DRAFT

2015 Lake Superior

Lakewide Action and Management Plan

November 12, 2015

By

The Lake Superior Partnership

ACKNOWLEDGEMENTS

This document was made possible by the many individuals and organizations working to restore and protect the Lake Superior ecosystem.

This document was prepared by the Lake Superior Lakewide Action and Management Plan Writing Team, which was co-chaired by Rob Hyde of Environment Canada and Liz LaPlante of the U.S. Environmental Protection Agency. Writing Team members included: Jen Burnett, Marilee Chase, Faith Fitzpatrick, John Jereczek, Ann McCammon-Soltis, Michelle McChristie, Henry Quinlan, Mike Ripley, Lisa Sealock, Stephanie Swart, Brent Schleck, Amy Thomas, Michele Wheeler and Laurie Wood. The contributions of many photographers, both amateur and professional, are greatly appreciated, as is the scientific input provided by Great Lakes researchers and managers, and the suggestions of numerous reviewers who helped to refine the document at various stages of development.

The document builds upon many relevant local, tribal, state provincial, national and binational plans. Special thanks to all those involved in preparing the Biodiversity Conservation Strategy for Lake Superior, 2015; to the Great Lakes Fishery Commission's Lake Superior Technical Committee; to the Great Lakes Water Quality Agreement Lakewide Management Annex (Annex 2) Sub-Committee and their LAMP Task Team; and to all the individuals of the Lake Superior Partnership who contributed to the LAMP's development and who will be collaborating during implementation.

Lake Superior Partnership Organizations, 2015

1854 Treaty Authority
Bad River Band of Lake Superior Chippewa
Bay Mills Indian Community
Chippewa-Ottawa Resource Authority
Environment Canada
Fisheries and Oceans Canada
Fond du Lac Band of Lake Superior Chippewa
Grand Portage Band of Lake Superior Chippewa
Great Lakes Indian Fish and Wildlife Commission
Keweenaw Bay Indian Community
Michigan Department of Environmental Quality
Minnesota Department of Health
Minnesota Department of Natural Resources
Minnesota Pollution Control Agency
National Oceanic and Atmospheric Administration
Natural Resources Conservation Service
Ontario Ministry of Natural Resources and Forestry
Ontario Ministry of the Environment and Climate Change
Parks Canada
Red Cliff Band of Lake Superior Chippewa
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey
U.S. National Park Service
University of Minnesota Sea Grant Program
University of Wisconsin Sea Grant Program
Wisconsin Department of Natural Resources

Cover page photo credits	
Left - Top to bottom	*Right - Clockwise from top*
Pebble Beach, Marathon, Ontario. Credit: K. Taillon. Lake Superior sunrise. Credit: T. Seilheimer, WI Sea Grant Lost Creek Falls, Wisconsin. Credit: G. Thompson.	Pukaskwa National Park, Ontario. Credit: D. McChristie Potato River Falls, Wisconsin. Credit: G. Thompson Nipigon Bay, Ontario. Credit: D. Crawford Oliver Bay on Bete Gris Pointe, Michigan. Credit: J. Koski, KBIC Swallow tail butterfly. Credit: H. Quinlan, USFWS.

Table of Contents

1.0 EXECUTIVE SUMMARY

The Lake Superior basin is one of the most beautiful and unique ecosystems in North America. Containing ten percent of the world's surface fresh water, Lake Superior is in the best ecological condition of all the Great Lakes.

Although the Lake Superior ecosystem is in relatively good condition, there are serious threats to the ecosystem including: chemical contaminants, substances of emerging concern, aquatic invasive species, climate change, habitat destruction, and reduced habitat connectivity between the open lake and the tributaries.

To address these challenges, the Lake Superior Lakewide Action and Management Plan (LAMP) was developed, building upon a wide variety of local, tribal, state, provincial, national and binational plans. The 2015 Lake Superior LAMP is a binational action plan for restoring and protecting the ecosystem. The LAMP does the following:

- Describes current environmental conditions;
- Identifies threats to the ecosystem;
- Sets forth lakewide objectives;
- Identifies priorities for future scientific investigation; and
- Identifies necessary actions and top projects to address priority threats and to achieve existing lakewide objectives.

What is the LAMP?

Under the *Great Lakes Water Quality Agreement (GLWQA)*, the governments of Canada and the United States have committed to restore and maintain the physical, biological and chemical integrity of the waters of the Great Lakes.

The Lake-wide Action and Management Plan (LAMP) is a binational action plan for restoring and protecting the ecosystem. The LAMP is developed by the Lake Superior Partnership, which is led by the U.S. EPA and Environment Canada, and will be implemented binationally in cooperation with all Lake Superior stakeholders.

The Lake Superior LAMP was written by the Lake Superior Partnership – a collaborative group of individuals from over 30 federal, state, provincial and tribal agencies from both the U.S. and Canada – agencies charged with managing and protecting their respective portions of the Lake Superior ecosystem. In turn, the Lake Superior Partnership works closely with other Lake Superior stakeholders including First Nations, Métis, municipalities, watershed management agencies, environmental groups, industry representatives, academia and members of the general public.

The Lake Superior Partnership will use this 2015 LAMP over the course of the next five years as a guide to identify, prioritize, and implement actions to restore and protect the Lake Superior ecosystem. A new LAMP will be developed in 2020 and every five years thereafter, with the goal of protecting this incomparable resource for generations to come.


Lake Superior has some true wilderness areas. Pukaskwa National Park alone includes 219 km (136 mi) of undeveloped coastline. Photo by Parks Canada

One of the key underlying principles of the Lake Superior Partnership is the importance of involvement of all Lake Superior stakeholders.

The ultimate success of restoring and maintaining the Lake Superior ecosystem depends on the efforts of everyone.

State of Lake Superior

The Lake Superior ecosystem continues to be in good-to-very good condition, as exemplified by:

- Fisheries in good to excellent condition, supported by a robust lower food web (e.g., small, shrimp-like *Diporeia*);
- Increasing populations of Lake Trout and Lake Sturgeon;
- Good ecological status of most major habitats on a lakewide scale, including coastal wetlands; and
- Generally decreasing or stable concentrations of legacy contaminants in the environment (e.g., PCBs).

However, the ecosystem faces a number of threats, including:

- Existing aquatic invasive species (e.g., Sea Lamprey) and the risk of new invaders;
- Effects of climate change on the ecosystem (e.g., warming surface waters are stressing some cold-water species);
- Areas of impaired habitat connectivity between the tributaries and the open lake;
- Fish consumption advisories due to legacy pollutants such as mercury and PCBs; and
- Substances of emerging concern, such as microplastics.


Pictured Rocks National Lakeshore, Michigan. Photo by S. Swart

Lakewide Ecosystem Objectives

The Great Lakes Water Quality Agreement (GLWQA) calls for the development of lake-specific ecosystem objectives, to serve as a “benchmark against which to assess status and trends in water quality and lake ecosystem health.” While GLWQA Lake Ecosystem Objectives (LEOs) have not been finalized for Lake Superior, there are nine existing lakewide objectives for water quality and habitat conditions, as found in Table 1, below.

The nine existing lakewide objectives seek to protect the physical, biological and chemical integrity of Lake Superior. Objectives for the seven major habitat types (objectives 1-7 in Table 1) were developed and assessed as part of the 2015 *Biodiversity Conservation Strategy for Lake Superior* (Lake Superior Binational Program, 2015). These seven objectives address the physical and biological integrity of Lake Superior. The remaining two objectives (objectives 8 and 9 in

Table 1) address the chemical integrity of Lake Superior. One chemical objective is to achieve zero release of nine specific toxic substances, which is the objective of a unique long-term pilot program in Lake Superior (see *Lake Superior Zero Discharge Demonstration Program and Critical Chemical Reduction Milestones Report*, 2012). The final objective seeks to protect Lake Superior from contamination due to additional substances of concern.

Table 1. Existing Lakewide Objectives

	Objective	Status*
1	Maintain deepwater and offshore waters in good ecological condition.	GOOD
2	Maintain nearshore zone and reefs in good ecological condition.	GOOD
3	Maintain embayments and inshore areas in good ecological condition.	GOOD
4	Maintain coastal wetlands in good ecological condition.	GOOD
5	Maintain islands in good ecological condition.	GOOD
6	Maintain coastal terrestrial habitats in good ecological condition.	GOOD
7	Maintain tributaries and watersheds in good ecological condition.	FAIR
8	Achieve zero release (from within the Lake Superior basin) of nine persistent bioaccumulative toxic substances.**	GOOD
9	Protect the Lake Superior basin from contamination resulting from additional substances of concern.	GOOD

*Definitions for status of existing lakewide objectives:
Good: In a state that is within the accepted range of variation, but some management intervention may be required for some elements.
Fair: In a state that is outside the range of acceptable variation and requires management.
Poor: Allowing the goal to remain in this condition for an extended period will result in permanent ecosystem change.
**The nine persistent bioaccumulative toxic substances include: mercury, PCBs, dioxin, hexachlorobenzene, octachlorostyrene and four pesticides (dieldrin, chlordane, DDT, and toxaphene).

Science and Monitoring Priorities

A wide range of ongoing and special intensive science and monitoring activities are undertaken to determine ecosystem conditions and trends, assess threats, and inform actions that are necessary to achieve lakewide objectives.

The primary effort to determine lakewide science and monitoring priorities is undertaken through the Lake Superior Coordinated Science and Monitoring Initiative (CSMI), an intensive, binational scientific examination which is conducted on a five-year rotational basis. The Lake Superior CSMI field year will be conducted in 2016, with data interpretation, analysis and reporting occurring in subsequent years.

Current Lake Superior science and monitoring priorities, as developed by the Lake Superior Partnership with input from hundreds of stakeholders, include but are not limited to, the following:

- Confirm lower food-web health and stability;
- Determine progress being made on reducing chemicals of concern;
- Determine progress being made on Lake Sturgeon rehabilitation;

- Provide information needed to support implementation of fish rehabilitation plans (e.g., Lake Trout and Lake Whitefish);
- Assess baseline water quality conditions in areas of critical habitat and potential significant land-use change; and
- Identify vulnerable cold-water tributaries to Lake Superior from various stressors such as climate change.

Management Actions to Address Threats

The LAMP includes a list of 74 overall management actions to address priority threats to water quality and achieve lakewide objectives. These actions provide guidance and support to the work of the Lake Superior Partnership and others. The actions are organized under eight categories:

- Aquatic invasive species;
- Climate change;
- Dams and barriers;
- Existing chemicals of concern;
- Chemicals of emerging concern;
- Other threats, including resource development;
- High-quality habitats; and
- Native species management.

Working Together

Lake Superior's generally good ecological condition is a result of a strong and ongoing history of action. Actions are occurring at all scales – from national, state, provincial, tribal, First Nation, Métis, and municipal programs, to lake-wide initiatives, to local projects by communities, businesses, and households.

The 74 overall management actions reflect the full range of actions to restore and protect the ecosystem, from actions like protecting high-quality habitats, to outreach and education on priority issues, to improved data management for decision-making.

The 74 overall management actions also can be used over the course of the next five years as a guide to identify, prioritize, and implement management interventions to restore and protect the Lake Superior ecosystem.

Top Projects for the Lake Superior Partnership

In addition to the list of 74 overall management actions, the Lake Superior Partnership has identified 29 top projects, as listed in Table 2, below. These represent a specific set of Lake Superior Partnership agreed-upon projects that require a high-degree of cooperative and coordinated implementation, and are a priority for the Partnership over the next-five years to help mitigate the top threats and achieve lakewide objectives.

The Lake Superior Partnership cooperates on actions to restore and protect the ecosystem. Terrace Bay, Ontario. Photo by Esteban Chiriboga, GLIFWC.

Table 2. Lake Superior Partnership Top Projects*

Top Projects 2015-2019
Aquatic Invasive Species
1. Add additional locations to the lakewide aquatic invasive species early detection rapid response surveillance project. 2. Undertake additional aquatic invasive species prevention outreach and education, including discussions with recreational boaters and lake access site signage. 3. Maintain and improve effectiveness of Sea Lamprey control, prevent introduction of new species, and limit expansion of previously established aquatic invasive species. 4. Contribute to the eradication of Common Reed (i.e., *Phragmites australis*) from the entire Lake Superior basin by undertaking or supporting lakewide mapping of distribution, early detection efforts, and control efforts.
Climate Change
1. Undertake or support outreach and education to stakeholders on the impacts of climate change in the Lake Superior ecosystem, including potential changes to habitat ranges, stormwater management, and nutrient/chemical cycling. 2. Support local climate change scenario planning to help natural resource managers develop adaptation plans for ecological communities.
Dams & Barriers
1. Improve access to high-resolution stream/river barrier data and species-specific benefit analyses in support of decision-making on Lake Superior habitat connectivity decisions. 2. Establish a collaborative Lake Superior streams improvement initiative in Canada to undertake stream monitoring, assessment, and data management activities, and to help identify stream protection and restoration priorities. 3. Prepare an environmental studies report to explore the feasibility, costs and benefits associated with the options surrounding the proposed decommissioning of Ontario's Camp 43 dam, and construction of a corresponding multi-purpose Sea Lamprey barrier at Eskwanonwatin Lake.
Chemical Contaminants
1. Increase the level of public education on mercury toxicity; pathways into fish, wildlife and humans; and actions that can be taken to help remove it from the basin. 2. Conduct a data synthesis of available mercury monitoring data for the Lake Superior basin to improve the inter-jurisdictional understanding and communication of mercury trends in the Lake Superior ecosystem. 3. Document which agency and local government entities collect and track the types and amounts of pesticides disposed to inform existing pesticide collection programs, such as clean sweeps, and the potential for expanding collections to additional geographic areas. 4. Continue to support open burning abatement programs, such as Bernie the Barrel, to achieve reductions in the release of dioxins and furans into the Lake Superior basin from the practice of residential burning of garbage.
Additional Substances of Concern
1. Increase the level of public education on new and emerging chemicals; their potential toxicity; pathways into fish, wildlife and humans; and how the public can help remove them from the basin. Special emphasis on the topics of microplastics and safer alternatives for personal care, household cleaning products, and pesticides/herbicides.

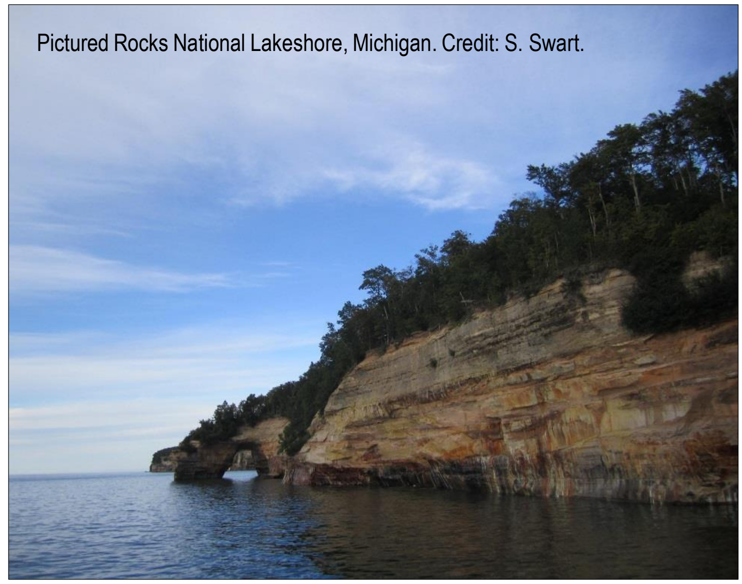
Top Projects 2015-2019
2. Compile information on the type and status of different pharmaceutical collections in the basin and other efforts to locate and properly dispose of unwanted medication. Use this information to identify opportunities for further action.
Other Existing and Emerging Threats
1. Provide oil spill responders with improved access to existing and new spatial data on ecologically important and sensitive habitats. 2. Support efforts to increase the sustainable use of Lake Superior basin resources, with specific emphasis on projects on green stormwater infrastructure, incorporating traditional ecological knowledge into projects, and/or recognizing the monetary value of ecosystem services. 3. Further connect with communities and others at local scales to help inform policies on water use and water value. 4. Map current and proposed mining activities in the Lake Superior basin to support understanding of the potential and cumulative impacts on important habitat sites and other stressors, such as climate change impacts.
High-Quality Habitats
1. Design and implement dredging solutions and habitat restoration for Buffalo Reef, Michigan. 2. Improve the mapping and quantification of important spawning, nursery and foraging habitat for key fish species to support protection and restoration decision-making. 3. Promote and support local and regional implementation of the Biodiversity Conservation Strategy and corresponding Regional Plans. 4. Formally establish the Lake Superior National Marine Conservation Area and Federal-Provincial harmonization committee to develop and implement management priorities for the area. 5. Integrate spatial data standards and methodologies to identify and prioritize sites for habitat protection and rehabilitation and develop targeted geomatics products for lakewide action and management. 6. Protect and enhance important coastal wetland habitats on priority state and tribal lands in western Lake Superior, including Bark Bay, Frog Bay, Bad River/Kakagon Sloughs and the St. Louis River estuary.
Diverse, Healthy and Self-sustaining Native Species Populations
1. Develop and update stock assessment models to improve management of self-sustaining commercial and sport fisheries for Lake Trout, Cisco, and Lake Whitefish. 2. Develop and implement improved monitoring approaches for inshore, embayment, and tributary fish populations. 3. Update the Ecopath model with Ecosim (Kitchell et al., 2000) with recently acquired data and knowledge in order to explore a) how recent changes in fish abundance could be influencing the food web; b) how the ecosystem may respond to current and potential threats; and c) how components of the ecosystem may respond to potential management actions. 4. Rehabilitate populations of indigenous aquatic species (e.g., Brook Trout, Muskellunge, Walleye, etc.).

* The top projects are not ranked in priority order.

2.0 INTRODUCTION

The Lake Superior Lakewide Action and Management Plan (LAMP) is a binational action plan for restoring and protecting the Lake Superior ecosystem. The LAMP also includes information on Lake Superior conditions, stressors, threats, current strategies and science priorities.

In outlining management actions, the LAMP will guide and support the work of natural resource managers, decision-makers, Lake Superior stakeholders and the general public in achieving restoration and protection priorities for Lake Superior.



2.1 GREAT LAKES WATER QUALITY AGREEMENT

The 1972 *Agreement between the United States of America and Canada on Great Lakes Water Quality* (known as the Great Lakes Water Quality Agreement, GLWQA) established formal commitments to restore and maintain the water quality of this international freshwater resource. The GLWQA was amended in 1983, 1987, and most recently, 2012. The 2012 protocol amending the GLWQA reaffirms the commitment of the United States and Canada "to protect, restore, and enhance water quality of the Waters of the Great Lakes and their intention to prevent further pollution and degradation of the Great Lakes Basin Ecosystem" (Canada and United States, 2012).

The GLWQA sets forth nine General Objectives which outline desired water quality conditions that are protective of environmental quality and provide a basis for water management guidance. As described in more detail in Section 4.0, the General Objectives direct that Great Lakes waters should: be a source of safe, high quality drinking water; allow for swimming and other recreational uses; allow for human consumption of fish and wildlife; be free from pollutants harmful to human health, aquatic organisms, and wildlife; support healthy wetlands and other habitats sustainable to native species; be free from nutrients that may cause harmful algae blooms; be free from the spread of invasive species; and be free from other substances which may affect the chemical, physical or biological integrity of the Great Lakes.

Annex 2 of the GLWQA, "Lakewide Management" commits to assessing the status of each Great Lake, identifying stressors and taking actions that will protect, restore and maintain the ecosystem.

2.2 LAKE SUPERIOR PARTNERSHIP

The LAMP is written, implemented and managed by the Lake Superior Partnership, a group of federal, state, provincial, and tribal government organizations tasked with protecting and restoring the Lake Superior ecosystem. The Partnership, led by Environment Canada and the United States Environmental Protection Agency (EPA), seeks to contribute to the achievement of the objectives of the GLWQA with the involvement and input from others, including First Nations, Métis, municipalities, watershed management agencies, other local public agencies, and the Public.

The origin of the Lake Superior Partnership goes back to 1991, in response to the International Joint Commission's (IJC) recommendation that Lake Superior be designated as a demonstration area where "no point source discharge of any persistent toxic substance will be permitted." In response to that IJC recommendation, the federal governments of Canada and the U.S., the Province of Ontario, and the States of Michigan, Minnesota, and Wisconsin announced a "Binational Program to Restore and Protect Lake Superior," known as the Lake Superior Binational Program (LSBP). In addition to public outreach and broader program activities, the LSBP included the Zero Discharge Demonstration Program (ZDDP). The ZDDP has contributed to the dramatic reduction in emissions of critical legacy pollutants, such as mercury and PCBs from within the Lake Superior basin. The Broader Ecosystem program led to the establishment of lakewide ecosystem objectives which have been used to assess progress toward restoration and protection. Although the LSBP was restructured into the Lake Superior Partnership in 2015 under a new GLWQA governance model, key components, such as the Zero Discharge Demonstration Program, and the commitment to stakeholder engagement, remain.

