

A Bi-National Program to
Restore and Protect
the Lake Superior Basin

September, 1991

A Bi-National Program to
Restore and Protect
the Lake Superior Basin

Introduction

In its Fifth Biennial Report on Great Lakes Water Quality, the International Joint Commission (IJC) recommended that "the Parties designate Lake Superior as a demonstration area where no point source discharge of any persistent toxic chemical will be permitted." This document identifies the responses of the federal governments of the United States and Canada, the States of Minnesota, Wisconsin and Michigan and the Province of Ontario (the governments) to this recommendation.

Lake Superior has not experienced the intense development, urbanization and pollution characteristics of the lower lakes and has remained relatively pristine. To protect the high quality waters of the Lake Superior basin, and to restore beneficial uses where they have been degraded, the United States and Canadian environmental protection programs will be expanded, coordinated and accelerated. This effort includes two major areas of activity: (A) a zero discharge demonstration program devoted to the goal of achieving zero discharge or emission of certain designated persistent bioaccumulative toxic substances, which may degrade the ecosystem of the Lake Superior basin, and (B) a broader program of identifying impairments and restoring and protecting the Lake Superior basin ecosystem.

A Taskforce of senior managers from resource management and environmental protection agencies from the governments is proposing the following approach to those areas of activity identified above. The ultimate goal of these activities is to restore and maintain the integrity of the Lake Superior ecosystem through prevention, control and restoration programs. In developing this action plan the Taskforce is consulting not only governmental entities, but also the public through a stakeholder advisory forum. Because of the significant diversity in philosophy, approach, statutory underpinnings and program maturity, the Taskforce identified parallel action plans for the portion of the basin in the United States and the portion in Canada. The actions identified as short term are expected to occur within the next three years. However, when actions are to occur over the longer term, over the next three to five years, they have been so identified. Wherever possible the governments have identified uniform activities in directing programs to meet the common goal, and remain committed to coordinating an effective and equitable basin-wide program.

The governments will ensure that their respective regulatory programs are compatible with the attainment of the goal and fair to dischargers on both sides of the basin. Furthermore, the governments will ensure a regular reporting on the progress of the plan through the semi-annual meetings of the Parties to the Great Lakes Water Quality Agreement.

The challenge to designate Lake Superior as a "demonstration area where no point source discharge of any persistent toxic substance will be permitted," is accepted. Following the process described in this document, the governments will use existing authorities, and seek expanded authorities, to pursue the goal of zero discharge.

At the same time, the development and implementation of Remedial Action Plans (RAPs) will continue, existing regulatory programs will be fully implemented, and new initiatives to identify Lakewide impairments, responsible source and corrective measures will be initiated. Public participation will be an important part of this program.

The Lake Superior Zero Discharge Demonstration Program

GOAL: To achieve zero discharge and zero emission of certain designated persistent, bioaccumulative toxic substances, which may degrade the ecosystem of the Lake Superior basin.

This goal will be pursued through actions taken in three areas. The waters in the Lake basin will be designated as meriting special protection and antidegradation requirements. Reduction in existing loadings will be secured both through voluntary pollution prevention activities and enhanced control and regulatory efforts. Each area is described in detail below.

1. Pollution Prevention

Policy: To eliminate or further reduce persistent bioaccumulative toxic substances at their sources, the governments agree to develop and implement pollution prevention approaches. The prevention of pollution is the preferred approach to environmental protection. When preventing pollution is not feasible, the remaining waste management options (in priority order) are reuse, recycling, treatment and disposal. Disposal or other release to air, water or land should occur only as a last resort, and when there are no prudent and feasible alternatives.

Status: The United States Environmental Protection Agency (USEPA) has identified Lake Superior as a focal point of the Great Lakes Pollution Prevention Action Plan announced in April of 1991. Most state programs or proposals are in the planning stages and have been developed using guidance from USEPA. Pollution Prevention activities can fall into many categories, but the present discussion is limited to include voluntary elimination/reduction programs and technical assistance activities.

Canada has identified Lake Superior as a priority area for implementation of its recently announced Great Lakes-St. Lawrence Pollution Prevention Initiative. The Ontario Ministry of the Environment is willing to participate with the federal government in programs directed at the protection of Lake Superior, and, will seek reductions of persistent toxic substances from all industrial operations in the Great Lakes, initially with a focus on Lake Superior.

Bi-National Action Plan

Action: The United States and Canada have funded a bi-national dialogue in pollution prevention, focused on Lake Superior. A Lake Superior Stakeholders Advisory Committee will facilitate a process to develop a strategy to reduce the current emissions of toxic substances and eliminate future sources. A Lake Superior Stakeholder Advisory Committee will consider what stakeholders can do to achieve immediate and near term reductions in toxic loadings and to clearly define the barriers to toxics reduction. The Lake Superior stakeholders will participate in the

Pollution Prevention Symposium in Traverse City, Michigan in conjunction with the IJC Biennial Meeting.

Action: The United States and Canada will encourage the twinning of two major municipalities in the Lake Superior basin to enhance citizen dialogue and to exchange ideas and practices respecting pollution prevention strategies.

United States Action Plan

Action: The States and USEPA will develop and implement educational programs and technical assistance activities to promote pollution prevention leading to the elimination or reduced use of toxic materials. A joint project, the Lake Superior Partnership, is being undertaken by the State of Minnesota and the Western Lake Superior Sanitary District in Duluth to conduct multi-media compliance inspections and identify pollution prevention opportunities. A training program for individuals involved in Remedial Action Planning will also be developed, with special attention to the St. Louis River Area of Concern.

Action: USEPA will seek voluntary reduction of the release and off-site transfer of toxic materials from major corporations. Collectively, these activities are known as the "33/50" program. Using 1990 as a baseline year, USEPA is seeking thirty-three percent reductions by 1992 and fifty percent reductions by 1995.

Canadian Action Plan

Action: Canada and Ontario will develop pollution prevention strategies for all sectors in the basin through consultation with governments, industry, municipalities, business and individuals. Funds will be directed toward assisting stakeholders with the development of sectoral toxic chemical reduction plans, as well as demonstration projects involving pollution prevention technologies and educational programs. The polluter pays principle will apply to implementation of these plans.

Action: Environment Canada, Environment Ontario and Domtar, a large Canadian corporation, will shortly investigate the feasibility of introducing a chlorine-free bleaching process to the mill at Red Rock, Ontario, through an initial bench scale study to be completed by 1992.

Action: The Conservation Council of Ontario is developing a program to improve the effectiveness of community involvement in solving environmental problems.

The Program builds on existing consultation processes and community based plans to develop and publicize a list of priority issues. Each participating community will also identify specific targets, the actions it wishes to undertake, and the support required to facilitate public and community involvement.

Communities in the Lake Superior basin will be particularly encouraged to participate in this exercise, and financial assistance will be provided to assist in the development of plans.

2. Special Protection Designations

Policy: Because of the unique character of the Lake Superior resource, the governments in the United States portion of the basin will seek to implement a "toxic freeze strategy". Under this strategy the governments will designate all U.S. Lake

Superior basin waters as a special resource, apply enhanced antidegradation approaches which require best technology for any proposed new or increased discharge of certain designated persistent bioaccumulative toxic substances into those waters, and designate certain portions of the Lake basin as areas where no new or increased point source discharges of these pollutants will be permitted.

Canada and Ontario also recognize the unique character and pristine nature of Lake Superior. The governments, in order to maintain this ecosystem, intend to be as diligent as possible regarding the approval of any proposed new or expanded industrial or municipal facility. The governments will encourage non-polluting industries to establish in the Lake Superior basin.

Status: Each State has an existing process for antidegradation evaluation. These processes will be standardized through the Great Lakes Water Quality Initiative, and will include enhanced requirements for Lake Superior.

The Canada Water Act is the legislative tool available to designate Lake Superior as a special Water Quality Management Area pursuant to a federal-provincial agreement.

United States Action Plan

Action: By written agreement, the Governors commit to initiate appropriate state procedures to designate all waters of the Lake Superior basin as an Outstanding International Resource Waters (OIRW). Under the OIRW designation, the increased discharge of certain designated persistent bioaccumulative toxic substances will not be allowed without an adequate antidegradation demonstration which includes the installation of the best technology in process and treatment. The States will develop the procedure for the antidegradation demonstration under the Great Lakes Water Quality Initiative.

Action: By written agreement, the Governors commit to initiate appropriate State procedures to designate certain special areas of the Lake Superior basin as Outstanding National Resource Waters (ONRW). The purpose of this ONRW designation is to prohibit the new or increased discharges of certain designated persistent bioaccumulative toxic substances by point sources in these areas, including respective buffer zones and transition areas as defined by the states. Examples of areas to be considered for such designation include:

National Parks, Lakeshores and Refuges, and
State Parks, Recreational Areas and Refuges.

The States will develop procedures under the Great Lakes Water Quality Initiative for state implementation of this ONRW designation.

Action: The States and USEPA will evaluate the possibility of pursuing and/or supporting other special designations of areas in the Lake Superior basin. Examples of these other designations include: the United Nations Biosphere Reserve Program and the International World Heritage Program.

Canadian Action Plan

Action: Canada and Ontario are presently reviewing the Canada-Ontario Agreement Respecting Great Lakes Water Quality. As part of this review process the two governments will pursue a federal-provincial designation respecting Lake Superior

under the Canada Water Act. The public will be involved in this review.

3. Controls and Regulations

Policy: In the United States, it is a national goal that the discharge of pollutants be eliminated. To ensure continued progress toward this goal, point source controls will be improved as a result of upgraded technology based requirements and revised Lake Superior Water Quality Standards designed to provide consistent protection of water quality in the basin. Best Management Practices will be required where nonpoint sources are significantly impairing water quality. Air emissions will be required to meet enhanced emission standards and other control measures as necessary to protect the Lake.

Canada and Ontario have agreed to adopt the goal of virtual elimination of persistent toxic substances from the ecosystem. They also agree to apply the philosophy of zero discharge of persistent toxic substances to the ecosystem.

Status: The United States has adopted technology-based effluent requirements for fifty-one categories of industrial dischargers and municipal sewage treatment works. The states have adopted Water Quality Standards for Lake Superior and its tributaries. These requirements are applied through state issued National Pollutant Discharge Elimination System (NPDES) permits for those facilities which discharge directly to surface waters and through pretreatment standards for industries which discharge into sanitary sewer systems.

At present, both the technology based requirements and the water quality standards are undergoing review and updating. A rulemaking involving multiple statutes is underway for the Pulp, Paper and Paperboard industry and will result in decreased releases to the environment. Water Quality Standards and related implementing procedures are being updated through the Great Lakes Water Quality Initiative, a joint state-USEPA effort to ensure that standards are adequately protective and consistently applied to dischargers.

The Clean Air Act requires the assessment of the role and relative importance of atmospheric deposition of hazardous air pollutants in the impairments on the Great Lakes. By 1995, USEPA is to promulgate any necessary emission standards or control measures. The design of the needed monitoring program is underway, and an air research "master station" has been established on the Keweenaw Peninsula.

The Lakewide Management Planning process described in the following section will be used to coordinate these activities.

Ontario is currently preparing new and revised regulations to reduce and eliminate point source discharges of persistent toxic substances. Ontario will be incorporating the philosophies of pollution prevention, multi-media considerations, and zero discharge of persistent toxic substances in the preparation of the regulations.

Bi-National Action Plan

Action: The governments will undertake the development of common water quality standards and implementing procedures for the Lake Superior basin. This effort will establish common interim water quality goals as progress is made toward the elimination of discharges of persistent, bioaccumulative toxic substances, and build on the Great Lakes Water Quality Initiative.

Action: The governments will pursue expanding bans of persistent bioaccumulative toxic substances, and/or the establishment of sunset restrictions for these substances as necessary.

Action: The governments will complete an inventory of toxic air emissions and an assessment of toxic air deposition in the Lake Superior basin.

United States Action Plan

Short-term Strategy

Action: The States and USEPA will continue enforcing existing standards through air and NPDES permits and pretreatment requirements. Facilities will continue to meet either technology, air quality or water quality based effluent limits or face enforcement actions.

Action: The States will require analysis for certain designated persistent, bioaccumulative toxic substances in stormwater discharges from municipalities with populations greater than five thousand. Stormwater permits and best management practices will be required for municipal and industrial stormwater dischargers that significantly impair water quality.

Action: The States will require toxics reduction plans in each new or reissued NPDES permit for point sources discharging to Lake Superior or its tributaries which have effluent limitations for toxic pollutants that are below levels reliably measured by present analytical methods. The plans will examine process modifications and use of alternative substances to eliminate or reduce the discharge of these pollutants and ensure progress toward the goal of zero discharge. Examples include on-site recycling, product substitution and use of closed loop systems.

Action: The States and USEPA will include pollution prevention components in enforcement settlements as appropriate. Such components can include comprehensive environmental audits, product substitution, and elimination or reuse of process wastes.

Action: The States, with the concurrence of USEPA, will designate the following as persistent, bioaccumulative substances of immediate concern for Lake Superior and its tributaries, as per Great Lakes Water Quality Initiative: 2,3,7,8 TCDD; octachlorostyrene; hexachlorobenzene; chlordanes; DDT, DDE and other metabolites; toxaphene; PCB's; and mercury. Contaminants known to cause fish and wildlife consumption advisories or impacts or accumulate to unacceptable levels in sediments will be considered by the Governors for designation in the future. New chemicals may be added following assessments of environmental effects and impacts and after public review and comment. These compounds will be the focus of the zero discharge demonstration project and form the basis for discussions with the Canadian governments.

Action: USEPA will adopt guidance and the states will revise/adopt water quality standards and enhanced antidegradation procedures in accordance with the Great Lakes Water Quality Initiative.

Action: USEPA is revising the technology based requirements for direct and indirect

dischargers. A "cluster" of regulations under multiple environmental laws is being developed for the Pulp, Paper and Paperboard industry to maximize environmental benefit. This "cluster" rulemaking is an integrated regulatory framework in which all regulations affecting the industry are considered together to identify prevention opportunities and develop a comprehensive environmental solution, consistent with the ecosystem approach under the Great Lakes Water Quality Agreement (GLWQA).

Action: The States will issue permits to implement revised standards and requirements.

Action: USEPA will propose Sediment Quality Criteria for use in identifying contaminated sediments. These criteria will identify sediment quality that is protective of aquatic life, and establish a process for deriving criteria protective of other beneficial uses.

Action: USEPA will develop emission standards based on Maximum Achievable Control Technology under the requirements of the reauthorized Clean Air Act. In the interim, the states will require the Best Available Control Technology for toxic compounds emitted by air sources as agreed in the Great Lakes States' Air Permitting Agreement.

Long-term Strategy

Action: The States and USEPA will initiate sediment remediation measures at AOC's and other impaired sites known to contribute persistent, bioaccumulative substances to the Lake Superior ecosystem.

Action: USEPA will develop emission standards and other control measures as might be necessary to control the emission of hazardous air pollutants in the Great Lakes basin.

Action: The states and USEPA will include appropriate limits for persistent bioaccumulative toxic substances in air emission permits to eliminate or further reduce the deposition of these substances in the Lake Superior basin.

Canadian Action Plan

Action: Canada will release a pulp and paper regulatory reform package that will set stringent controls on Biochemical Oxygen Demand, Total Suspended Solids and acute toxicity as well as prevent the formation of dioxins and furans. Under the Canadian Environmental Protection Act (CEPA), Canada is reviewing the adequacy of existing regulations with a view to possibly strengthening them, or the need for additional regulations.

Action: Canada has established a priority substances list under CEPA that will be expanded and revised in 1994. Control options will be evaluated for substances that are found to be toxic and recommended control measures will be developed and implemented.

Action: Environmental effects monitoring programs will be required to assess the adequacy of control measures.

Action: The Great Lakes Cleanup Fund is supporting technology development and a demonstration program on pulp and paper mill effluents. The first priority of this program is directed towards the removal and treatment of chlorinated organic contaminants in effluents, particularly from bleached kraft mills.

Action: Under Ontario's Municipal and Industrial Strategy for Abatement (MISA), regulations are being developed to virtually eliminate persistent toxic substances from industrial effluents.

Action: In addition to the above, Ontario, in rescoping its MISA program, will feature zero discharge and pollution prevention principles, beyond the requirements for acute toxicity elimination and Best Available Technology. Ontario will be preparing a list of persistent toxic substances whose discharge will be banned.

Action: Bottom sediment adjacent to the Northern Wood Preservers site in Thunder Bay are highly contaminated with PAHs, PCPs and possibly dioxins from current and historical runoff from the facility. Pending the completion of an Environment Canada assessment of sediment contamination, a technology demonstration project for removal of contaminated materials will be conducted under the Cleanup Fund in 1992. A tandem project will also be undertaken to demonstrate sediment treatment technology to render the dredgate harmless.

Action: Ontario is committed to ensuring an adequate level of treatment for all municipal wastewater discharges to Lake Superior. Thunder Bay is undertaking a phased upgrade of its sewage treatment plant, to progress to secondary treatment by 1995. Provincial Support is being provided to individual phases of this upgrade.

Action: Canada and Ontario are working to ensure a complementary approach to regulation of industrial discharges is achieved.

Action: Ontario is currently reviewing its control programs respecting air quality with the aim of strengthening regulations to further reduce emissions of persistent toxics and other contaminants.

Action: Ontario is developing new sediment quality guidelines which set numerical objectives for the protection of aquatic life and outline procedures for the management of contaminated sediments. Release for public consultation is expected by the end of this year.

The Broader Program to Restore and Protect the Lake Superior Ecosystem

Policy: As progress is made toward the goal of zero discharge and emissions from sources of persistent, bioaccumulative toxic substances, the governments will undertake an integrated, ecosystem based program to protect and restore the Lake Superior basin. This program will include a systematic evaluation of chemical-induced environmental impairments in the basin and the identification of measures to ameliorate those impacts. This broader program also includes an inventory of existing habitat, activities to protect those resources, with special emphasis on the habitats required by threatened or endangered species, and activities to re-

store/reclaim impaired areas.

Status: A Lakewide Management Planning (LaMP) process will be initiated in 1992 to provide a framework for all of the discharge and/or emission control programs impacting the Lake basin and to set the stage for the submission of a Lakewide Management Plan. Information on the state of the Lake will be assembled. Such information will include an inventory of impairments, identification of pollutants believed to be responsible for those impairments, identification of sources, and identification of action items to reduce the contribution of pollutants to the system. Work will also begin on identification of ecosystem objectives and monitoring strategies to support the LaMP process. The monitoring strategy will include an improved international air toxic monitoring network and modeling to identify major local and distant sources impacting the basin. Consistent with the Clean Air Act control strategies for these sources will be devised and implementation will be initiated. A critical component of the LaMP process is the identification and implementation of fast-track actions that can immediately be undertaken. It is expected that this process will include all of the activities identified in the Zero Discharge Demonstration Program above. This process will be an inclusive effort, involving not only the public, but federal (bi-national), state, and provincial environmental protection and resource management agencies.

Discussions have begun between the environmental protection and resource management agencies in the basin so that the quantity and quality of fish and wildlife habitat are appropriately protected. In 1989, Canada announced a five year Great Lakes Action Plan. This plan, which has been extended, more than doubled the resources devoted to work on the Lakes, and included for the first time a Health Effects program and a Cleanup Fund.

Action: The United States will implement its 5-year strategy to coordinate its efforts in the basin. This Strategy includes all of the major actions on the Great Lakes by Great Lakes States and federal agencies.

Action: The governments will continue to support and where possible accelerate the development and implementation of Remedial Action Plans. This effort provides a mechanism for focusing the prevention, control and remediation tools available to all levels of government in the basin and will contribute to the reduction of risks to human health and the environment.

Action: The governments will inventory habitats in the basin.

Action: The governments will continue the habitat reclamation projects currently underway to restore fisheries and wetlands in Areas of Concern, and in the United States portion of the basin, other impacted areas, where appropriate.

Action: The governments will coordinate their lakewide planning process with fisheries management agencies through the Great Lakes Fisheries Commission.

Action: The governments will use existing authorities to review the impacts of hydroelectric power generation in the basin on habitat and water quality, and propose mitigative measures to ensure those impacts are minimized and/or mitigated.

Action: The governments will develop a coordinated monitoring program to identify problems and measure the successes of programs. Appropriate environmental indicators of progress, programmatic measures, measurement methods and databases will be developed.

