Use reusable products, and limit use of single use plastic products.
- Recycle plastic products.
- Pick up litter on the beach or organize a group shoreline clean-up.

Sunset at the north shore of Georgian Bay, Emma Kirke

6.0 LAKEWIDE MANAGEMENT

Achieving the General Objectives of the Agreement is a challenging task and one that requires collective action by many partners throughout the Lake Huron basin. The 2022-2026 Lake Huron *LAMP* presents current ecosystem conditions and threats, sets priorities for research and monitoring, and identifies actions for governments and the public to take. The *LAMP* is a resource for anyone interested in the Lake Huron basin ecosystem, its water quality, and the actions necessary to help protect this Great Lake.

6.1 Implementation, Engagement and Reporting

Lake Huron Partnership agencies commit to incorporate *LAMP* actions in their decisions on programs, funding and staffing to the extent feasible. Each Lake Huron Partnership member agency will contribute to the implementation of one or more of the *LAMP*'s 54 actions.

Implementation of the *LAMP* is guided by a governance system overseen by the Great Lakes Executive Committee and illustrated in Figure 24. Lake Huron Partnership agencies are guided by a set of principles and approaches found in the *GLWQA*, including those presented in Table

15. An update to the public on *LAMP* implementation accomplishments and challenges will be released annually.

Great Lakes Executive Committee	Lead by senior federal government agency representatives from Canada and the United States to delivery major programs under the Great Lakes Water Quality Agreement (*GLWQA*).
Lake Huron Partnership Management Committee	Senior level representatives from federal, state and provincial governments, tribal governments, First Nation, Métis, municipal government and watershed management agencies with decision-making authority on direction, development, and implementation efforts in the Lake Huron basin ecosystem.
Lake Huron Partnership Working Group	Government agency representatives who contribute to and coordinate *LAMP* development, implementation and reporting.
Lake Huron Partnership Subcommittees	Lead by one or more Lake Huron Partnership Working Group member to engage experts and facilitate issue-specific collaboration and development of recommended priorities for science and action.

Figure 24: Lake Huron lakewide management under the GLWQA.

Table 15: Selected principles and approaches found in the Agreement

Principles & Approaches	Implementation Description
Accountability	Tracking and evaluating agency actions. Regular reporting, including public annual updates.
Coordination	Undertaking opportunities to coordinate on protection and restoration projects, science and monitoring, communications and engagements.
Ecosystem Approach	Taking actions that integrate the interacting components of air, land, water, living organisms including humans.
Public Engagement	Incorporating public opinion and advice gathered through agency engagements, as well as Lake Huron Partnership public webinars, presentations, and updates.
Science Based Management	Using current and best available science and traditional knowledge in management decisions.

The Cooperative Science and Monitoring Initiative (CSMI) is a joint United States and Canadian effort implemented under the Science Annex of the Agreement. CSMI provides managers with the science and monitoring information necessary to make management decisions on each Great Lake. CSMI follows a five-year rotating cycle in which one lake undergoes intensive investigation each year. The emphasis on a single lake per year allows for coordination of science and monitoring activities focusing on the information needs of lakewide management for the particular lake. The current 5-year CSMI cycle for Lake Huron is depicted in Figure 25. Previous Lake Huron intensive field years took place in 2017 and 2012.

Figure 25: Lake Huron CSMI 2022-2026 timeline.

Another effective *LAMP* implementation strategy is to educate the large number of regional and local businesses, academic institutions, and community groups on the actions in the Lake Huron *LAMP*.

Everyone has a role to play in protecting, restoring, and conserving Lake Huron. Engagement, collaboration, and active participation of all levels of government, watershed management agencies, and the public are the cornerstone of current and future actions. Collective action is essential for the successful implementation of this *LAMP* and for the achievement of the General Objectives of the *GLWQA*. The challenges and threats to Lake Huron need to be more widely recognized, as do opportunities for everyone to play a role in finding solutions that ensure a healthy watershed and lake ecosystem now and into the future.