2.3 VALUE OF LAKE SUPERIOR

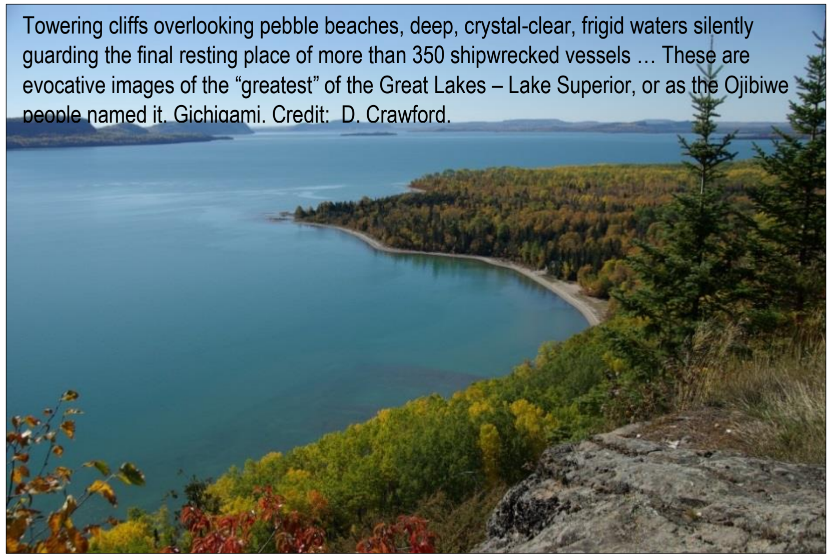
Lake Superior is one of the most beautiful, unique and valuable ecosystems in the world. Containing nearly 10% of the world's surface freshwater, Lake Superior is the world's largest lake by surface area, with a volume of 3 quadrillion gallons (11.4 quadrillion liters). The lake has 2,730 miles (4,393 km) of shoreline (including islands). The lake's natural resources support many industrial and business operations, including tourism, fishing and other outdoor recreation activities. The lake's natural resources are culturally significant to local communities, tribes, First Nations and Métis peoples.

Lake Superior Physical Facts

- Average depth: 147 meters (483 ft)
- Maximum depth: 405 meters (1,330 ft)
- Drainage basin: 127,686 km^2 (49,300 mi^2)
  - 85% forested,
  - 10.4% water,
  - 1.7% agriculture
  - 1.5% developed land
  - 1.0% wetland

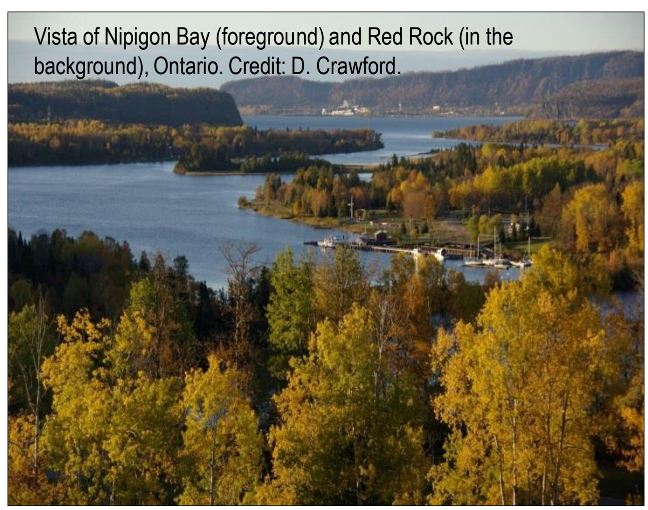
Source: Beall, 2011

Lake Superior has extraordinary biodiversity, containing species found nowhere else on the planet, such as Siscowet, a large deep water form of Lake Trout, and Kiyi (*Coregonus kiyi*), the primary prey of Siscowet. Parts of Lake Superior's coastline provide habitat for arctic-alpine plant species that began to recolonize in the region around 15,000 years ago as the last ice sheet retreated. The most southern populations of Woodland Caribou still roam parts of Lake Superior's coast and islands.



Towering cliffs overlooking pebble beaches, deep, crystal-clear, frigid waters silently guarding the final resting place of more than 350 shipwrecked vessels … These are evocative images of the "greatest" of the Great Lakes – Lake Superior, or as the Ojibwe people named it, Gichigami. Credit: D. Crawford.

Indigenous inhabitants (also known as the Anishinaabeg people, including the Ojibwe nation) of the watershed have called Lake Superior home for thousands of years, and play an important role in managing the lake. As the place where they found "the food that grows on the water" (Northern Wild Rice, *Zizania palustris*), Mooningwanekaaning (Madeline Island in Wisconsin, part of the Apostle Islands) is the center of the Ojibwe nation. In the United States, the homelands of Ojibwe tribes stretch from central Minnesota to the Upper Peninsula of Michigan, with treaty-ceded territories throughout the Lake Superior basin. In Canada, over a dozen First Nations communities are located along the coast or within the Lake Superior basin. The waters, fish, plants and wildlife in the Lake Superior basin continue to provide a sense of identity and continuity with traditional lifeways. Culturally-significant wildlife include Lake Sturgeon, Bald Eagles, and Walleye, while culturally-significant plant species include Wild Rice, Paper Birch, and Cedar. Indigenous inhabitants continue to use subsistence harvesting practices throughout the basin, a maintaining healthy local food source to these communities.



Vista of Nipigon Bay (foreground) and Red Rock (in the background), Ontario. Credit: D. Crawford.

Traditional Ecological Knowledge (TEK), a knowledge system arising from the symbiotic relationship of indigenous people and places and deeply embedded in indigenous ways of life, was developed over the course of the long relationship between the Lake Superior ecosystem and the Anishinaabeg people. TEK is vital to understanding the lake and its ecosystem. According to the Ojibwe world view, Lake Superior and its connected lakes, rivers and streams are not simply the sum total of their constituent parts, or the property of a state, nation, or person. Instead, they are integral parts of the web of life that support the continuation of Anishinaabe life-ways and provide life-giving benefits to all who now call Lake Superior home. (LSBP, 2015).

Tourism is one of the economic engines of the Lake Superior region. An abundance of outdoor activities, festivals, concerts, athletic events, and unique dining and shopping opportunities draw thousands of visitors each year, particularly to vibrant metropolitan areas such as Duluth, Minnesota, and Thunder Bay, Ontario. Summer brings boaters, sightseers, campers, kayakers, anglers, and swimmers to the shore, while winter attracts skiers, snowmobilers, snowshoers from surrounding states and provinces, and beyond. (Minnesota Sea Grant, 2014a).

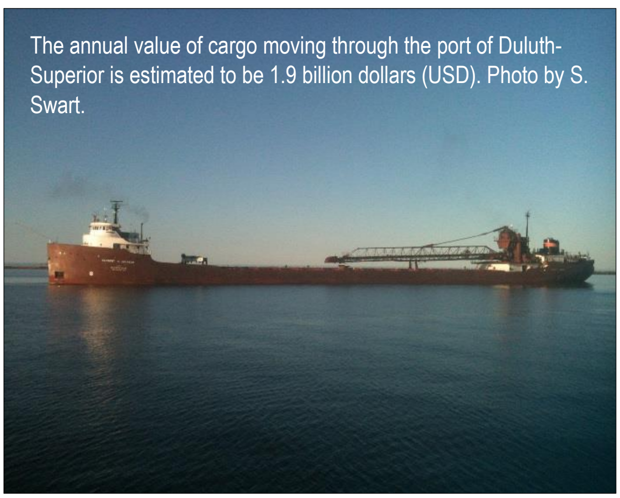
Kayaking (left photo), swimming (middle), and ice fishing (right) are popular recreational activities on Lake Superior. Credit: J. Bailey (left photo), L. LaPlante (middle), and D. Viebeck (right).

Lake Superior contains dozens of different federal, provincial, tribal, and non-governmental **parks and conservation areas** which provide a wide array of recreational experiences in the Lake Superior region. Pukaskwa National Park and Lake Superior Provincial Park on the eastern coast of Lake Superior in Ontario book-end the longest undeveloped coastline in the entire Great Lakes basin. In Michigan, sandstone cliffs and white sand beaches beckon visitors to Pictured Rocks National Lakeshore. In Wisconsin, lighthouses backdrop the exploration of sea caves, ice caves, and majestic islands that comprise the Apostle Island National Lakeshore. In Minnesota, the lighthouse in Split Rock Lighthouse State Park provides a historical starting point to experiencing Lake Superior’s famous cobble beaches and rocky shores. In the north, Canada’s proposed Lake Superior National Marine Conservation Area (NMCA) will encompass over 10,000 km^2 (3,861 mi^2) of protected aquatic and terrestrial habitat. This protected marine area will safeguard aspects of the ecosystem and provide benefits to local coastal communities that depend on marine industries, such as commercial fishing, sport fishing, recreational boating, and shipping (Parks Canada, 2015).


Resolute Forest Products, Thunder Bay, Ontario. Credit: D. McChristie.

Lake Superior's **natural resources** are the backbone of the regional economy. Various industries such as shipping, forestry, mining, agriculture, charter and recreational fishing, and tourism, contribute greatly to the local economies of coastal communities, as well as to the economy of the Great Lakes region as a whole. While no formal, comprehensive economic assessment has been completed to date, the importance of these industries to the health and viability of coastal communities and residents cannot be overstated.

For example, the Great Lakes and St. Lawrence Seaway connects the Atlantic Ocean (and the world) to Lake Superior. The port of Duluth-Superior, Lake Superior's largest port by metric tons of cargo, averages around 40 million metric tons of cargo annually, primarily consisting of iron ore, coal, and grain. The value of this cargo is estimated to be $1.9 billion (USD), and the port supports approximately 2,000 jobs (Minnesota Sea Grant, 2014b). The shipping industry contributes greatly to many other Lake Superior communities including Marquette, Michigan; Sault St. Marie, Michigan; and Thunder Bay, Ontario (Minnesota Sea Grant, 2014b).


The annual value of cargo moving through the port of Duluth-Superior is estimated to be 1.9 billion dollars (USD). Photo by S. Swart.

3.0 EXISTING LAKEWIDE OBJECTIVES

3.1 BACKGROUND

Through the GLWQA, the governments of Canada and the United States have committed to establishing Lake Ecosystem Objectives (LEOs) that will specify interim or long-term ecological conditions necessary to achieve the General Objectives of the GLWQA. LEOs will be used as a benchmark against which to assess status and trends in water quality and lake ecosystem health. LEOs will be chosen using a systematic approach that is consistent among the Lakes, but also flexible enough to accommodate the unique characteristics and challenges faced by each Lake. LEOs for Lake Superior are scheduled to be developed by the end of 2017. The current, existing lakewide objectives for Lake Superior are presented below.

3.2 EXISTING LAKEWIDE OBJECTIVES

In the short term, the Lake Superior Partnership is using previously established conservation targets for habitats and species, and established chemical objectives. These existing lakewide objectives and their current status are summarized in Table 3-1. For details on the status assessment for these lakewide objectives, refer to the Biodiversity Conservation Strategy for Lake Superior, 2015 and the Lake Superior Zero Discharge Demonstration Program and Critical Chemical Reduction Milestones Report, 2012.

Table 3-1. Existing Lakewide Objectives for Lake Superior

	Lakewide Objective	Description	Status*
1	Maintain deepwater and offshore waters in good ecological condition.	Waters that are over 80 meters (262 ft) in depth. The offshore waters provide habitat for a number of native fish. Example species include Siscowet, Kiyi and other ciscoes, Burbot, and Deepwater Sculpin.	GOOD
2	Maintain nearshore zone and reefs in good ecological condition.	Waters between 15-80 meters (49-262 ft) in depth, and shallow reefs. Lake Superior's major sport and commercial fisheries are located in the nearshore zone. Example species include Lake Trout and Lake Whitefish.	GOOD
3	Maintain embayments and inshore areas in good ecological condition.	Embayments and the inshore zone at depths of 0-15 meters (0-49 ft). These habitats are critical for the fish abundance and diversity, since these areas provide spawning and nursery habitat for many nearshore and offshore fish species, as well as waterfowl staging and feeding zones. Example species include Lake Sturgeon, Walleye, and Yellow Perch.	GOOD
4	Maintain coastal wetlands in good ecological condition.	Wetlands within 2 km (1.2 mi) of Lake Superior's coast, with an emphasis on wetlands that have historic and current hydrologic connectivity to, and are directly influenced by the lake. Example species include Northern Pike, waterfowl, and many amphibians.	GOOD
5	Maintain islands in good ecological condition.	All land masses that are surrounded by water, including both natural and artificial islands. Lake Superior has many of the largest and most isolated islands on the Great Lakes. Islands support colonial nesting waterbirds such as gulls, and unique ecological communities.	GOOD

	Lakewide Objective	Description	Status*
6	Maintain coastal terrestrial habitats in good ecological condition.	Habitats within 2 km (1.2 mi) from the coast or to the extent of delineation. Many rare species and habitats are found in this zone including shorebirds, bald eagle, and rare plant communities.	GOOD
7	Maintain tributaries and watersheds in good ecological condition.	All rivers, streams and inland lakes that flow into Lake Superior and their associated watersheds. Lakes, rivers and streams in the basin are influenced by land use, which affects water quality in Lake Superior. Native Lake Superior fish that migrate to and depend on tributaries as part of their natural life cycle. Examples of species that depend on tributaries and watersheds include Coaster Brook Trout, suckers, and Northern Wild Rice.	FAIR
8	Achieve zero release (from within the Lake Superior basin) of nine persistent bioaccumulative toxic substances.**	This is a demonstration initiative, called the Lake Superior Zero Discharge Demonstration Program. With 1990 as the baseline year, a staged reduction plan was developed with the year 2020 as the target for the aspirational goal of virtual elimination.	GOOD
9	Protect the Lake Superior basin from contamination resulting from additional substances of concern.	There are a large number of substances, under an umbrella term called *substances of emerging concern*. These include substances used in flame retardants, personal care products, and pharmaceuticals.	GOOD

* Ratings for Ecological Status:
Good: In a state that is within the accepted range of variation, but some management intervention may be required for some elements.
Fair: In a state that is outside the range of acceptable variation and requires management.
Poor: Allowing the goal to remain in this condition for an extended period will result in permanent ecosystem change.
** The nine persistent bioaccumulative toxic substances include: mercury, PCBs, dioxin, hexachlorobenzene, octachlorostyrene and four pesticides (dieldrin, chlordane, DDT, and toxaphene).

4.0 STATE OF LAKE SUPERIOR

4.1 GLWQA OBJECTIVES AND 2015 STATE OF LAKE SUPERIOR

This section describes the state of Lake Superior and current and potential threats to the Lake Superior ecosystem.

Information on the state of Lake Superior is organized under the nine General Objectives of the Great Lakes Water Quality Agreement. Information is also provided on the top threats to Lake Superior's habitats, species and water quality.

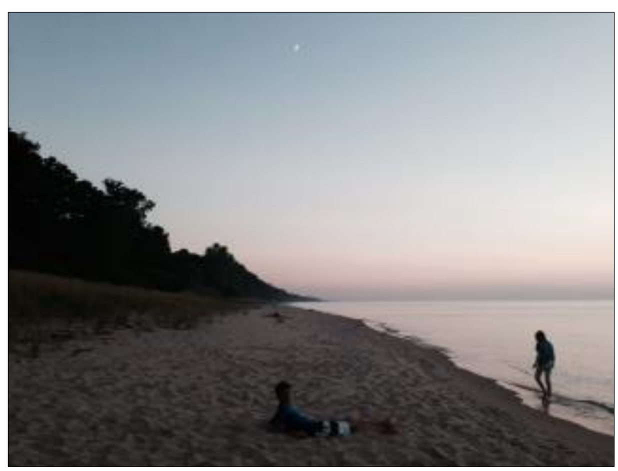
Unless otherwise noted, the source of the information is the *State of the Great Lakes 2011 Technical Indicator Report* by Environment Canada and U.S. EPA (2013).

In the year 2020, the next Lake Superior LAMP will use newly developed Lake Ecosystem Objectives as the benchmark with which to assess ecosystem status and trends

The Lake Superior ecosystem is in generally good condition. Fisheries are in good to excellent condition, supported by a robust lower food web (e.g., small, shrimp-like Diporeia); there are increasing populations of Lake Trout and Lake Sturgeon; most major habitats are in good condition on a lakewide scale, including coastal wetlands; and concentrations of legacy contaminants in the environment (e.g., such as PCBs) are generally decreasing or remaining stable.

Lake Superior faces a variety of challenges. Fish consumption advisories due to legacy pollutants such as mercury and PCBs; continued damage from aquatic invasive species (e.g., Sea Lamprey) and the risk of new invaders; effects of climate change on the ecosystem (e.g., warming surface waters stressing some cold-water species); areas of impaired habitat connectivity between the tributaries and the open lake; and chemical substances of emerging concern, such as microplastics; and balancing resource development with environmental protection.

The beauty of Lake Superior elicits a favorable reaction from toddler. Photo by M. Collingsworth



Relaxing on the beach at sunset. Photo by L. LaPlante

Status of GLWQA General Objectives in Lake Superior

The GLWQA contains nine General Objectives for the waters of the Great Lakes. The status of each General Objective in Lake Superior is summarized below.

(i) ***Be a source of safe, high-quality drinking water***;

Lake Superior is a safe, high-quality source of water for drinking water systems. In Ontario overall, nearly 100% of tests meet drinking water standards. In Michigan, Minnesota and Wisconsin, health-based violations from drinking water systems are rare.

(ii) ***Allow for swimming and other recreational use, unrestricted by environmental quality concerns***;

Over 90% of the time, Lake Superior beaches are open and safe for swimming.

(iii) ***Allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants***;

Lake Superior fish are a healthy and nutritious food source Consumption advisories are issued to avoid impacts of some harmful pollutants found in some fish in some areas.

(iv) ***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***;

In the waters, concentrations of most contaminants are the lowest in Lake Superior, compared to the other Great Lakes. However, there are exceptions; a few chemicals have their highest concentration in Lake Superior. In whole fish, concentrations of some contaminants are above guidelines. In waterbirds and sediments, there are locations where higher concentrations of contaminants are found, but overall concentrations are generally low compared to the other Great Lakes.

(v) ***Support healthy and productive wetlands and other habitats to sustain resilient populations of native species***;

Lake Superior's coastal wetlands are in good overall health from a lake-wide perspective, as are most other major habitat types. Tributaries and watersheds are the exception, being in fair condition.

(vi) ***Be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote growth of algae and cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem***;

Offshore nutrient targets continue to be met, and conditions remain acceptable. Localized, low toxicity harmful algal blooms, however, have been observed in some locations.

(vii) ***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***;

Aquatic invasive species are a high threat to the Lake Superior ecosystem, due to the persistence of established invaders, expanding ranges, and the threat of new invaders.

(viii) ***Be free from the harmful impact of contaminated groundwater***;

The full extent and impact of contaminated groundwater discharges on Lake Superior is not known.

(ix) ***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***;

Atmospheric deposition is the top source of many contaminants into Lake Superior. The highest threats to Lake Superior's habitats and species are aquatic invasive species, climate change, and dams and barriers.

Be a Source of Safe, High Quality Drinking Water

Lake Superior is a safe, high-quality source of water for public drinking water systems. In Ontario, nearly 100% of tests meet drinking water standards. In Michigan, Minnesota and Wisconsin, health-based violations from drinking water systems are very rare. Health-based exceedances can be caused by microbiological or chemical contaminants. Outside of public drinking water systems, the quality of water may vary on a local basis, depending on potential sources of contamination and treatment processes.

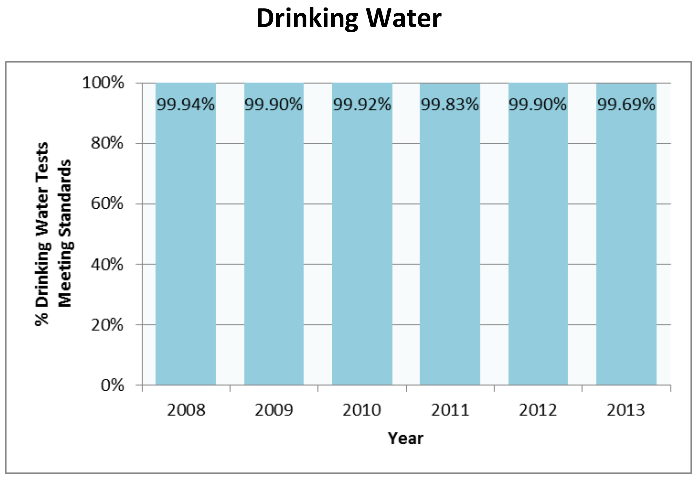


Figure X. Percentage of Lake Superior drinking water tests meeting standards (municipal residential drinking water systems in Ontario). Source: Data from Chief Drinking Water Inspector Annual Reports.

Allow for Swimming and Other Recreational Use, Unrestricted by Environmental Quality Concerns

On average, Lake Superior's beaches are open and safe for swimming and other recreational use over 90% of the time. Increased beach monitoring and assessment is helping to inform the public when beaches are safe for recreational use.

Major rain events and flooding can wash contaminants into the lake and overwhelm wastewater treatment plants. In 2012, record flooding in the southwest part of the basin resulted in significant numbers of beach advisories. For example, beaches in Douglas County, Wisconsin, were open and safe for swimming only 70% of the time that year.

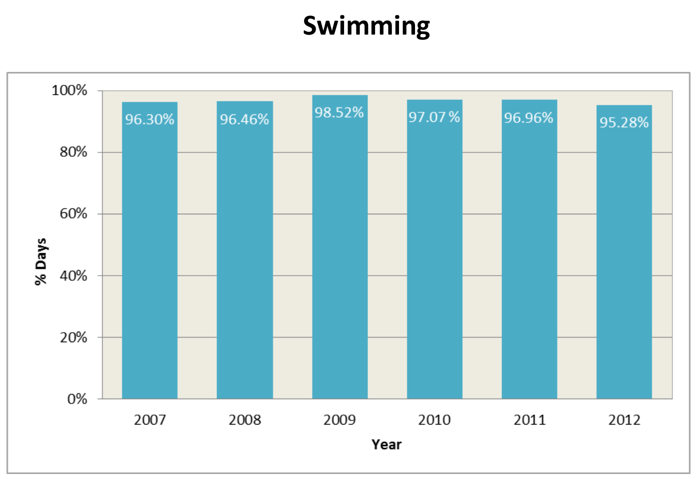


Figure X. Percentage of days U.S. Lake Superior beaches are open and safe for swimming. Source: U.S. States reporting to USEPA's Beach Advisory and Closing On-Line Notification system.