Implementation

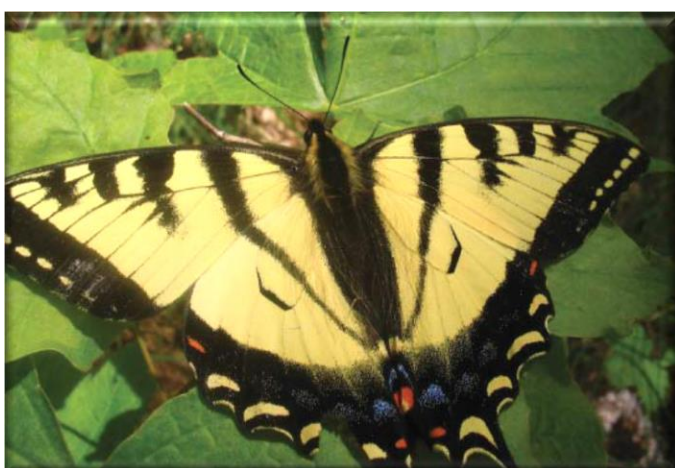
The Lakewide Management Planning process will ultimately be used to monitor progress with the commitments identified in the Zero Discharge Demonstration Program. A LaMP management committee will be convened no later than early 1992. In the interim, the Taskforce which produced this document will track commitments and report on progress through the semi-annual meetings of the Parties to the Great Lakes Water Quality Agreement. The Taskforce will continue to seek public involvement through the Stakeholders Advisory Forum.

Activities identified in The Broader Program to Restore and Protect the Lake Superior Ecosystem will be monitored through the 5-Year Strategies and subsequent annual workplans developed by the governments.

Lake Superior

Lakewide Action and Management Plan

2015 - 2019



ACKNOWLEDGEMENTS

This document was made possible by the many individuals and organizations working to restore and protect the Lake Superior ecosystem. The document builds upon many relevant local, tribal, state provincial, national and binational plans. Special thanks to all those involved in preparing *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015); to the Great Lakes Fishery Commission's Lake Superior Technical Committee; to the Great Lakes Water Quality Agreement Lakewide Management Annex (Annex 2) Subcommittee; to the numerous stakeholder groups that helped to refine the document through their review and comments at various stages of development; and to all the individuals of the Lake Superior Partnership who contributed to the LAMP's development and who will be collaborating during the implementation of this plan.

This document was prepared by the Lake Superior Lakewide Action and Management Plan Writing Team, co-chaired by Rob Hyde of Environment and Climate Change Canada (formerly Environment Canada) and Liz LaPlante of the U.S. Environmental Protection Agency. Writing Team members included: Jen Ballinger (GLIFWC), Marilee Chase (MNRF), Faith Fitzpatrick (USGS), John Jereczek (MNDNR), Ann McCammon-Soltis (GLIFWC), Michelle McChristie (MOECC), Henry Quinlan (USFWS), Mike Ripley (CORA), Lisa Sealock (ECCC), Stephanie Swart (MDEQ), Brent Schleck (NOAA), Amy Thomas (Battelle), Michele Wheeler (WDNR) and Laurie Wood (ECCC). The contributions of many photographers, both amateur and professional, are greatly appreciated, as is the scientific input and reviews provided by Great Lakes researchers and managers.

Lake Superior Partnership Agencies, 2015

| | |
|--|--|
| 1854 Treaty Authority | Natural Resources Conservation Service |
| Bad River Band of Lake Superior Chippewa | Ontario Ministry of Natural Resources and Forestry (MNRF) |
| Bay Mills Indian Community (BMIC) | Ontario Ministry of the Environment and Climate Change (MOECC) |
| Chippewa-Ottawa Resource Authority (CORA) | Parks Canada |
| Environment and Climate Change Canada (ECCC) | Red Cliff Band of Lake Superior Chippewa |
| Fisheries and Oceans Canada (DFO) | U.S. Army Corps of Engineers (USACE) |
| Fond du Lac Band of Lake Superior Chippewa | U.S. Environmental Protection Agency (USEPA) |
| Grand Portage Band of Lake Superior Chippewa | U.S. Fish and Wildlife Service (USFWS) |
| Great Lakes Indian Fish and Wildlife Commission (GLIFWC) | U.S. Forest Service (USFS) |
| Keweenaw Bay Indian Community (KBIC) | U.S. Geological Survey (USGS) |
| Michigan Department of Environmental Quality (MDEQ) | U.S. National Park Service (NPS) |
| Minnesota Department of Health (MDH) | University of Minnesota Sea Grant Program |
| Minnesota Department of Natural Resources (MNDNR) | University of Wisconsin Sea Grant Program |
| Minnesota Pollution Control Agency (MPCA) | Wisconsin Department of Natural Resources (WDNR) |
| National Oceanic and Atmospheric Administration (NOAA) | |

Cover page photo credits

Left:

Nipigon Bay, Ontario. Credit: D. Crawford.
Oliver Bay on Bete Gris Pointe, Michigan. Credit: J. Koski, KBIC.

Right

Pebble Beach, Marathon, Ontario. Credit: K. Taillon.
Swallow tail butterfly. Credit: H. Quinlan, USFW

Cat. No. En164-52/2016E-PDF
ISBN 978-0-660-06296-9

TABLE OF CONTENTS

| | | |
|------|---|----|
| 1.0 | EXECUTIVE SUMMARY..... | 1 |
| 2.0 | INTRODUCTION | 10 |
| 2.1 | Great Lakes Water Quality Agreement (GLWQA)..... | 10 |
| 2.2 | Lake Superior Partnership..... | 11 |
| 2.3 | Significance of Lake Superior | 11 |
| 3.0 | EXISTING LAKEWIDE OBJECTIVES | 16 |
| 3.1 | Background | 16 |
| 3.2 | Existing Lakewide Objectives | 16 |
| 4.0 | STATE OF LAKE SUPERIOR | 18 |
| 4.1 | State of Lake Superior in Relation to GLWQA General Objectives..... | 18 |
| 4.2 | Lakewide Threats | 37 |
| 5.0 | SURVEYS, INVENTORIES AND OUTREACH | 52 |
| 5.1 | Cooperative Science and Monitoring Initiative (CSMI)..... | 52 |
| 5.2 | Ongoing Science and Research | 52 |
| 5.3 | Outreach and Engagement | 54 |
| 6.0 | BINATIONAL STRATEGIES | 57 |
| 7.0 | NEARSHORE FRAMEWORK..... | 59 |
| 8.0 | SCIENCE AND MONITORING PRIORITIES | 60 |
| 9.0 | ACTIONS, PROJECTS, AND IMPLEMENTATION | 63 |
| 9.1 | Lakewide Management Actions and Projects | 64 |
| 9.2 | Areas of Concern..... | 91 |
| 9.3 | Implementation and Accountability | 92 |
| 10.0 | REFERENCES | 93 |

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 of the Great Lakes.

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

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, including "A Binational Program to Restore and Protect the Lake Superior Basin." The 2015 Lake Superior LAMP is a binational action plan for restoring and protecting the ecosystem. The LAMP documents the following:

- Current environmental conditions;
- Threats to the ecosystem;
- Lakewide objectives;
- Priorities for future scientific investigations; and
- Actions and projects to address threats and to achieve lakewide objectives.

The Lake Superior LAMP was written by members of the Lake Superior Partnership, including representatives of federal, state, provincial and tribal agencies from both the U.S. and Canada. In turn, these agencies work closely with many others to manage and protect their respective portions of the Lake Superior ecosystem.

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. Protection of this resource is of the highest priority and a central tenet of ecosystem management for the Lake

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 Lakewide 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 USEPA and Environment and Climate Change Canada, and will be implemented binationally in cooperation with all Lake Superior stakeholders.



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

Superior Partnership. 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.

One of the key underlying principles of the Lake Superior Partnership is the importance of involving all Lake Superior stakeholders. The ultimate success of restoring and maintaining the Lake Superior ecosystem depends on the efforts of everyone.

1.1 State of Lake Superior

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

- Fisheries in good condition, supported by a robust lower food web (e.g., small, shrimp-like *Diporeia* and *Mysis*);
- Self-sustaining populations of Lake Trout and increasing abundance of 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;
- Substances of emerging concern, such as microplastics; and
- Other threats (e.g., mining impacts and energy sector activities).



Pictured Rocks National Lakeshore, Michigan. Credit: S. Swart.

1.2 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 *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 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-related 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 1990-2010 Critical Chemical Reduction Milestones* report; LSBP, 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 |

* Ecological status was determined through the Conservation Action Planning (CAP) Framework, as described in *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015). Available Great Lakes indicators (i.e., “SOLEC indicators”) were utilized through the CAP process; details of the assessment and all indicators used are available in technical documents posted on binational.net.

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).

*** Additional substances of concern include pharmaceuticals and personal care products, microplastics, and nutrients.

1.3 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 Cooperative Science and Monitoring Initiative (CSMI), an intensive, binational scientific examination which is conducted on a five-year rotational basis. The next Lake Superior CSMI field year is 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 the nine persistent, bioaccumulative and toxic substances;
- Determine progress being made on Lake Sturgeon rehabilitation;
- Provide information needed to support implementation of fish rehabilitation plans (e.g., Walleye, Coaster Brook Trout, and Lake Sturgeon);
- 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.

Working Together

Lake Superior's generally good ecological condition is a result of a history of strong and ongoing actions, with an emphasis on prevention. Actions are occurring at all scales – from national, state, provincial, tribal, First Nation, Métis, and municipal programs, to lakewide initiatives, to local projects by communities, businesses, and households.

1.4 Actions to Address Threats and Achieve Lakewide Objectives

The LAMP includes a list of 74 management actions to address threats to water quality and achieve lakewide objectives. These actions can be used to help identify, support or coordinate ongoing or new projects. The actions are organized under eight categories:

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

Actions have been identified by the Lake Superior Partnership in consultation with Lake Superior stakeholders and the public. The primary sources of the actions are: *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015), *Lake Superior Climate Change Impacts and Adaptation Report* (Huff and Thomas, 2014), the *Lake Superior Aquatic Invasive Species Complete Prevention Plan* (LSBP, 2014), the *Zero Discharge Demonstration Program* (ongoing) and *1990-2010 Critical Chemical Reduction Milestones* report (LSBP, 2012).

The actions are fairly broad in their scope and can be used to help identify, support or coordinate ongoing or new projects for Lake Superior. For example, the actions were used to help identify Lake Superior Partnership projects over the years 2015-2019, as described below.

1.5 Lake Superior Partnership Projects for 2015-2019

To narrow down the list of 74 management actions, the Lake Superior Partnership has identified 29 projects, as listed in Table 2, below. Projects were identified by Lake Superior management experts who comprise the Lake Superior Partnership. To be identified and confirmed as a project, several factors were considered: relevancy to the broader actions needed to address a threat (referred to above), current work underway, current state of the issue, potential for a high-degree of coordinated action, contribution to achieving lakewide objectives, and achievability over the next five years.

1.6 Implementation and Accountability

Implementation of projects will remain one of the highest priorities of the individual organizations that make up the Lake Superior Partnership. Organizations identified in Section 9.1 will take action, to the extent feasible, given budget constraints and domestic policy considerations.

Internal agency work planning and reporting will help track commitment progress and provide an accountability mechanism for the results of each individual organization. Internal Lake Superior Partnership committee workplans will help track implementation at a higher level to support coordination between organizations and in the engagement of others, as well as to support lakewide reporting on LAMP implementation (e.g., annual updates to the public on the LAMP).

Table 2. Lake Superior Partnership Projects: 2015-2019

| Projects 2015-2019 | Agencies Involved |
|--|--|
| Aquatic Invasive Species | |
| 1. Add additional locations to the lakewide aquatic invasive species early detection/rapid response surveillance projects. | 1854 Treaty Authority, CORA, DFO, Fond du Lac, KBIC, MDEQ, MNRF, NOAA, NPS, Parks Canada, USEPA, USFS, USFWS, WDNR |
| 2. Undertake additional aquatic invasive species prevention outreach and education, including discussions with recreational boaters, and installation of lake access site signage. | 1854 Treaty Authority, Bad River, BMIC, Fond du Lac, GLIFWC, Grand Portage, KBIC, MDEQ, Minnesota Sea Grant, MNRF, NPS, Parks Canada, Red Cliff, USFS, WDNR |
| 3. Maintain and improve effectiveness of Sea Lamprey control, prevent introduction of new species, and limit expansion of previously-established aquatic invasive species. | 1854 Treaty Authority, Bad River, BMIC, CORA, DFO, GLIFWC, NPS, Parks Canada, Red Cliff, USFWS, USGS |
| 4. Contribute to the elimination of European Common Reed (i.e., <i>Phragmites australis</i> , <i>subsp. australis</i>) from the Lake Superior basin by undertaking or supporting lakewide distribution mapping, early detection efforts, and control efforts. | 1854 Treaty Authority, Bad River, Fond du Lac, GLIFWC, MDEQ, MNDNR, MNRF, NPS, Parks Canada, Red Cliff, USEPA, USFS, WDNR |
| 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. | 1854 Treaty Authority, Bad River, BMIC, CORA, ECCC, Fond du Lac, GLIFWC, Grand Portage, KBIC, MOECC, NOAA, NPS, Red Cliff, USEPA, USFS, USGS |
| 2. Support local climate change initiatives to help communities and/or natural resource managers develop adaptation plans. | 1854 Treaty Authority, Bad River, BMIC, CORA, Fond du Lac, GLIFWC, Grand Portage, KBIC, Minnesota Sea Grant, MNDNR, MOECC, NOAA, NPS, Red Cliff, USFS, USFWS, USGS |
| 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. | Bad River, Fond du Lac, KBIC, MNRF, Red Cliff, USFS, USFWS, WDNR |
| 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. | MNRF |

| Projects 2015-2019 | Agencies Involved |
|--|--|
| Dams & Barriers (continued) | |
| 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 the construction of a corresponding multi-purpose Sea Lamprey barrier at Eskwanonwatin Lake. | MNRF |
| Chemical Contaminants | |
| 1. Continue outreach and education to the public on mercury toxicity; pathways into fish, wildlife and humans; and actions that can be taken to help remove mercury from the basin. | Bad River, CORA, Fond du Lac, GLIFWC, Grand Portage, KBIC, MDEQ, MOECC, NOAA, NPS, Red Cliff, USEPA, USFS, USFWS, USGS |
| 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. | Bad River, ECCC, Fond du Lac, MPCA, NOAA, NPS, USGS |
| 3. Document which agencies and local governments collect and track the types and amounts of pesticides disposed, as feasible, so as to inform existing pesticide collection programs, such as clean sweeps. Information will be used to assess the potential for expanding collections to additional geographic areas. | ECCC, MDEQ, WDNR |
| 4. Continue to support open burning abatement programs, such as "Bernie the Burn Barrel," to achieve reductions in the release of dioxins and furans into the Lake Superior basin from the practice of residential burning of garbage. | Bad River, CORA, Fond du Lac, KBIC, MOECC, MPCA, Red Cliff, WDNR |
| Additional Substances of Concern | |
| 1. Increase efforts to educate the public on new and emerging chemicals; their potential toxicity; pathways into fish, wildlife and humans; and how the public can help remove these chemicals from the basin. Put special emphasis on the topics of microplastics and safer alternatives for personal care, household cleaning products, and pesticides/herbicides. | BMIC, ECCC, Fond du Lac, Grand Portage, KBIC, MOECC, NOAA, NPS, Red Cliff, USGS, USFWS |
| 2. Compile information on the type and status of different pharmaceutical collection efforts in the basin and other efforts to locate and properly dispose of unwanted medication. Use this information to identify opportunities for further action. | Bad River, ECCC, KBIC, MPCA, USFWS, USGS, WDNR |

| Projects 2015-2019 | Agencies Involved |
|--|--|
| Other Existing and Emerging Threats | |
| 1. Provide oil spill responders with better access to existing and new spatial data (as available) on ecologically-important and sensitive habitats. | Bad River, CORA, Fond du Lac, GLIFWC, MOECC, NOAA, NPS, Parks Canada, USFWS, USGS |
| 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. | 1854 Treaty Authority, Bad River, BMIC, CORA, Fond du Lac, GLIFWC, KBIC, MOECC, NOAA, NPS, Parks Canada, Red Cliff, USEPA, USFWS |
| 3. Outreach and engage with communities and others at the local scale on the value of water and best water use practices and policies. | Bad River, CORA, Fond du Lac, GLIFWC, KBIC, MDEQ, Red Cliff, USFWS, USGS, WDNR |
| 4. Map current and proposed mining activities in the Lake Superior basin to support understanding of the potential and cumulative impacts of mining on important habitat sites. Assess impacts due to other stressors, such as climate change. | 1854 Treaty Authority, CORA, Fond du Lac, GLIFWC, MPCA, NPS, USGS |
| High-Quality Habitats | |
| 1. Investigate, evaluate, and if feasible, implement dredging solutions or other habitat restoration efforts at Buffalo Reef, Michigan. | GLIFWC, NOAA, USACE, USEPA |
| 2. Improve the mapping and quantification of important spawning, nursery and foraging habitat for key fish species to support protection and restoration decision-making. | 1854 Treaty Authority, CORA, Fond du Lac, GLIFWC, MNRF, NPS, Parks Canada, Red Cliff, USEPA, USFWS, USGS, WDNR |
| 3. Promote and support local and regional implementation of <i>A Biodiversity Conservation Strategy for Lake Superior</i> (LSBP, 2015) and corresponding Regional Plans. | 1854 Treaty Authority, Bad River, BMIC, CORA, ECCC, Fond du Lac, GLIFWC, Grand Portage, KBIC, MDEQ, MNDNR, MNRF, NOAA, NPS, Parks Canada, Red Cliff, USFS, USFWS, WDNR |
| 4. Formally establish the Lake Superior National Marine Conservation Area in Canada, and Federal-Provincial harmonization committee to develop and implement management priorities for the area. | MNRF, Parks Canada |
| 5. Integrate spatial data standards, methodologies and geomatic products to help identify and prioritize sites for habitat protection and rehabilitation. | GLIFWC, MNDNR, NOAA, NPS, USEPA, USFWS, USGS |
| 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. | 1854 Treaty Authority, Bad River, Fond du Lac, GLIFWC, KBIC, MNDNR, NOAA, NPS, Red Cliff, USEPA, USFS, USFWS, USGS, WDNR |

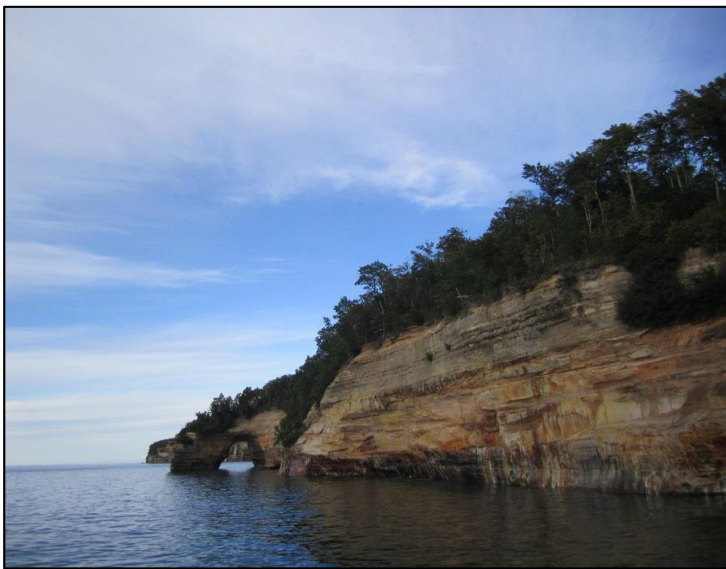
| Projects 2015-2019 | Agencies Involved |
|--|--|
| Diverse, Healthy and Self-sustaining Native Species Populations | |
| 1. Develop and update stock assessment models to improve management of self-sustaining commercial and sport fisheries for Lake Trout, Cisco, and Lake Whitefish. | Bad River, BMIC, CORA, GLIFWC, Grand Portage, MNRF, NPS, Red Cliff, USFWS, USGS, WDNR |
| 2. Rehabilitate populations of indigenous aquatic species (e.g., Brook Trout, Lake Sturgeon, Muskellunge, Walleye, etc.). | Bad River, CORA, DFO, Grand Portage, KBIC, MNRF, NPS, Red Cliff, USFWS, WDNR |
| 3. Update the Ecopath with Ecosim (EwE) ecological model (www.ecopath.org) 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. | CORA, GLIFWC, Grand Portage, MNRF, USEPA, USFWS, USGS |
| 4. Develop and implement improved monitoring approaches for inshore, embayment, and tributary fish populations. | 1854 Treaty Authority, BMIC, CORA, Fond du Lac, GLIFWC, Grand Portage, NPS, Red Cliff, USFWS, USGS |

Projects are not ranked in priority order. Agencies are listed in alphabetical 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.



Pictured Rocks National Lakeshore, Michigan. Credit: S. Swart.

2.1 Great Lakes Water Quality Agreement (GLWQA)

The 1972 *Agreement between the United States of America and Canada on Great Lakes Water Quality* (known as the Great Lakes Water Quality Agreement or 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 in 2012. The 2012 protocol amending the GLWQA reaffirms the United States' and Canada's determination "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. 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 algal 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.