Engagement, education, and involvement will support and move the public from the role of observer to active participant. Local communities, groups, and individuals are among the most effective champions to achieve environmental sustainability in their own backyards and communities. Member agencies of the Partnership will pursue binational and domestic outreach and engagement activities to consult on challenges, priorities, and strategies and to encourage and support active community-based environmental action.

Individuals can get more involved by:

- Reviewing and providing input on the development of Lakewide Action and Management Plans;
- Keeping informed, through access to *LAMP* annual updates at www.binational.net;
- Attending public meetings or summits hosted by government agencies of the Lake Huron Partnership;
- Participating in Great Lakes events, many of which are captured on www.glc.org/greatlakescalendar/;
- Contributing to projects administered by local organizations to improve water quality and ecosystem health; and
- Attending the triennial Canada-U.S. Great Lakes Public Forums, https://binational.net/?s=public+forum.

6.2 Collective Action for a Healthy Lake Huron

The 2022-2026 *LAMP* identifies actions needed to address priority threats in Lake Huron. The public plays a key role as partners, advocates, and implementers for lakewide protection and management. Together, with federal, State and Provincial governments, Tribal governments, First Nations, Métis, Municipal governments, watershed management agencies, and other local public agencies we can collectively:

- **Prevent and reduce chemical contaminant pollution** by controlling and reducing Chemicals of Mutual Concern and Chemicals of Emerging Concern through existing programs, undertaking site-specific remedial action where appropriate, and studying and characterizing pollutants. Everyone can help prevent the release of harmful chemicals into the environment through activities such as taking household hazardous materials to hazardous waste collection depots and refraining from burning garbage in barrels, open pits, or outdoor fireplaces.

- **Prevent and reduce nutrient and bacterial pollution** by investing in climate resiliency through green infrastructure and forest health in order to prevent excessive run-off and erosion from the land to the lake. Everyone can help to prevent nutrient and bacterial pollution through actions such as picking up pet waste and avoiding the use of lawn and garden fertilizers containing phosphorus when possible.

- **Protect and restore habitats and species** by remediating and protecting habitats, rehabilitating native species, increasing habitat resiliency to climate change impacts, and by increasing scientific understanding of the aquatic food web, fish dynamics and coastal wetlands. Everyone can help protect habitats and species through activities such as protecting and restoring local natural spaces.

- **Prevent and control invasive species** by preventing their introduction, limiting their spread or eradicating where possible, by early detection and response, and by improving our understanding of their impacts. Everyone can help control invasive species through activities such as learning how to spot, report and control the most harmful invasive species in your local natural spaces.

Together, our collective action will help advance the achievement of the nine *Great Lakes Water Quality Agreement*'s General Objectives by reducing chemical contamination, preventing nutrient and bacteria pollution, protecting habitats and species, preventing and controlling invasive species, and helping to address other threats such as plastics, risks from oil transport, and cumulative impacts on the nearshore areas of the lake.

Trail along the north shore of Georgian Bay, Emma Kirke

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APPENDIX A: Areas of Concern

The *Great Lakes Water Quality Agreement* defines an Area of Concern (AOC) as a geographic area designated by Canada and the United States of America where significant impairment of beneficial uses has occurred as a result of human activities at the local level.

Saginaw River and Bay Area of Concern

The Saginaw River and Bay AOC has nine remaining BUIs. Several of the existing BUIs are linked to the need for sediment contamination remediation. Sediment cleanup efforts continue upstream of the AOC, through the Superfund program. The remaining BUIs are being addressed through collaboration with local partners and federal agencies.

There are several ongoing evaluation and assessment projects occurring within the AOC. These monitoring and data assessments are necessary to collect baseline information, identify current conditions and track trends. The results of these efforts will be used to determine the status of each related BUI and help determine which actions will need to be implemented for BUI removal. Local partners and federal agencies will continue to monitor and evaluate data collected, until decisions on management actions can be made.

Spanish Harbour Area of Concern in Recovery

Spanish Harbour AOC was originally recognized as an Area of Concern due to past degraded water and sediment quality caused by effluent from local and regional industries, municipal wastewater works, development, and historic log-driving operations (Spanish Harbour: Area of Concern, 2017). Remedial actions were completed at Spanish Harbour, and it is currently designated as an AOC in Recovery as natural recovery takes place. Restrictions on Dredging was removed as an impairment in December 2020.