Allow for Human Consumption of Fish and Wildlife Unrestricted by Concerns Due to Harmful Pollutants

Lake Superior fish continue to be a healthy and nutritious food source. Some of the most popular species include Lake Whitefish, Lake Trout and Cisco (Lake Herring). Consumption advice is issued by the States, Tribes and Province in efforts to avoid impacts of harmful pollutants found in some fish in some areas. Overall, there are fewer Lake Superior's fish consumption advisories as compared to the other Great Lakes.

The two main contaminants responsible for fish advisories are polychlorinated biphenyls (PCBs) and mercury, and in a few locations, dioxins and toxaphene. Large predator fish, such as older Lake Trout, are likely to have higher contaminant levels than other species.

The eggs of Great Lakes fatty fish, especially spawning Salmon species, such as Chinook and Coho Salmon, can contain elevated levels of PCBs and other organic contaminants because of their high fat content, and therefore should avoid being eaten (Ontario Ministry of the Environment and Climate Change, 2015).

Fish consumption recommendations are provided by:

- Great Lakes Indian Fish and Wildlife Commission: glifwc.org/Mercury/mercury
- Michigan: michigan.gov/eatsafefish
- Minnesota: health.state.mn.us/fish
- Ontario: Ontario.ca/fishguide
- Wisconsin: dnr.wi.gov/topic/fishing/consumption

Snapping turtles may have high levels of contaminants in their fat, liver, and eggs. As a precaution, individuals are advised to trim away the fat prior to cooking turtle meat.

As part of their traditional culture, Tribal, First Nation and Métis peoples on average consume more local fish, compared to others living in the basin. In 2011-2012, samples of the full range of traditional food across Ontario were collected for contaminant analyses 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 for children and women of childbearing age (Chan et. al., 2014). These findings are consistent with Ontario Ministry of the Environment and Climate Change's *Guide to Eating Ontario Fish*, which advises a restriction of the amount of fish consumed each month from some Lake Superior locations.

During 2013, population-based contaminant biomonitoring was conducted on individuals from the Fond du Lac Band of Lake Superior Chippewa, in Minnesota. All results of contaminants found in their bodies were below levels of health concern. The results again suggest that fish may be safely consumed by following fish consumption guidelines (Fond du Lac and MDH, 2014).

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

In the waters, concentrations of most contaminants are the lowest in Lake Superior, compared to the other Great Lakes. However, there are exceptions; a few chemicals have their highest concentration in Lake Superior. In whole fish, concentrations of some contaminants are above guidelines. In waterbirds and sediments, there are locations where higher concentrations of contaminants are found, but overall concentrations are generally low compared to the other Great Lakes.

Contaminants in Whole Fish

Organochlorine pesticides and total PCBs contribute equally to the chemical body burden of lake trout and make up approximately two-thirds of the total chemical presence (McGoldrick & Murphy, in review). Total PCBs in Lake Trout are declining in Lake Superior at an annual rate between 4 and 5 percent. In 2013, the most recent year reported, 33 of 53 measurements of PCBs were above the 1987 GLWQA criteria value of .1ppm. Unlike the other Great Lakes, toxaphene is the most abundant organochlorine pesticide measured in Lake Superior. Total mercury concentrations in Lake Superior Lake Trout appear to have increased slightly since 1987 but remain below the 1987 GLWQA criteria of .5ppm. The remaining chemicals measured in fish from Lake Superior are PBDEs, PFCs, other flame retardants, and siloxanes.

Contaminants in Whole Fish

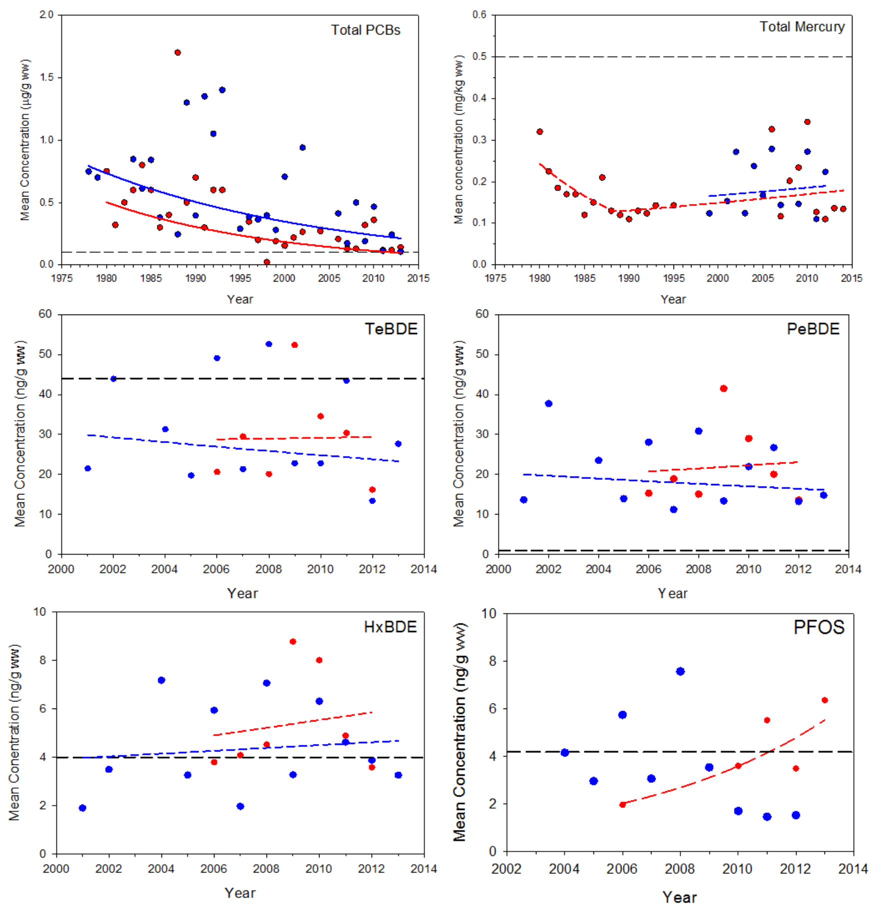


Figure x. Temporal trends of polychlorinates biphenyls (PCBs), total mercury, tetra-, penta-, and hexa-brominated diphenyl ethers (Te-, Pe-, Hx-BDEs), and perfluorooctane sulfonate (PFOS) in Lake Trout from Lake Superior. Environment Canada data is shown in red and USEPA data is shown in blue. Dashed horizontal line denotes the environmental quality objective for each parameter. Source: McGoldrick, D.J., Murphy, E.W., Concentration and distribution of contaminants in Lake Trout and Walleye from the Laurentian Great Lakes (2008 – 2012)., *in review*.

Contaminants in Fish-Eating Birds

Contaminants, such as DDE, PCBs, and dioxins (TCDD), which interfere with the reproduction of some birds have declined significantly in Herring Gulls and Bald Eagles compared to the 1970s and 1980s. In general, there was an exponential decline in contaminant burdens in gulls on Lake Superior from the 1970s to 2013, although concentrations appear to have stabilized in the last few years. The half-lives of contaminants in gull eggs averaged 9.9 years for pesticides, 8.2 years for dioxin, and 11.6 years for PCBs. However, DDE (associated with historical pesticide use) can still be found at levels above the threshold for healthy populations in 50% of the eagles tested.

Contaminants in Herring Gulls

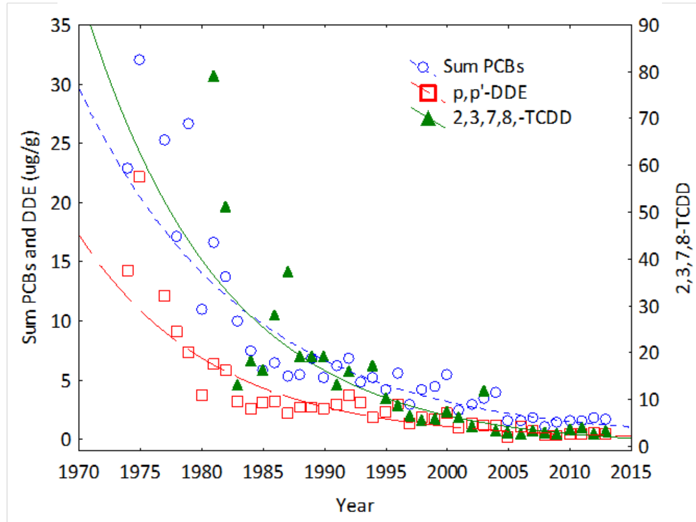


Figure X. Changes in concentrations of sum PCBs, *p,p'*-DDE, and 2,3,7,8-TCDD (ug/g, wet weight) in Great Lakes Herring Gull eggs at Agawa Rocks, from year of first measurement to 2013. Source: deSolla et al., *in press*.

Contaminants in Offshore Waters

Contaminants are found at very low concentrations in Lake Superior's offshore waters. For example, no exceedances of Canadian federal water quality guidelines are observed for any contaminant in Lake Superior's offshore waters. Compared to the other Great Lakes, concentrations of some compounds (e.g., atrazine) are lowest in Lake Superior, but several compounds that are delivered to Lake Superior by atmospheric deposition (e.g. a-HCH and lindane) are found at higher concentrations. The lowest concentrations of mercury are observed in Lake Huron and Georgian Bay, intermediate concentrations are observed in Lake Superior and Lake Ontario, and the highest concentrations were observed in Lake Michigan and Lake Erie (EC-U.S. EPA, 2013). Trends in Lake Superior are varied. For example, the concentration of HCB is unchanging, the concentration of dieldrin is declining, and the concentration of atrazine is increasing.

Contaminants in Offshore Waters

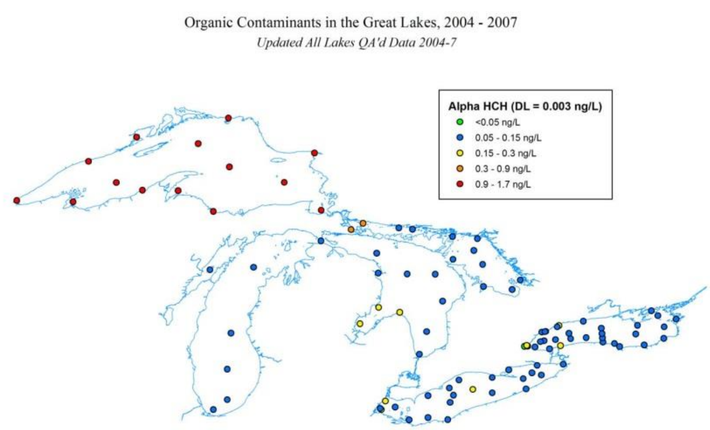


Figure X. Spatial distribution of dissolved alpha-hexachlorocyclohexane (HCH) in Great Lakes surface waters, 2004-2007. Source: Environment Canada's Great Lakes Surveillance Program

Contaminants in Sediment

Sediment contaminant levels in the offshore waters consistently meet aquatic life protection guidelines (i.e., PEL, CCME, 1999). Lake Superior is the largest, coldest and deepest of the Great Lakes, resulting in slow rates of decrease in chemical concentrations in sediment. This is especially true for mercury, where no decline in concentrations are being observed, given the natural sources of mercury from within the watershed and the sources associated with past or present mining and smelting around Lake Superior (EC-U.S. EPA, 2013).

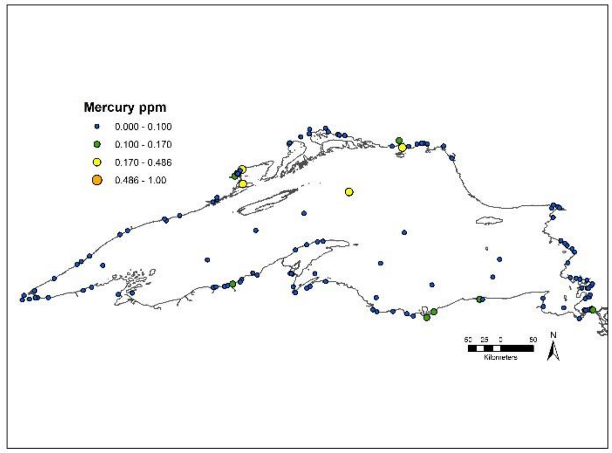


Figure X. Spatial distribution of mercury contamination in Lake Superior's surface sediments. Sources: Environment Canada and USEPA.

The presence of contaminated sediment in specific nearshore locations within Lake Superior are heavily influenced by shoreline-based urban and industrial activities. For example, sediment in Peninsula Harbour, near Marathon, Ontario was contaminated with mercury and PCBs from a pulp mill that operated from 1946 to 2009. The sediment was capped with a layer of clean sand in 2012, thereby reducing the risks associated with contaminants and providing clean habitat for aquatic organisms.

Peninsula Harbour, Ontario. Credit: OMOECC.

Contaminated sediment remains in a number of locations, including: an area adjacent to a former paper mill located in the northern end of the harbor in Thunder Bay, Ontario; multiple sites in the St. Louis River, Minnesota/Wisconsin; the Ashland/Northern States Power Lakefront site in Wisconsin; and Torch Lake, Michigan.

Support Healthy and Productive Wetlands and Other Habitats to Sustain Resilient Populations of Native Species

Lake Superior's coastal wetlands are in good overall health, as are most other major habitat types. Tributaries and watersheds are the exception, being in fair condition.

Coastal Wetlands

There are 26,626 hectares of coastal wetlands documented on Lake Superior, or approximately 10% of the coast (Ingram et al., 2004). The overall condition of Lake Superior's coastal wetlands is 'good,' although the confidence of this ranking is low because the full suite of indicators is under development and results are not yet fully available. The 'good' assessment is driven by the small total amounts of artificial shorelines and structures, low numbers of terrestrial invasive species (including wetland species such as the common reed) and high amount of forest cover. Many coastal wetlands in Lake Superior are also subject to relatively low levels of watershed development (Trebitz et al., 2011).

Coastal Wetlands

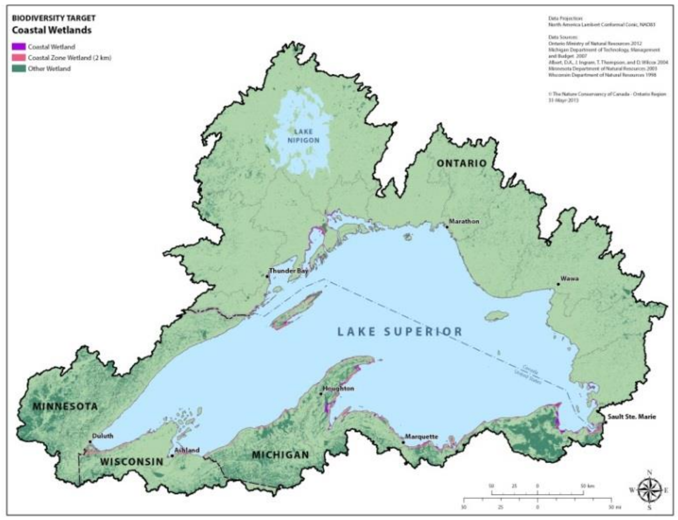


Figure X. Coastal Wetlands. Purple shading depicts coastal wetlands of Lake Superior that intersect the shore. Pink shading depicts coastal wetlands within 2 kms of the shore, and green shading depicts coastal wetlands greater than 2 kms from the shore. Source: Natural Conservancy of Canada.

Water Levels

One of the longest droughts for the Lake Superior basin started in the late 1990s and lasted into the 2000s due to a 25% drop in annual precipitation and increase in air temperatures of about 1°C (1.8°F). The low water levels included a two-month period of record low in 2007. Stream flow was reduced by as much as 30% in some watersheds. These changes in water levels and stream flow affect fish migration, erosion, Wild Rice growth, and nutrient/contaminant transport and transformation. In 2014, Lake Superior water levels rose above average for the first time in 15 years. There is no evidence of a shift in water level averages over the long term, and the water levels for the coming years are uncertain.

Water Levels

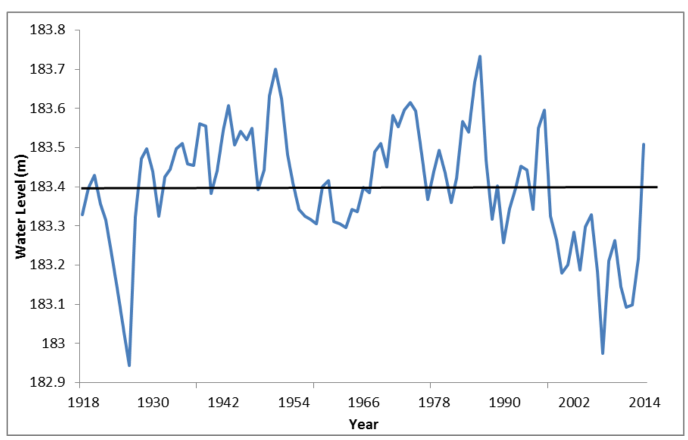


Figure x. Lake Superior water levels 1918-2014. Long-term mean is represented by the straight black line. Source: US Army Corps of Engineers, Detroit District, Great Lakes Hydraulics and Hydrology.

Land Cover

The Lake Superior basin has high forest cover (85%) and low rates of agriculture and development (3.2%). Developed land (e.g. urban areas) and agricultural land impact coastal areas, because these land uses are concentrated in river mouths and surrounding areas. Forest cover in the Lake Superior basin is increasing, although the composition of species is changing. Pines and maples are increasing while early successional species like Birch and Aspen are on the decline.

Land Cover

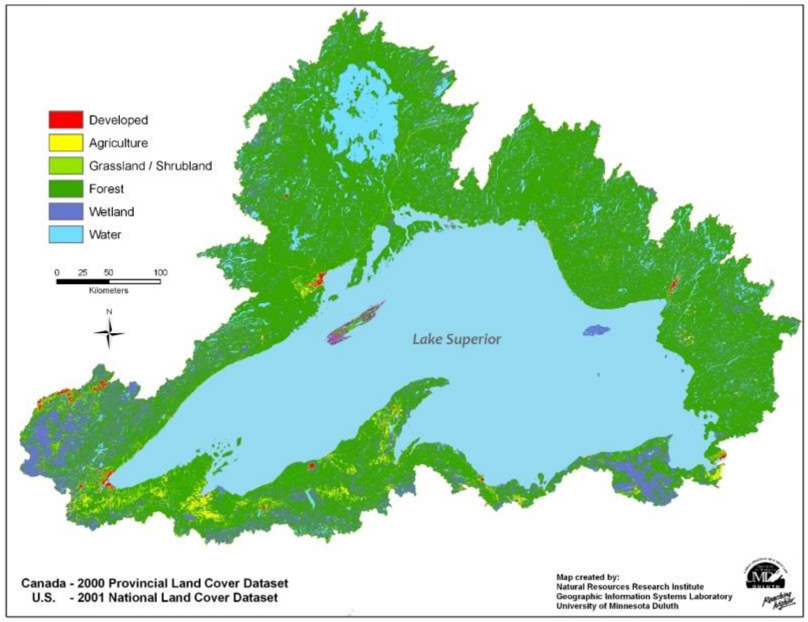


Figure X. Distribution of land use across the Lake Superior basin in 2000 (Canada) and 2001 (US) color-coded according to six land use classes. Source: Ciborowski et al., 2011.

Land Cover around Chequamegon Bay, Wisconsin

Figure X. Chequamegon Bay, Wisconsin in 2010. Source: NOAA Office for Coastal Management Coastal Change Analysis Program. Land Cover 2010.

Species of the Lower Food Web

The populations of small, shrimp-like *Mysis* and *Diporeia,* sources of food for fish in Lake Superior, although highly variable, remain in 'good' condition. The zooplankton community, dominated by large calanoid copepods, is 'good and unchanging'. The benthic (or bottom-dwelling) community's diversity and abundance is 'good and unchanging'.

Photo: *Mysis diluviana*. Photo by University of Montana.

Preyfish

Preyfish community biomass, dominated by native planktivores (e.g., juvenile Lake Whitefish), continues to fluctuate. Despite fluctuations and current lower overall population levels, the preyfish community is considered healthy due to the high number of different native species present, the high proportion of biomass of native versus non-native species, and the ability of the preyfish community to support a healthy sustaining predator fish population (e.g. Lake Trout).

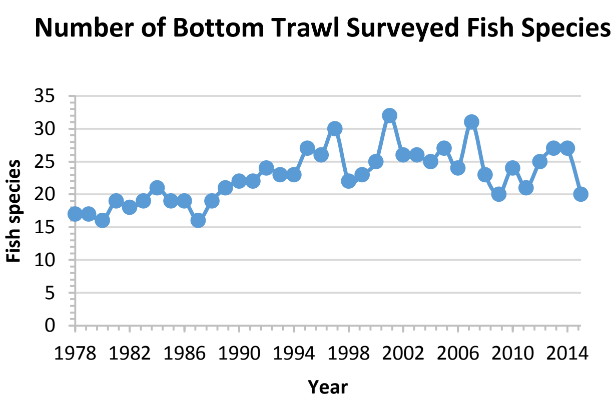


Figure X. Number of fish species collected in annual lakewide nearshore bottom trawl surveys from 1978-2015. Data sources: US Geological Survey - Great Lakes Science Center.