In Annex 2 of the GLWQA, "Lakewide Management," the United States and Canada jointly commit to assessing the status of each Great Lake by addressing environmental stressors that adversely affect the waters of the Great Lakes and which are best addressed on a lakewide scale through an ecosystem approach.

2.2 Lake Superior Partnership

The LAMP was written, and will be implemented and managed, by the Lake Superior Partnership, including federal, state, provincial, and tribal governments or agencies tasked with protecting and restoring the Lake Superior ecosystem. The Partnership, led by Environment and Climate Change Canada and the United States Environmental Protection Agency, seeks to contribute to the achievement of the objectives of the GLWQA with the involvement and input of others, including 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 the Lake Superior Basin," 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, 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. The agencies of the Lake Superior Partnership are discussing the future status of the LSBP and its relationship to the GLWQA.

2.3 Significance 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.

Lake Superior Physical Facts

- Average depth: 147 m (483 ft)
- Maximum depth: 405 m (1,330 ft)
- Drainage basin: 127,686 km² (49,300 mi²)
 - 85% forested,
 - 10.4% water,
 - 1.7% agriculture
 - 1.5% developed land
 - 1.0% wetland

Source: Beall, 2011

Lake Superior has unique fauna, containing species and subspecies found nowhere else on the planet, such as Siscowet, a large deep water form of Lake Trout, and 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 southernmost populations of Woodland Caribou still roam parts of Lake Superior's coast and islands.

Indigenous peoples (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 through the Upper Peninsula of Michigan, with treaty-ceded territories located throughout the Lake Superior basin. In Canada, over a dozen First Nations communities are located along the coast or within the Lake Superior basin. Figure 1 shows First Nation and tribal lands in 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 ways of life. Culturally-significant wildlife include Lake Sturgeon, Bald Eagle, and Walleye, while culturally-significant plant species include Wild Rice, Labrador Tea, Paper Birch, and Cedar. Indigenous inhabitants continue to use subsistence harvesting practices throughout the basin.

Traditional Ecological Knowledge (TEK) is a term that encompasses the knowledge system of indigenous people based upon direct observations of the surrounding environment. This indigenous knowledge is passed down generation to generation and is used to explain their place in complex and interdependent relationships with all of creation. TEK enhances the understanding and appreciation of Lake Superior and is useful in local, regional, and lakewide management. TEK will be incorporated into implementation of the LAMP. According to the Ojibwe world view, Lake Superior and its connected lakes, rivers and streams are not simply the sum of their constituent parts, or the property of a state, nation, or person. Instead, they are



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 Ojibiwe people named it, Gichigami. Nipigon Bay, Ontario. Credit: D. Crawford.

integral parts of the web of life that supports the continuation of Anishinaabe ways of life and provides life-giving benefits to all who now call Lake Superior home.

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, and snowshoers from surrounding states and provinces and beyond (Minnesota Sea Grant, 2014a).



Nipigon Bay. Credit: D. Crawford.



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

Lake Superior contains dozens of 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 are the book ends of 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 Islands 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. Once formally established, Canada's Lake Superior National Marine Conservation Area (NMCA) will encompass over 10,000 km² (3,861 mi²) 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).

Lake Superior's **natural resources** are the backbone of the regional economy. Industries such as shipping, forestry, mining, agriculture, charter and recreational fishing, and tourism, contribute greatly to the local economies of coastal



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

communities, as well as to the economy of the Great Lakes region as a whole. While no formal, comprehensive economic assessment has been completed for the Lake Superior basin to date, the importance of these industries to the health and viability of coastal

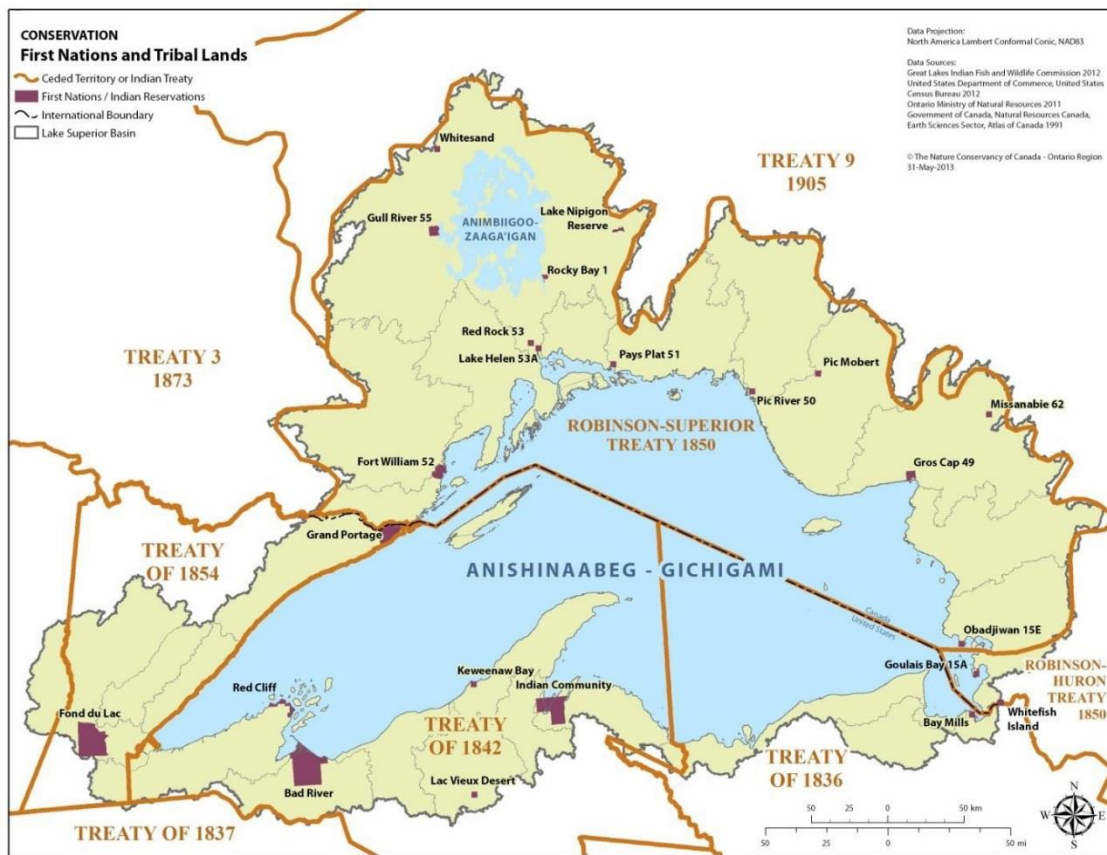


Figure 1. First Nations and tribal lands in the Lake Superior basin. Source: The Nature Conservancy of Canada.

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), while 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). Credit: 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 GLWQA General Objectives. LEOs will be used as a benchmark against which to assess status and trends in water quality and lake ecosystem health. LEOs will be determined 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 previously-established chemical objectives. These existing lakewide objectives and their current status are summarized in Table 3. For details on the status assessment for these lakewide objectives, refer to *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015) and the Lake Superior Zero Discharge Demonstration Program and *1990-2010 Critical Chemical Reduction Milestones* report (LSBP, 2012).

Table 3. 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 m (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 m (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 m (0-49 ft). These habitats are critical for 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 |

| # | Lakewide Objective | Description | Status* |
|---|---|--|---------|
| 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 |
| 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 eagles, 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 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 of these substances. | GOOD |
| 9 | Protect the Lake Superior basin from contamination resulting from additional substances of concern.*** | In addition to the nine legacy chemicals, there are a large number of substances, under an umbrella term called <i>substances of emerging concern</i> . These include substances used in flame retardants, personal care products, and pharmaceuticals. | GOOD |

* Ecological status was determined through the Conservation Action Planning (CAP) Framework, as described in *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015). Available Great Lakes indicators (i.e., "SOLEC indicators") were utilized through the CAP process; details of the assessment and all indicators used are available in technical documents posted on binational.net.

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).

*** Additional substances of concern include pharmaceuticals and personal care products, microplastics, and nutrients.

4.0 STATE OF LAKE SUPERIOR

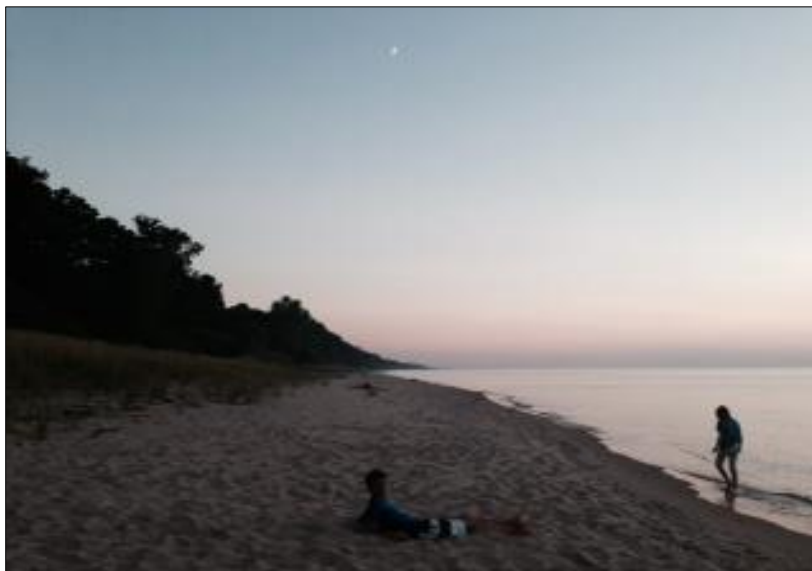
Information on the state of Lake Superior is organized under the nine General Objectives of the Great Lakes Water Quality Agreement. Information is also provided on threats to Lake Superior's habitats, species and water quality.

Unless otherwise noted, the source of the information is the [State of the Great Lakes 2011 Technical Indicator Report](#) by Environment Canada¹ and USEPA (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* and *Mysis*); there are self-sustaining populations of Lake Trout and increasing abundance of 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., 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; chemical substances of emerging concern, such as microplastics; and balancing resource development with environmental protection.



Relaxing on the beach at sunset. Credit: L. LaPlante.

¹ References authored by Environment Canada prior to the agency's name change in 2015 continue to use the former name for consistency with the references listed in Section 10.

4.1 State of Lake Superior in Relation to GLWQA General Objectives

State of Lake Superior in relation to GLWQA General Objectives

The GLWQA contains [nine General Objectives](#) for the waters of the Great Lakes.

(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, nearly 100% of drinking water tests meet 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 limit exposure to 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;*

Concentrations of most contaminants are lower in Lake Superior waters than in the other Great Lakes. However, there are exceptions, including a few chemicals found at 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 lakewide 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. However, localized, low toxicity harmful algal blooms 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 found in 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 drinking water tests meet 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.

Drinking Water

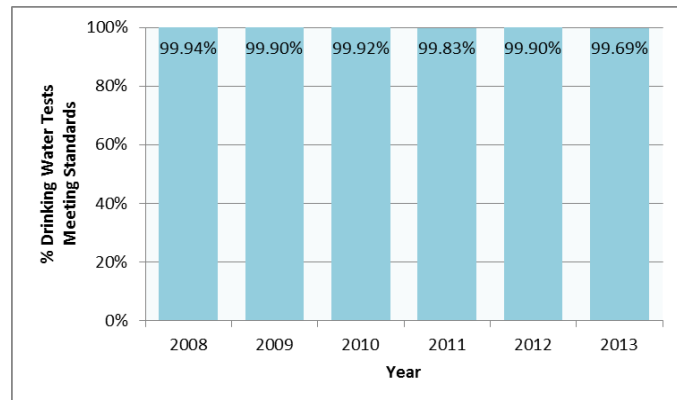


Figure 2. Percentage of Lake Superior drinking water tests meeting standards from Ontario municipal residential drinking water systems using Lake Superior water. Source: Data from Chief Drinking Water Inspector Annual Reports.

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 95% of the time in the U.S. and over 88% of the time in Canada. Note that the U.S. and Canada use different criteria for determining when a beach is considered safe for swimming (i.e., less than 235 or 300 *E.coli* colony-forming units per 100 mL in the U.S. versus less than 100 *E.coli* colony-forming units per 100 mL in Canada). Increased beach monitoring and assessment is helping

Swimming

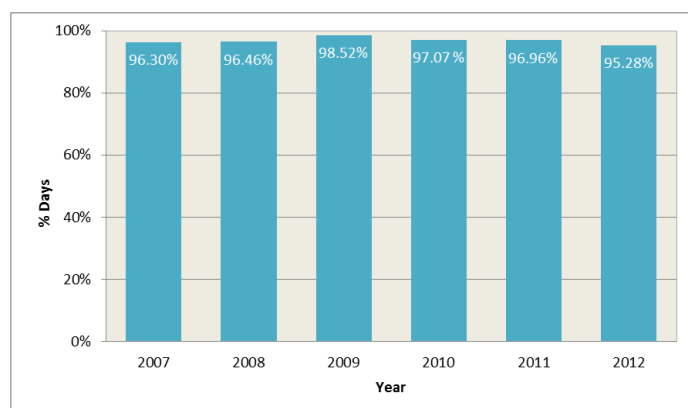


Figure 3. Percentage of days U.S. Lake Superior beaches are open and considered safe for swimming. Source: U.S. States reporting to USEPA's Beach Advisory and Closing On-Line Notification System.

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' capability. 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.

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 states, tribes and the Province of Ontario in efforts to avoid impacts of harmful pollutants found in some fish in some areas. Developing fetuses and young children are affected by contaminants at lower levels than the general population. Therefore, it is especially important that women of child-bearing age and young children follow fish consumption recommendations (Guide to Eating Ontario Fish, 2015). Overall, there are fewer Lake Superior fish consumption advisories as compared to the other Great Lakes.

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

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 MOECC, 2015).

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 communities consume more local fish, on average, 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 recommends restrictions on 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. Levels 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

Concentrations of most contaminants are the lowest in Lake Superior water, 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.



Brook trout. Credit: H. Quinlan, U.S. Fish and Wildlife Service.

Contaminants in Whole Fish

Organochlorine pesticides and total PCBs contribute equally and together make up approximately two-thirds of the chemical body burden of Lake Trout (the total amount of chemicals in the body of an organism) in Lake Superior (McGoldrick and Murphy, 2015). 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 0.1 ppm. Toxaphene is the most abundant organochlorine pesticide measured in Lake Superior, unlike the other Great Lakes. Total mercury concentrations in Lake Superior Lake Trout appear to have increased slightly since 1987 but remain below the 1987 GLWQA criteria of 0.5 ppm. Some of the remaining chemicals reported in fish from Lake Superior are PBDEs, PFCs, other flame retardants, and siloxanes.

Contaminant Trends in Lake Trout

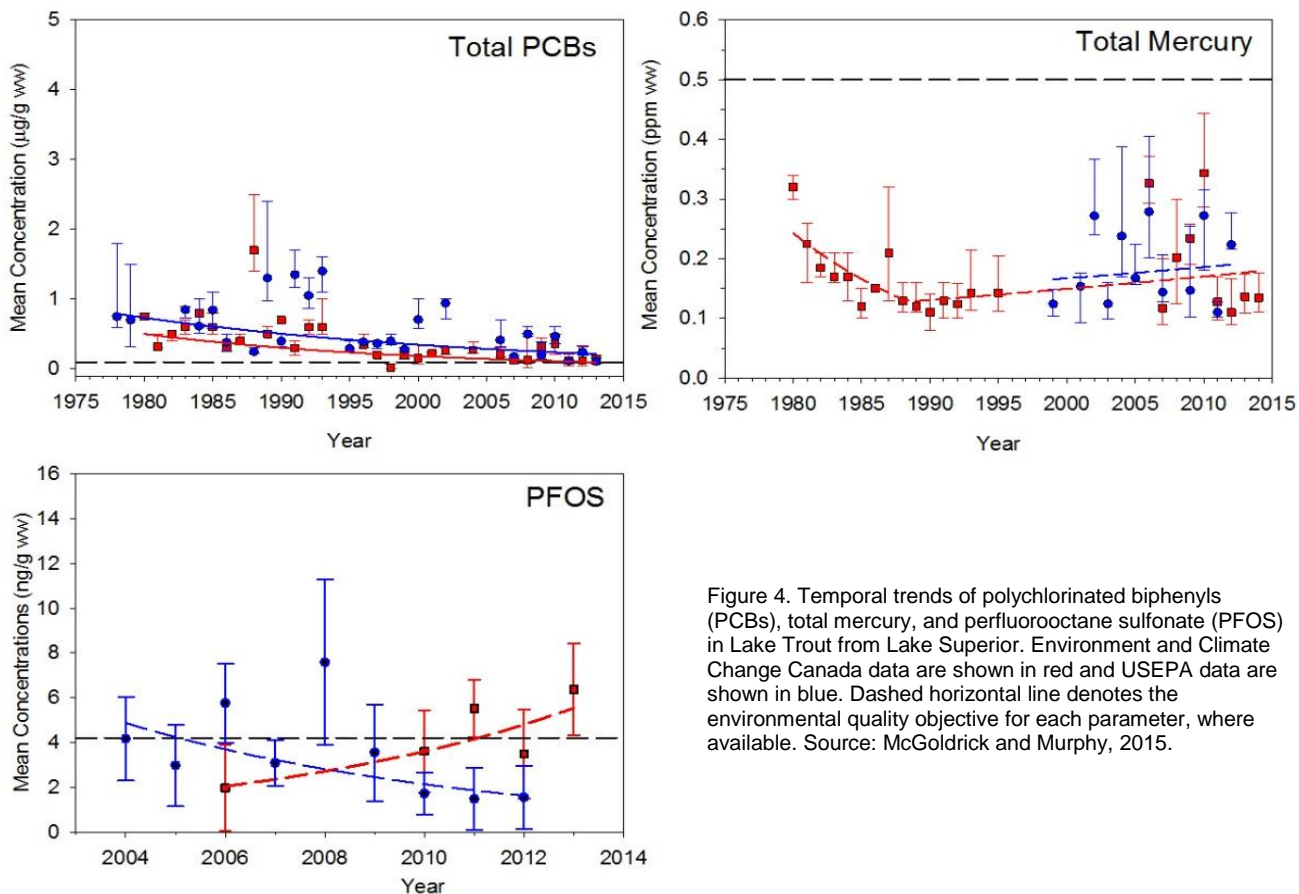


Figure 4. Temporal trends of polychlorinated biphenyls (PCBs), total mercury, and perfluorooctane sulfonate (PFOS) in Lake Trout from Lake Superior. Environment and Climate Change Canada data are shown in red and USEPA data are shown in blue. Dashed horizontal line denotes the environmental quality objective for each parameter, where available. Source: McGoldrick and Murphy, 2015.

Chemicals in Great Lakes Fish

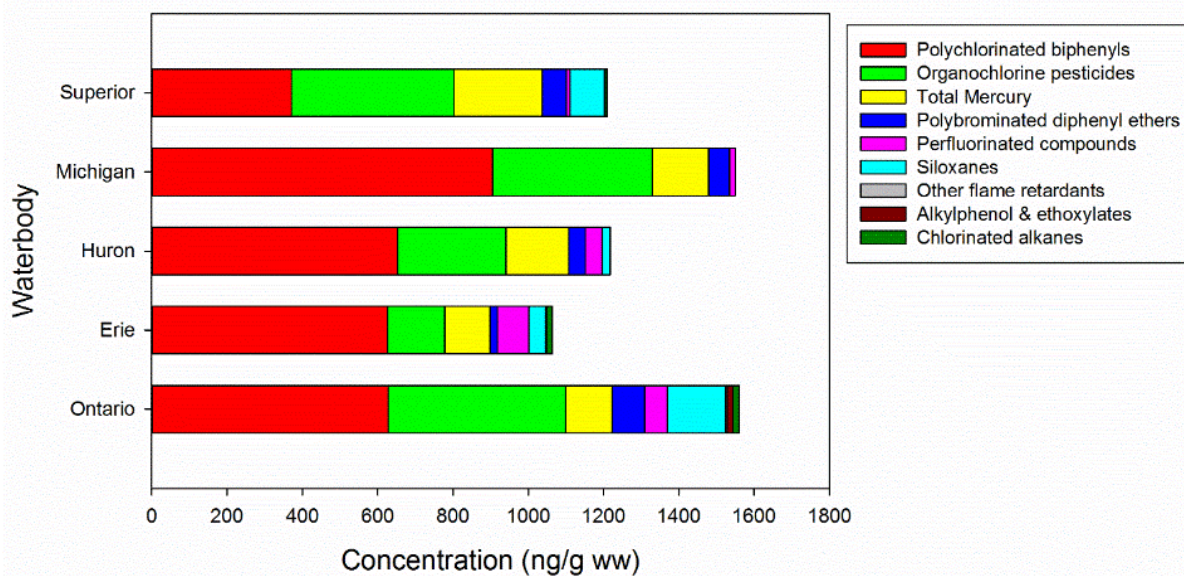


Figure 5. Contribution to Body Burden of Monitored Chemicals in Great Lakes Whole Fish (Lake Trout and Walleye in Lake Erie). Source: Environment and Climate Change Canada and USEPA.