St. Marys River Area of Concern

St. Marys River AOC is a binational AOC (shared by Canada and the U.S.), that historically had degraded habitat and impacted water and sediment quality from development, river and shoreline alteration, and effluent from municipal and industrial sources. Through the combined efforts of many partners, major strides have been made in improving water quality and ecosystem health in the binational St. Marys River AOC, and assessment studies are showing a number of the original impairments have been restored, with community engagement on the results now underway. The three BUI’s on the U.S. side are benthos degradation, fish tumors, and fish consumption. All management actions for these BUI’s have been completed

Severn Sound - Delisted

Collingwood Harbour - Delisted

APPENDIX B: Selected Legislation That Contributes to the Protection and Restoration of Lake Huron

Lake Huron Partnership member agencies work within the context of laws and regulations to adopt common objectives, implement cooperative programs, and collaborate to address environmental threats to Lake Huron. Selected legislation is presented in Table B1.

Table B 1: Selected Legislation That Contributes to the Protection and Restoration of Lake Huron

Selected Legislation	Lake Huron Issue(s)	Description
Canada		
Canadian Environmental Protection Act, 1999	• Chemical contaminants • Nutrient & bacterial pollution	Pollution prevention and the protection of the environment and human health in order to contribute to sustainable development
Fisheries Act, 2016	• Chemical contaminants • Habitat & species • Nutrient & bacterial pollution	Conservation and protection of fish and fish habitat, including by preventing pollution.
Canada Shipping Act, 2001	• Chemical contaminants • Invasive species	Protect the marine environment from damage due to navigation and shipping activities, including ballast water control and management regulations.
Canadian Environmental Assessment Act, 2012	• Chemical contaminants • Habitat & species	Outlines approach for determining and undertaking a federal environmental assessment for proposed projects.
Canada National Marine Conservation Areas Act, 2002	• Habitat & species	Protect and conserve marine areas for the benefit, education and enjoyment of the people. Prohibits mining and oil/gas exploration.
Canada National Parks Act, 2000	• Habitat & species	Protects the ecological integrity of national park managed lands and waters.
Species at Risk Act, 2002	• Habitat & species	Protect endangered or threatened organisms and their habitats.

Selected Legislation	Lake Huron Issue(s)	Description
United States		
Clean Water Act, 1972	• Chemical contaminants • Nutrient & bacterial pollution	Regulates discharges of pollutants into the waters of the U.S. and establishes water quality standards for surface waters. Implementation and enforcement may be delegated to the States and incorporated into their regulatory programs.
Safe Drinking Water Act, 1974	• Chemical contaminants • Nutrient & bacterial pollution	Protects public water supplies from harmful contaminants by establishing standards and treatment requirements for public water supplies, control underground injection of wastes, finance infrastructure projects, and protect sources of drinking sources.
Clean Air Act, 1990	• Chemical contaminants	Regulates air emissions from stationary and mobile sources and establishes National Ambient Air Quality Standards to protect public health. Implementation and enforcement may be delegated to States and incorporated into their regulatory programs.
Pollution Prevention Act, 1990	• Chemical contaminants	Directs U.S.EPA to undertake a series of activities aimed at preventing the generation of pollutants, rather than controlling pollutants after they are created.
Protecting our Infrastructure of Pipelines and Enhancing Safety (PIPES) Act, 2016	• Chemical contaminants • Other	Requires annual federal reviews of all pipelines' age and integrity.
U.S. Toxic Substances Control Act, 1976	• Chemical contaminants	Addresses human health and environmental impacts of chemicals in industrial use through a combination of voluntary and regulatory risk management activities.