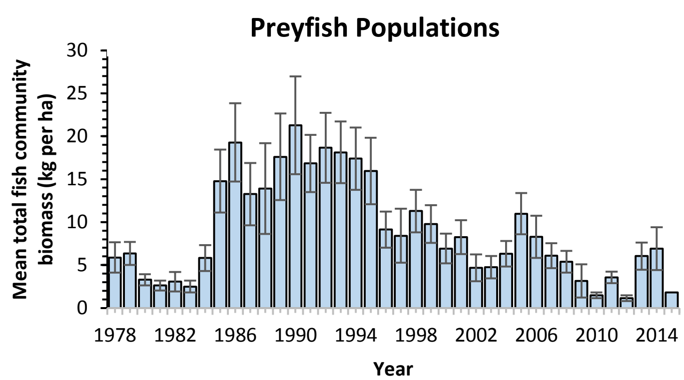


Figure X. Fish community biomass (kg/ha, mean ± standard error) trends based on annual lakewide bottom trawl surveys from 1978-2015. Data sources: US Geological Survey - Great Lakes Science Center.

Lake Trout

Lake Trout, historically the top predator fish, have self-sustaining populations throughout Lake Superior. Stocking of Lake Trout is limited to a few select management areas. Lake Trout populations are genetically diverse, with four different forms of Lake Trout (lean, siscowet, humper, and redfin).

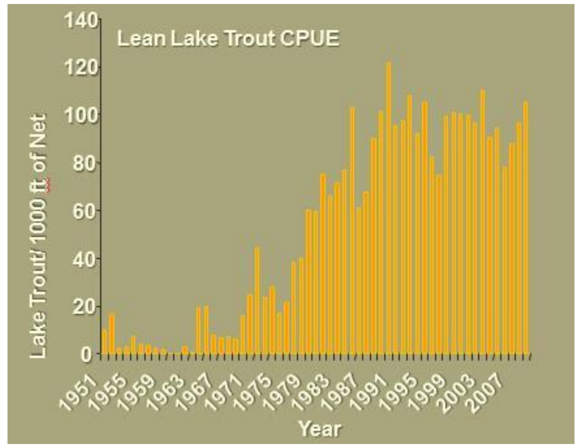


Figure X. Lake Trout population trends over time Source: Lake Superior Technical Committee. Note: get latest data and regraph…continue to show trends back to the 1950s.

Lake Sturgeon

Lake Sturgeon is listed as 'Threatened' by the Province of Ontario. Populations have been considered "fair" and slowly increasing over the last decade, with stocking programs and habitat restoration contributing to the increased abundance. The total population in Lake Superior is estimated to be approximately 870,000, which is only a small fraction of historical abundance.

Lake Sturgeon

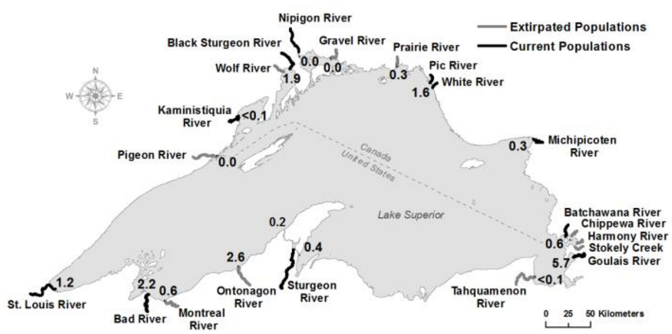


Figure x. Catch-per-unit-effort of lake sturgeons in inshore waters and embayments surveyed in 2011. Surveys associated with tributaries where lake sturgeon currently or historically spawned. Current populations indicate evidence of natural reproduction. Source: Lake Superior Lake Sturgeon Work Group, GLFC.

Walleye

Walleye populations in Lake Superior are lower than historical levels, with healthy self-sustaining populations only in the St. Louis and Kaministiquia Rivers. Many Walleye populations in Lake Superior continue to be maintained or enhanced through stocking. To date, despite stocking and fishery regulation, and presence of Walleye in locations around Lake Superior, recovery toward historic population levels has had limited success. Agencies continue to address this challenge through strategies to improve and protect the quality and quantity of spawning habitat.

Fish-Eating Colonial Waterbirds

In the early 1970s, populations of many colonial waterbirds nesting in the Great Lakes suffered from high embryonic mortality, eggshell thinning and poor reproductive success, largely due to contaminants such as DDT. In Lake Superior, populations of Great Blue Herons have been stable from 1978 to 2008. Herring Gulls, however, declined from 24,900 nests in 1989 to 15,200 nests in 2008, whereas Ring-Billed Gulls declined from 18,700 nests in 1999 to 15,600 nests in 2008. Conversely, Double-Crested Cormorants increased from 35 nests in 1978 to 4,800 nests in 2008. The cause of the decline of gulls is not clear, although it may be linked to a lack of prey fish availability in the late 2000's. The increase in cormorant nests is consistent with trends throughout the Great Lakes.

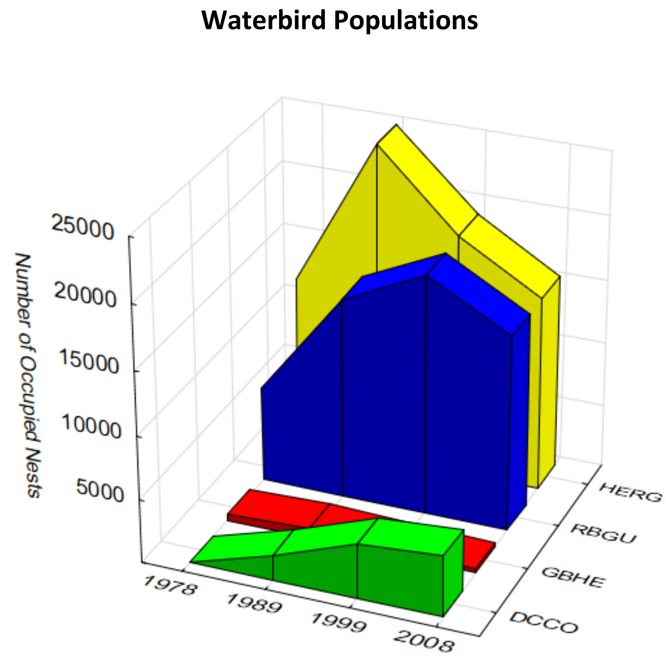


Figure X. Number of occupied nests of four species of colonial waterbirds from Lake Superior, based upon decadal surveys from 1978 to 2008. HERG (Herring Gull); RBGU (Ring-Billed Gull); GBHE (Great Blue Heron); DCCO (Double-Crested Cormorant). Source: Canadian Wildlife Service, Environment Canada, and US Fish and Wildlife Service.

Be Free from Nutrients That Directly or Indirectly Enter the Water as a Result of Human Activity, in Amounts That Promote Growth of Algae and Cyanobacteria That Interfere with Aquatic Ecosystem Health, or Human Use of the Ecosystem

Nutrients in Offshore Waters

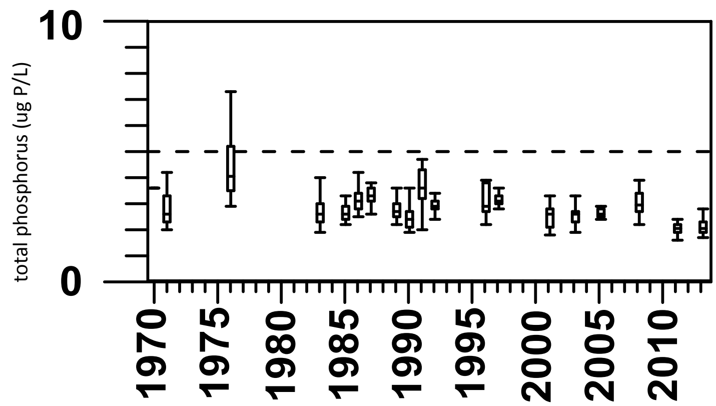


Figure X. Long-term trend of total phosphorus (ug P/L) in Lake Superior. Dashed horizontal line denotes the environmental quality objective. Source: Dove and Chapra, 2015.

Offshore water phosphorus targets are consistently being met in Lake Superior. Severe harmful algal bloom outbreaks, like those experienced at times in the lower Great Lakes, have not been documented in Lake Superior. Cyanobacterial biomass has been at low levels in those cases where algae have been evaluated.

Occasional and site specific algal blooms do occur in some locations in the nearshore zone. For example, in 2012, in conjunction with very warm water temperatures and an extreme rain event, a rare blue-green algal bloom was recorded in Lake Superior along a stretch of Wisconsin beach (Wisconsin Department of Natural Resources and Apostle Islands National Lakeshore, 2012). Other example locations where elevated levels of algae have been observed include the connecting channels across the Keweenaw Peninsula (Michigan), Lake Superior Provincial Park (Ontario), and the Duluth Harbor (Minnesota).

Unlike the lower Great Lakes, shoreline fouling by mats of *Cladophora*, a green algae, has not historically been an issue in Lake Superior. There is no observational evidence that the occurrence of *Cladophora* has changed in recent years.

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

Due to the persistence of established invaders, expanding ranges, and threat of new invaders, aquatic invasive species are a high threat to the Lake Superior ecosystem.

Lake Superior has 98 known non-native fishes, plants, invertebrates, and diseases (Minnesota Sea Grant, 2015). In 2015, the most recent new non-native species, Banded Mystery Snail, was confirmed in macroinvertebrate samples collected in 2014 from Chequamegon Bay and marinas around the Bayfield Peninsula, Wisconsin (United States Fish and Wildlife Service, 2015). According to the United States Geological Survey's Non-indigenous Aquatic Species web site, "At present there are no known impacts associated with this introduced species in the Great Lakes basin." Impacts of many non-native species are often unknown until they cause very noticeable effects.

A significant number of non-native species are known to be invasive. Invasive species are those non-native species whose introduction or spread threatens the environment, the economy, or society, including human health. The most harmful aquatic invasive species established in Lake Superior are listed in Table x.

Table X. Most Harmful Aquatic Invasive Species Established in Lake Superior

Species	Native Range	Pathway
Sea Lamprey	North America	Canals
Rainbow Smelt	North America	Stocked
Alewives	North America	Canals
Zebra Mussels	Ponto-Caspian	Ballast water
Spiny Waterflea	Ponto-Caspian	Ballast water
Round Goby	Ponto-Caspian	Ballast water
Eurasian Ruffe	Eurasia	Ballast water
Viral Hemorrhagic Septicemia (VHS)	U.S. Pacific West Coast	Uncertain, possibly migrating fish

There is a large watchlist of potential new invaders to Lake Superior, considering that a total of 186 non-native species have already established themselves in various locations in the Great Lakes basin and an additional 53 more species have been identified as a threat to being established in the Great Lakes basin (USGS, 2012).

More information on Lake Superior's aquatic invasive species are described below in Section 4.2, "Lakewide Threats".

Be Free from the Harmful Impact of Contaminated Groundwater

The full extent and impact of contaminated groundwater discharges on surface water bodies in the Great Lakes basin, including Lake Superior, is not known. It is known, however, that many sources of groundwater contamination exist in the basin including contaminated industrial sites, releases at hazardous waste sites, spills, leaking underground storage tanks, leachate from unlined landfills, seepage from abandoned mine sites, septic system discharges and leaking sewer lines.

Both directly and indirectly, groundwater is a major source of water to the Great Lakes and is expected to significantly affect both the quantity and quality of the water. Overall, 75% of the streamflow in Lake Superior's tributaries are fed by groundwater (Granneman et al., 2000). In the Lake Superior Basin, large urban areas and areas with mining activities are the places which are likely to have the most significant disturbance of groundwater flow systems and contamination of groundwater quality. In turn, the water quality of streams, rivers and possibly nearshore lake environment would be most impacted in these areas.

Contaminants which are relatively polar and soluble in water, such as PFOS and many personal care products, are susceptible to being transported in groundwater within the Lake Superior Basin. This has implications for future monitoring programs, site investigations and restoration efforts, as well as for science activities related to water quality protection and management.

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

The highest threats to Lake Superior's habitats and species are aquatic invasive species, climate change, and dams and barriers. Atmospheric deposition is the top source of many contaminants into Lake Superior. Information on these and other threats that may negatively impact Lake Superior are presented below, in the context of lakewide threats.

4.2 LAKEWIDE THREATS

Lake Superior faces a number of existing and emerging threats to the ecosystem. These threats have the potential to impede and/or derail progress toward achieving lakewide objectives. Understanding these threats help inform decisions on what actions can be taken. Threats are described below.

Aquatic Invasive Species

Aquatic invasive species (AIS) have been designated as a "high threat" in Lake Superior because they have impacted, and have the potential to further impact, many of Lake Superior's habitats and species. Once invasive species are established, they are very difficult, if not impossible, to eradicate. Similarly, their impacts are difficult to reverse. Compared to the other Great Lakes, Lake Superior's food-web is relatively simple, meaning the introduction of a single non-native species can have a greater consequence. In fact, while Lake Superior has fewer non-native fish species established, it has the highest ratio of non-native to native fish species compared to the other Great Lakes. In total, Lake Superior has 98 known non-native fishes, plants, invertebrates, and diseases (Minnesota Sea Grant, 2015), many of which are deemed invasive because they threaten the environment, the economy, or society, including human health. Once an invasive species has become established in one location, the spread of that species can be hard to control.

The invasive Common Reed (a.k.a. *Phragmites*) is found in scattered occurrences in the Lake Superior watershed. It forms large, dense stands, and reduces wetland plant and animal species diversity. Credit: H. Quinlan. US Fish and Wildlife Service.

Well-known invasive species include Sea Lamprey, Zebra Mussel, Eurasian Ruffe, Round Goby, Spiny Waterflea, and Purple Loosestrife. Ninety-three percent of introductions of non-native species were unintentional while 7% were intentional. Of the nine main pathways for entering Lake Superior, 49% of non-native species were introduced by ballast water discharge, 17% by diseases and parasites with introduced fish, 6% stocked fish, 6% canals and diversions, 4% aquarium releases, 4% live bait release, 3% recreational boaters, and 1% by packaging "hitchhikers". As the endpoints of shipping for the Great Lakes, the Duluth-Superior harbor and Thunder Bay harbor are considered two invasion "hot spots".

A testament to the tremendous effort in recent years to block the pathways that invasive species use to enter Lake Superior, the rate of introductions has slowed considerably. Since 2010, only two new potential invasive species have been identified in Lake Superior: the deadly infectious fish disease (i.e., viral hemorrhagic septicemia or VHS) was discovered in 2010, and in 2015 the presence the Banded Mystery Snail was discovered (U.S. Fish and Wildlife Service, 2015). Constant vigilance is required to continue to block potential new arrivals, particularly in light of warming waters (i.e., more hospitable habitat conditions for some more southern invasive species) due to climate change.

Sea Lamprey

The Sea Lamprey, a parasitic jawless fish that has devastated native fish populations in all the Great Lakes, contributed to the collapse of Lake Superior Lake Trout populations in the mid-twentieth century. The Sea Lamprey preys on sport and commercial fish, and is the focus of significant control efforts. The Sea Lamprey wounding rate on Lake Trout in Lake Superior has been declining and is below the target for the first time since 1994. Sea Lamprey abundance has declined in the past 10 years, while Lake Trout abundance has increased in recent years.

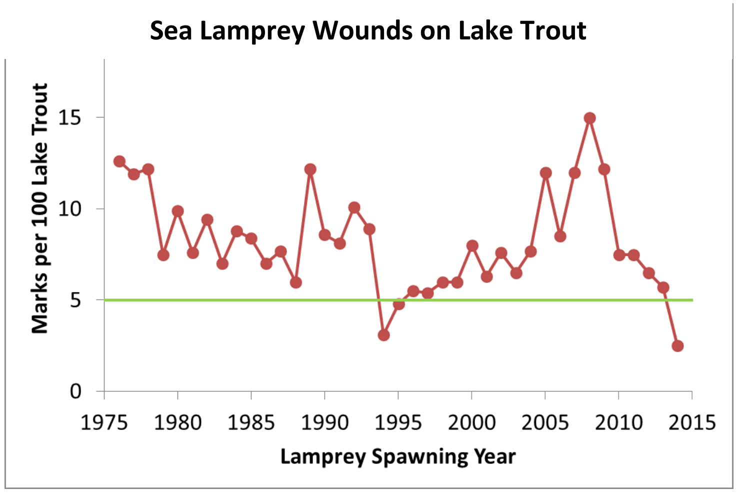


Figure x. Yearly lake-wide Sea Lamprey marking rates on Lake Trout (red circles) greater than 21" (532 mm) captured in April-May assessments plotted against Sea Lamprey spawning year. Green horizontal line represents the marking rate target for Superior which is 5 marks per 100 Lake Trout. Source: Great Lakes Fishery Commission

Climate Change

Climate change is expected to alter the physical, chemical, and biological aspects of Lake Superior (LSBP, 2012a). Climate change will likely exacerbate existing stressors to the lake ecosystem, making it more vulnerable to expected temperature and precipitation extremes. Expected changes to the Lake Superior climate include:

Relative Impact of Climate Change

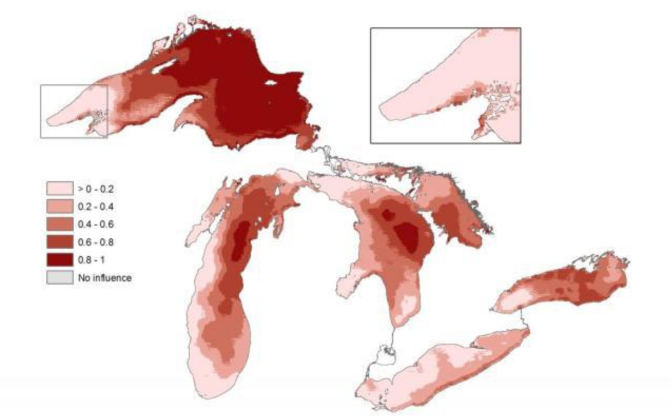


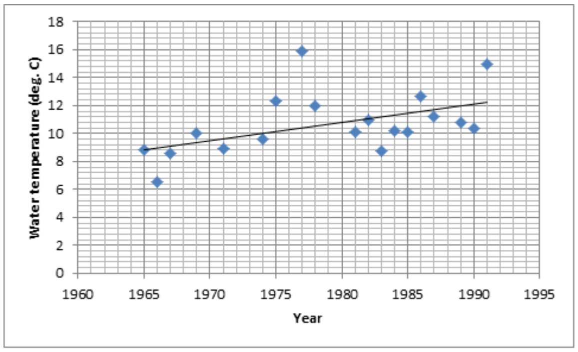
Figure x. Weighting of the relative impact of climate change on the waters of the Great Lakes. Source: GLEAM 2012, Allan et al. 2013.

- Increase in air temperatures by 3 to 4.5°C (5.4 to 8.1°F) by the end of the 21st century;
- Slight increase in annual precipitation, with seasonal shifts;
- Increase in annual average water temperatures of 5 to 7°C (9 to 12.6°F) throughout the 21st century;
- Increased water temperatures of Lake Superior's streams and rivers;
- Continued decrease in the extent and duration of ice cover throughout the 21st century;

- Increased wind speeds;
- Long-term decrease in water levels (although periods of higher-than-average levels are possible); and
- Earlier onset of spring and summer and an increased growing season (LSBP 2012a).

Evidence suggests that some of these changes are already underway, including increases in open-water summer temperatures, changes in lake stratification, and reductions in winter ice cover (Austin and Colman 2008).

Temperature of Washington Creek, MI



Changes in the Lake Superior climate could have the following effects on the Lake Superior ecosystem (LSBP 2012a):

- Higher water temperatures, favoring aquatic invasive species such as Sea Lamprey.
- Increased water temperatures, which could alter the plankton communities with potential implications for the entire food web.
- Creation of unfavorable ecosystem conditions to cold-water fish communities that require cold-water rivers and streams.
- Shifting northward of deciduous forests due to warmer air temperatures and changes in precipitation.
- Spread of forest pests, such as gypsy moth, due to higher air temperatures.
- Reduction of suitable habitat for disjunct and boreal species that are dependent on cooler temperatures and microclimates, due to increased air and water temperatures.
- Increased concentrations of toxic pollutants through increased intensity of precipitation, or the exposure of previously submerged toxic sediments through lower water levels.
- Lower dissolved oxygen levels due to warmer waters, increased duration of summer stratification, and increase in algal blooms.
- Lower water levels, which would be favorable to some invasive species, such as the Common Reed (*Phragmites*).
- Diminishing coastal wetlands, negatively affecting fish and wildlife populations.

Dams and Barriers

Over 23,600 dams and other potential barriers, such as wiers and poorly installed road-stream crossings, have been documented within the Lake Superior watershed. Dams and other barriers disrupt habitat connectivity for aquatic organisms and can degrade water quality through the disruption of natural movement of woody debris, sediment and nutrients. Dams are a major factor in the low population of some Lake Superior fish stocks compared to historical observations, since the fish cannot access spawning areas above the dam. Many dams in the basin are now more than 50 years old and deteriorating. The removal of dams and other barriers can be a difficult issue: While these barriers prevent native fishes from accessing their tributary habitats, they also limit the spread of invasive species and prevent the invasive Sea Lamprey from accessing their spawning area.

Older dams have a greater impact because newer dams were constructed with newer regulations and stronger environmental assessments.

A culvert barrier. Credit: M. Fedora, US Forest Service.