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 Herring 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 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 in the Great Lakes 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-USEPA, 2013). Trends in Lake Superior are varied. For example, the concentration of hexachlorobenzene (HCB) is unchanging, and the concentration of dieldrin is declining.

Contaminants in Herring Gulls

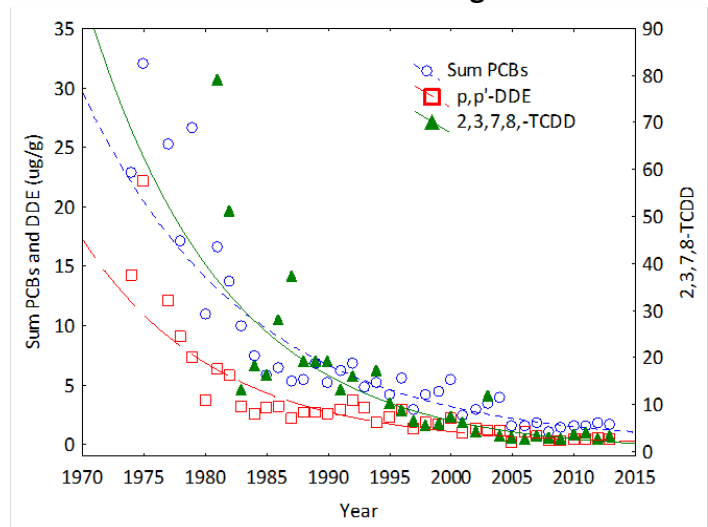


Figure 6. Changes in concentrations of sum PCBs, *p,p'*-DDE, and 2,3,7,8-TCDD (ug/g, wet weight) in Great Lakes Herring Gull eggs at Agawa Rocks, from year of first measurement to 2013. Source: deSolla et al., *in press*.

Contaminants in Offshore Waters

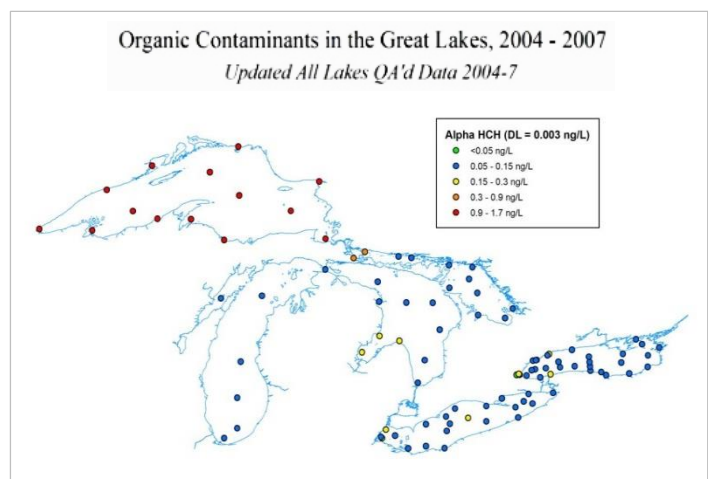


Figure 7. Spatial distribution of dissolved alpha-hexachlorocyclohexane (HCH) in Great Lakes surface waters, 2004-2007. Source: Environment and Climate Change Canada's Great Lakes Surveillance Program.

Contaminants in Air

Atmospheric PCB concentrations are decreasing relatively slowly across the Great Lakes basin. As measured by the Integrated Atmospheric Deposition Network (IADN), concentrations of PCBs are halving about every 13 years in air collected at Eagle Harbor, Michigan (Salamova et al., 2015). This declining trend is consistent with the trends seen at other IADN sites suggesting a relatively homogeneous decrease across the Great Lakes region (even with concentrations much higher at the more urbanized IADN monitoring stations).

Atmospheric concentrations of organochlorine pesticides that have been banned are also generally declining. Chlordanes and DDT-related substances have halving times of about 10 years in air collected at Eagle Harbor (Salamova et al. 2015). Concentrations of α -HCH and γ -HCH are decreasing rapidly in air, with halving times of about 4 years at all U.S. sites (Salamova et al., 2015). These are the most rapid halving times observed for any compound measured as part of IADN. The insecticides, α -endosulfan and B-endosulfan, are still on the market, but they are slated for complete elimination in 2016. Even though endosulfan is currently in use, vapor phase atmospheric concentrations around the Great Lakes are decreasing with halving times ranging from 7 to 13 years (Salamova et al., 2015).

IADN data for total polycyclic aromatic hydrocarbons (PAH) concentrations at Eagle Harbor also show some significant decreases over time, with a halving time of about 17 years. Concentrations of PAHs at Eagle Harbor are about 10 times lower than at the more urbanized IADN monitoring stations.

However, the concentrations are decreasing more rapidly at urban stations (Salamova et al., 2015).

Concentrations of PBDEs were decreasing at the urban sites at Chicago and Cleveland, but were generally unchanging at the remote sites, Sleeping Bear Dunes and Eagle Harbor.

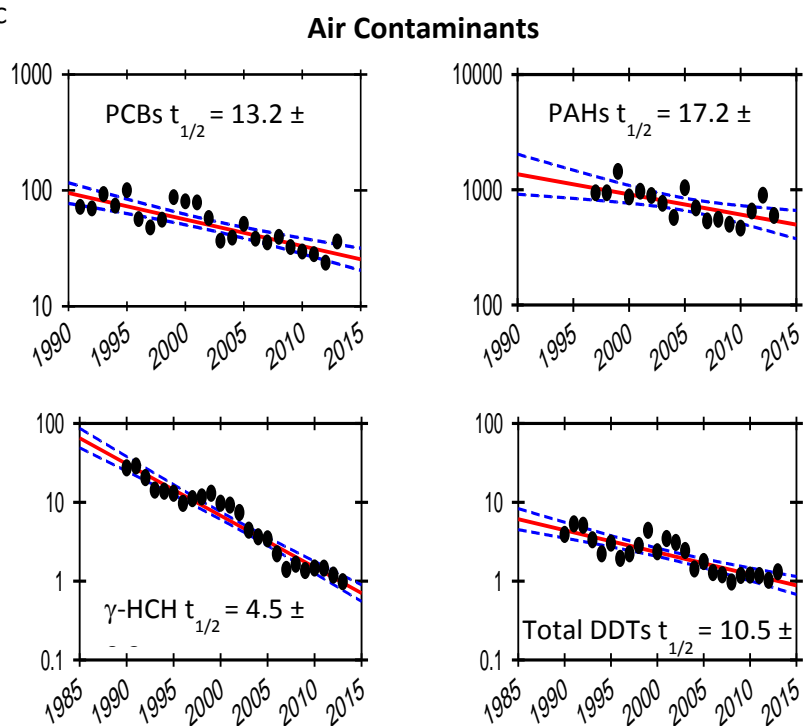


Figure 8. Concentrations of Selected Contaminants at Eagle Harbor, Michigan. Source: Integrated Atmospheric Deposition Network, at Indiana University.

Contaminants in Sediment

Sediment contaminant levels in the offshore waters consistently meet aquatic life protection guidelines. 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 is being observed, due in part to natural sources of mercury from within the watershed and mercury sources associated with past or present mining and smelting activities around Lake Superior (Environment Canada and USEPA, 2013).

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. On the Keweenaw Peninsula, contaminated sediments or “stamp sands” are remnants of previous mining activity that continue to adversely impact the lake.

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. A few Areas of Concern (AOCs) are affected by contaminated sediment, as can be found in the discussion on the status of AOCs in Section 4.2.

Contaminants in Sediment

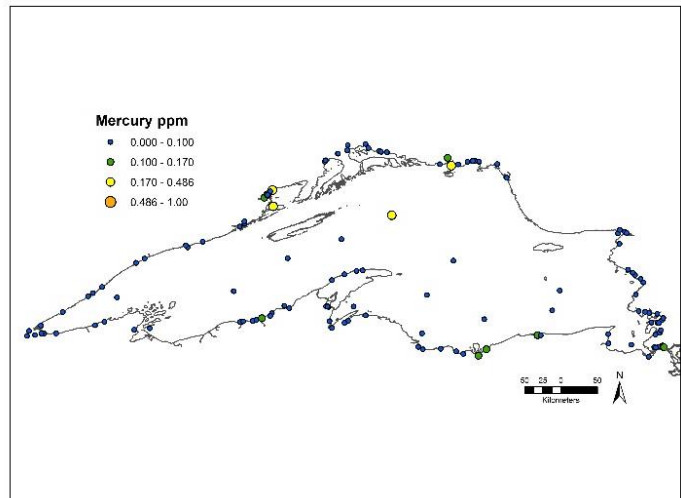
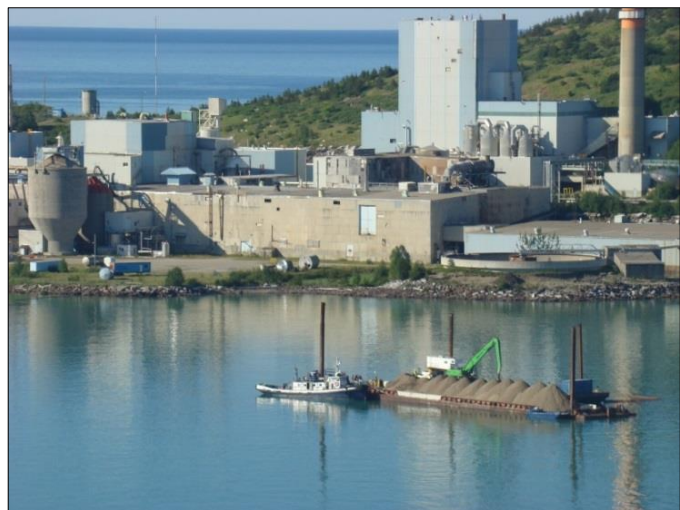


Figure 9. Spatial distribution of mercury contamination in Lake Superior's surface sediments. Sources: Environment and Climate Change Canada and USEPA.



Peninsula Harbour, Ontario. Credit: Ontario MOECC.

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 (103 mi²) 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 available. The "good" assessment is driven by the small total amounts of artificial shorelines and structures, low numbers of 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 (Treibitz et al., 2011).

Water Levels

One of the longest droughts in the Lake Superior basin started in the late 1990s and lasted into the 2000s due to a 25% drop in annual precipitation and an increase in air temperatures of about 1°C (1.8°F). The low water levels included a two-month period of record low levels in 2007. Stream flow was reduced by as much as 30% in some watersheds. These changes in water levels and stream flow affected 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, with water levels for the coming years remaining uncertain. Great Lakes water levels are primarily influenced by precipitation, evaporation, and runoff, with increased evaporation playing a larger role than changes in precipitation (Gronewold and Stow, 2014).

Water Levels

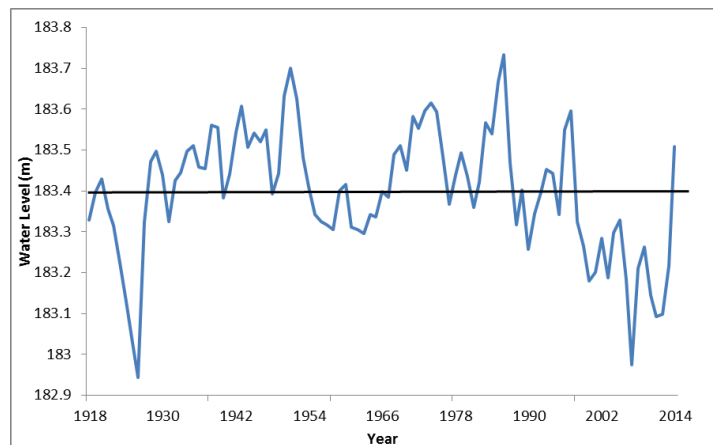


Figure 10. Annual average Lake Superior water levels 1918-2014. Long-term mean is represented by the straight black line. Source: U.S. Army Corps of Engineers, Detroit District, Great Lakes Hydraulics and Hydrology.

Land Use/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 near river mouths and surrounding areas. Forest cover in the Lake Superior basin continues to increase, although the composition of species is changing. Pines and maples are increasing, while species like Birch and Aspen are on the decline.

As shown in Figure 12 below, the Chequamegon Bay area in Wisconsin provides an example of development in coastal areas that can impact wetlands and other habitats. A wide diversity of wetland and forested land cover types exists in the Chequamegon Bay area, with increasing urban development around Ashland, Wisconsin.

Land Use/Land Cover

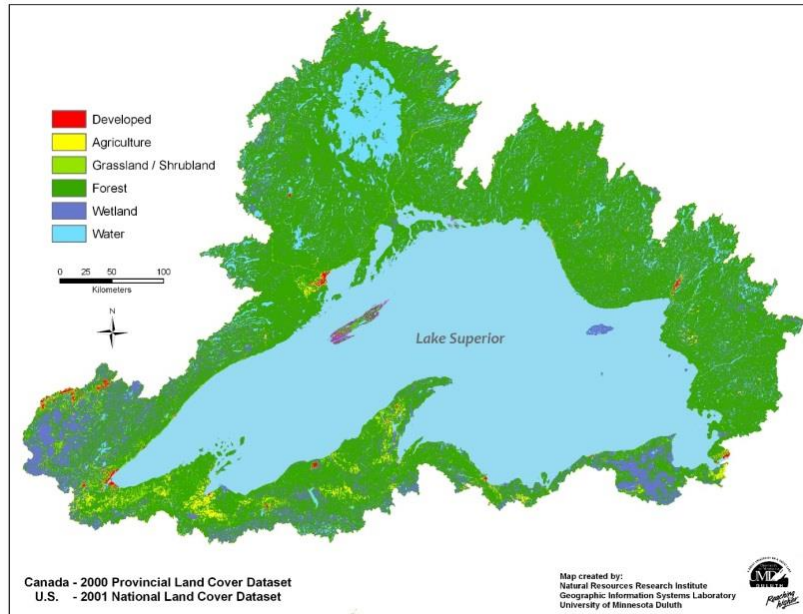


Figure 11. Distribution of land use/land cover across the Lake Superior basin in 2000 (Canada) and 2001 (U.S.) color-coded according to six land use classes. Source: Ciborowski et al., 2011.

Land Use/Land Cover around Chequamegon Bay, Wisconsin

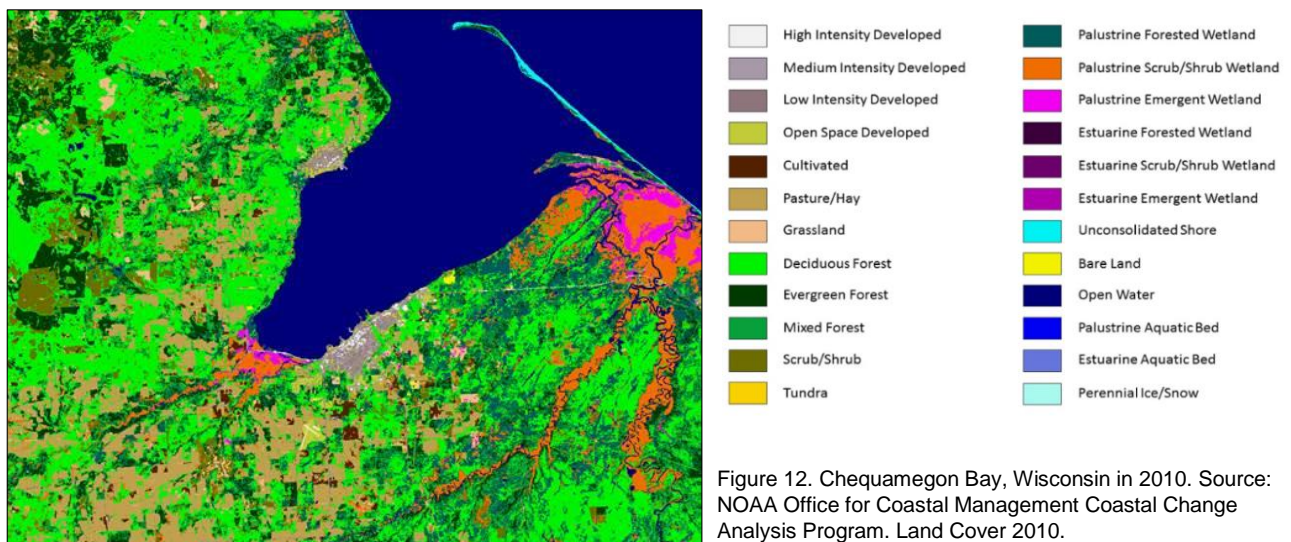


Figure 12. Chequamegon Bay, Wisconsin in 2010. Source: NOAA Office for Coastal Management Coastal Change Analysis Program. Land Cover 2010.

Species of the Lower Food Web

The animal portion of the lower food web is made up of numerous invertebrate species. One of the largest and most widespread species is *Mysis*, a small, shrimp-like animal that is eaten by most fish in Lake Superior. *Mysis* populations are considered to be in “good and stable” condition. Recent data suggest that populations are relatively unchanged over the past several decades. The zooplankton community, dominated by large calanoid copepods, is also considered to be in “good and stable” condition. Zooplankton are the primary prey of offshore *Coregonus* species, which include Bloater, Cisco, Kiyi, and Shortjaw Cisco. The benthic (or bottom-dwelling) invertebrate community is made up of another shrimp-like species, *Diporeia*, as well as many species of aquatic insects, worms, clams, and other species. The diversity and abundance of this community is “good and unchanging” as well. Like *Mysis*, *Diporeia* is consumed by most Lake Superior fish at some point in their lives. The lower food web components play an important role in recycling organic matter and are the energy link between primary producers, algae, and fish. As a whole, this part of the food web is considered to be in “good” condition.



Mysis diluviana. Credit: USGS.

Preyfish

Preyfish are the intermediate player between the lower food web and predacious fish, principally Lake Trout, at the top of the food chain. The preyfish community is made up of benthic invertebrate and zooplankton-eating fish. Benthic-eating fish are dominated by native species such as Lake Whitefish. Plankton-eating fish include native *Coregonus* species such as Cisco, Kiyi, and Shortjaw Cisco. The overall biomass of Lake Superior preyfish is dominated by and reflects population trends of the many native *Coregonus* species, with Cisco being the most dominant. In recent years, recruitment of Cisco has been low, which affects the overall preyfish biomass. In general, Lake Superior’s preyfish community is considered healthy due to the high number of native species, 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).

Number of Fish Species Collected in Bottom Trawl Surveys

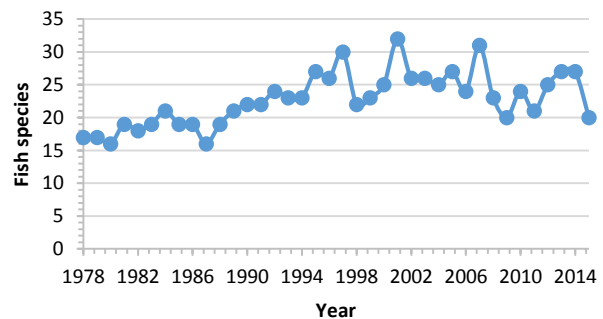


Figure 13. Number of fish species collected in annual lakewide nearshore bottom trawl surveys from 1978-2015. Source: U.S. Geological Survey - Great Lakes Science Center.