Selected Legislation	Lake Huron Issue(s)	Description
Solid Waste Disposal Act and Resource Conservation and Recovery Act	• Chemical contaminants	Regulates solid and hazardous wastes, and mandates corrective action to address improper waste management practices.
Comprehensive Environmental Response, Compensation (Superfund), 1980	• Chemical contaminants	Cleans up abandoned chemical contamination sties, which threaten human health. Toxics Release Inventory (TRI), developed under the Emergency Planning and Community Right-to-Know Act.
Agricultural Improvement Act of 2018 (U.S. Farm Bill)	• Nutrient & bacterial pollution • Habitat & species	Provides authorization for services and programs by the U.S. Department of Agriculture, which include several agricultural environmental conservation programs that benefit water quality and habitat.
U.S. Great Lakes Legacy Act, 2002	• Chemical contaminants	Provides federal funding to accelerate contaminated sediment remediation in Areas of Concern.
Coastal Zone Management Act, 1972	• Nutrient & bacterial pollution	Provides for the management of the nation's coastal resources, including the Great Lakes. The Act outlines three national programs, the National Coastal Zone Management Program, the National Estuarine Research Reserve System, and the Coastal and Estuarine Land Conservation Program.
Endangered Species Act, 1973	• Habitat & species	Protect and recover imperiled species and the ecosystems upon which they depend.
National Invasive Species Act, 1996	• Invasive species	U.S. federal law intended to prevent invasive species from entering inland waters through ballast water carried by ships.
Lacey Act, 1900	• Invasive species	U.S. federal act that prevents transport of species designated as 'Injurious to Wildlife'.

Selected Legislation	Lake Huron Issue(s)	Description
Oil Pollution Act, 1990	• Chemical contaminants • Habitat & species	Streamlined and strengthened EPA's ability to prevent and respond to catastrophic oil spills.
	Ontario	
Nutrient Management Act, 2002	• Nutrient & bacterial pollution	A nutrient management framework for Ontario’s agricultural industry, municipalities, and other generators of materials containing nutrient; includes environmental protection guidelines.
Ontario Water Resources Act, 1990 and Environmental Protection Act, 1990	• Chemical contaminants • Nutrient & bacterial pollution	Provincial regulation of private and industrial discharges of contaminants from prescribed industrial sectors into surface waters, prohibition of the discharge of a contaminant/polluting material without the required permissions.
Ontario Invasive Species Act, 2015	• Invasive species	Rules to prevent and control the spread of invasive species in Ontario.
Fish and Wildlife Conservation Act	• Habitat & species	Provides the protections and regulations for fishing and hunting activities in Ontario
Great Lakes Protection Act, 2015	• Nutrient & bacterial pollution • Habitat & species	Requires the development of science-based targets and action plans to address threats such as nutrients. Ensures that programs or other actions will be used to monitor and report on array of ecological conditions.
Environmental Assessment Act, 1990	• Chemical contaminants • Nutrient & bacterial pollution	Requires governments and public bodies to consider potential environmental effects before an infrastructure project begins.
Conservation Authorities Act, 1990	• Habitat & species	Provides for the organization and delivery of programs and services that further the conservation, restoration, development, and

Selected Legislation	Lake Huron Issue(s)	Description
		management of natural resources in watersheds.
Safe Drinking Water Act, 2002	• Chemical contaminants • Nutrient & bacterial pollution	Provides the control and regulation of drinking-water systems and drinking-water testing.
Tribal Nations		
Water laws	• Chemical contaminants	A number of Tribal Nations are authorized to develop and administer water quality standards under the U.S. Clean Water Act, including: Bay Mills Indian Community, Little Traverse Bay Bands of Odawa Indians, Saginaw Chippewa Indian Tribe of Michigan, Sault Ste. Marie Tribe of Chippewa Indians
Michigan		
Natural Resources and Environmental Protection Act, 1994	• Invasive species • Chemical contaminants	Defines prohibited and restricted species in Michigan and limits the possession, import or sale of such species. Establishes permitting and regulatory programs for water quality.

APPENDIX C: Climate Change Vulnerability Index and Confidence Rankings

Vulnerability ranks include: extremely vulnerable (EV), highly vulnerable (HV), moderately vulnerable (MV), and less vulnerable (LV). Confidence ranks include: Very High, High, Moderate (Mod*), and Low.