Dams and Barriers

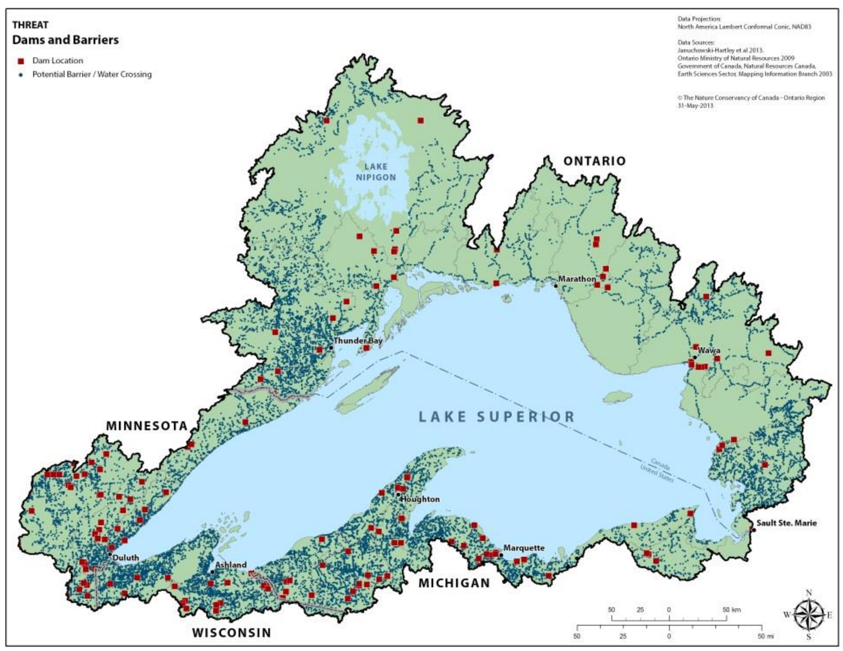


Figure X. Dams and road stream crossings in the Lake Superior basin. Source: The Nature Conservancy of Canada.

Chemical Contaminants

Special efforts have been made to eliminate the Lake Superior basin sources of many legacy chemicals, through the pilot Lake Superior Zero Discharge Demonstration Program. Legacy chemicals remain in the environment long after they were first introduced, and oftentimes not recognized as harmful when first being used in past generations. The results of local, regional and national actions have resulted in achieving Lake Superior's chemical reduction targets. As reductions continue, and as the "low-hanging fruit" of emission sources are addressed, it is becoming increasingly challenging to make further reductions from the remaining sources (LSBP, 2012).

Lake Superior Zero Discharge Demonstration Program

In 1991, the Zero Discharge Demonstration Program was established in Lake Superior as a demonstration project to achieve zero discharge and zero emission of nine toxic, persistent, and bioaccumulative chemicals: mercury, total polychlorinated biphenyls (PCBs), dieldrin/aldrin, chlordane, DDT, toxaphene, 2,3,7,8-TCDD (dioxin), hexachlorobenzene (HCB), and octachlorostyrene (OCS). The target date for zero discharge is 2020, with interim reduction targets in 2000, 2005, 2010 and 2015.

<u>In-Basin Sources of Legacy Chemicals</u>

Compared to the baseline year of 1990, notable achievements have been made in reducing the emissions of legacy chemicals from within the Lake Superior basin:

- 80% reduction in mercury
- 85% reduction in dioxin, HCB, and octachlorostyene
- Significant reduction of materials containing PCBs
- Ongoing collection and safe disposal of waste pesticides: aldrin/dieldrin, chlordane, DDT/DDE, and toxaphene.

Figure 5 - Percentage of Dioxin Releases from Different Sectors in the Lake Superior Basin, 2010.

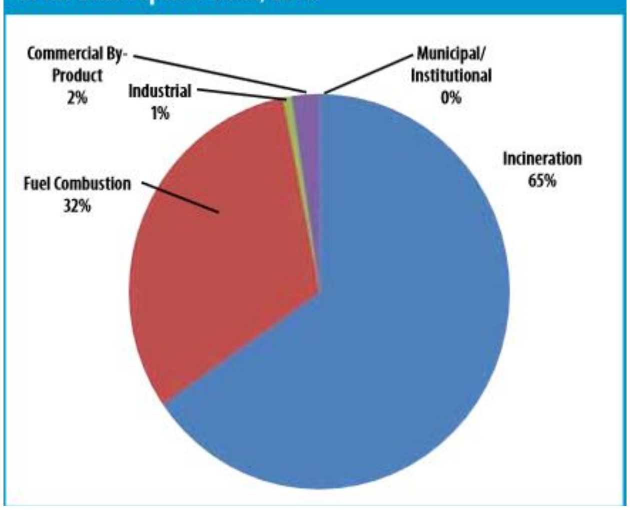


Figure x. Backyard burning of household waste (burn barrels / incineration) is a largely preventable source of dioxin and HCB emissions to Lake Superior.

Figure 4 - Percentage of Mercury Releases from Different Sectors in the Lake Superior Basin, 2010.

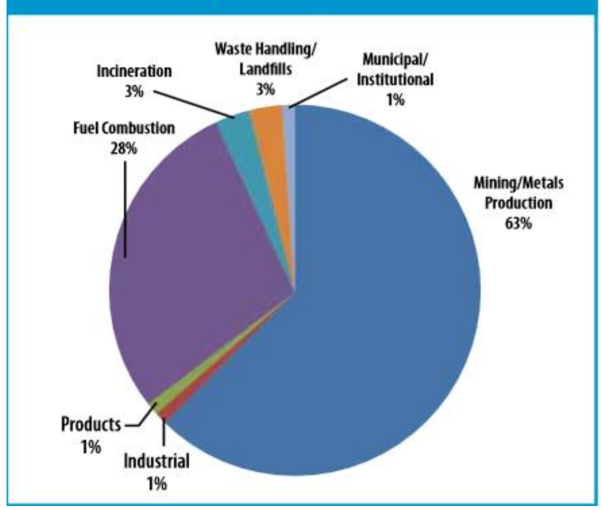


Figure x. The taconite industry concentrated in Minnesota is the greatest source of mercury emissions in the Lake Superior basin.

Chemicals of Mutual Concern

Under the 2012 GLWQA, Canada and the United States committed to designate certain chemicals found in the Great Lakes as *chemicals of mutual concern* that are potentially harmful to human health or the environment. To date, eight chemicals have been recommended for designation as CMCs.

- Mercury
- PCBs
- Brominated flame retardants Hexabromocyclododecane (HBCD) and Polybrominated Diphenyl Ethers (PBDEs)
- Perfluorinated Chemicals perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and long-chain perfluorinated carboxylic acids (PFCAs)
- Short-Chain Chlorinated Paraffins

Mercury

Mercury is a heavy metal that can enter the environment as a result of a natural process (e.g. forest fire, volcanic activity) or as a result of anthropogenic activities (e.g. combustion of coal and refined petroleum products, extraction of metals from ore, the use and disposal of mercury-containing consumer products, and use in some manufacturing processes).

Total atmospheric mercury emissions from anthropogenic sources from within the entire Great Lakes basin declined by approximately 50% between 1990 and 2005 (Evers et al., 2011). Modeling using the Community Multi-scale Air Quality system estimates that 87.5% of mercury deposition to Lake Superior is originating from global sources outside of the United States and Canada (GLRC, 2010).

Atmospheric Deposition

Lake Superior's large surface area and small human population relative to the other lakes contribute to the importance of atmospheric deposition as a source of chemical contamination relative to the other Great Lakes. Sources of air contamination come from local activities, such as cars, trucks and industry, and from activities far away such as pesticide applications in other parts of North America, and from power plants in China. Chemicals from atmospheric deposition affect the lake by contaminating offshore waters, sediments, fish and waterbirds.

PCBs

PCBs are a mixture of synthetic chemicals that do not occur naturally in the environment. They had been used primarily as coolants and lubricants in a wide variety of applications such as electric transformers, capacitors and switches, electrical components in fluorescent lighting fixtures and appliances, and hydraulic and heat transfer systems.

PCBs are declining in the atmosphere over the Great Lakes, but at a slow rate, due to residual sources found in transformers, capacitors, and other equipment. This rate of decline is expected to continue into the future. In a 2011-2012 lake-by-lake water quality study by Vernier et al., the highest concentrations of total PCBs were measured in Lake Ontario (623 ±113 pg/L) and the lowest were in Lake Superior (average 117 ± 18 pg/L). For individual samples, the highest concentration measured in Lake Superior was at a station in Whitefish Bay (165 pg/L).

Brominated Flame Retardants

Flame retardants, such as polybrominated diphenyl ethers (PBDEs), are compounds added to manufactured materials and surface finishes to inhibit, suppress or delay the production of flames and to help prevent the spread of fire. In general, penta-BDE concentrations in a range of environmental media (air, sediment, landfill effluent, aquatic biota and birds) increased until approximately 2000, when levelling off or decreasing trends were observed (Backus et al., 2010). Concentrations seem to have stabilized in Lake Superior, but have not begun to decline significantly. A study by Vernier et al. collected water samples in the spring of 2011 and 2012 at 18 stations throughout the Great Lakes, finding that total polybrominated diphenyl ethers (PBDEs) concentrations were lowest in Lake Superior, with an average of 34 ±11 pg/L.

HBCD is another category of brominated flame retardants, and in the study by Vernier et al., HBCD was detected in all five Great Lakes at concentrations ranging from 0.2 to 4.36 pg/L. Of the five Lake Superior stations sampled, HBCD was detected at the Thunder Bay station and the station outside Duluth at concentrations of 1.6 pg/L and 0.8 pg/L respectively.

Perfluorinated Chemicals PFOS, PFOA and long-chain PFCAs

Perfluorinated chemicals (PFCs), which include perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and long-chain perfluorocarboxylic acids (PFCAs) have been used successfully for a wide number of applications which take advantage of their surfactant-like properties including aqueous film forming foams, lubricants, polishes, cosmetics and paints. PFOS concentrations in top-predator fish species and herring gull eggs exceed relevant guidelines derived for the protection of avian and mammalian predators and consumers of fish and wildlife. PFOS concentrations in Herring Gull eggs in the Great Lakes show that colonies in urban environments have not been consistently declining in concentrations, while in remotely-located colonies, such as Lake Superior, a decline is evident (EC, 2013). Increasing concentrations of PFOS and PFOA, and to a lesser extent long-chain PFCAs, have been observed in sediment.

Short-Chain Chlorinated Paraffins

Chlorinated Paraffins (CPs) are divided into groups according to their carbon chain length, namely short chain (SCCP), medium chain (MCCP) and long chain (LCCP) chlorinated paraffins. They have been used as flame retardants and plasticizers and as additives in metal working fluids, in sealants, paints and coatings. CPs can be released into the environment during production, storage, transportation, industrial and consumer usage of CP-containing products, disposal and burning of waste, and land filling of products. Short-chain chlorinated paraffins (SCCPs) are bioccumulative in wildlife and humans, are persistent and transported globally in the environment, and toxic to aquatic organisms at low concentrations. CPs occur in complex mixtures that are very difficult to analyze in environmental matrices, and data for Lake Superior is very limited.

Additional Substances of Concern

Commercial and consumer-use chemicals, and other substances (such as microplastics), can be detected in Lake Superior at very low levels. While the science continues to advance with respect to detecting these chemicals of concern, there is still much to be studied with respect to the potential adverse effects associated with acute and chronic exposure.

Pharmaceuticals and personal care products (PPCPs) are a diverse group of chemicals that enter waterways through wastewater treatment plant discharges after human use, and from agricultural run-off due spreading of biosolids or use in livestock. There are concerns about the presence of pharmaceutical and personal care products chemicals in water as many are bioactive, some have the potential to bioaccumulate, some are persistent, and as the sources are often continuous (wastewater), there are constant exposures in waters where discharges occur. Pharmaceuticals include therapeutic substances for pain and inflammation (e.g., ibuprofen, naproxen), epilepsy/mood (e.g., carbamazepine), anti-biotics (e.g., sulfamethoxazole), blood pressure (valsartan), and hypertension (atenolol), to name a few. They also include recreational compounds such as caffeine, narcotics, and cotinine from cigarettes. Personal care products (PCPs) are a diverse group of compounds used in personal hygiene (e.g., shampoos, conditions, lotions, soaps, toothpaste, deodorant) and for beautification (e.g., cosmetics, hair dye, perfumes). The primary classes of PCPs include disinfectants (e.g., triclosan), fragrances (e.g., musks), insect repellants (e.g., DEET), preservatives (e.g., parabens) and UV filters (e.g., methylenzylidene camphor).

Two recent studies have been conducted in the Lake Superior region to screen for chemicals of emerging concern in the nearshore waters impacted by urban run-off, municipal wastewater treatment plant effluent and industrial effluent discharges (Christensen et al., 2012; MOECC unpublished). In the vicinity of the St. Louis River, St. Louis Bay, and Superior Bay, 33 of 89 (37%) chemicals were detected in the water samples (Christensen et al., 2012). Using passive samplers in water near Thunder Bay and Sault Ste. Marie, Ontario, 40 compounds were detected out of the 135 (30%) that were being screened (MOECC unpublished). In both studies, DEET was the most commonly detected and at the highest concentrations. Some of the chemicals detected most frequently and in the highest amounts in the Canadian samples included codeine, atenolol, valsartan, DEET, sulfamtheoxazole, carbamazepine, and naproxen. Estimated concentrations were very low ranging from <0.1 to 10 ng/L (MOECC unpublished) In the U.S. samples, frequently detected compounds included caffeine, benzophenone, carbamazepine, esterone, cotinine, and a fragrance hexahydrohexa-methyl cyclopentabensopyran (Christensen et al., 2012).

Microplastics are plastic particles that are generally less than 5 millimeters in size and made of non-biodegradable organic polymers such as polyethylene, polypropylene, and polystyrene. Microplastics include fibers, such as those from clothing and rope, plastic particles from the breakdown of bags, packaging and containers, and plastic beads. They are also used in a variety of products, including personal care products, certain over-the-counter drugs and sand-blasting. An open water survey investigated plastic pollution within Lakes Superior, Huron and Erie in 2012 (Eriksen et al., 2013). Results showed that the concentration of plastic particles increased as they moved from Lake Superior through to the lower Great Lakes; consistent with greater populations in the Lake Erie region and given the water flows from one lake to the next. Abundance counts at the five sites sampled in Lake Superior ranged from 1,277 to 12,645 particles per square kilometer, based on the presence of 3 to 16 plastic particles collected in 2-4 km long trawls (Eriksen et al., 2013). In comparison, the highest abundances found in Lake Erie was over 450,000 particles per square kilometer.

Microplastics Distribution

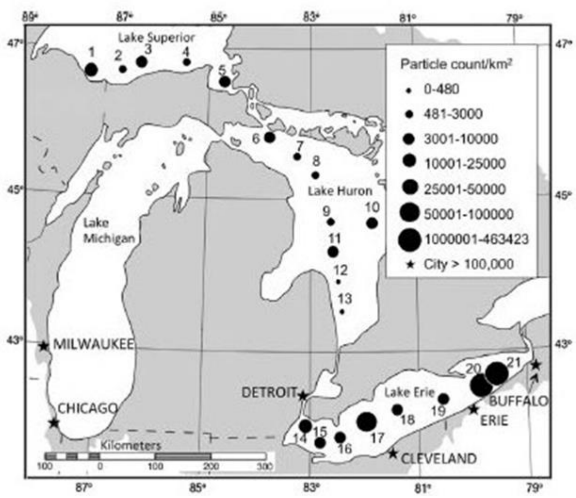


Figure x. Distribution of plastic particles by count for 21 samples collected in three of the Great Lakes, 2012. Source: Eriksen et al., 2013

Excessive nutrients (e.g., phosphorus) are a top threat in the lower Great Lakes, but not in Lake Superior. The SPARROW model (Robertson and Saad, 2011), applied to the U.S. side of the Lake, predicted the largest source of phosphorus was from forests and wetlands, followed by point sources (e.g., regulated wastewater treatment plant discharges). Most eutrophic occurrences are generally limited to the nearshore areas with greater municipal or industrial activity. In particular, shallow bays that do not mix as readily with offshore waters are more vulnerable to the effects of increased nutrients. The SPARROW model does not attribute agriculture land uses as a major input to Lake Superior; however, in some regions around the lake agricultural land is more concentrated (primarily the southwest shore in the U.S.), and provides a greater relative contribution of nutrients in those areas. In the future, climate change is expected to increase water temperature and the frequency of extreme precipitation events (Huff and Thomas 2014). These changes, combined with additional developments, could potentially increase the likelihood of nutrient enrichment to some specific locations in Lake Superior (LaBeau et al., 2014). Ongoing efforts are being made to better understand nutrient dynamics in Lake Superior and identify the most vulnerable locations for eutrophication.

Nutrient Loadings

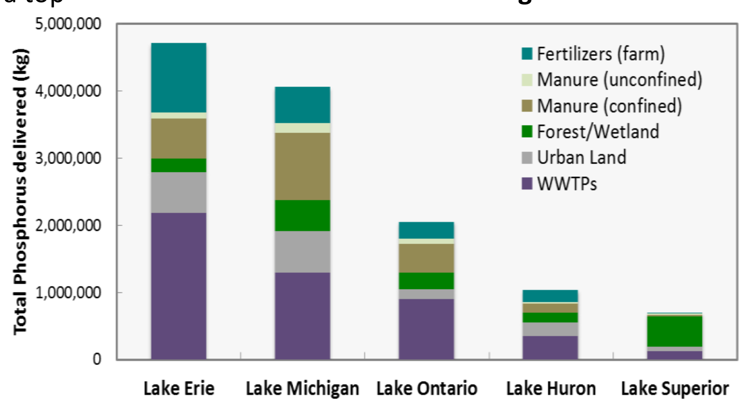


Figure x. SPARROW model of total phosphorus delivered (kg) in the U.S. to each Great Lakes. Source: Robertson and Saad, 2011.

Other Threats

Threats to the Lake Superior ecosystem are not limited to the issues identified above. At regional and local scales, the risk of a wide range of any particular threat varies greatly. Other threats described below include the impacts of coastal development, oil transport, mining, and Areas of Concern. In some locations, other issues that can impact the achievement of lakewide objectives include discharges from vessels, unsustainable forestry practices, energy transport and development, and point source pollution. Through research, monitoring and other science, current and future threats are assessed regularly.

Coastal Development: Structures that protect shoreline properties can also alter sediment transport process along the coast and, in turn, impact the quality of beaches and wetlands. Artificial shorelines replace natural habitat, and these developments are often found in the important habitat areas of river estuaries and embayments. Overall, the Lake Superior shoreline remains in a largely natural state compared to the other Great Lakes - less than 5% of the shoreline has been developed and converted into an artificial or hardened shoreline. In some communities, former industrial lands are being reclaimed for public waterfront access, or to create green space along the shore. At the same time, however, some stretches of shoreline are becoming increasingly developed for roads and residential, commercial or industrial land uses.

Oil Transportation: The transport of crude oil from Bakken shale oil and Alberta bitumen sources presents risks to Lake Superior due to proposed increases in the amount of oil being refined and transported. In the U.S., 9,500 carloads of crude oil were carried by train in 2008, with 650,000 carloads forecasted by the end of 2014, a more than 68 fold increase (GLC, 2015). In Canada, 500 carloads were carried in 2009 and an estimated 140,000 carloads will be carried by the end of 2014, a 28-fold increase. Existing pipelines are being upgraded to carry oil from west to east, and new pipelines are proposed or underway. Shipping depots and oil storage and transfer facilities are proposed in the Lake Superior basin. Transfer of oil by shipping vessels across Lake Superior to refineries located on the shores of the lower Great Lakes has been proposed.

Mining Impacts: The Lake Superior basin has a long history of mining operations and related impacts. While mining operations can offer economic benefits, they also present threats to the environment. For example, two Great Lakes Areas of Concern, Deer Lake and Torch Lake, were so designated in Lake Superior due to impacts from past mining operations. Fourteen mines currently operate in the Lake Superior basin, with many explorations and expansions underway. Current and/or past mines in the basin have extracted gold, silver, copper, platinum, palladium, nickel, zinc, diamond, lead, iron-ore and taconite, as well as quarried brownstone. Mining impacts cannot be easily reversed – some can cause far reaching and lasting environmental damage. Mining activity has the potential to impair water quality (e.g., mining is currently the largest source of mercury emissions in the basin) and degrade habitat (e.g., through increased sediments). Mining sediments in the nearshore, embayments, and river mouths may cover or degrade fish spawning habitats, Wild Rice and other natural resources. After a mine closes, it can remain a source of contamination from chemicals and waste rock piles; tailing ponds must be monitored and maintained for centuries to avoid environmental impacts.

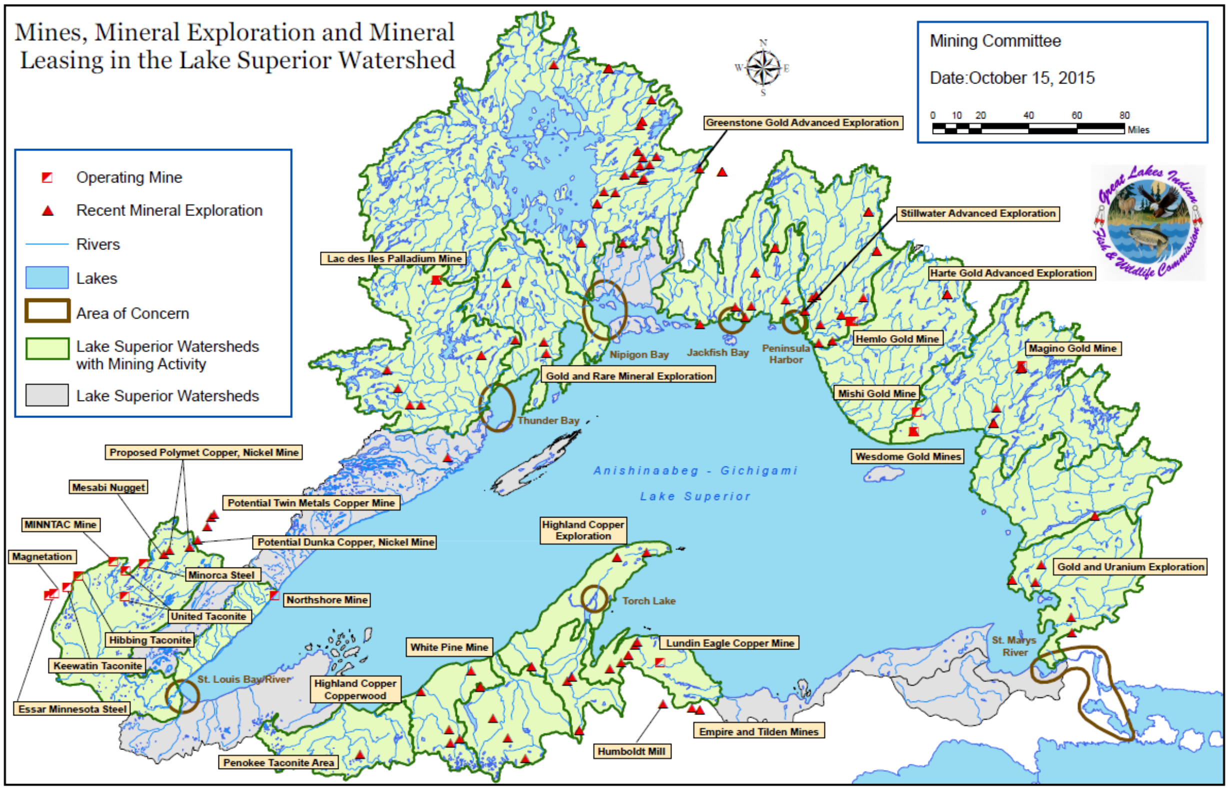


Figure X. Mines, mineral exploration and mineral leasing in the Lake Superior watershed. Source: Great Lakes Indian Fish and Wildlife Commission, 2015.