Preyfish Biomass

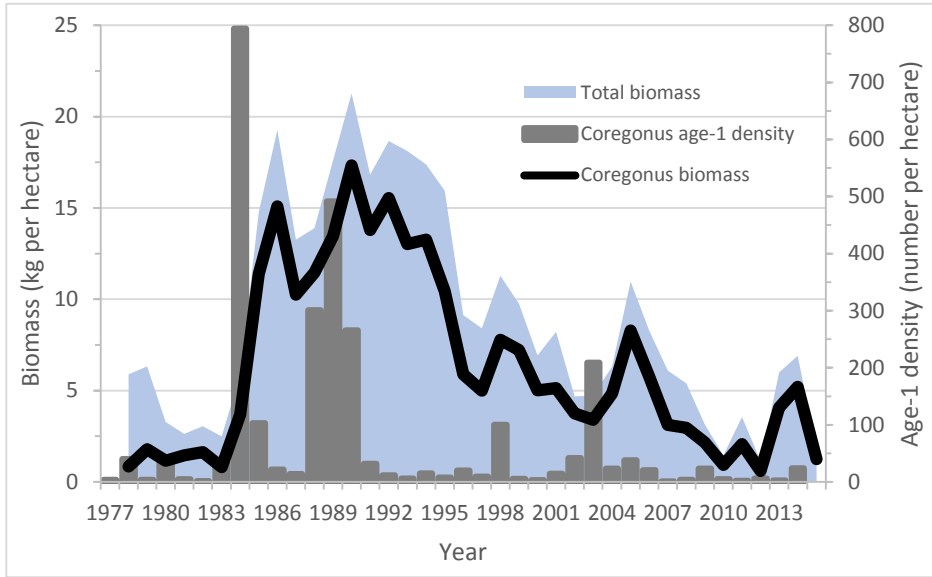


Figure 14. Mean annual total preyfish community and *Coregonus* species biomass (kg/ha) and *Coregonus* species recruitment trends (number of age-1 fish/ha) based on lakewide bottom trawl surveys from 1978-2015. *Coregonus* species include Bloater, Cisco, Kiyi, Lake Whitefish, and Shortjaw Cisco. Source: U.S. 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, such as western Wisconsin waters. Lake Trout populations are genetically diverse, with four different forms of Lake Trout (lean, siscowet, humper, and redfin).

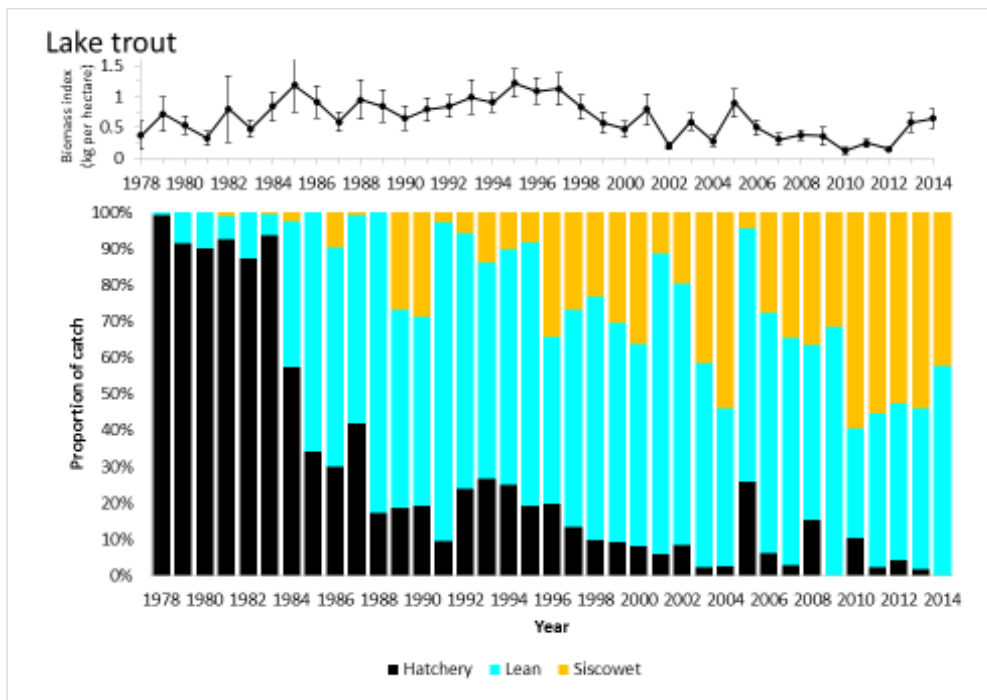


Figure 15. Lake Trout population trends, 1978-2014. Source: U.S. Geological Survey

Lake Sturgeon

Lake Sturgeon in the Great Lakes-Upper St Lawrence River and Northwestern Ontario are 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 fewer than 30,000 adults, a small fraction of the estimated historical abundance of approximately 870,000.

Lake Sturgeon

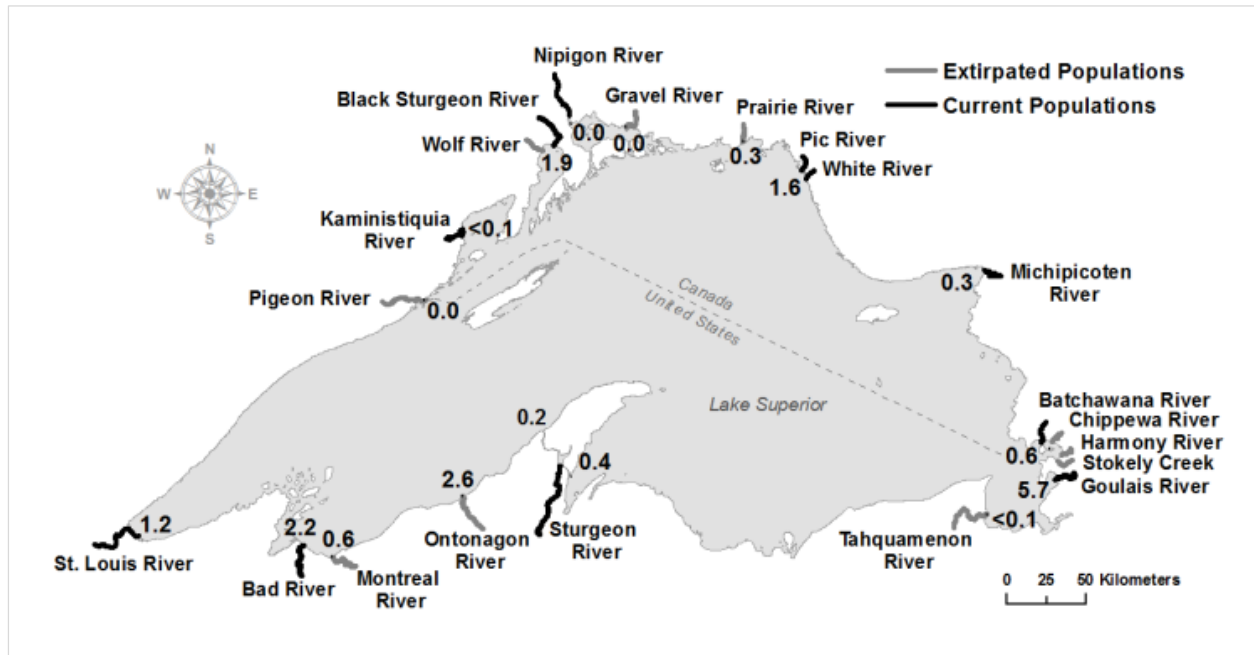


Figure 16. Catch-per-unit-effort (a relative measure of abundance) of Lake Sturgeon in inshore waters and embayments surveyed in 2011. Numbers represent the relative number of Lake Sturgeon present, meaning a river numbered 2.0 has about two times more Lake Sturgeon than a river numbered 1.0. Surveys 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, efforts to restore the population to historic levels have 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 2000s. The increase in Cormorant nests is consistent with trends throughout the Great Lakes.

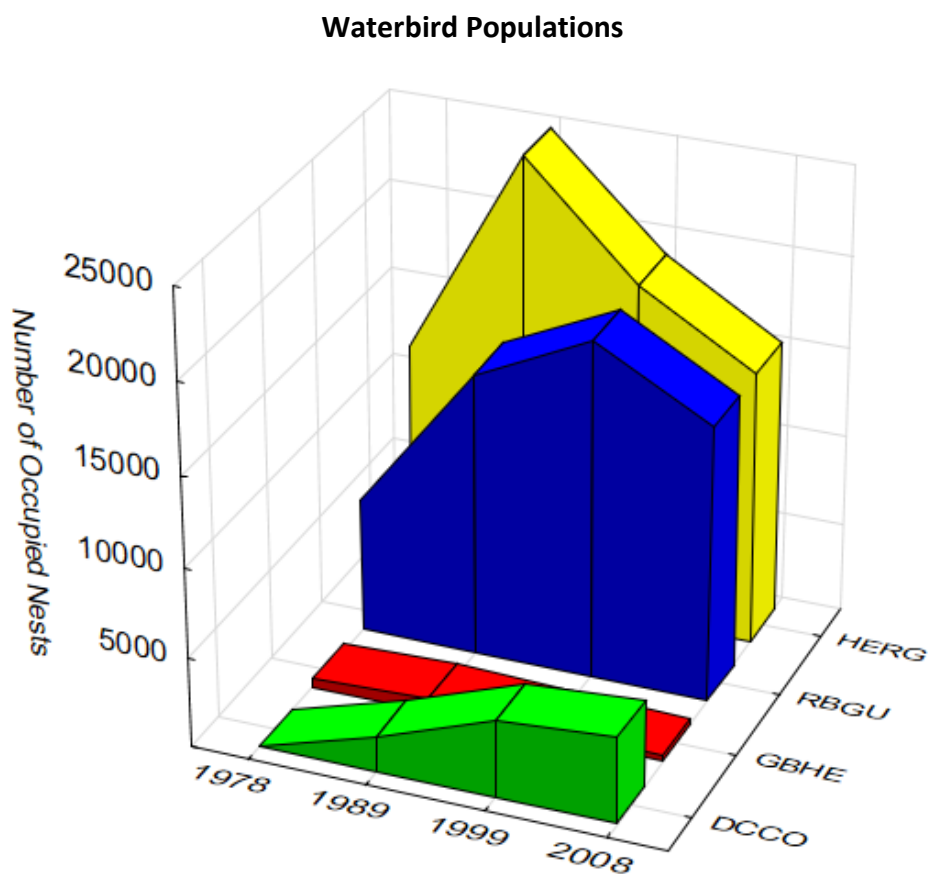


Figure 17. Number of occupied nests of four species of colonial waterbirds from Lake Superior, based upon decadal surveys from 1978 to 2008. HERG (Herring Gull); RBGU (Ring-Billed Gull); GBHE (Great Blue Heron); DCCO (Double-Crested Cormorant). Sources: Canadian Wildlife Service, Environment and Climate Change Canada, and U.S. Fish and Wildlife Service.

Be Free from Nutrients That Directly or Indirectly Enter 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 water phosphorus targets are consistently being met in Lake Superior. Unlike the lower Great Lakes such as Lake Erie, Lake Superior did not experience significant eutrophication due to anthropogenic nutrient releases. Lake Superior has very low natural levels of phosphorus.

Environment and Climate Change Canada has recently documented a statistically significant, long-term decline in total phosphorus in Lake Superior, using data from 1970 to 2013 (Dove and Chapra, 2015). The

concentrations of phosphorus and its rate of the decline are lower in Lake Superior than those changes noted in the other Great Lakes. The future record will bear careful scrutiny to determine if the trend is continuing. Monitoring and research scientists are working collaboratively to investigate the causes of the declines.

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 locations where elevated levels of algae have been observed include the connecting channels across the Keweenaw Peninsula (Michigan) and Lake Superior Provincial Park (Ontario).

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.

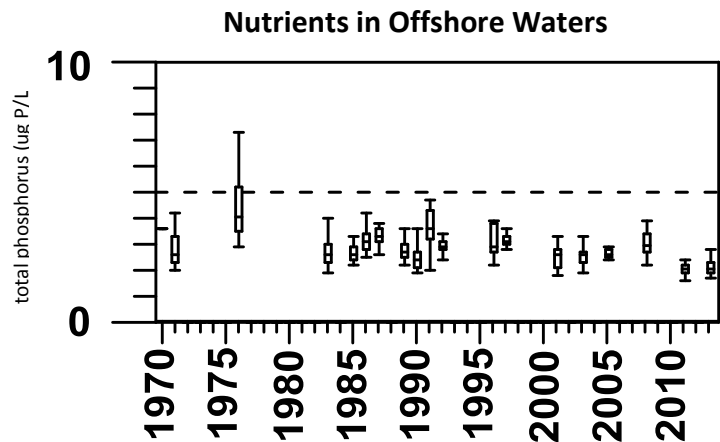


Figure 18. Long-term trend of total phosphorus (ug P/L) in Lake Superior. Dashed horizontal line denotes the environmental quality objective. Source: Dove and Chapra, 2015.

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 present a significant threat to the Lake Superior ecosystem.

Lake Superior has 98 known non-native fishes, plants, invertebrates, and diseases (Minnesota Sea Grant, 2015). The newest non-native species, Banded Mystery Snail, was collected in 2014 in Waiska Bay, Michigan (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." On the other hand, impacts of many non-native species are often unknown until they cause very noticeable effects.

Some non-native species are known to be invasive, i.e., their introduction or spread threatens the environment, the economy, or society (including human health). By far, the most harmful aquatic invasive species currently established in Lake Superior, in terms of economic, societal and/or environmental cost, is the Sea Lamprey. This species has been the focus of control efforts for over 50 years at a cost of hundreds of millions of dollars. Aquatic invasive species with wide distribution and/or economic, societal, and/or environmental costs are listed in Table 4 on the following page.



Higgins eye mussel with zebra mussels. Credit: H. Quinlan, U.S. Fish and Wildlife Service.

Table 4. Most Harmful¹ Aquatic Invasive Species Established in Lake Superior

| Species | Native Range | Pathway² | Economic/Societal/Environmental Impact |
|------------------------------------|----------------------|----------------------------|--|
| Sea Lamprey | North Atlantic | Canals and Diversions | Kill valuable sport and commercial fish species; destabilize food web and fish community |
| Rainbow Smelt | North Atlantic | Agency Activities | Prey on young fish reducing productivity of commercial fish species |
| Eurasian Ruffe | Europe and Asia | Maritime Commerce | Resulted in prohibition of bait harvest from Lake Superior; Nuisance for anglers; Competes for food with native fish |
| Common Carp | Europe | Multiple Pathways | Damage and uproot emergent aquatic vegetation such as wild rice |
| Viral Hemorrhagic Septicemia (VHS) | Northern Hemisphere | Multiple Pathways | Potential for large fish kills |
| Bacterial Kidney Disease | Northern Hemisphere | Agency Activities | Impact use of wild brood stock for rehabilitation stocking programs and hatchery production |
| Spiny Waterflea | Ponto-Caspian region | Maritime Commerce | Impacts recreational fishing by fouling fishing line; Causes declines in food resources for fish |
| Zebra Mussels | Ponto-Caspian region | Maritime Commerce | Establish on substrate, infrastructure and shipwrecks |
| Eurasian Watermilfoil | Europe and Asia | Multiple Pathways | Form mats that impede water recreation; Cause declines in shoreland property values. |

Source: U.S. Fish and Wildlife Service and Minnesota Sea Grant, Personal communication.

¹ Harmful invasive species are considered those non-native species whose introduction or spread threatens the environment, the economy, or society (including human health).

² Pathways (vectors) identified in Lake Superior Aquatic Invasive Species Complete Prevention Plan (LSBP, 2014).

A total of 186 non-native species have already been established in the Great Lakes basin. An additional 53 more species have been identified as having a moderate-to-high probability of introduction AND establishment in the Great Lakes basin (GLANSIS, NOAA).

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 including contaminated industrial sites, hazardous waste sites, spills, underground storage tanks, unlined landfills, abandoned mine sites, septic systems and sewer lines exist in the basin (Grannemann and Van Stempvoort, 2015).

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 environments would be most affected in these areas.

Some contaminants, such as perfluorooctane sulfonate (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 greatest threats to Lake Superior's habitats and species are aquatic invasive species, climate change, and dams and barriers. Atmospheric deposition is a source of many contaminants into Lake Superior. Information on these and other threats that may negatively affect 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. For purposes of this section, the term “invasive species” refers to those non-native species that are causing harm to the ecosystem, not non-native species intentionally introduced by one or more government agencies. Once



The invasive European 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, U.S. Fish and Wildlife Service.

established, invasive species are extremely difficult to eradicate, and their impacts may be impossible to reverse. The introduction of a non-native species in Lake Superior may have a greater effect on the ecosystem than in other lakes, due to Lake Superior’s relatively simple food web. In fact, while Lake Superior has a lower number of non-native fish species established than other Great Lakes, it has the highest ratio of non-native to native fish species. 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 (through human health effects).

Ninety-three percent of introductions of non-native species were unintentional while 7% were intentional. Of the nine known pathways for entering Lake Superior, 48% of non-native species were introduced by ballast water discharge, 17% by diseases and parasites with introduced fish, 6% through stocked fish, 6% through canals and diversions, 5% by cultivation, 4% by aquarium releases, 4% through live bait release, 3% by recreational boaters, and 1% by packaging “hitchhikers” (Minnesota Sea Grant, 2015). As one end of the Great Lakes – St. Lawrence Seaway, the Duluth-Superior harbor is considered an invasion “hot spot” due to the potential for ships introducing invasive species through ballast water discharge.

As 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 invasive species have been identified in Lake Superior: the deadly infectious fish disease viral hemorrhagic septicemia (or VHS) discovered in 2010, and the Banded Mystery Snail in 2014. 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 marking rate on Lake Trout in Lake Superior has been declining and is below the target for the first time since 1994. Sea Lamprey marking rates have declined in the past 10 years, while Lake Trout abundance has remained stable.

Sea Lamprey Marks on Lake Trout

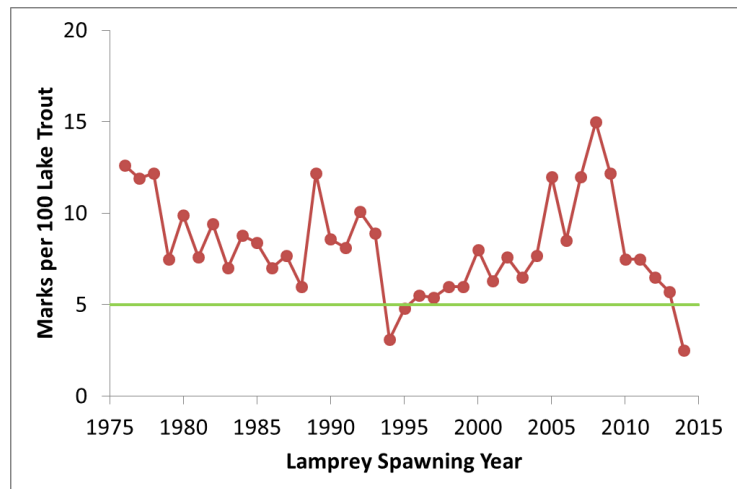
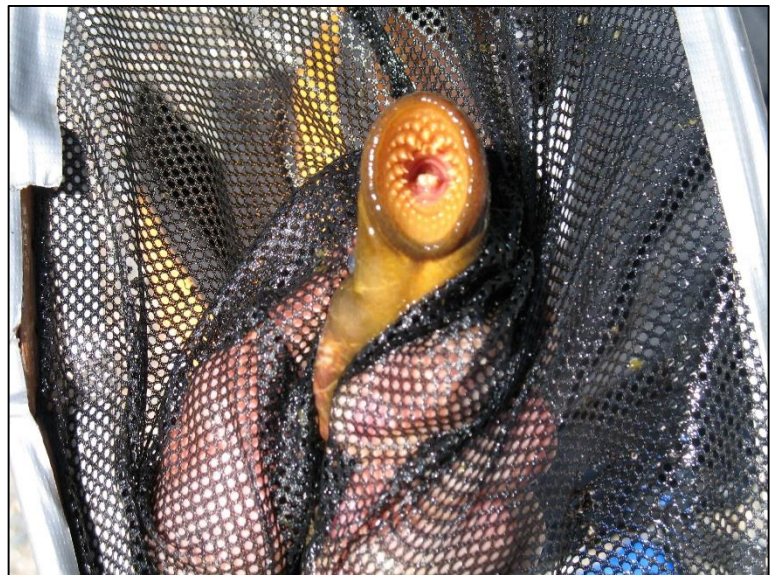


Figure 19. Yearly lakewide Sea Lamprey marking rates on Lake Trout greater than 21" (532 mm) captured in April-May assessments. The green horizontal line represents the marking rate target for Lake Superior, which is 5 marks per 100 Lake Trout. Source: Great Lakes Fishery Commission.



The mouth of a Sea Lamprey. Credit: Ontario Ministry of Natural Resources and Forestry.

Climate Change

Climate change is expected to alter the physical, chemical, and biological aspects of Lake Superior, as summarized in the *Lake Superior Climate Change Impacts and Adaptation* report (Huff and Thomas, 2014), include:

- 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 (Huff and Thomas, 2014).