Table C 1: Michigan Tribal Climate Change Vulnerability Assessments, 2016

Michigan Tribal Climate Change Vulnerability Assessments 2016									
Vegetation Species		CCVI Vulnerability Rank				Confidence Ranking			
Scientific Name	**Common Name**	**WUP**	**EUP**	**NLP**	**SLP**	**WUP**	**EUP**	**NLP**	**SLP**
Andromeda polifolia	Bog Rosemary	HV	EV	HV	EV	Very High	Low	Very High	Low
Zizania palustris	Northern Wild Rice	HV	HV	HV	EV	Low	Very High	Mod*	Very High
Zizania aquatica	Southern Wild Rice	MV	HV	MV	EV	High	Very High	Mod*	High
Fraxinus nigra	Black Ash	MV	HV	HV	HV	Mod*	High	High	Mod*
Picea mariana	Black Spruce	HV	HV	HV	-	Low	Very High	Very High	-
Carex scirpoidea	Bulrush Sedge	HV	HV	HV	HV	Low	Mod*	High	Mod*
Polygala paucifolia	Fringed Polygala	MV	HV	HV	MV	Mod*	High	High	Mod*
Ledum groenlandicum	Labrador Tea	MV	HV	HV	HV	Low	Mod*	Mod*	Mod*
Vaccinium macrocarpon	Large Cranberry	MV	HV	HV	HV	Very High	Mod*	Mod*	Mod*
Thuja occidentalis	Northern White Cedar	MV	HV	HV	HV	Very High	Very High	Very High	Very High
Betula papyrifera	Paper Birch	MV	HV	HV	HV	Very High	Low	High	Mod*
Mitchella repens	Partridge Berry	MV	HV	HV	HV	High	Mod*	Mod*	Low
Chimaphila umbellata	Pipsissewa / Prince's Pine	HV	HV	HV	HV	Low	Low	Low	High
Vaccinium oxycoccos	Small Cranberry	MV	MV	MV	HV	Mod	High	High	Mod
Cypripedium parviflorum	Yellow Lady's Slipper	HV	HV	HV	HV	Very High	Mod*	Mod*	High
Fagus grandifolia	American Beech	MV	MV	MV	MV	Low	Very High	Very High	High
Ulmus americana	American Elm	LV	LV	LV	MV	High	Mod*	Low	Low
Abies balsamea	Balsam Fir	MV	MV	MV	MV	Mod*	High	High	Mod*
Gaylussacia baccata	Black Huckleberry	MV	MV	MV	MV	High	Very High	Very High	Low
Salix nigra	Black Willow	LV	MV	MV	MV	Low	Very High	Very High	High
Sagittaria latifolia	Broadleaf Arrowhead	LV	MV	MV	MV	Mod*	Mod*	Mod*	Mod*
Lobelia cardinalis	Cardinal Flower	LV	MV	MV	MV	High	Mod*	Mod*	Mod*