Areas of Concern: The GLWQA defines Areas of Concern (AOCs) as “geographic areas that fail to meet the general or specific objectives of the GLWQA where such failure has caused or is likely to cause impairment of beneficial use of the area's ability to support aquatic life.” In short, an AOC is a location that has experienced environmental degradation as a result of human activities at the local level. The status of the seven AOCs located in the Lake Superior basin is presented below.

Beneficial Use Impairments (BUIs)

Impairment of a beneficial use is a reduction in the chemical, physical, or biological integrity of the waters of the Great Lakes sufficient to cause any of 14 specific problems

1. restrictions on fish and wildlife consumption;
2. tainting of fish and wildlife flavor;
3. degradation of fish and wildlife populations;
4. fish tumors or other deformities;
5. bird or animal deformities or reproduction problems;
6. degradation of benthos;
7. restrictions on dredging activities;
8. eutrophication or undesirable algae;
9. restrictions on drinking water consumption, or taste and odor problems;
10. beach closings;
11. degradation of aesthetics;
12. added costs to agriculture or industry;
13. degradation of phytoplankton and zooplankton populations; and
14. loss of fish and wildlife habitat.

http://binational.net/annexes/a1/.

Delisted AOCs

- In October 2014, Michigan’s Deer Lake AOC on the southern shore of Lake Superior, was delisted from the binational list of toxic hotspots in the Great Lakes.

AOCs in Recovery

- Canada and Ontario formally recognized Jackfish Bay as an “AOC in Recovery” in 2011. Fish health and sediment quality in the area will continue to be monitored to assess progress toward environmental recovery.

Listed AOCs

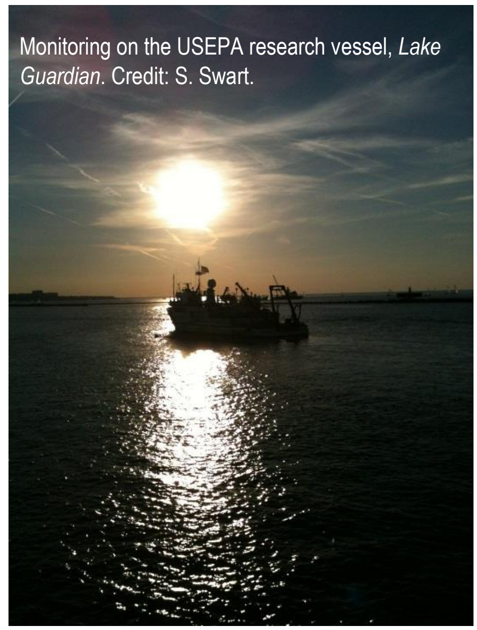
- At the Torch Lake AOC, the State of Michigan is leading a multi-year project to identify the source(s) of PCBs that are causing levels in fish and sediments to remain high.
- Feasibility studies, design work, and permitting are underway for large-scale restoration and remediation projects on the Wisconsin and Minnesota sides of the St. Louis River AOC. Construction began in 2015. Eight BUIs remain.
- Most remedial actions for the Thunder Bay AOC are complete, with positive effects on the environment.. Work is underway to develop the best solution for managing 22 hectares of contaminated sediment in the north harbor. The sediment cleanup is the largest and most significant project needed to address remaining environmental issues in the area.
- Thanks to the collaborative efforts of governments, industry, and community partners over more than two decades, the environmental goals set for the Nipigon Bay AOC have been met. The governments of Ontario and Canada, with support from the Nipigon Bay Public Advisory Committee, are recommending the removal of Nipigon Bay from the list of Great Lakes AOCs.
- In 2012, Canada and Ontario completed sediment remediation via thin-layer capping, which was the last major action needed to address environmental problems in the Peninsula Harbour AOC. Long-term monitoring is underway to make sure the environment is recovering, and to date, results show that cap materials have remained in place and some aquatic vegetation is growing in the capped area.

5.0 SURVEYS, INVENTORIES AND OUTREACH

5.1 COOPERATIVE SCIENCE AND MONITORING INITIATIVE

As part of a five-year cycle to assess and monitor the chemical, physical, and biological integrity of Lake Superior, the Lake Superior Partnership implements a Cooperative Science and Monitoring Initiative (CSMI). CSMI results are used to assess the state of the lake (reported in Section 4). The binational research and monitoring program involves an intensive, management-related scientific examination of each Great Lake, on a staggered five-year rotational basis. The current five-year cycle for Lake Superior consists of the following steps:

- Identify science needs (completed in 2014)
- Develop priorities (completed in 2015)
- Conduct field work (planned for 2016)
- Perform laboratory analysis and compile results (planned for 2017)
- Report results (planned for 2018)


Monitoring on the USEPA research vessel, *Lake Guardian*. Credit: S. Swart.

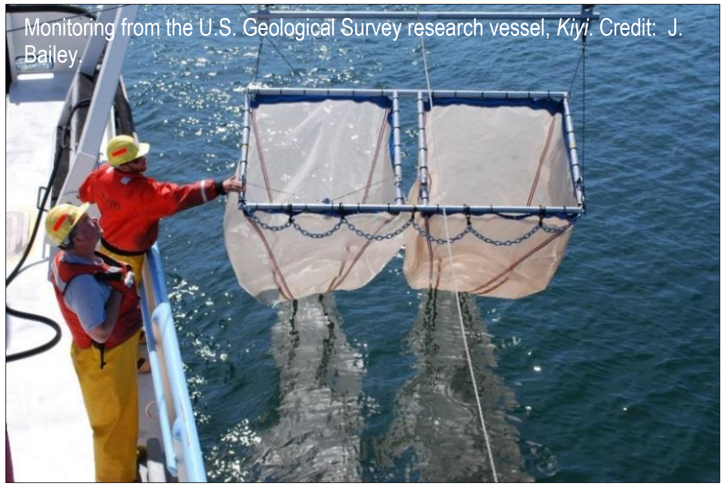
Science and monitoring priorities are identified through the lakewide management process, with open discussion and input opportunities among all stakeholders and interested public. For Lake Superior, the last year of intensive monitoring took place in 2011. Several studies were completed by various Partnership members and together they present a comprehensive assessment of the state of the Lake Superior ecosystem. Priority research topics ranged from emerging and legacy contaminant trends in water, fish, wildlife, and humans to ecosystem-wide assessments of fish, coastal wetlands, invasive species, and lakewide trends in tributary flows.

As part of the reporting phase of the last CSMI cycle, Environment Canada and the U.S. EPA hosted a monitoring workshop on September 24-25, 2013, in Duluth, Minnesota. The workshop had a dual purpose: first, to allow researchers to present their recent Lake Superior science and monitoring results (with a focus on activities undertaken as part of the 2011 monitoring year); and second, to begin discussions of ongoing and new information needs, potential partners and potential funding mechanisms for conducting new field studies in 2016. See Section 8 for a list of Lake Superior CSMI priorities for 2016.

5.2 ONGOING SCIENCE AND RESEARCH

In addition to CSMI, the Lake Superior Partnership conducts a wide range of ongoing science and monitoring. Together this work provides a foundational understanding of Lake Superior's conditions and threats, as well as guidance to various restoration and protection programs and initiatives. The results of the Partnership's science and monitoring efforts are shared, and where applicable, coordinated among various natural resource agencies.

For example, every state and province monitors contaminant levels in fish on an ongoing basis in order to provide public advice on safe fish consumption, such as the *Guide to Eating Ontario Fish*. Furthermore, the U.S. federal government supports the Great Lake Indian Fish and Wildlife Commission in ongoing monitoring and communication of mercury levels in fish in targeted areas of importance to tribal communities who depend on these fish for food and their traditional ways of life. Similar programs exist in each of the Lake Superior states.


Monitoring from the U.S. Geological Survey research vessel, *Kiyi*. Credit: J. Bailey.

Coordination of fisheries activities across Lake Superior is undertaken by the Lake Superior Technical Committee, under the Great Lakes Fisheries Commission. Fishery agencies have developed protocols to standardize collection of biological data such as age structure.

These are two of many examples of the ongoing science and monitoring activities undertaken by over 30 organizations that make up the Lake Superior Partnership.

5.3 OUTREACH AND ENGAGEMENT

The Lake Superior Partnership has a long history – over 25 years – of extensive public engagement in the LAMP program. Historically, outreach and engagement activities have been undertaken by two entities:

1. The Lake Superior Partnership Communications Committee; and
2. The Lake Superior Binational Forum.

Lake Superior Binational Forum

The Lake Superior Binational Forum, a binational group of stakeholders from a wide array of sectors, helped establish an effective multi-sector stakeholder process through public meetings, webinars, workshops, radio shows, publications, newspaper inserts, social media and websites. In particular, through social media and their website, the Forum shared important information on the Lake Superior ecosystem and helped foster an appreciation and awareness of the lake through Lake Superior Day and annual stewardship awards. Past Lake Superior Binational Forum activities included:

- Annual Lake Superior Day celebrations
- Annual Lake Superior stewardship awards
- Hazardous, e-waste and pesticides disposal days
- Outreach on reduction of backyard trash burning, the largest source of dioxins to Lake Superior
- Public meetings and webinars around the basin on mining, AIS, and other issues
- Contributions to establishment of chemical reduction targets and timeframes.

Although the Lake Superior Binational Forum is no longer operational, the Partnership is committed to formulating a robust, meaningful, and substantive outreach and engagement program and process. Under the 2012 GLWQA, the Lake Superior Partnership is specifically responsible for conducting outreach activities, identifying the need for further engagement by governments and the public, and providing annual updates to the public under each LAMP. The Lake Superior Partnership is committed to these activities and more, in accordance with the requirements of GLWQA Annex 2.

EcoSuperior sponsored a home cleaner trade-in project in which the public was invited to trade in a typical household cleaning product for a kit to make their own cleaning products. Credit: M. McChristie.

A new Lake Superior Outreach and Engagement Committee will continue these types of activities and further strengthen outreach and awareness to ensure that the needs and concerns of the diverse population in the Lake Superior basin are being met.

The Lake Superior Partnership's Outreach and Engagement Committee, comprised of staff from government and non-government organizations, helps plan, deliver and support communication and outreach activities and products. Examples of outreach activities which will continue into the future are presented below.

Purpose of Outreach and Engagement

- Provide information on GLWQA, particularly Annex 2
- Provide opportunity for stakeholder input on GLWQA Annex 2 products
- Tech transfer of information on the Lake Superior ecosystem
- Create a direct link between Lake Superior stakeholders and the government partnership
- Disseminate information on LAMP implementation, and how to be involved
- Identify opportunities for projects related to LAMP goals and priorities
- Promote LAMP to the public---help people take ownership of issues within their watershed
- Help identify emerging issues of concern about Lake Superior.

Outreach on AIS: A significant project related to public outreach is the lakewide effort to raise awareness about aquatic invasive species. In Ontario, this effort has been led by the Ontario Federation of Anglers and Hunters with funding from the Ontario Ministry of Natural Resources and Forestry (OMNRF). Other organizations, including state governments, tribal organizations and non-government organizations such as Minnesota Sea Grant, are also leading AIS outreach and education programs. In 2014, the Ontario Federation of Anglers and Hunters published *The Lake Superior Aquatic Invasive Species Guide* as an informational resource for recreational lake users to be aware of potential invaders and how to report a sighting.

Burn Barrel Outreach: Open burning of household wastes continues to be a basinwide problem that contributes to air quality and human health issues by releasing particulates, specifically dioxin, and other contaminants. The “Bernie the Burn Barrel” program is based on a cartoon character who teaches children about the problems associated with open burning. Bernie has been used throughout the Lake Superior basin over the last 15 years to instill the idea of reducing trash burning in school children.

Emerging Contaminants: Outreach activities will continue on educating basin stakeholders about the environmental health issues associated with personal care products. Although the Lake Superior Partnership has focused past efforts on legacy pollutants through the ZDDP, the Lake Superior Partnership also conducts research and outreach on emerging chemicals such as those found in cleaning products, personal care products and pharmaceuticals. Outreach efforts have ranged from establishing pharmaceutical take back programs and promoting medicine cabinet clean-ups to supporting hands-on workshops where participants learn how to make household cleansers or bath products. These workshops help teach stakeholders that simple, natural products are effective and safer for humans and the environment.

Potential Public Outreach and Engagement Activities: Going forward, outreach and engagement activities for the public conducted by the Lake Superior Partnership include the following:

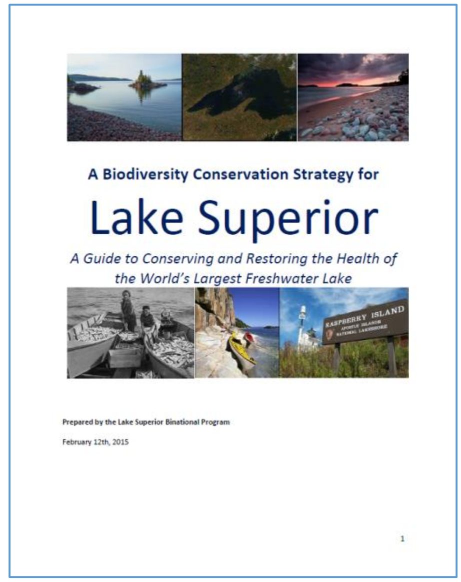
- Publish Lake Superior annual reports;
- Develop Lake Superior ecosystem objectives;
- Develop a nearshore framework;
- Prepare Lake Superior LAMP 2020;
- Assess science priorities, i.e., workshops, publications;
- Develop binational strategies;
- Conduct Outreach and Engagement committee activities;
- Host Lake Superior State of the Lake Conferences; and
- Organize subject matter webinars.

6.0 BINATIONAL STRATEGIES

Under the 2012 GLWQA, the Lake Superior Partnership is directed to develop and implement lake-specific binational strategies to address current and future potential threats to water quality. The first binational strategy developed under the 2012 GLWQA was the *Biodiversity Conservation Strategy for Lake Superior*, *2015* (Lake Superior Binational Program, 2015).

Biodiversity Conservation Strategy for Lake Superior, 2015

This Strategy provides a summary of the health of and threats to the biodiversity of Lake Superior, and presents a guide to implementing effective lakewide and regional conservation strategies. This Strategy contributes to the 2012 GLWQA commitment of developing lakewide habitat and species protection and restoration conservation strategies.



A Biodiversity Conservation Strategy for Lake Superior, 2015 is available at binational.net

Government agencies, local stakeholders, organizations, and groups were all instrumental in developing the Lake Superior Biodiversity Conservation Strategy. The information in the Strategy is intended to help all parties to identify and implement necessary actions pertaining to Lake Superior`s watersheds, coasts, and waters. The Strategy has been highly influential in the development of the Lake Superior LAMP.

In conjunction and coordination with the Strategy, 20 corresponding regional plans identifying local and regional conservation opportunities were developed. The conservation actions identified in the regional plans were developed with extensive input from local stakeholders. Together, the Strategy and the Regional Plans will support and encourage actions around Lake Superior that meet the overarching goal of protecting and restoring Lake Superior's habitat and species.

Map of Regional Planning Areas, for the Biodiversity Conservation Strategy for Lake Superior, 2015.

Corresponding regional plans highlight special features, issues and local conservation opportunities.

Past Lake Superior Partnership Binational Strategies

Binational strategies initiated under the 1987 GLWQA continue to inform, or are being incorporated into efforts of, the Lake Superior Partnership. Table 6-1 lists these strategies.

Table 6-1. Past Lake Superior Partnership Strategy Documents

Title	Date	Summary
Initiated under the 1987 GLWQA		
Climate Change Impacts and Adaptation	2014	Synthesizes the current science on climate change impacts to the Lake Superior ecosystem, lists current adaptation actions undertaken by Lake Superior partners, and outlines possible actions and strategies that can be implemented in the future.
Aquatic Invasive Species Complete Prevention Plan	2014	Documents the current status of AIS in the Lake Superior basin, the vector pathways of entry, current actions and projects undertaken by LAMP partners; and outlines strategies and actions to prevent future AIS from entering the basin.
1990-2010 Critical Chemical Reduction Milestones	2012	Describes and analyzes the sources and emissions of the nine ZDDP critical pollutants and sets strategies for achieving future milestone reductions; includes actions presently being undertaken by Lake Superior partners.
1990-2005 Critical Chemical Reduction Milestones	2006	Describes and analyzes the sources and emissions of the nine ZDDP critical pollutants and lays out strategies for achieving future milestone reductions; includes actions presently being undertaken by Lake Superior partners.
Zero Discharge Demonstration Program	1991	Created as part of the Lake Superior Binational Program, the ZDDP targets nine critical legacy pollutants for zero discharge in the Lake Superior basin by 2020. So far, the reduction targets have been reached for each chemical through 2015.

7.0 NEARSHORE FRAMEWORK

The 2012 protocol amending the GLWQA contains a commitment to develop an integrated nearshore framework for the Great Lakes (hereafter referred to as the Nearshore Framework or Framework) which will provide an overall assessment of the state of the nearshore waters of the Great Lakes (Canada and U.S. EPA, 2012). The Framework is to be developed within three years of entry into force of the GLWQA (i.e., by end of February 2016) and will be implemented collaboratively through the lakewide management process for each Great Lake. Once the Framework is complete, it will be incorporated into the Lake Superior Partnership and will be reported in the next LAMP (produced in 2020).

The nearshore regions of the Great Lakes are the geographic and ecological link between our watersheds, rivers, wetlands, and groundwater to the open deep waters of the lakes. The shallow warm water at the land-water interface provides habitat critical to maintaining our native biodiversity in the Great Lakes basin. It is also the region where human use of lake resources is most intense, from reliance on clean water for recreational uses, such as swimming and fishing, to supporting our residential populations and economic pursuits and supplying our communities with clean sources of drinking water. For the purposes of the Framework, the nearshore is defined as "*the littoral area of the Great Lakes where nearshore waters are subject to land-based and tributary inputs, which will vary depending on the stressor or process being considered.*" Thus, the nearshore area will not be rigidly defined by depth or distance from shore, but by zone of influence of the land-lake interactions.

The Framework will identify nearshore areas that are or may become subject to high stress due to individual or cumulative impacts on the chemical, physical, or biological integrity of those areas. Since the last version of the GLWQA in 1987, the focus on areas of high stress has centered on the 43 designated Great Lakes AOCs. Lessons learned from the AOC experience will provide valuable guidance for the identification of criteria that could be used to determine areas of high stress within the nearshore. In addition, the Framework will identify areas within the nearshore that are of high ecological value. Ultimately, the goal is to attain best-use water quality criteria with a focus on human health for all nearshore areas, and to restore or prevent the impairment of beneficial uses.

Manitou Island off the northeastern tip of the Keweenaw Peninsula. Credit: P. Nankervis.

8.0 SCIENCE AND MONITORING PRIORITIES

As described in Section 5.1, the CSMI is an intensive, binational research and monitoring program that follows a five-year cycle. As part of that cycle, science and monitoring priorities for Lake Superior were determined through multi-stakeholder discussions, taking into account the results of previous studies and recommendations, long-term trends and emerging issues.

The Lake Superior Partnership has grouped science and monitoring priorities into three themes: chemicals and nutrients, aquatic communities, and habitat and wildlife. Table 8-1 lists current Lake Superior science and monitoring priorities. These priorities support Lake Superior lakewide objectives, and results will inform future assessments of the state of the lake as well as threats to the ecosystem that need to be addressed.