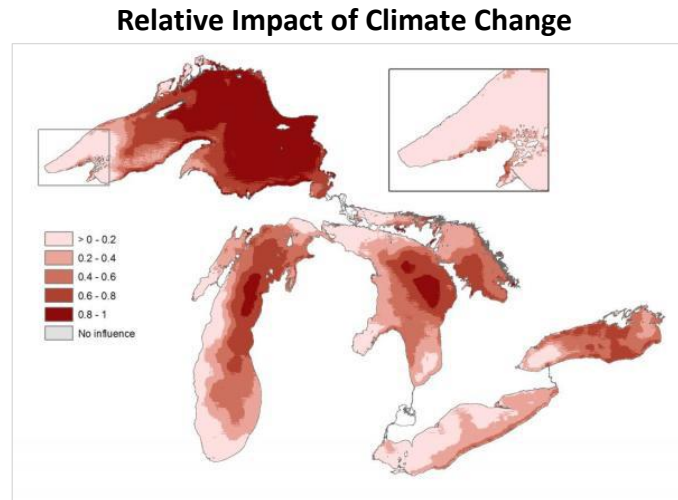


Figure 20. Weighting of the relative impact of climate change on the waters of the Great Lakes. Source: Allan et al., 2013.

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).

Changes in the Lake Superior climate could have the following effects on the Lake Superior ecosystem (Huff and Thomas, 2014):

- 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 ecosystem conditions unfavorable to cold-water fish communities that require cold-water rivers and streams;
- Northward shifting 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 arctic-alpine 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 European Common Reed (i.e., *Phragmites*); and
- Diminishing coastal wetlands, negatively affecting fish and wildlife populations.

Lake Superior Water Temperatures

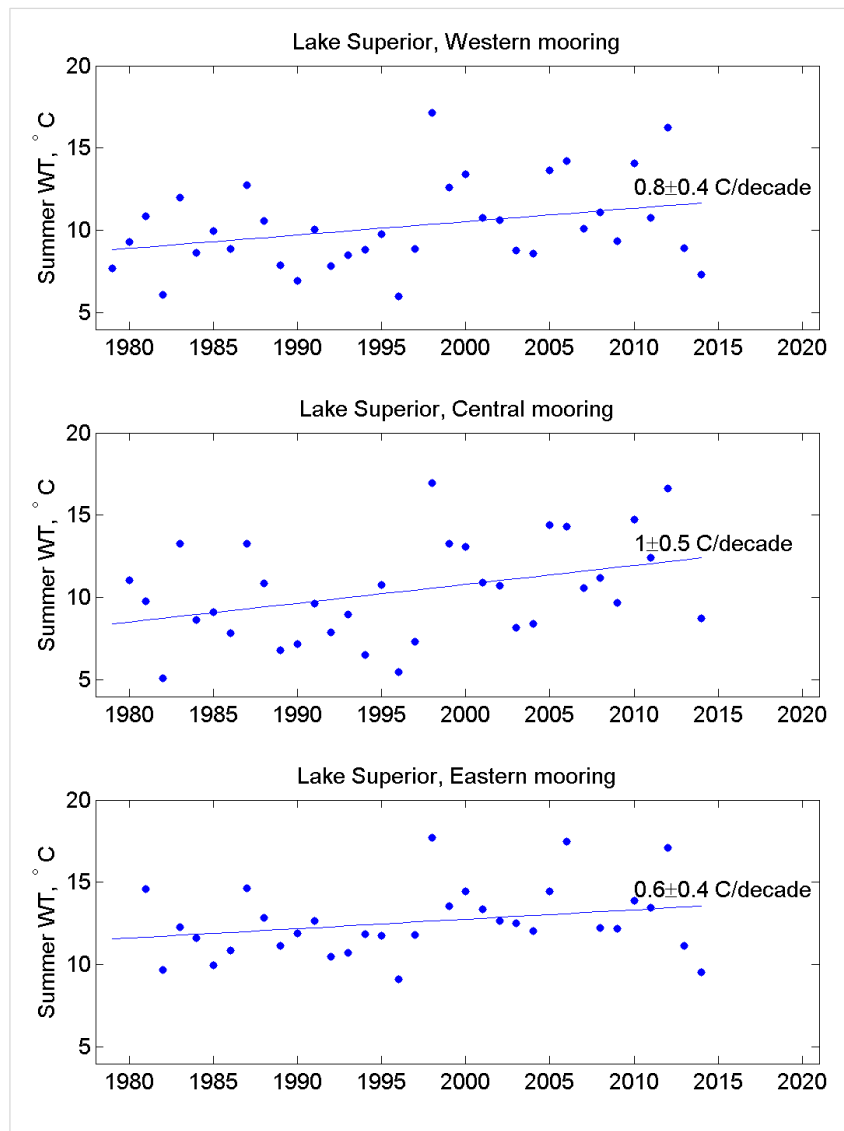


Figure 21. Lake Superior summer water temperatures, 1978-2014, collected from NOAA buoys in the western, central, and eastern basins. Source: J. Austin, UMN.

Dams and Barriers

Over 23,600 dams and other potential barriers, such as weirs 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 the 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 additional spawning areas.



A culvert barrier. Credit: M. Fedora, U.S. Forest Service.

Older dams have a greater impact because newer dams were constructed with newer regulations and stronger environmental assessments. Protecting and restoring connectivity, where appropriate, requires removing dams, upgrading stream/road crossing infrastructure, or implementing other solutions, and prioritizing barrier removal considering the benefits and costs of various options.

Dams and Barriers

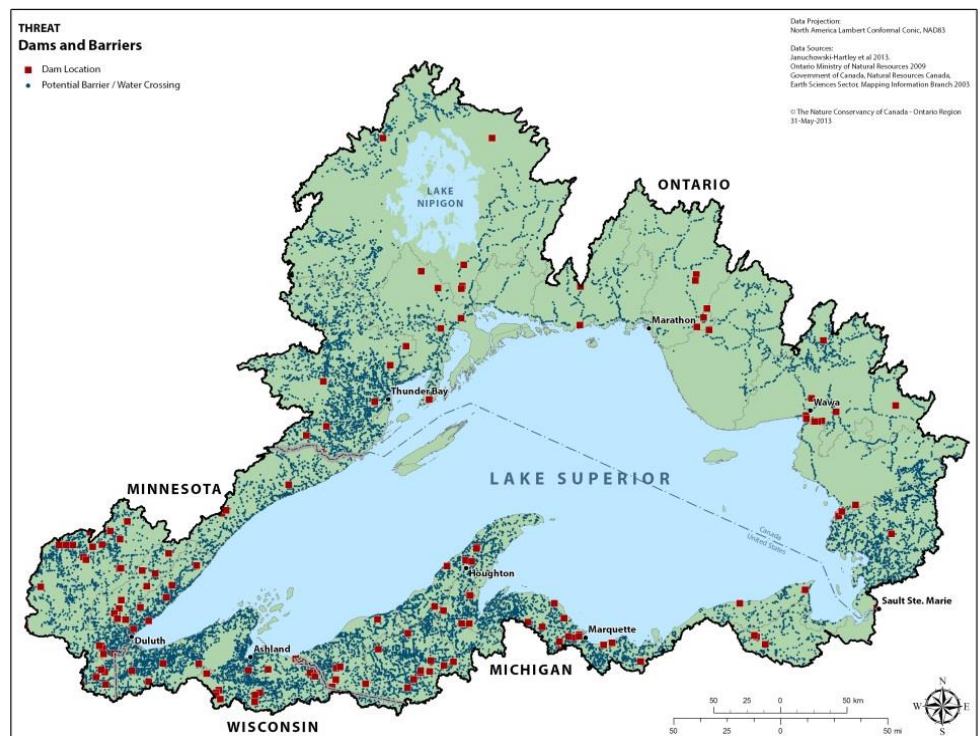


Figure 22. Dams and road stream crossings in the Lake Superior basin. Source: The Nature Conservancy of Canada.

Chemical Contaminants

Special efforts have been made to eliminate Lake Superior basin sources of many legacy chemicals through the Lake Superior Zero Discharge Demonstration Program. Local, regional and national actions targeting the nine critical pollutants have resulted in the achievement of chemical reduction targets to date. 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.

In-Basin Sources of Legacy Chemicals

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

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

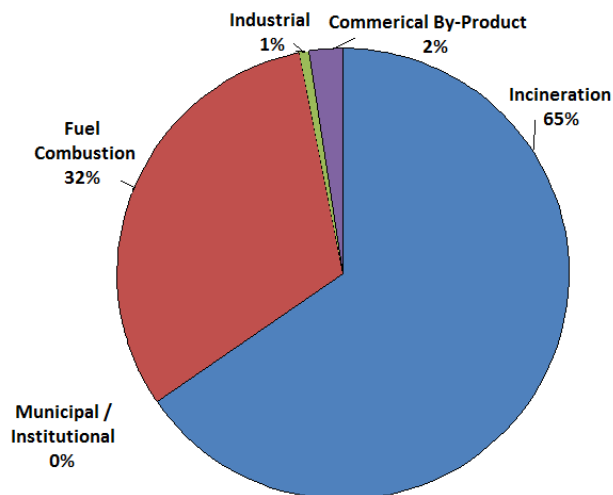


Figure 23. Percentage of dioxin releases from different sectors in the Lake Superior Basin, 2010. Source: LSBP, 2012.

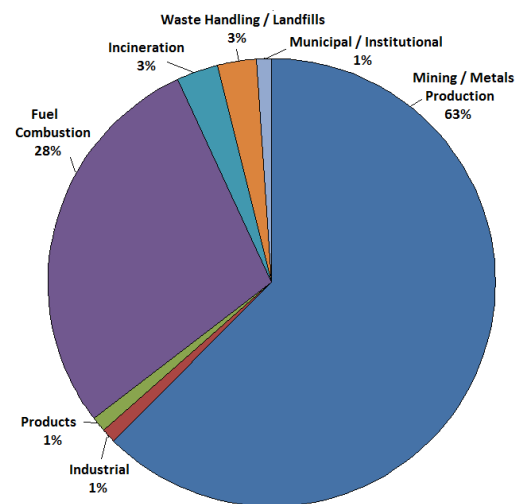


Figure 24. Percentage of mercury releases from different sectors in the Lake Superior Basin, 2010. Source: LSBP, 2012.

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 (or categories of chemicals) have been recommended for designation as Chemicals of Mutual Concern.

- 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); and
- Short-chain chlorinated paraffins.

Mercury

Mercury is a heavy metal that can enter the environment as a result of natural processes (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). A recent study found that atmospherically derived mercury is the dominant contributor of mercury to Lake Superior sediment, though watershed sources are significant near river mouths, such as the St. Louis River and Thunder Bay (Lepak et al., 2015).

Atmospheric Deposition

Lake Superior's large surface area and small human population relative to the other lakes contribute to the significance 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.

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). Since 2005, atmospheric mercury concentrations have decreased about 2% per year as measured in Canada's Experimental Lakes Area (west of Lake Superior). Wet deposition measurements from the North American Mercury Deposition Network follow these trends, with deposition decreasing about 1.6% per year since 1996 (Zhang et al., 2016).

PCBs

PCBs are a mixture of synthetic chemicals that do not occur naturally in the environment. They were used up through the 1970s 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 were banned in 1977 but are still being found in the environment.

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 Venier et al. (2014), the highest concentrations of total PCBs were measured in Lake Ontario (623 ± 113 pg/L) and the lowest were measured 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 Venier et al. (2014) in which water samples were collected in the spring of 2011 and 2012 at 18 stations throughout the Great Lakes, found that total PBDE concentrations were lowest in Lake Superior, with an average of 34 ± 11 pg/L.

A passive air and water sampling study in Lake Superior in 2011 showed that atmospheric (gaseous) and dissolved PBDEs, in particular BDE-47, were greatest near urban and populated sites (Ruge et al., 2015). Net gaseous deposition of BDE-47 was observed at coastal sites, while the central open lake and at Lake Superior's IADN station of Eagle Harbor generally displayed volatilization of PBDEs into the atmosphere, mainly of BDE-47.

IADN measurements show that Great Lakes concentrations of an alternative flame retardant, pentabromoethyl benzene, or PBEB, are highest at Eagle Harbor (Liu et al., 2016). While trends of PBEB in the air are decreasing at most other IADN sites, they are not at Eagle Harbor. It is unknown why Great Lakes concentrations of PBEB are highest at Eagle Harbor.

2-ethylhexyl-2,3,4,5-tetrabromobenzoate (TBB) and bis(2-ethylhexyl)-tetrabromophthalate (TBPH) are the two main components of FireMaster 550, which is a replacement for the penta-BDE commercial mixture. The atmospheric concentrations of TBB+TBPH are significantly and rapidly increasing at all IADN sites including Eagle Harbor, with doubling times of 2–5 years.

HBCD is another category of brominated flame retardants, and in the study by Venier 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 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 some Great Lakes fish 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 (Environment Canada, 2013). PFCs can accumulate in different ways, and trends vary in wildlife. Fish and birds, for example, represent two very different trophic levels with different food sources and ecosystems that influence their PFOS levels. 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 bioaccumulative in wildlife and humans, are persistent and transported globally in the environment, and are 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 to 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, conditioners, 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 repellents (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; Ontario 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 (Ontario MOECC, unpublished). In both studies, DEET was the most commonly detected chemical of emerging concern. While estimated concentrations were very low in the Canadian samples, some of the chemicals detected most frequently included codeine, atenolol, valsartan, DEET, sulfamethoxazole, carbamazepine, and naproxen (Ontario 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 abundance found in Lake Erie was over 450,000 particles per square kilometer.

Microplastics Distribution

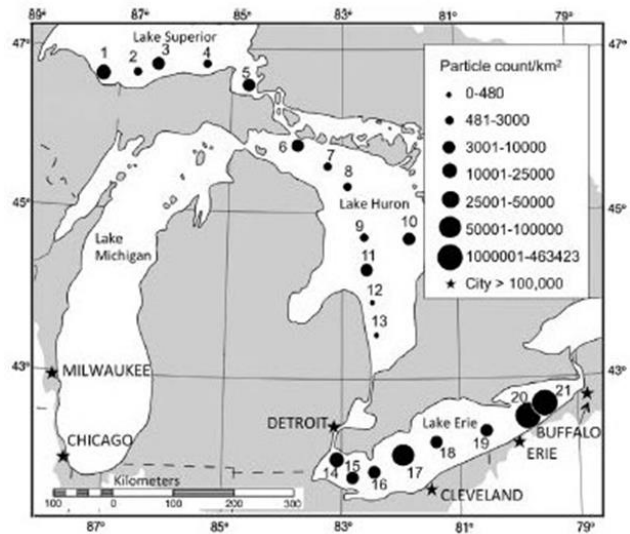


Figure 25. Distribution of plastic particles by count for 21 samples collected in three of the Great Lakes, 2012. Source: Eriksen et al., 2013.

Excessive nutrients (e.g., phosphorus) are a 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 agricultural 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

Nutrient Loadings

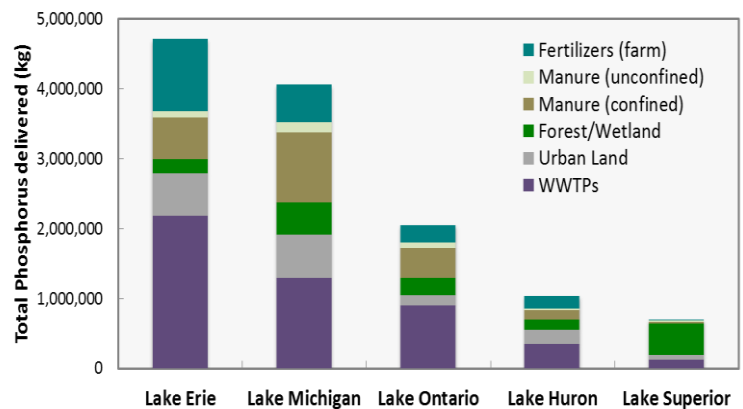


Figure 26. SPARROW model of total phosphorus delivered (kg) in the U.S. to each Great Lakes. Source: Robertson and Saad, 2011.

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.

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 particular threats 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.

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 the Lake Superior basin due to impacts from past mining operations. Fourteen mines

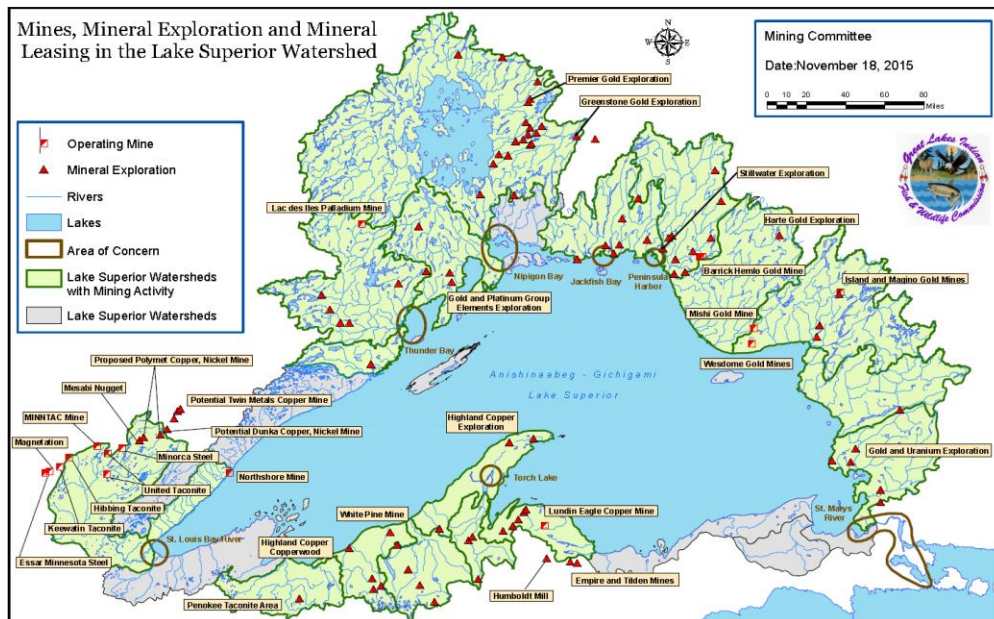


Figure 27. Mines, mineral exploration and mineral leasing in the Lake Superior watershed. Source: Great Lakes Indian Fish and Wildlife Commission, 2015.

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 from within the Lake Superior 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.

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 with 140,000 carloads estimated to 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 in the past.

Unknown threats

New, previously unidentified threats will be addressed as they are identified, using an adaptive management approach, and appropriate actions will be initiated as needed.

Areas of Concern

The 1987 GLWQA defined 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.

Delisted AOCs

- In October 2014, [Deer Lake AOC](#), located in Michigan 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.

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/>

- 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 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. To date, results show that cap materials have remained in place and some aquatic vegetation is growing in the capped area.



Vistas of Nipigon Bay (foreground) and Red Rock (background). Credit: D. Crawford.

5.0 SURVEYS, INVENTORIES AND OUTREACH

5.1 Cooperative Science and Monitoring Initiative (CSMI)

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 CSMI 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); and
- Report results (planned for 2018).

Science and monitoring priorities are identified through the lakewide management process, with open discussion and input opportunities available to all stakeholders and the interested public. For Lake Superior, the last year of intensive field work and monitoring took place in 2011.

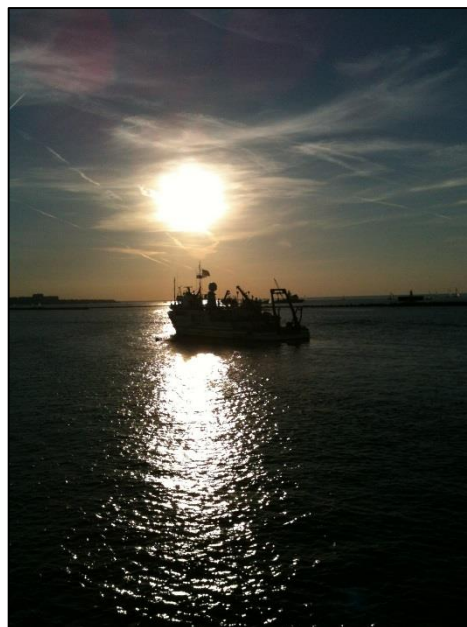
A number of resulting studies were completed by various agencies and together they present a comprehensive assessment of the state of the Lake Superior ecosystem. Priority research topics ranged from

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 and Climate Change Canada and the USEPA 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 agencies of the Lake Superior Partnership conduct a wide range of ongoing science and monitoring activities. This work provides a foundational understanding of



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

Lake Superior’s conditions and threats, as well as guidance to various restoration and protection programs and initiatives. The results of the 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*. Similarly, the Great Lakes Indian Fish and Wildlife Commission has undertaken monitoring of and communication regarding 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.

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

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



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

5.3 Outreach and Engagement

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

1. The Lake Superior Partnership Communications Committee; and
2. The 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; and
- Contributions to establishment of chemical reduction targets and timeframes.

Although the Lake Superior Binational Forum is no longer operational, the Lake Superior 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, in accordance with the requirements of GLWQA Annex 2.

A Lake Superior Partnership 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.

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 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.

The Lake Superior Partnership’s Outreach and Engagement Committee helps plan, deliver and support communication and outreach activities and products. Examples of outreach activities which are proposed to continue into the future are presented below.