Trillium grandiflorum	Common Trillium	MV	MV	MV	MV	Mod*	High	High	High
Gaultheria hispidula	Creeping Snowberry	LV	MV	MV	MV	High	Mod*	Mod*	Mod*
Crataegus douglasii	Douglas/Black Hawthorn	MV	MV	MV	MV	Very High	Mod*	Mod*	Mod*
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Coptis trifolia ssp. Groenlandica	Goldthread	LV	MV	MV	MV	Low	Mod*	Mod*	Mod*
Schoenoplectus acutus	Hardstem Bulrush	MV	MV	MV	MV	Very High	Very High	Very High	Very High
Tsuga canadensis	Hemlock	MV	MV	MV	MV	Very High	Very High	Very High	Very High
Athyrium filix-femina ssp. Angustum	Ladyfern	LV	MV	MV	MV	High	Mod*	Mod*	Mod*
Vaccinium angustifolium	Lowbush Blueberry	LV	MV	MV	MV	Mod*	Very High	High	High
Caltha palustris	Marsh Marigold	LV	MV	MV	MV	Mod*	Mod*	Mod*	Mod*
Acer pensylvanicum	Moosewood / Striped Maple	LV	MV	MV	MV	Mod*	Mod*	High	Low
Ilex mucronata	Mountain Holly	LV	LV	MV	MV	Very High	Low	Mod*	Low
Prunus pensylvanica	Pin Cherry	LV	MV	MV	MV	Mod*	High	Very High	Mod*
Cypripedium acaule	Pink Lady's Slipper	MV	MV	MV	MV	High	High	High	Mod*
Lycopodium obscurum	Princess Pine	LV	MV	MV	MV	Mod*	Very High	Very High	Low
Impatiens capensis	Spotted Touch Me Not/Jewelweed	MV	MV	MV	MV	Mod*	High	High	High
Acer saccharum	Sugar Maple	MV	MV	MV	MV	Mod*	Very High	Very High	Low
Asclepias incarnata	Swamp Milkweed	LV	MV	MV	MV	Low	Mod*	Mod*	Very High
Acorus americanus	Sweetflag	LV	MV	MV	MV	Low	Very High	Very High	High
Hierochloe odorata	Sweetgrass	MV	MV	MV	MV	Very High	Very High	Very High	Very High
Larix laricina	Tamarack	MV	MV	MV	MV	Very High	Very High	Very High	Very High
Schoenoplectus americanus	Three-square bulrush	MV	MV	MV	MV	Mod*	High	High	High
Pinus strobus	White Pine	MV	MV	MV	MV	Mod*	Very High	Very High	High
Betula alleghaniensis	Yellow Birch	MV	MV	MV	MV	Mod*	Very High	Very High	Mod*
Sphagnum capillifolium	Northern Peatmoss	LV	MV	MV	MV	Mod*	Mod*	Mod*	Mod*
Sphagnum central	Sphagnum	LV	MV	MV	MV	Mod*	Mod*	Mod*	Mod*
Myrica gale	Sweetgale	MV	MV	MV	MV	Low	Very High	Very High	High
Tilia americana	Basswood	LV	LV	LV	LV	Very High	Mod*	Mod*	High
Corylus cornuta	Beaked hazelnut	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Arctostaphylos uva-ursi	Bearberry	LV	LV	LV	LV	Very High	Very High	Very High	Very High
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Populus grandidentata	Bigtooth Aspen	LV	LV	LV	LV	High	Mod*	Mod*	Very High
Carya cordiformis	Bitternut Hickory	-	-	-	LV	-	-	-	Very High
Caulophyllum thalictroides	Blue Cohosh	LV	LV	LV	LV	Very High	Low	Low	Mod*
Pteridium aquilinum	Bracken Fern	LV	LV	LV	LV	Very High	High	High	Very High
Typha latifolia	Broadleaf Cattail	LV	LV	LV	LV	Very High	Low	Low	Low
Eupatorium perfoliatum	Common Boneset	LV	LV	LV	LV	Very High	Mod*	Mod*	High
Equisetum hyemale	Common Horsetail/ Scouring rush	LV	LV	LV	LV	Very High	High	High	Very High
Asclepias syriaca	Common Milkweed	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Phragmites australis	Common Reed	LV	LV	LV	LV	High	Low	Low	Low
Lithospermum caroliniense	Golden Puccoon	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Medeola virginiana	Indian Cucumber Root	LV	LV	LV	LV	Very High	Low	Low	Mod*
Apocynum cannabinum	Indian Hemp	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Lobelia inflate	Indian Tobacco	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Ostrya virginiana	Ironwood	LV	LV	LV	LV	Very High	Mod*	Low	Mod*
Arisaema triphyllum ssp. Triphyllum	Jack in the Pulpit	LV	LV	LV	LV	Very High	Low	Low	Low
Adiantum pedatum	Maidenhair Fern	LV	LV	LV	LV	Very High	Mod*	Low	High
Quercus rubra	Northern Red Oak	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Anaphalis margaritacea	Pearly Everlasting	LV	LV	LV	LV	Very High	Mod*	Mod*	High
Acer rubrum	Red Maple	LV	LV	LV	LV	Very High	Mod*	Mod*	High
Cornus sericea	Red Osier Dogwood	LV	LV	LV	LV	Very High	High	High	Very High
Vitis riparia	Riverbank Grape	LV	LV	LV	LV	Very High	Low	Low	Mod*
Onoclea sensibilis	Sensitive Fern	LV	LV	LV	LV	Very High	Mod*	Mod*	Mod*
Ulmus rubra	Slippery Elm	LV	LV	LV	LV	Very High	High	High	Very High