Lake Sturgeon. Credit: H. Quinlan, US Fish and Wildlife

Table 8.1 Lake Superior Science and Monitoring Priorities, 2016

Science and Monitoring Priority	Context	Link to Action Areas and Lakewide Objectives
Chemicals and Nutrients		
Concentrations and cycling of Zero Discharge Demonstration Program chemicals in the Lake Superior basin.	While demonstrating the extent that the emissions of these chemicals can be reduced within the basin, it is also important to understand and communicate the actual concentrations and trends of these contaminants in the environment.	Action area on chemical contaminants. Lakewide objective to achieve zero release of nine persistent bioaccumulative toxic substances.
Chemicals of emerging concern - toxicity, persistence and bioaccumulative properties. Preference to all candidate 'chemicals of mutual concern' under the GLWQA that are not already captured above.	While the 'cleanest' of the Great Lakes, there are existing chemicals of management concern and many new substances being detected in the waters. Even if meeting acceptable concentrations, it is important to communicate that evidence, and continue to ensure Lake Superior is benefitting from pollution prevention actions.	Action area on additional substances of concern. Lakewide objective to protect the Lake Superior basin from contamination resulting from additional substances of concern.
Mercury trends in Lake Superior fish	Lake Superior data is demonstrating a vacillation (i.e., decrease/increase/decrease) in mercury. Is this a management concern? Mercury is a cause of some fish consumption advisories.	Action area on chemical contaminants. Lakewide objective to achieve zero release of nine persistent bioaccumulative toxic substances, which includes mercury.
Identify the most susceptible nearshore eutrophication areas based on loadings, climate	Occasional algal blooms do occur in some localized areas. In 2012, an extreme rain event and high temperatures was associated with a rare, small blue-green bloom in the southwest of the lake.	Action area on additional substances of concern. Lakewide objectives to protect the Lake Superior basin from contamination

Science and Monitoring Priority	Context	Link to Action Areas and Lakewide Objectives
changes, lake currents and hydrodynamics		resulting from additional substances of concern, and to maintain good ecological condition of coastal wetlands, embayments and the nearshore waters.
Follow-up studies on effects of stamp sands	Stamp sands (legacy mining waste piles) that contain elevated levels of contaminants and are eroding into Lake Superior (e.g. near Gay, Michigan) can threaten water quality, habitat and species. Is this a management concern?	Action areas on additional substances of concern, high quality habitats, and native species. Lakewide objectives to protect the Lake Superior basin from contamination resulting from additional substances of concern, and to maintain good ecological condition of embayments and the nearshore waters.
Aquatic Communities		
Monitoring of the lower-trophic food-web / energy transfer.	Lake Superior has a largely native and self-sustaining food-web, despite ongoing and new and cumulative stressors. Significant management actions have been taking place to restore and maintain conditions.	Action area on native species. Lakewide objective to maintain good ecological condition of the nearshore and offshore waters.
Lake Sturgeon Index Survey	Lake Sturgeon is not only a species of conservation concern, and ongoing rehabilitation efforts have positive impacts on quality of tributary habitats, currently assessed to be ‘fair’ condition.	Action areas on native species and dams and barriers. Lakewide objectives to maintain good ecological condition in tributaries and watersheds.
Aquatic invasive species early detection monitoring	Aquatic invasive species is a top threat to biodiversity conservation and management of self-sustaining commercial and recreational fishery.	Action areas on aquatic invasive species, and native species. Lakewide objectives to maintain good ecological condition of tributaries, inshore, nearshore and offshore waters.
Support to fish rehabilitation plans	Brook Trout and Walleye are species of conservation concern, and among the species with rehabilitation plans. Understanding status and trends of fish populations help prioritize management actions.	Action areas on high quality habitat and native species. Lakewide objectives to maintain good ecological condition of tributaries, coastal wetlands, inshore, nearshore and offshore waters.
Habitat and Wildlife		
Identify and rank vulnerability of cold-water tributaries to Lake Superior to various stressors, including climate change	Lake Superior has a unique network of cold-water streams. Cold-water habitats are threatened by climate change, but current and predicted distribution, extent, and risk are not known.	Action areas on climate change, high quality habitat and native species. Lakewide objective to maintain good ecological condition of tributaries and watersheds.
Baseline water quality monitoring areas of potential future land use change.	There remain gaps in knowledge of water quality, groundwater assessment, and the land-lake interface in some areas, such as the Keweenaw Peninsula.	Action area on other existing and emerging threats.

Science and Monitoring Priority	Context	Link to Action Areas and Lakewide Objectives
		Lakewide objective to maintain good ecological condition in the tributaries and watersheds, and protect the Lake Superior basin from contamination resulting from additional substances of concern.
Identify species of conservation concern	Recent assessments in support of the Biodiversity Conservation Strategy for Lake Superior, 2015 identified the need to better identify presence of species of conservation concern, their habitats, habitat range limits, and sensitivity to climate change.	Action areas on climate change, native species, and high-quality habitats. Lakewide objectives to maintain good ecological condition on the islands, coastal wetlands, coastal zones and tributaries and watersheds.
Land use / Land cover	The extent and rate of land use change (e.g. forested, developed, agriculture) is not fully understood, nor is the impacts of these changes to Lake Superior. Opportunity to help better inform future land use planning with regard to lakewide objectives.	Action areas on dams and barriers, climate change and high-quality habitats. Lakewide objectives to maintain good ecological condition of tributaries and watersheds, coastal zones, coastal wetlands, embayment and nearshore waters.
Explore use of lakewide macroinvertebrate monitoring to assess state of the lake, threats, stress impacts, and success of restoration and protection investments	Various macroinvertebrate monitoring efforts are taking place to track local conditions and inform local decision-making. Assess the similarities and differences, and applicability for potential lakewide standardization for lakewide reporting and decision-making.	Action areas on dams and barriers, climate change and high-quality habitats. Lakewide objectives to maintain good ecological condition of tributaries and watersheds, coastal zones, coastal wetlands, embayment and nearshore waters.

9.0 PRIORITY ACTIONS TO ADDRESS PRIORITY THREATS AND ACHIEVEMENT OF LEOS

The tables on the following pages present management actions to restore and protect the Lake Superior basin: protecting high-quality habitats, outreaching and educating on priority issues, and improving data management for decision-making, to name a few. Although the actions are not ranked within each area, the first three action areas do represent the highest threats to biodiversity. The order of remaining action areas does not represent a formal prioritization.

In addition to the management actions, a short list of 'top projects' is presented for each action area. The top projects represent a specific set of Lake Superior Partnership agreed-upon projects that require a high-degree of cooperative and coordinated implementation. These projects are a priority for the Partnership over the next five years to help mitigate the top threats and achieve lakewide objectives.

The management actions and top projects present opportunities for Lake Superior stakeholders to address the threats identified in Section 4, achieve lakewide objectives for Lake Superior, and meet the GLWQA goal of restoring and maintaining the chemical, physical, and biological integrity of Lake Superior.

Top photo: Falls River culvert on Golf Course Road, Baraga County, Michigan, before removal. Bottom photo: Falls River Golf Course Road after culvert removal. Credit: E. Johnston, Keweenaw Bay Indian Community.

9.1 LAKEWIDE MANAGEMENT ACTIONS

Aquatic Invasive Species: Reduce the impact of existing aquatic invasive species and prevent the introduction of new ones

The table below presents 15 management actions that seek to achieve several lakewide objectives for Lake Superior (objectives 1-4, 7) by addressing threats to water quality from existing or new AIS. These actions also support GLWQA General Objectives that aim to protect Great Lakes waters from the introduction and spread of invasive species, and support healthy and productive habitats to sustain resilient populations of native species. AIS were identified as a high threat to habitats and species on a lakewide scale in *A Biodiversity Conservation Strategy for Lake Superior* (Lake Superior Binational Program, 2015).

#	AIS Actions
1	Establish first response control protocols in anticipation of newly discovered aquatic invasive species, where not already in place.
2	Implement control and/or eradication plans, where feasible, for priority aquatic invasive species at appropriate geographic scales.
3	Undertake actions that reduce the risk of AIS being transferred between Lake Superior and the lower Great Lakes, the Mississippi River Basin, or other inland waters.
4	Maintain Sea Lamprey at population levels that do not cause significant mortality on adult Lake Trout.
5	Perform best management practices to prevent AIS introductions during dredging operations, lock operations, construction, and other maintenance activities.
6	Establish screening processes to classify species proposed for trade into three lists: prohibited, permitted, and conditionally prohibited/permitted; and place an immediate moratorium on the trade of prohibited species.
7	Require permits for shore land work, which identify AIS introduction issues and establish best management practices and restrictions.
8	Implement compatible, federal regulatory regimes for ballast water discharge that are protective of the Great Lakes for both the U.S. and Canada.
9	Use regulations, policies and best management practices to reduce the risk of introduction of AIS by all possible pathways, including boaters, travel guides, equipment and bait dealers, plant nurseries, airplane charter companies, and those who recreate in the water.
10	Protect exposed or seasonally exposed wetland environments from off-road vehicular use that may be a vector for invasive plants (e.g., Common Reed [*Phragmites australis*]).
11	Undertake outreach, education, enforcement and research on preventing and managing AIS.
12	Monitor AIS movement and establishment in the Lake Superior basin.
13	Maintain a list of the AIS that are most likely to reach the Lake Superior basin and monitor appropriately.
14	Support development, testing and implementation of effective ballast treatment systems.
15	Identify ecosystems that may be more vulnerable to new AIS under changing environmental conditions.

Lake Superior Partnership Top Projects 2015-2019

1. Add additional locations to the lakewide aquatic invasive species early detection rapid response surveillance project.
2. Undertake additional aquatic invasive species prevention outreach and education, including discussions with recreational boaters and lake access site signage.
3. Maintain and improve effectiveness of Sea Lamprey control, prevent introduction of new species, and limit expansion of previously established aquatic invasive species.
4. Contribute to the eradication of Common Reed (i.e., *Phragmites australis)* from the entire Lake Superior basin by undertaking or supporting lakewide mapping of distribution, early detection efforts, and control efforts.

Located at the end of the northern breakwater, the Duluth Harbor lighthouse marks the entrance to the canal in Duluth, Minnesota. Credit: S. Bayer.

Climate Change: Respond to climate change

The table below presents 13 management actions that seek to achieve several lakewide objectives for Lake Superior (objectives 2-6) by addressing threats to water quality from changes in climate. These actions also support GLWQA General Objectives that aim to support healthy and productive habitats to sustain resilient populations of native species, protect against conditions that may negatively impact water quality, and allow for swimming and other recreational use unrestricted by environmental quality concerns. Climate change was identified as a high threat to habitats and species on a lakewide scale in *A Biodiversity Conservation Strategy for Lake Superior* (Lake Superior Binational Program, 2015).

#	Climate Change Actions
1	Review and revise conservation, restoration and management plans, guidelines and regulations as required in response to projected climate change impacts (e.g., increased water temperatures).
2	Implement adaptation actions to account for changes in variability and/or frequency in air and water temperatures, water levels, storm events, droughts, etc.
3	Implement adaptive plant and forestry management practices that respond to climate change to minimize possible disturbances to Lake Superior.
4	Create coastal development setbacks or rolling easements to allow ecosystems to migrate in response to changes in water levels due to climate change.
5	Develop away from potentially newly-sensitive and/or hazard-prone areas due to changing conditions.
6	Increase the incorporation of climate change information into the communications, management, technical assistance, science, research and development programs of parks and protected areas.
7	Undertake climate change education and outreach activities, with a focus on disseminating materials and information available from domestic climate change programs.
8	Monitor the effectiveness of the Lake Superior Regulation Plan (i.e., water levels) in responding to changing climate conditions with regard to protecting and preserving Lake Superior coastal ecosystems.
9	Modify invasive species pathway analysis and prediction models to include climate change parameters.
10	Use parks or sentinel sites as long-term integrated monitoring sites for climate change (e.g., monitoring of species, especially those at-risk or extinction-prone).
11	Continue to support and enhance scientific research designed to understand resilience of ecosystems to climate change and other cumulative effects.
12	Make climate models, scenarios, and impact information available and accessible to those making large and small scale natural resource management decisions, growth plan decisions, and socio-economic analyses.
13	Conduct climate change vulnerability assessments for forests, fisheries, priority habitats and species, and nearshore water quality.

Lake Superior Partnership Top Projects 2015-2019

1. Undertake or support outreach and education to stakeholders on the impacts of climate change in the Lake Superior ecosystem, including potential changes to habitat ranges, stormwater management, and nutrient/chemical cycling.
2. Support local climate change scenario planning to help natural resource managers develop adaptation plans for ecological communities.

Dams and Barriers: Reduce the negative impacts of dams and barriers by increasing connectivity and natural hydrology between the lake and tributaries

The table below presents 4 management actions that seek to achieve the Lake Superior lakewide objective related to tributaries and watersheds (objective 7) by addressing threats to habitats and species arising from habitat connectivity issues. These actions also support GLWQA General Objectives that aim to protect Great Lakes waters from the introduction and spread of invasive species, and support healthy and productive habitats to sustain resilient populations of native species. Dams and barriers were identified as a high threat to habitats and species on a lakewide scale in *A Biodiversity Conservation Strategy for Lake Superior* (Lake Superior Binational Program, 2015).

#	Dams and Barriers Actions
1	On a watershed scale, assess and prioritize habitat connectivity opportunities (e.g., culvert upgrade, road/stream crossing upgrade) with consideration of the benefits (e.g., quality or amount of habitat connected) versus the costs (e.g., community disruptions, potential spread of invasive species, financial cost).
2	Protect and restore connectivity, where appropriate, by removing dams, upgrading stream/road crossing infrastructure, or by other means.
3	Adopt flow standards to sustain key environmental processes, critical species habitat and ecosystem services.
4	Pursue, continue or enhance sustainable hydropower planning that adequately protects aquatic ecosystems, habitats and species.

Lake Superior Partnership Top Projects 2015-2019

1. Improve access to high-resolution stream/river barrier data and species-specific benefit analyses in support of decision-making on Lake Superior habitat connectivity decisions.
2. Establish a collaborative Lake Superior streams improvement initiative in Canada to undertake stream monitoring, assessment, and data management activities, and to help identify stream protection and restoration priorities.
3. Prepare an environmental studies report to explore the feasibility, costs and benefits associated with the options surrounding the proposed decommissioning of Ontario's Camp 43 dam, and construction of a corresponding multi-purpose Sea Lamprey barrier at Eskwanonwatin Lake.

Chemical Contaminants: Work to achieve zero releases of the nine persistent bioaccumulative chemicals, by 2020 under the Zero Discharge Demonstration Program

The table below presents 9 management actions that seek to achieve the Lake Superior lakewide objective related to persistent bioaccumulative and toxic substances (objective 8). These actions also support GLWQA General Objectives that aim to maintain a source of safe, high-quality drinking water; protect Great Lakes waters from pollutants in quantities or concentrations that could be harmful to human health, wildlife, or aquatic organisms; and allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants. Chemical contaminants were identified as a medium threat to habitats and species on a lakewide scale in *A Biodiversity Conservation Strategy for Lake Superior* (Lake Superior Binational Program, 2015).

#	Chemical Contaminants Actions
1	Support efforts that increase the level of public education on mercury, PCBs and dioxin toxicity; and pathways into fish, wildlife, and humans. Educate the public on reduction and/or elimination actions and projects.
2	Continue to build on knowledge of existing and proposed mining projects in the basin for incorporation into lakewide chemical inventories and to promote where necessary, best mining practices with regard to achievement of Lake Superior ecosystem objectives.
3	Promote wide-spread bans, restrictions, and voluntary phase-out of mercury-containing products to households, schools, municipalities, and businesses.
4	Investigate any potential further opportunities to remove mercury from wastewater, including through voluntary and regulatory means (e.g., local ordinances). Recognize many completed successful innovations and toxic reduction strategies in the basin (e.g., Western Lake Superior Sanitary District, Thunder Bay, Superior, Bayfield, Marquette, Ishpeming, and others) and look for opportunities to tech transfer their success.
5	Showcase agencies and local governments that collect and track the types and amounts of pesticides disposed, to support efforts to virtually eliminate those pesticides listed in the Zero Discharge Demonstration Program from the basin.
6	Support existing pesticide collection programs, such as clean sweeps, and explore the expansion of collections to additional geographic areas.
7	Track and reduce atmospheric deposition of persistent, bioaccumulative, and toxic pollutants from in-basin sources through research, voluntary actions, and enforcement of controls and regulations.
8	Where possible, participate in and encourage out-of-basin actions to reduce toxic chemicals from being imported into the Lake Superior basin via atmospheric deposition.
9	Support open burning abatement programs (e.g., burning residential garbage in backyard burn-barrels), and track the extent of open burning practice from a lakewide perspective.

Lake Superior Partnership Top Projects 2015-2019

1. Increase the level of public education on mercury toxicity; pathways into fish, wildlife and humans; and actions that can be taken to help remove it from the basin.
2. Conduct a data synthesis of available mercury monitoring data for the Lake Superior basin to improve the inter-jurisdictional understanding and communication of mercury trends in the Lake Superior ecosystem.
3. Document which agency and local government entities collect and track the types and amounts of pesticides disposed to inform existing pesticide collection programs, such as clean sweeps, and the potential for expanding collections to additional geographic areas.
4. Continue to support open burning abatement programs, such as Bernie the Barrel, to achieve reductions in the release of dioxins and furans into the Lake Superior basin from the practice of residential burning of garbage.

Additional Substances of Concern: Protect the Lake Superior Basin from future contamination resulting from additional substances of concern

The table below presents 5 management actions that seek to achieve the Lake Superior lakewide objective related to additional substances of concern (objective 9). Aside from the legacy chemicals that are the focus of the ZDDP, additional contaminants such as pharmaceuticals and substances identified as GLWQA Chemicals of Mutual Concern have the potential to adversely impact water quality. These actions support GLWQA General Objectives that aim to maintain a source of safe, high-quality drinking water; protect Great Lakes waters from pollutants in quantities or concentrations that could be harmful to human health, wildlife, or aquatic organisms; and allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants.

#	Additional Substances of Concern Actions
1	Implement activities identified in Binational Strategies for future GLWQA Chemicals of Mutual Concern, as appropriate.
2	Seek opportunities to support, coordinate or expand the different pharmaceutical collection initiatives taking place in the Lake Superior basin.
3	Develop policies or programs that assist nursing homes and other health care facilities in proper disposal of unwanted medication.
4	Consider adopting cosmetic pesticide policies or resolutions, using as a guide the 2009 Ontario Pesticides Act: Cosmetic Pesticide Ban Regulations.
5	Support various energy efficiency and energy conservation programs (e.g., Leadership in Energy and Environmental Design) and provide resources to the public, private businesses, and municipal governments.

Lake Superior Partnership Top Projects 2015-2019

1. Increase the level of public education on new and emerging chemicals; their potential toxicity; pathways into fish, wildlife and humans; and how the public can help remove them from the basin. Special emphasis on the topics of microplastics and safer alternatives for personal care, household cleaning products, and pesticides/herbicides.
2. Compile information on the type and status of different pharmaceutical collections in the basin and other efforts to locate and properly dispose of unwanted medication. Use this information to identify opportunities for further action.

Other Existing and Emerging Threats: Address other existing and emerging threats that may impact important habitat or native plant and animal communities

The table below presents 7 management actions that seek to achieve several lakewide objectives for Lake Superior (objectives 6, 8) by addressing other existing and emerging threats that have the potential to impact important habitat or native plant and animal communities. These actions also support GLWQA General Objectives that aim to maintain a source of safe, high-quality drinking water; protect Great Lakes waters from pollutants in quantities or concentrations that could be harmful to human health, wildlife, or aquatic organisms; allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants; support healthy and productive habitats to sustain resilient populations of native species; and protect against conditions that may negatively impact water quality. Other existing and emerging threats were identified as a medium threat on a lakewide scale in *A Biodiversity Conservation Strategy for Lake Superior* (Lake Superior Binational Program, 2015).

#	Other Existing and Emerging Threats Actions
1	Promote proactive consideration of important habitat areas and species during environmental assessment and regulatory processes for mining, supported by comprehensive binational mapping (existing and historical mining activities and exploration) and sharing knowledge of best management practices, best available technologies and other activities, as appropriate.
2	Reduce non-point source pollution from urban areas, agriculture, and other sources to levels that are safe for plants, fish and wildlife.
3	Integrate green infrastructure principles in coastal development projects.
4	Use only sustainable forestry practices in the Lake Superior basin.
5	Develop, implement, and integrate early detection and rapid response networks for terrestrial invasive species.
6	Track and implement control and/or eradication plans, where feasible, for terrestrial invasive species at appropriate geographic scales.
7	Research or monitor potentially new or emerging threats to the biological integrity of Lake Superior.

Lake Superior Partnership Top Projects 2015-2019

1. Provide oil spill responders with improved access to existing and new spatial data on ecologically important and sensitive habitats.
2. Support efforts to increase the sustainable use of Lake Superior basin resources, with specific emphasis on projects on green stormwater infrastructure, incorporating traditional ecological knowledge into projects, and/or recognizing the monetary value of ecosystem services.
3. Further connect with communities and others at local scales to inform policies on water use and water value.

4. Map current and proposed mining activities in the Lake Superior basin to support understanding of the potential and cumulative impacts on important habitat sites and other stressors such as climate change impacts.

Lakehead University students monitoring fish in the recently restored Kama Creek, just east of Nipigon, Ontario. Credit: J. Bailey.

High-quality Habitats: Restore and protect a system of representative, high-quality habitats

The table below presents 12 management actions that seek to achieve several lakewide objectives for Lake Superior (objectives 1, 2-4, 6, 7) by restoring and protecting habitats. These actions also support GLWQA General Objectives that aim to support healthy and productive habitats to sustain resilient populations of native species, and protect against nutrients that directly or indirectly enter the water.

#	High-quality Habitat Actions
1	Restore or protect wetlands, native riparian forests, and coastal habitats such as rocky shorelines, beaches and dunes.
2	Achieve an overall net gain of the productive capacity of habitat supporting fish and wildlife.
3	Where feasible, restore habitats that have been degraded in their ecological capacity to support fish and wildlife communities.
4	Protect oligotrophic conditions (i.e. high in oxygen, low in nutrients) in nearshore and offshore waters, and restore and protect water quality in embayments and tributaries.
5	Develop or refine ecologically based integrated watershed management plans in priority areas.
6	Use special land and water designations to protect important habitat on public property.
7	Develop and implement a policy that results in zero loss of wetland areas and function within the basin.
8	Educate and engage people about restoring or protecting important habitat and related ecosystem services.
9	Develop comprehensive inventories of important fish and wildlife habitats.
10	Inventory and assess impacts to degraded habitats and communities.
11	Develop and distribute information and/or indicators on ecosystem conditions, trends, stressors and important restoration or protection sites.
12	Maintain and share data through existing and new mechanisms, as appropriate.