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 (MNRF). 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 in school children the idea of reducing trash burning.

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 Zero Discharge Demonstration Program, 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.



The beauty of Lake Superior elicits a jubilant reaction from toddler. Credit: M. Collingsworth.

Potential Public Outreach and Engagement Activities

Going forward, proposed outreach and engagement activities for the public conducted by the Lake Superior Partnership include the following:

- Publish Lake Superior annual updates;
- 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.



The lake on Manitou Island. Credit: P. Nankervis.

6.0 BINATIONAL STRATEGIES

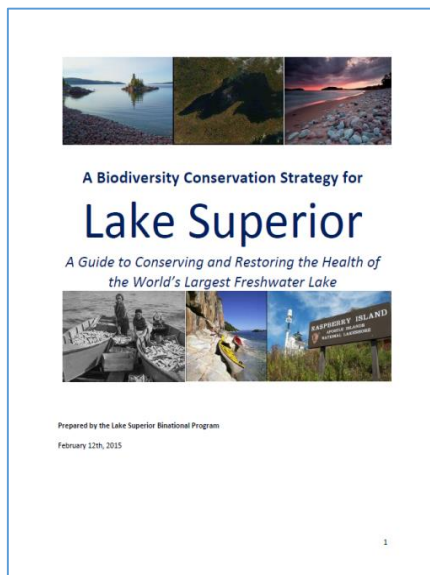
Under the 2012 GLWQA, the Lake Superior Partnership is directed to develop and implement lake-specific binational strategies to address current and future potential threats to water quality. The first binational strategy developed under the 2012 GLWQA was *A Biodiversity Conservation Strategy for Lake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

A 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.

Government agencies, local stakeholders, organizations, and groups were all instrumental in developing *A Biodiversity Conservation Strategy for Lake Superior*. The information in the Strategy is intended to help all stakeholders 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.



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

Map of Regional Planning Areas, for *A Biodiversity Conservation Strategy for Lake Superior*

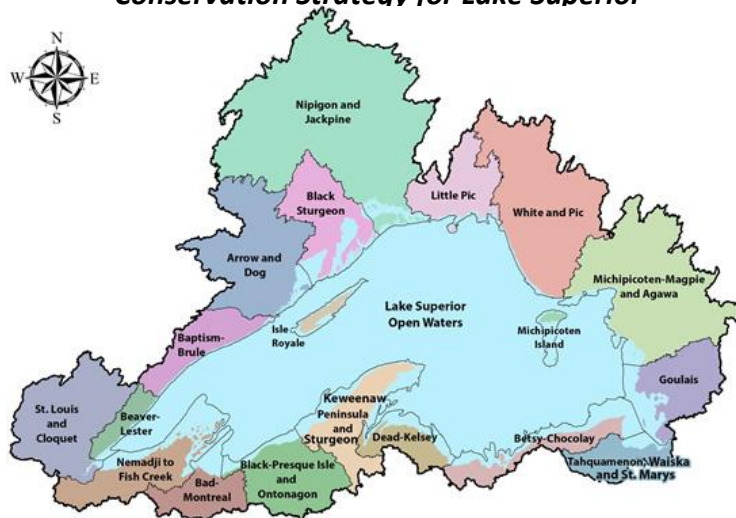


Figure 28. Corresponding regional plans highlight special features, issues and local conservation opportunities. Source: LSBP, 2016.

Past Lake Superior Partnership Binational Strategies

Other binational strategies developed under previous versions of the GLWQA continue to inform, or are being incorporated into efforts of, the Lake Superior Partnership. Table 5 lists these strategies.

Table 5. 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 the United States, 2012). The GLWQA directed that the Framework be developed within three years of entry into force of the GLWQA (i.e., by end of February 2016) and 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 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 where the water meets the land, *“the littoral area of the Great Lakes and connecting rivers where waters are subject to direct influences from shorelands and watersheds.”* Thus, the nearshore area will not be rigidly defined by depth or distance from shore, but by zone of impact where these influences are observed.

The Nearshore Framework’s assessment 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. The Nearshore Framework will provide a comprehensive assessment of nearshore waters; share information from the assessment; identify areas requiring protection, restoration or prevention activities; and identify stressors at a broad scale. Agencies can then factor these findings into their priority setting and engage and empower communities to create collaborative approaches to addressing the identified issues and take action.



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 collaborative 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 6 lists current Lake Superior science and monitoring priorities. These priorities support Lake Superior lakewide objectives, and results will inform future assessments, including the 2020 LAMP, of the state of the lake as well as threats to the ecosystem that need to be



Lake Sturgeon. Credit: H. Quinlan, U.S. Fish and Wildlife Service.

addressed. A CSMI Task Team will provide three levels of reporting that include details of completed projects (approximately 6 months after the field year), a CSMI workshop overview (2 years after the field year), and scientific journal articles published in ensuing years.

Table 6. Lake Superior Science and Monitoring Priorities, 2016

| Science and Monitoring Priority | Context | Link to Action Areas and Lakewide Objectives |
|---|---|--|
| 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, requiring intervention, but ongoing rehabilitation efforts also have positive impacts on the 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 are a threat to biodiversity conservation and management of a 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. |

| Science and Monitoring Priority | Context | Link to Action Areas and Lakewide Objectives |
|--|---|--|
| 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 regarding the impact of past and present mining activity conducted in the watershed on nearshore environments. | Action area on other existing and emerging threats. 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 <i>A Biodiversity Conservation Strategy for Lake Superior</i> (LSBP, 2015) identified the need to better identify the presence of species of conservation concern, their habitats, habitat range limits, sensitivity to climate change, and other concerns such as habitat connectivity. | 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. |

| 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 Lake Superior is the “cleanest” of the Great Lakes, there are existing chemicals of emerging concern and 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 nearshore areas most susceptible to eutrophication based on loadings, climate changes, lake currents and hydrodynamics | 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. | Lakewide objectives 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. |

9.0 ACTIONS, PROJECTS, AND IMPLEMENTATION

The following section presents actions that may be taken to restore and protect Lake Superior. It is important to emphasize that all stakeholders play a role, i.e., federal, state and provincial governments, tribal governments, First Nations, Metis, municipal governments, watershed management agencies, other local public agencies, and the public. To successfully implement these actions, coordination, science-based management, public engagement, adaptive management and a prevention approach are all essential. These concepts are discussed below, with sections organized as follows:

Section 9.1 includes: 1) **Actions** to address threats to water quality and to achieve lakewide objectives. This information can be used to help identify, support or coordinate ongoing or new projects; 2) Lake Superior Partnership **Projects** that can help focus cooperative implementation and reporting under the Lake Superior LAMP over the next five years; and, 3) **Activities that everyone can take** to help protect Lake Superior.

Section 9.2 emphasizes the importance of restoring Lake Superior’s degraded **Areas of Concern** (AOCs). AOCs are designated geographic areas that have their own specific “Remedial Action Plans” (RAPs) to guide remediation and restoration actions. Restoring AOCs will help improve conditions in the lake, thereby contributing to achievement of lakewide ecosystem objectives. RAPs can be considered a complementary effort to the LAMP.

Section 9.3 emphasizes the **commitment to implement LAMP actions and be accountable** for results.



Left: Falls River culvert on Golf Course Road, Baraga County, Michigan, before removal. *Right:* Falls River Golf Course Road after culvert removal. Credit: E. Johnston, Keweenaw Bay Indian Community.

9.1 Lakewide Management Actions and Projects

Lakewide management **actions** and **projects** are organized under the different threats identified in Section 4:

- Aquatic invasive species;
- Climate change;
- Dams and barriers;
- Chemical contaminants;
- Additional substances of concern; and
- Other threats (e.g., mining impacts and energy sector activities).

Two additional categories are included, to fully capture actions identified in *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015):

- High-quality habitats; and
- Native species.

Actions

Actions needed to address threats to water quality and achieve lakewide objectives have been identified by the Lake Superior Partnership in consultation with Lake Superior stakeholders and the public. The primary sources of the identified actions are: *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015), *Lake Superior Climate Change Impacts and Adaptation Report* (Huff and Thomas, 2014), the *Lake Superior Aquatic Invasive Species Complete Prevention Plan* (LSBP, 2014), the *Zero Discharge Demonstration Program* (ongoing) and *1990-2010 Critical Chemical Reduction Milestones report* (LSBP, 2012).

The actions are fairly broad in their scope and can be used to help identify, support or coordinate ongoing or new projects for Lake Superior. For example, the actions were used to help identify Lake Superior Partnership projects over the years 2015-2019, as described below.

Lake Superior Partnership Projects

Projects were identified by Lake Superior management experts who comprise the Lake Superior Partnership. To be identified and confirmed as a project, several factors were considered: relevancy to the broader actions needed to address a threat (referred to above), current work underway, current state of the issue, potential for a high-degree of coordinated action, contribution to achieving lakewide objectives, and achievability over the next five years.

A total of 29 projects were identified. These projects can help focus cooperative implementation efforts and reporting under the Lake Superior LAMP.

Aquatic Invasive Species: Reduce the Impact of Existing Aquatic Invasive Species and Prevent the Introduction of New Ones

Context

As described in Section 4, the threat of aquatic invasive species (AIS) is ranked high, as evaluated in *A Lake Superior Biodiversity Conservation Assessment* (LSBP, 2015). This assessment examined scope, severity, and irreversibility of threats to Lake Superior. Some factors in the assessment included:

- Existing invasive species continue to impact the ecosystem (e.g., Sea Lamprey);
- Existing invasive species (found in limited areas of Lake Superior) have the potential to spread (e.g., Phragmites);
- Lake Superior waters are warming, thereby reducing the natural barrier of very cold waters that are inhospitable to many species found in the lower lakes;
- Establishment of even a single invasive species can have a greater negative consequence to Lake Superior because of the lake's relatively simple food-web, as compared to the other Great Lakes;
- Lake Superior is at one end of the Great Lakes – St. Lawrence Seaway, making it susceptible to invasive species that hitchhike via ballast water, live bait dumping, aquarium releases, water garden escapes, or as parasites or disease from introduced fish; and
- Constant vigilance is required to prevent and/or manage the risk of new invasive species becoming established in Lake Superior.

Actions

The following list of actions was developed by the Lake Superior Partnership through stakeholder comment processes and engagement (e.g., development of the *Lake Superior Aquatic Invasive Species Complete Prevention Plan* (LSBP, 2014) and *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015)). Results of these actions will contribute to achieving several lakewide objectives for Lake Superior (objectives 1-4 and 7, found in Section 3). These actions also support the GLWQA General Objective that calls for the Great Lakes to be free from the introduction and spread of aquatic invasive species.

- Establish first-response control protocols, where not already in place, in anticipation of newly-discovered aquatic invasive species;
- Implement control and/or eradication plans, where feasible, at appropriate geographic scales for priority aquatic invasive species;

- 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;
- Maintain Sea Lamprey at population levels that do not cause significant mortality for adult Lake Trout;
- Undertake best management practices to prevent AIS introductions during dredging operations, lock operations, construction, and other maintenance activities;
- Continue screening processes to classify species proposed for trade into three lists: prohibited, permitted, and conditionally prohibited/permitted;
- Identify AIS introduction issues and establish best management practices and restrictions for shore-land work;
- Implement compatible, federal regulatory regimes for ballast water discharge that are protective of the U.S. and Canadian Great Lakes;
- Use regulations, policies and best management practices to reduce the risk of introduction of AIS through all possible pathways, including boaters, guides, equipment and live bait dealers, hatchery operators, pet stores, home garden centers, sea plane pilots, scuba divers, and water recreationists;
- Protect exposed or seasonally-exposed wetland environments from off-road vehicular use that may be a vector for invasive plants (e.g., European Common Reed [*Phragmites australis subsp. australis*]);
- Undertake outreach, education, enforcement and research on preventing and managing AIS;
- Monitor AIS movement and establishment in the Lake Superior basin;
- Maintain a list of the AIS that are most likely to reach the Lake Superior basin, and monitor appropriately;
- Support development, testing and implementation of effective ballast treatment systems; and
- Identify ecosystems that may be more vulnerable to new AIS under changing environmental conditions.

Addressing the Issue

To address this issue across the Great Lakes, a number of binational efforts are being taken under the GLWQA 2012 (i.e., Annex 5 Discharges from Vessels, and Annex 6 Aquatic Invasive Species). These efforts include programs and measures to protect the Great Lakes from the discharge of aquatic invasive species from ships' ballast water and sediment; aquatic invasive species risk assessments; and an early detection and rapid response initiative.

Several organizations work collaboratively to tackle aquatic invasive species issues in the Great Lakes. For example, the Great Lakes Fishery Commission is working across borders to lead and implement a comprehensive Sea Lamprey control program. Since 1991, the Great Lakes Commission has supported the Great Lakes Panel on Aquatic Nuisance Species, a binational body comprised of representatives from government (state, provincial, federal, and tribal), business and industry, universities, citizen environmental groups and the larger community.

The Panel provides guidance on aquatic invasive species research initiatives, policy development and information/education programs. In 2009, the U.S. Saint Lawrence Seaway Development Corporation, in conjunction with the International Joint Commission, initiated the formation of the Great Lakes Ballast Water Collaborative, which shares information in an effort to facilitate communication and collaboration among key stakeholders and complement existing efforts to reduce the risk of introduction and spread of invasive species through ballast water.

In addition, domestic efforts in both Canada and the United States are underway across the Great Lakes. Many of these commitments are found in the *Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health*, and the U.S. Great Lakes Restoration Initiative Action Plan II.

Lake Superior Partnership Projects: 2015-2019

The Lake Superior Partnership identified a specific set of projects and agencies involved in implementing them (Table 7). The selection of these projects originated from Lake Superior management experts who comprise the various binational committees of the Lake Superior Partnership. The projects were selected in consideration of the list of actions identified above, accomplishments to date, work underway, current state of the issue on Lake Superior, benefits of a high-degree of coordinated action, contribution to achieving lakewide objectives, and achievability over the next five years. These projects have been vetted through the larger Lake Superior Partnership, and have undergone internal and public review.

The projects identified will help further focus coordination, tracking and reporting on specific work from a lakewide perspective. Implementation will take place, to the extent feasible, by agencies with mandates to undertake work in these areas. Not all of the agencies that make up the Lake Superior Partnership will be involved in implementing all of the projects. At the same time, contributions to these projects will not be limited to the agencies listed.

Table 7. Lake Superior Partnership Projects to Address Aquatic Invasive Species

| # | Lake Superior Partnership Projects: 2015-2019 | Agencies Involved |
|---|---|---|
| 1 | Add additional locations to the lakewide aquatic invasive species early detection/rapid response surveillance projects. | 1854 Treaty Authority, CORA, DFO, Fond du Lac, KBIC, MDEQ, MNRF, NOAA, NPS, Parks Canada, USEPA, USFS, USFWS, WDNR |
| 2 | Undertake additional aquatic invasive species prevention outreach and education, including discussions with recreational boaters, and installation of lake access site signage. | 1854 Treaty Authority, Bad River, BMIC, Fond du Lac, GLIFWC, Grand Portage, KBIC, MDEQ, Minnesota Sea Grant, MNRF, NPS, Parks Canada, Red Cliff, USFS, WDNR |

| # | Lake Superior Partnership Projects: 2015-2019 | Agencies Involved |
|---|---|---|
| 3 | Maintain and improve effectiveness of Sea Lamprey control, prevent introduction of new species, and limit expansion of previously-established aquatic invasive species. | 1854 Treaty Authority, Bad River, BMIC, CORA, DFO, GLIFWC, NPS, Parks Canada, Red Cliff, USFWS, USGS |
| 4 | Contribute to the elimination of European Common Reed (i.e., <i>Phragmites australis, subsp. australis</i>) from the Lake Superior basin by undertaking or supporting lakewide distribution mapping, early detection efforts, and control efforts. | 1854 Treaty Authority, Bad River, Fond du Lac, GLIFWC, MDEQ, MNDNR, MNRF, NPS, Parks Canada, Red Cliff, USEPA, USFS, WDNR |

Activities That Everyone Can Take

The general public is encouraged to help address this issue by undertaking the following actions:

- Learn to recognize invasive species and report sightings to federal, state or provincial, tribal or Sea Grant authorities;
- Never release fish or transplant invasive plants along lakes, streams, and stormwater ponds;
- Purchase and use safe alternatives for shoreland restoration, water gardens and waterscapes, instead of potentially-invasive species; and
- Clean all aquatic plants, animals, and mud from watercraft, trailers, docks, lifts, anchors, and other recreational equipment before leaving access areas.



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

Context

As detailed in Section 4, climate change is expected to alter the Lake Superior ecosystem, and exacerbate many existing stressors. Impacts include increases in air and water temperatures, decreased extent and duration of ice cover and a possible long-term decrease in water levels. Direct effects on species and habitat will include: increased stress on cold-water fish communities as streams and rivers become warmer; a northward shift in deciduous forests and the reduction of suitable habitat for boreal species; and negative effects on fish and wildlife populations due to changing ecological conditions, which may diminish coastal wetlands. The issue of climate change was identified as a high threat to habitats and species on a lakewide scale in *A Biodiversity Conservation Assessment for Lake Superior* (LSBP, 2015).

Actions

The following list of actions was developed by the Lake Superior Partnership, through stakeholder comment processes and engagement (e.g., development of the *Lake Superior Climate Change Impacts and Adaptation* report (Huff and Thomas, 2014)). The results of these actions will contribute to achievement of several lakewide objectives for Lake Superior (objectives 2-6, found in Section 3). These actions also support the GLWQA General Objective for the Great Lakes to be free from conditions that may negatively impact its chemical, physical or biological integrity.

- 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);
- Implement adaptation actions to account for changes in variability and/or frequency in air and water temperatures, water levels, storm events and droughts, among other effects;
- Implement adaptive plant and forestry management practices that respond to climate change to minimize possible disturbances to Lake Superior;
- Create coastal development setbacks or rolling easements to allow ecosystems to migrate in response to changes in water levels;
- Prevent development near potentially newly-sensitive and/or flood risk areas;
- Increase the incorporation of climate change information into the communications, management, technical assistance, science, research and development programs of parks and protected areas;

- Undertake climate change education and outreach activities, with a focus on disseminating materials and information available from domestic climate change programs;
- Monitor the effectiveness of the Lake Superior Regulation Plan (i.e., water levels) in response to changing climate conditions with regard to protecting and preserving Lake Superior coastal ecosystems;
- Modify invasive species pathway analysis and prediction models to include climate change parameters;
- 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);
- Continue to support and enhance scientific research designed to understand resilience of ecosystems to climate change and cumulative effects;
- 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; and
- Conduct climate change vulnerability assessments for forests, fisheries, priority habitats and species, and nearshore water quality.

Addressing the Issue

To address this issue across the Great Lakes, a number of binational efforts are being taken under the GLWQA 2012 (i.e., Annex 9 Climate Change Impacts). These efforts include taking into account climate change impacts during implementation of the GLWQA, using domestic programs to address climate change impacts, and communicating binationally regarding ongoing developments of domestic climate change science, strategies and actions.

The binational Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee was established in 2015 to address the issue of water level regulation, including the potential impact of climate change. The GLAM will undertake the monitoring, modeling and assessment needed to support ongoing evaluation of the regulation of Lake Superior water levels and flows. The GLAM Committee reports to the International Lake Superior Board of Control.

In addition, domestic efforts in both Canada and the United States are underway across the Great Lakes. Many of these commitments are found in the *Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health*, and the U.S. Great Lakes Restoration Initiative (GLRI) Action Plan II.

Lake Superior Partnership Projects: 2015-2019

The Lake Superior Partnership identified a specific set of projects and agencies involved in implementing them (Table 8). The selection of these projects originated from Lake Superior management experts who comprise the various binational committees of the Lake Superior Partnership. The projects were selected in consideration of the list of actions identified above, accomplishments to date, work underway, current state of the issue on Lake Superior, benefits

of a high-degree of coordinated action, contribution to achieving lakewide objectives, and achievability over the next five years. These projects have been vetted through the larger Lake Superior Partnership and have undergone internal and public review.

The projects identified will help further focus coordination, tracking and reporting on specific work from a lakewide perspective. Implementation will take place, to the extent feasible, by agencies with mandates to undertake work in these areas. Not all of the agencies that make up the Lake Superior Partnership will be involved in implementing all of the projects. At the same time, contributions to these projects will not be limited to the agencies listed.