Alnus incana Rugosa	Speckled/Tag Alder	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Eupatorium maculatum	Spotted Joe Pye Weed	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Nymphaea odorata	White Water Lily	LV	LV	LV	LV	Very High	Very High	High	Very High
Ilix verticillata	Winterberry/Michigan Holly	LV	LV	LV	LV	Very High	Very High	Very High	Very High
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Castor canadensis	Moose	EV	EV	-	-	Very High	Very High	-	-
Lepus americanus	Snowshoe hare	EV	EV	EV	EV	Very High	Very High	Very High	Very High
Castor canadensis	American Beaver	MV	MV	MV	MV	High	Mod*	Mod*	Very High
Martes americana	American Marten	MV	MV	MV	MV	High	Mod*	Mod*	Mod*
Martes pennanti	Fisher	MV	MV	MV	-	Mod*	Mod*	High	-
Gavia immer	Common Loon	LV	MV	MV	MV	Low	High	High	Very High
Bonasa umbellus	Ruffed Grouse	LV	LV	LV	MV	Mod*	Low	Low	Mod*
Falcipennes canadensis	Spruce Grouse	LV	MV	-	-	Low	Mod*	-	-
Tympanuchus phasianellus	Sharp-tailed Grouse	LV	LV	MV	-	Very High	Low	High	-
Taxidea taxus	American Badger	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Ursus americanus	American Black Bear	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Neovison vison	American Mink	LV	LV	LV	LV	Very High	High	High	High
Lynx rufus	Bobcat	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Canis latrans	Coyote	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Sylvilagus floridanus	Eastern Cottontail Rabbit	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Cervus elaphus	Elk	-	-	LV	LV	-	-	Mod*	High
Canis lupus	Gray Wolf	LV	LV	LV	LV	Very High	Low	Low	Low
Erethizon dorsatum	North American Porcupine	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Lontra canadensis	North American River Otter	LV	LV	LV	LV	Very High	Mod*	Mod*	High
Odocoileus virginianus	White-tailed Deer	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Haliaeeetus leucocephalus	Bald Eagle	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Anas discors	Blue Winged Teal	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Branta canadensis	Canada Goose	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Ardea herodias	Great Blue Heron	LV	LV	LV	LV	Very High	Mod*	Mod*	Mod*
Anas platyrhynchos	Mallard	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Grus canadensis	Sandhill Crane	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Meleagris gallopavo	Wild Turkey	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Chrysemys picta	Northern Painted Turtle	LV	LV	LV	LV	Very High	High	Mod*	Mod*
Chelydra serpentina	Snapping Turtle	LV	LV	LV	LV	Very High	Low	Low	Low
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Acipenser fulvescens	Lake Sturgeon	MV	EV	MV	HV	Very High	Very High	Very High	Very High
Sander vitreus	Walleye	MV	MV	HV	MV	Very High	Very High	Mod*	Low
Salvelinus fontinalis	Brook Trout	MV	MV	MV	MV	Very High	Very High	Very High	Low
Lota lota	Burbot	GL: MV				Very High	Very High	Very High	Very High
Salvelinus namaycush	Lake Trout	GL: MV				Very High	Very High	Very High	Very High
Coregonus artedi	Cisco/Lake Herring	GL: MV				Very High	Very High	Very High	Very High
Coregonus clupeaformis	Whitefish	GL: MV				Very High	Very High	Very High	Very High
Esox lucius	Northern Pike	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Perca flavescens	Yellow Perch	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Osmerus mordax	Smelt	GL: LV				Very High	Very High	Very High	Very High
Esox masquinongy	Muskellunge	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Pemoxis nigromaculatus	Black Crappie	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Lepomis microchirus	Bluegill	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Catostomus commersonii	White Sucker	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Catostomus catostomus	Longnose Sucker	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Micropterus salmoides	Largemouth Bass	LV	LV	LV	LV	Very High	Very High	Very High	Very High
Micropterus dolomieu	Smallmouth Bass	LV	LV	LV	LV	Very High	Very High	Very High	Very High
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