Lake Superior Partnership Top Projects 2015-2019

1. Design and implement dredging solutions and habitat restoration for Buffalo Reef, Michigan.
2. Improve the mapping and quantification of important spawning, nursery and foraging habitat for key fish species to support protection and restoration decision-making.
3. Promote and support local and regional implementation of the Biodiversity Conservation Strategy and corresponding Regional Plans.
4. Formally establish the Lake Superior National Marine Conservation Area and Federal-Provincial harmonization committee to develop and implement management priorities for the area.
5. Integrate spatial data standards and methodologies to identify and prioritize sites for habitat protection and rehabilitation and develop targeted geomatics products for lakewide action and management

6. Protect and enhance important coastal wetland habitats on priority state and tribal lands in western Lake Superior, including Bark Bay, Frog Bay, Bad River/Kakagon Sloughs and the St. Louis River estuary.

Diverse, Healthy and Self-sustaining Native Species Populations: Manage plants and animals in a manner that ensures diverse, healthy and self-sustaining populations

The table below presents 9 management actions that seek to achieve several lakewide objectives for Lake Superior (objectives 1-7) by addressing threats to diverse, healthy and self-sustaining native species populations. These actions also support GLWQA General Objectives that aim to support healthy and productive habitats to sustain resilient populations of native species, protect against conditions that may negatively impact water quality.

#	Diverse, Healthy and Self-sustaining Native Species Populations Actions
1	Develop and implement plans to detect and prevent disease outbreaks.
2	Use local native species, to the extent possible, in restoration projects and natural resource management, supported by the development or maintenance of lists of the native species, use standards, sources, and seed zones.
3	Implement native fish and wildlife species restoration, protection or rehabilitation plans, as appropriate.
4	Manage the harvest of fish, wildlife and plants to ensure their health, long-term sustainability and balance in the ecosystem.
5	Manage over-abundant populations of species where there is strong evidence of sustained detrimental effects on habitats and / or species diversity.
6	Educate citizens about the importance and appropriate use of local native plants in restoration and landscaping projects.
7	Undertake comprehensive biological surveys in the watershed to identify species of conservation interest and remaining natural communities.
8	Catalogue Lake Superior basin's genetic diversity.
9	Develop and distribute information and/or indicators on species conditions, trends, stressors and potential rehabilitation locations.

Lake Superior Partnership Top Projects 2015-2019

1. Develop and update stock assessment models to improve management of self-sustaining commercial and sport fisheries for Lake Trout, Cisco, and Lake Whitefish.
2. Develop and implement improved monitoring approaches for inshore, embayment, and tributary fish populations.
3. Update the Ecopath model with Ecosim (Kitchell et al., 2000) with recently acquired data and knowledge in order to explore a) how recent changes in fish abundance could be influencing the food web; b) how the ecosystem may respond to current and potential threats; and c) how components of the ecosystem may respond to potential management actions.
4. Rehabilitate populations of indigenous aquatic species (e.g., Brook Trout, Muskellunge, Walleye, etc.).

9.2 IMPLEMENTATION AND ACCOUNTABILITY

9.2.1 Partnership Organizations

Lake Superior Partnership organizations commit to incorporating, to the extent feasible, LAMP objectives and priorities in their decisions on programs, funding, and staffing. In implementing the LAMP, Lake Superior Partnership organizations will be guided by the principles and approaches outlined in the GLWQA, including:

- Accountability – the effectiveness of actions will be evaluated by individual partner agencies, and progress will be reported through LAMP Annual Reports and the next 5-year LAMP report;
- Adaptive management – the effectiveness of actions will be assessed and future actions will be adjusted as outcomes and ecosystem processes become better understood;
- Coordination – actions will be coordinated across jurisdictions and stakeholder agencies, where possible.

9.2.2 Actions in AOCs

Remedial Action Plans (RAPs) have been developed for each AOC, and a team of partners cooperates to implement a RAP and restore an AOC, including federal governments, state and provincial governments, and local stakeholders.


Peninsula Harbour AOC in Ontario. Credit: Environment Canada.

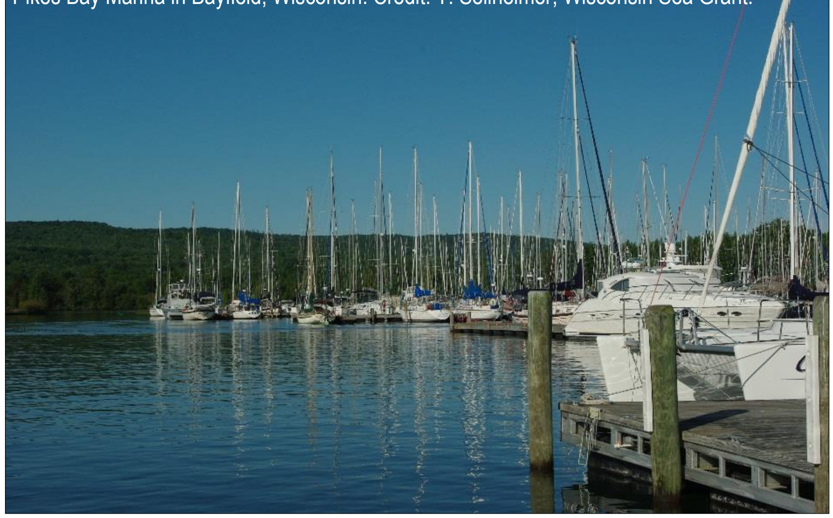
The LAMPs and AOCs are linked in that AOCs often contribute to toxic releases and discharges to the lakes, may prevent the attainment of LEOs, and are areas that, by definition, do not comport with the ecosystems objectives and goals of the LAMPs. Conversely, actions completed in AOCs, such as those to restore fish and wildlife habitat, also support the objectives of the LAMP. RAPs and LAMPs are similar in that they both use an ecosystem approach to assess and remediate environmental degradation. It is essential that the AOC partners and the Lake Superior Partnership continue to work collaboratively to achieve common goals. Much of the expertise and land use control of BUIs, possible remediation efforts, and watershed planning reside at the local level. Cooperation between the two efforts is essential for the Lake Superior Partnership to remove lakewide impairments, and for the AOC partners to remove site-specific impairments.

Once an AOC is delisted, the area will come under the purview of the Lake Superior Partnership, particularly insofar as long-term monitoring is concerned. Local watershed groups will be engaged in Partnership activities, goal setting, and implementation of actions that will build on the positive efforts completed as part of the RAP and support ongoing environmental improvement.

9.2.3 Potential Actions by the Public and NGOs

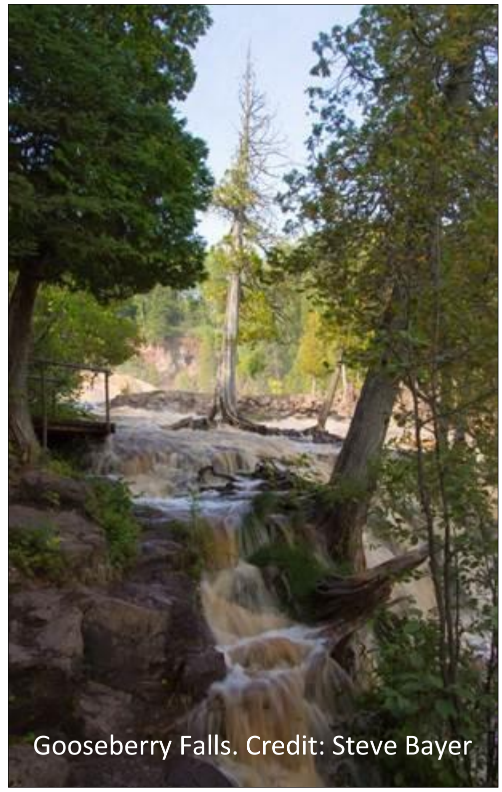
Every individual can take action to help address priority threats and achieve the lakewide objectives for Lake Superior. Potential actions include:

- Create an energy efficient home
- Install water saving devices
- Use a rain barrel for watering the garden
- Reduce, reuse, repair, and recycle
- Take household hazardous materials to hazardous waste collection depots
- Never burn garbage
- Return unused medicines, including over-the-counter drugs, to your pharmacy; never flush them down the toilet or dump them down the sink


Pikes Bay Marina in Bayfield, Wisconsin. Credit: T. Seilheimer, Wisconsin Sea Grant.

- Choose natural fabrics, natural cleaning products, and reusable containers
- Use more environmentally friendly asphalt-based sealants as an alternative to those with coal tar
- Landscape with native plants, compost, and natural pest-control methods
- Plant trees to capture carbon dioxide and prevent erosion
- When boating, clean your boat and trailer thoroughly before leaving the boat access
- Whenever possible, refuel your boat at an approved area on land using a fuel pump; avoid fuel and oil spills by ensuring you do not overfill your tanks
- Don't release live bait, aquarium fish and plants, or other exotic animals into the wild
- Work with community groups and local authorities to develop watershed management plan

- Protect and restore coastal and riparian habitat
- Ensure effective fish passage in new infrastructure projects and work to remove barriers, such as perched culverts and road crossings
- Support citizen monitoring programs for water quality and invasive species
- Support green infrastructure, including low impact development to manage stormwater
- Support active transportation, carpool, or use the most fuel-efficient vehicle possible
- Reduce work and personal travel by using online, video and telephone conferencing options and vacationing closer to home
- Support long-term strategies to assess risks and vulnerabilities and prepare for climate change at the local and regional level
- Promote corporate social responsibility and support businesses with sustainability initiatives



Gooseberry Falls. Credit: Steve Bayer

10.0 REFERENCES

5 Gyres Institute. Accessed March 2015. *Beat the Microbead*. Website. Accessed at http://5gyres.org/how_to_get_involved/campaigns-microbead/.

Allan et al. 2013. Need citation …

Austin, J., and Colman, S. 2008. A century of temperature variability in Lake Superior. *Limnology and Oceanography*, 53(6), 2724-2730.

Bailey, Jim (Interviewer). February 2014. *Infosuperior Podcast Series – Interview with Laura Gallagher*. Audio podcast. Retrieved from http://infosuperior.com/blog/2014/02/10/infosuperior-podcast-series-february-edition/.

Beall, F. 2011. Draft State of the Lakes 2012 Indicator Report: Forest Cover. United States Environmental Protection Agency, Chicago, IL and Environment Canada, Burlington, ON. Available at http://www.solecregistration.ca/documents/Forest%20Cover%20DRAFT%20Oct2011.pdf.

Binational.net. Accessed March 2015. *Status of Great Lakes Areas of Concern*. Canada-United States Collaboration for Great Lakes Water Quality. Accessed at http://binational.net/2014/10/31/status-aocs/.

Burniston, D., et al. 2012. Spatial distributions and temporal trends in pollutants in the Great Lakes 1968–2008, *Water Quality Research Journal of Canada.* 46.4, 269-289.

Canada and United States, 2012. Need GLWQA citation …

Chan et. al., 2014. *First Nations Food, Nutrition and Environment Study (FNFNES*): *Results from Ontario (2011/2012)*. Ottawa: University of Ottawa. Print.

Christensen, V.G., Lee, K.E., Kieta, K.A., and Elliott, S.M., 2012, Presence of selected chemicals of emerging concern in water and bottom sediment from the St. Louis River, St. Louis Bay, and Superior Bay, Minnesota and Wisconsin, 2010: U.S. Geological Survey Scientific Investigations Report 2012–5184, 23 p. with appendixes.

Ciborowski, J. et al. 2011. Need citation …

deSolla SR, Weseloh DVC, Hughes KD, Moore DJ. In Press. 40 year decline of organic contaminants in eggs of herring gulls (*Larus argentatus*) from the Great Lakes, 1974 to 2013. *Waterbirds*.

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

Eberhardt, R., Michigan Department of Environmental Quality. 2014. Personal communication.

Environment Canada (EC). 2013. Perfluorooctane Sulfonate in the Canadian Environment. Environmental Monitoring and Surveillance in Support of the Chemicals Management Plan. Available from: http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=7331A46C-1.

Environment Canada and U.S. EPA. 2013. State of the Great Lakes 2011 Technical Indicator Report. Cat No. En161-3/1-2011E-PDF. EPA 950-R-13-002. Retrieved from http://binational.net.

Eriksen, M., Mason, S., Wilson, S., Box, C., Zellers, A., Edwards, W., Farley, H. Amato, S. (2013). Microplastic pollution in the surface waters of the Laurentian Great Lakes. Marine pollution bulletin, 77(1), 177-182.

Evers, D., Wiener, J., Basu, N., Bodaly, R.A., Morrison, A., and K. A. Williams. 2011. Mercury in the Great Lakes region: bioaccumulation, spatiotemporal patterns, ecological risks and policy. Ecotoxicology, 20:1487-1499.

Fond du Lac. 2014. *Biomonitoring Newsletter*. Fond du Lac Community Biomonitoring Study. Retrieved from http://www.fdlrez.com/humanservices/biomonitornews.htm.

Fond du Lac and Minnesota Department of Health. 2014. Community Report for Cadmium, Lead, and Mercury. Retrieved from http://www.fdlrez.com/humanservices/biomonitoring.htm.

Golder Associates Ltd., 2011. Recovery Strategy for Lake Sturgeon (*Acipenser fulvescens*) – Northwestern Ontario, Great Lakes-Upper St. Lawrence River and Southern Hudson Bay-James Bay populations in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources, Peterborough, Ontario. vii + 77 pp.

Government of Canada. Accessed March 2015. *Species Profile: Shortjaw Cisco*. Species at Risk Public Registry. Website. Accessed at http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=82#ot18.

Grannemann, N. and D. Van Stempvoort, Eds. 2015. Groundwater science relevant to the Great Lakes Water Quality Agreement: A status report. Prepared for the Great Lakes Executive Committee by the Annex 8 Subcommittee.

Granneman, N.G., R.J. Hunt, J.R. Nicholas, T.E. Reilly, and T.C. Winter, 2000. The importance of ground water in the Great Lakes Region. U.S. Geological Survey Water-Resources Investigation Report 00-4008.

Great Lakes Commission. 2015. *Lake by lake: Superior*. Human Health and the Great Lakes. Website. Accessed at http://www.great-lakes.net/humanhealth/lake/superior.html.

Great Lakes Regional Collaboration (GLRC). 2010. Great Lakes mercury reduction strategy.

Huff, A. and A. Thomas. 2014. Lake Superior Climate Change Impacts and Adaptation. Prepared for the Lake Superior Lakewide Action and Management Plan – Superior Work Group. Accessed at http://www.epa.gov/glnpo/lakesuperior/index.html.

Ingram, J., L. Dunn and D. Albert. 2004. Coastal Wetland Area by Type (Indicator ID: 4510). Available at: http://www.glc.org/wetlands/pdf/Area-status.pdf. Accessed 12 November 2012.

Kitchell et al. 2000. Need citation …

Koster A. and M. Hansen, 2014. Evaluating Future Need of the Gull Island Shoal Lake Trout Refuge in Lake Superior. Conference paper, American Fisheries Society 144th Annual Meeting.

LSBP, 2006a. Need citation …

Lake Superior Binational Program. 2015. A Biodiversity Conservation Strategy for Lake Superior. Accessed at http://binational.net/2015/02/23/biodiversity-strategies/.

Lake Superior Binational Program. 2014. Lake Superior Aquatic Invasive Species Complete Prevention Plan. Accessed at http://www.epa.gov/glnpo/lakesuperior/index.html.

LSBP 2012a. Need citation …

Lake Superior Binational Program. 2012. *Lake Superior Lakewide Management Plan: 1990-2010 Critical Chemical Reduction Milestones*. Prepared by the Superior Work Group – Chemical Committee. 104 pages. Toronto and Chicago.

LaBeau, M.B., Robertson, D.M., Mayer, A.S., Pijanowski, B.C., and Saad, D.A., 2014, Effects of future urban and biofuel crop expansions on the riverine export of phosphorus to the Laurentian Great Lakes: Ecological Modelling v. 277, p. 27–37, DOI: 10.1016/j.ecolmodel_2014.01.016.

Mason, S.A., Eriksen, M., and Edwards, W.J. 2014. "Great Lakes Plastic Pollution Survey," 57th Annual Conference on Great Lakes Research (IAGLR 2014), Hamilton, Ontario. Accessed at http://www.lakescientist.com/microplastics-pollution-great-lakes-ecosystem-summary-presentations-iaglr-2014/.

Michigan Tech Research Institute. Accessed March 2015. *Great Lakes Cladophora Mapping*. Website. Accessed at http://www.mtri.org/cladophora.html.

Minnesota Department of Health. 2013. Beaches and Recreational Waters in Minnesota. Accessed at http://www.health.state.mn.us/divs/eh/beaches/howsafe.html.

Minnesota Nutrient Planning Portal. Accessed March 2015. *Statewide Nitrate Trends*. Website. Accessed at http://mrbdc.mnsu.edu/mnnutrients/lake-superior-basin.

Minnesota Sea Grant, 2014a. *Superior Facts*. Website. Accessed at http://www.seagrant.umn.edu/superior/facts.

Minnesota Sea Grant, 2014b. *Duluth-Superior Port*. Website. Accessed at http://www.seagrant.umn.edu/maritime/duluth-superior.

Minnesota Sea Grant, 2015. *Fish.* Website. Accessed at http://www.seagrant.umn.edu/fisheries/.

Murphy, E., Holson, T., Pagano, J. and Milligan, M. 2015. *Great Lakes Fish Monitoring and Surveillance program (GLFMSP) Emerging Chemical Discovery*. Webinar. Prepared by U.S. EPA Great Lakes Fish Monitoring and Surveillance Program and Clarkson University. Retrieved from http://glc.org/files/projects/lmmcc/LMMCC-20140326-Murphy-GLFMSP-Emerging-Chemical-Discovery.pdf.

Murphy, Elizabeth, U.S. EPA. 2015. *Great Lakes Fish Monitoring and Surveillance Program: Background, Trends, and General Conclusions*. Presentation.

NOAA. 2000. Lake Superior Basin Statistics. Website. Accessed at http://www.glerl.noaa.gov/pr/ourlakes/lakes.html#superior.

NOAA. 2015. Great Lakes Regional Land Cover Change Report, 1996–2010. Accessed at http://coast.noaa.gov/digitalcoast/_/pdf/CCAPGreatLakesChangeReport508C.pdf.

Ontario, 2015. *Ontario's parks and protected areas*. Website. Accessed at www.ontario.ca/environment-and-energy/ontarios-parks-and-protected-areas.

Ontario Ministry of Environment and Climate Change. 2015. Chief Drinking Water Inspector Annual Reports. Accessed at http://www.ontario.ca/page/drinking-water#!/

Parks Canada. June 2015. *Lake Superior National Marine Conservation Area Receives Highest Level of Federal Protection*. Press release. Accessed at http://news.gc.ca/web/article-en.do?mthd=advSrch&crtr.page=1&crtr.dpt1D=68&nid=990859.

Robertson, D.M. and Saad, D.A., 2011, Nutrient inputs to the Laurentian Great Lakes by source and watershed estimated using SPARROW watershed models: Journal of the American Water Resources Association. v. 47, p. 1011-1033, DOI: 10.1111/j.1752-1688.2011.00574.

Schuldt, N. 2011. *Lake Superior – Mining*. Presentation at State of the Lakes Ecosystem Conference.

Sterner, RW. 2011. C:N:P stoichiometry in Lake Superior: Freshwater sea as end member. *Inland Waters* 1: 29-46.

Stoor, R.W., Hurley, J.P., Babiarz, C.L., D.E. Armstrong. Subsurface sources of methylmercury to Lake Superior from a wetland-forested watershed. Science of the Total Environment. September, 2006. 368: 99-110.

Superior Work Group. 2013. *Lake Superior Biodiversity Conservation Assessment: Final Draft, June 2013*. Superior Work Group of the Lake Superior Lakewide Action and Management Plan. Retrieved from https://secure2.convio.net/ncc/pdf/on/lake-superior/Biodiversity-Conservation-Assessment-for-Lake-Superior-Vol1-FinalDraft.pdf.

Trebitz et al. 2011. Need citation …

United States Army Corps of Engineers. 2014. *Great Lakes Update 2014 Annual Summary*. U.S. Army Corps of Engineers Detroit District. Retrieved from http://www.lre.usace.army.mil/Portals/69/docs/GreatLakesInfo/docs/UpdateArticles/update192.pdf.

United States Army Corps of Engineers. 2012. Commercial Fisheries Baseline Economic Assessment - U.S. Waters of the Great Lakes, Upper Mississippi River, and Ohio River Basins by the GLMRIS team, led by the Corps of Engineers.

United States Department of Agriculture (USDA). 2014. *USDA to Focus on Lake Superior Forest Project: NRCS and Forest Service Partner to Improve Forest Health*. News Release, February 6, 2014. Retrieved from http://www.nrcs.usda.gov/wps/portal/nrcs/detail/az/home/?cid=stelprdb1247272.

United States Environmental Protection Agency (U.S. EPA). 2014. Data from the Great Lakes Fish Monitoring and Surveillance Program: Mercury.

United States Environmental Protection Agency (U.S. EPA). 2014. *Lake Superior*. Website. Accessed at www.epa.gov/grtlakes/lakesuperior.

United States Fish and Wildlife Service, 2015. Need citation …

United States Geological Survey (USGS). 2010. Need citation …

VanderMeulen, David. 2015. National Park Service. Personal correspondence.

Vernier, M., Dove, A., Romanak, K., Backus, S., and R. Hites. Flame retardants and legacy chemicals in Great Lakes' water. Environmental Science and Technology. 2014. 48(16) 9563-9572.

WI DNR and Apostle Islands National Lakeshore. 2012. *Blue-green Algae Observed in Lake Superior*. Joint Press Release.