Table 8. Lake Superior Partnership Projects to Address Climate Change

| # | Lake Superior Partnership Projects: 2015-2019 | Agencies Involved |
|---|---|--|
| 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. | 1854 Treaty Authority, Bad River, BMIC, CORA, ECCC, Fond du Lac, GLIFWC, Grand Portage, KBIC, MOECC, NOAA, NPS, Red Cliff, USEPA, USFS, USGS |
| 2 | Support local climate change initiatives to help communities and/or natural resource managers develop adaptation plans. | 1854 Treaty Authority, Bad River, BMIC, CORA, Fond du Lac, GLIFWC, Grand Portage, KBIC, Minnesota Sea Grant, MNDNR, MOECC, NOAA, NPS, Red Cliff, USFS, USFWS, USGS |

Activities That Everyone Can Take

The general public is encouraged to help address this issue by undertaking the following actions:

- Reduce unnecessary driving where possible; walk, bike, carpool or take mass transportation to reduce greenhouse gas emissions;
- Install rain gardens, green roofs, native landscaping and other green infrastructure measures as feasible; and
- Consider the use of passive solar energy and other forms of renewable energy.

Dams and Barriers: Reduce the Negative Impacts of Dams and Barriers by Increasing Connectivity and Natural Hydrology between the Lake and Tributaries

Context

As described in Section 4, the Lake Superior watershed contains thousands of dams and other barriers, many of which degrade water quality and disrupt habitat connectivity for aquatic organisms. Dams are a major factor in the low populations of some fish stocks, because the fish cannot access their traditional spawning areas above the dam. Some aging dams and other barriers are deteriorating, and some do not adhere to present day environmental regulatory standards. Dams and barriers were identified as a high threat to habitats and species on a lakewide scale in *A Biodiversity Conservation Assessment for Lake Superior* (LSBP, 2015).

While dams do disrupt habitat connectivity, they also have the benefit of preventing some aquatic invasive species from spreading. The question of what to do about aging dams and other barriers is an important topic in various jurisdictions and organizations all around Lake Superior.

Actions

The following list of actions was developed by the Lake Superior Partnership through stakeholder comment processes and engagement (e.g., development of *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015)). The results of these actions will contribute to lakewide objective 7, found in Section 3. These actions also support the GLWQA General Objective to support healthy and productive habitats to sustain resilient populations of native species.

- 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);
- Protect and restore connectivity, where appropriate, by removing dams, upgrading stream/road crossing infrastructure, or by other means;
- Adopt flow standards to sustain key environmental processes, critical species habitat and ecosystem services; and
- Pursue, continue or enhance sustainable hydropower planning that adequately protects aquatic ecosystems, habitats and species.

Addressing the Issue

To address these issues across the Great Lakes, a number of binational efforts are being taken through the GLWQA (i.e., Annex 7 Habitat and Species). These efforts include assessing gaps in current binational and domestic programs to restore and maintain native species and habitat, and increasing awareness of native species and habitat and the methods to restore and maintain them.

In addition, domestic efforts in both Canada and the United States are underway across the Great Lakes. Many of these commitments are found in the *Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health* and the U.S. Great Lakes Restoration Initiative Action Plan II.

Lake Superior Partnership Projects: 2015-2019

The Lake Superior Partnership identified a specific set of projects and agencies involved in implementing them (Table 9). The selection of these projects originated from Lake Superior management experts who comprise the various binational committees of the Lake Superior Partnership. The projects were selected in consideration of the list of actions identified above, accomplishments to date, work underway, current state of the issue on Lake Superior, benefits of a high-degree of coordinated action, contribution to achieving lakewide objectives, and achievability over the next five years. These projects have been vetted through the larger Lake Superior Partnership, and have undergone internal and public review.

The projects will help further focus coordination, tracking and reporting on specific projects from a lakewide perspective. Implementation will take place, to the extent feasible, by agencies with mandates to undertake work in these areas. Not all of the agencies that make up the Lake Superior Partnership will be involved in implementing all of the projects. At the same time, contributions to these projects will not be limited to the agencies listed.

Table 9. Lake Superior Partnership Projects to Address Dams and Barriers

| # | Lake Superior Partnership Projects: 2015-2019 | Agencies Involved |
|---|--|--|
| 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. | Bad River, Fond du Lac, KBIC, MNRF, Red Cliff, USFS, USFWS, WDNR |
| 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. | MNRF |
| 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 the construction of a corresponding multi-purpose Sea Lamprey barrier at Eskwanonwatin Lake. | MNRF |

Activities That Everyone Can Take

The general public is encouraged to help address this issue by undertaking the following actions:

- Volunteer with your local watershed group to identify those barriers in your area which need to be removed; and
- Talk to local officials to remind them about the importance of both “fish crossing the road” and “cars crossing the creek.”



Lake Superior Day volunteers. Credit: C. Clements.

Chemical Contaminants: Work to Achieve Zero Releases of the Nine Persistent Bioaccumulative Chemicals by 2020, Under the Zero Discharge Demonstration Program

Context

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* (LSBP, 2015).

The Zero Discharge Demonstration Program (ZDDP), established in 1991, targets nine critical legacy pollutants for zero discharge in the Lake Superior basin by 2020. The nine ZDDP critical contaminants are: mercury, PCBs, dioxin, hexachlorobenzene (HCB), octachlorostyrene (OCS), chlordane, DDT and metabolites, dieldrin/aldrin, and toxaphene. The *1990-2010 Critical Chemical Reduction Milestones* report documents progress toward achieving the ZDDP reduction schedules for the nine critical chemicals (LSBP, 2012).

While the program has had many successes, including significant reductions in mercury and dioxin releases, it will be challenging to achieve the program's goal of zero release of all pollutants by 2020. Despite the success of the ZDDP, contaminants continue to be present in amounts that can be a risk to human health or cause degradation to habitat. For example, although mercury discharges and emissions in the Lake Superior basin decreased by 80% from 1990 to 2010, mercury levels in some fish in some areas continue to warrant advisories for human fish consumption.

Actions

The following list of actions was developed by the Lake Superior Partnership through stakeholder comment processes and engagement (e.g., development of the *1990-2010 Critical Chemical Reduction Milestones* report (LSBP, 2012)). The results of these actions will contribute to the Lake Superior lakewide objective 8, found in Section 3. These actions also support GLWQA General Objectives 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.

- 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;
- Continue to build on knowledge of existing and proposed mining projects in the basin, and possible chemical emissions, for incorporation into the Lake Superior Partnership's ZDDP chemical inventory (used to assess chemical reduction milestones) and to promote, where necessary, the use of best mining practices with regard to achievement of Lake Superior lakewide objectives;
- Promote restrictions and voluntary phase-out of non-essential mercury-containing products in households, schools, municipalities, and businesses;
- 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;
- Showcase agencies and local governments that collect and track the types and amounts of pesticides disposed, to support efforts to virtually eliminate from the basin, those pesticides listed in the Zero Discharge Demonstration Program;
- Support existing pesticide collection programs, such as clean sweeps, and explore the expansion of collections to additional geographic areas;
- 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;
- 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;
- 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; and
- 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.

Addressing the Issue

To address chemical contaminants across all the Great Lakes, a number of binational efforts are being taken under the GLWQA 2012 (i.e., Annex 3 Chemicals of Mutual Concern). These efforts include identifying chemicals of mutual concern that originate from anthropogenic (human) sources, and that are agreed to by both countries as being potentially harmful to human health or the environment; reducing anthropogenic releases of chemicals of mutual concern and products containing chemicals of mutual concern throughout their entire life cycles; and promoting the use of safer chemical substances and the use of technologies that reduce or eliminate the uses and releases of chemicals of mutual concern.

In addition, domestic efforts in both Canada and the United States are underway across the Great Lakes. Many of these commitments are listed in the *Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health* and the U.S. Great Lakes Restoration Initiative Action Plan II.

Lake Superior Partnership Projects: 2015-2019

The Lake Superior Partnership identified a specific set of projects and agencies involved in implementing them (Table 10). The selection of these projects originated from Lake Superior management experts who comprise the various binational committees of the Lake Superior Partnership. The projects were selected in consideration of the list of actions identified above, accomplishments to date, related work underway, current state of the issue on Lake Superior, benefits of a high degree of coordinated action, contribution to achieving lakewide objectives, and achievability over the next five years. These projects have been vetted through the larger Lake Superior Partnership, and have undergone internal and public review.

The projects will help further focus coordination, tracking and reporting on specific work from a lakewide perspective. Implementation will take place, to the extent feasible, by agencies with mandates to undertake work in these areas. Not all of the agencies that make up the Lake Superior Partnership will be involved in implementing all of the projects. At the same time, contributions to these projects will not be limited to the agencies listed.

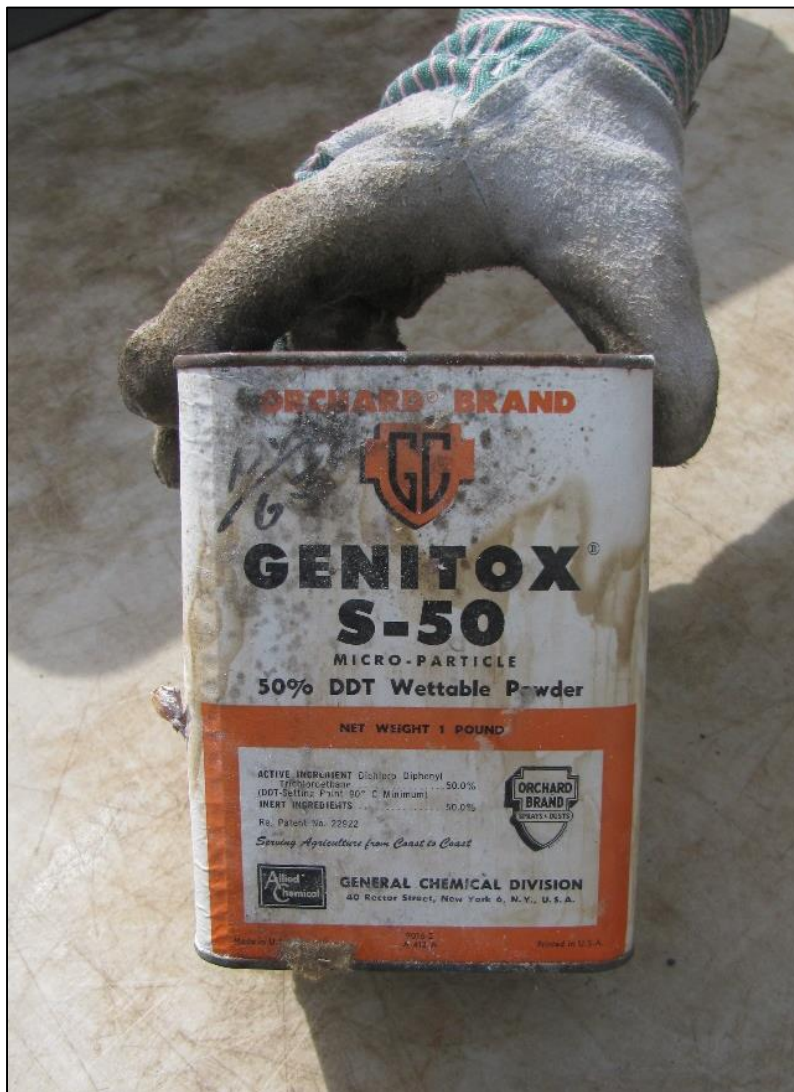
Table 10. Lake Superior Partnership Projects to Address Chemical Contaminants

| # | Lake Superior Partnership Projects: 2015-2019 | Agencies Involved |
|---|---|--|
| 1 | Continue outreach and education to the public on mercury toxicity; pathways into fish, wildlife and humans; and actions that can be taken to help remove mercury from the basin. | Bad River, CORA, Fond du Lac, GLIFWC, Grand Portage, KBIC, MDEQ, MOECC, NOAA, NPS, Red Cliff, USEPA, USFS, USFWS, USGS |
| 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. | Bad River, ECCC, Fond du Lac, MPCA, NOAA, NPS, USGS |
| 3 | Document which agencies and local governments collect and track the types and amounts of pesticides disposed, as feasible, so as to inform existing pesticide collection programs, such as clean sweeps. Information will be used to assess the potential for expanding collections to additional geographic areas. | ECCC, MDEQ, WDNR |
| 4 | Continue to support open burning abatement programs, such as “Bernie the Burn Barrel,” to achieve reductions in the release of dioxins and furans into the Lake Superior basin from the practice of residential burning of garbage. | Bad River, CORA, Fond du Lac, KBIC, MOECC, MPCA, Red Cliff, WDNR, MPCA |

Activities That Everyone Can Take

The general public is encouraged to help address this issue by undertaking the following actions:

- Reduce, reuse, repair, and recycle;
- Take household hazardous materials to hazardous waste collection depots;
- Never burn garbage;
- Use more environmentally-friendly asphalt-based sealants as an alternative to those with coal tar, which contain toxic substances; and
- Compost your garbage, and use natural pest-control methods.



DDT collected during collection event in 2013. Credit: C. Spruce.

Additional Substances of Concern: Protect the Lake Superior Basin from Future Contamination Resulting from Additional Substances of Concern

Context

In addition to the nine critical legacy pollutants that are the focus of the Zero Discharge Demonstration Program, contaminants such as pharmaceuticals and personal care products (PPCPs), microplastics, excessive nutrients, and substances identified as GLWQA Chemicals of Mutual Concern (e.g., brominated flame retardants and perfluorinated chemicals) have the potential to adversely impact the Lake Superior basin. At the same time, there is a great opportunity to maintain good water quality in Lake Superior because in most cases the concentrations of these substances are very low.

As described in Section 4, concerns about additional substances of concern include the following:

- PPCPs have been detected in nearshore waters and in bottom sediments of Lake Superior at low concentrations;
- Atmospheric concentrations of in-use flame retardants (i.e., TBB & TBPH) are increasing;
- Personal care products and contaminants such as perfluorooctane sulfonate (PFOS) and are susceptible to being transported in groundwater within the Lake Superior basin; and
- Human activities such as agriculture, urban development and forestry can increase non-point source runoff into the lake, which can include pollutants that degrade water quality and affect biological communities.

Actions

The following list of actions was developed by the Lake Superior Partnership through such processes as stakeholder review and engagement opportunities (e.g., *1990-2010 Critical Chemical Reduction Milestones* report (LSBP, 2012)). The results of these actions will contribute to the Lake Superior lakewide objective 9, found in Section 3. These actions also support GLWQA General Objectives which 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.

- Implement activities identified in GLWQA Binational Strategies for future GLWQA Chemicals of Mutual Concern, as appropriate;
- Seek opportunities to support, coordinate or expand the various pharmaceutical collection initiatives taking place in the Lake Superior basin;

- Develop policies or programs that assist nursing homes and other health care facilities in proper disposal of unwanted medication;
- Consider adopting policies or resolutions restricting the use of cosmetic pesticides (i.e., pesticides used for aesthetic purposes only), using as a guide the 2009 Ontario Pesticides Act: Cosmetic Pesticide Ban Regulations; and
- 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.

Addressing the Issue

To address additional substances of concern across the Great Lakes, a number of binational efforts are being taken under the GLWQA 2012 (i.e., Annex 3 Chemicals of Mutual Concern). These efforts include identifying chemicals of mutual concern that originate from anthropogenic (human) sources, and that are agreed to by both countries as being potentially harmful to human health or the environment; reducing anthropogenic releases of chemicals of mutual concern and products containing chemicals of mutual concern throughout their entire life cycles; and promoting the use of safer chemical substances and the use of technologies that reduce or eliminate the use and release of chemicals of mutual concern.

In addition, domestic efforts in both Canada and the United States are underway across the Great Lakes. Many of these commitments are listed in the *Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health* and the U.S. Great Lakes Restoration Initiative Action Plan II.

Lake Superior Partnership Projects: 2015-2019

The Lake Superior Partnership identified a specific set of projects and agencies involved in implementing them (Table 11). The selection of these projects originated from Lake Superior management experts who comprise the various binational committees of the Lake Superior Partnership. The projects were selected in consideration of the list of actions identified above, accomplishments to date, related work underway, current state of the issue on Lake Superior, benefits of a high-degree of coordinated action, contribution to achieving lakewide objectives, and achievability over the next five years. These projects have been vetted through the larger Lake Superior Partnership, and have undergone internal and public review.

The projects will help further focus coordination, tracking and reporting on specific projects from a lakewide perspective. Implementation will take place, to the extent feasible, by agencies with mandates to undertake work in these areas. Not all of the agencies that make up the Lake Superior Partnership will be involved in implementing all of the projects. At the same time, contributions to these projects will not be limited to the agencies listed.

Table 11. Projects to Address Additional Substances of Concern

| # | Lake Superior Partnership Projects: 2015-2019 | Agencies Involved |
|---|---|--|
| 1 | Increase efforts to educate the public on new and emerging chemicals; their potential toxicity; pathways into fish, wildlife and humans; and how the public can help remove these chemicals from the basin. Put special emphasis on the topics of microplastics and safer alternatives for personal care, household cleaning products, and pesticides/herbicides. | BMIC, ECCC, Fond du Lac, Grand Portage, KBIC, MOECC, NOAA, NPS, Red Cliff, USGS, USFWS |
| 2 | Compile information on the type and status of different pharmaceutical collection efforts in the basin and other efforts to locate and properly dispose of unwanted medication. Use this information to identify opportunities for further action. | Bad River, ECCC, KBIC, MPCA, USGS, USFWS, WDNR |

Activities That Everyone Can Take

The general public is encouraged to help address this issue by undertaking the following actions:

- Return unused medicines, including over-the-counter drugs, to pharmacies; never flush them down the toilet or dump them down the sink;
- Choose natural fabrics, natural cleaning products, and reusable containers; and
- Read the labels of your personal care products, and use online tools to learn which chemicals to avoid.



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.

Other Existing and Emerging Threats: Address Other Existing and Emerging Threats That May Impact Important Habitat or Native Plant and Animal Communities

Context

As described in Section 4, other threats can impact the Lake Superior ecosystem. While high threats from a lakewide perspective are addressed individually in the LAMP, there are other threats that can impact the lake or are of high importance to a particular area. Many different threats were assessed and ranked within the process to develop *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015). Other existing and emerging threats include the following:

- Fourteen mines currently operate in the Lake Superior basin, with many explorations and expansions underway. Mining activity has the potential to impair water quality and degrade habitats;
- Domestic production of crude oil has increased in both the U.S. and Canada, with an increasing amount of oil being transported through the Lake Superior basin;
- Some stretches of shoreline are becoming increasingly developed for residential, commercial or industrial land uses, which can alter natural processes and degrade habitat; and
- Adverse impacts to Lake Superior can result from unsustainable forestry practices, terrestrial invasive species, and other energy sector activities.

Actions

The following list of actions was developed by the Lake Superior Partnership through stakeholder comment processes and engagement (e.g., development of *A Biodiversity Conservation Strategy for Lake Superior*). The results of these actions will contribute to the lakewide objectives for Lake Superior (found in Section 3), and the actions also support the GLWQA General Objective for the Great Lakes to 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.

- Promote proactive consideration of important habitat areas and species during environmental assessment and regulatory processes for mining, supported by comprehensive binational mapping (of existing and historical mining activities and exploration) and sharing knowledge of best management practices, best available technologies and other activities, as appropriate;
- Identify and assess the risk of any newly-discovered or orphaned contaminated sites;
- Reduce non-point source pollution from urban areas, agriculture, and other sources to levels that are safe for plants, fish and wildlife;

- Integrate green infrastructure principles in coastal development projects;
- Use only sustainable forestry practices in the Lake Superior basin;
- Develop, implement, and integrate early detection and rapid response networks for terrestrial invasive species;
- Track and implement control and/or eradication plans, where feasible, for terrestrial invasive species at appropriate geographic scales; and
- Research or monitor potentially new, emerging, or cumulative threats to Lake Superior.

Addressing the Issue

Over the past several decades, there have been tremendous technological advancements, increased understanding of impacts, meaningful voluntary actions, and regulatory changes to reduce the impacts of resource extraction activities. Oversight of these activities occurs domestically by agencies with jurisdictional authority in Canada and the U.S.

To further address these threats across the Great Lakes, a number of commitments have been made in the GLWQA 2012 (i.e., Annex 2 Lakewide Management, and Article 6 Notification and Response). These commitments include identifying science priorities for the assessment of current and future threats to water quality, and for the identification of priorities to support management actions. Further, the Governments of Canada and the United States have agreed to notify each other of planned activities that could lead to a pollution incident or that could have significant cumulative impacts on the waters of the Great Lakes.

Lake Superior Partnership Projects: 2015-2019

The Lake Superior Partnership identified a specific set of projects and agencies involved in implementing them (Table 12). The selection of these projects originated from Lake Superior management experts who comprise the various binational committees of the Lake Superior Partnership. The projects were selected in consideration of the list of actions identified above, accomplishments to date, related work underway, current state of the issue on Lake Superior, benefits of a high-degree of coordinated action, contribution to achieving lakewide objectives, and achievability over the next five years. These projects have been vetted through the larger Lake Superior Partnership, and have undergone internal and public review.

The projects will help further focus coordination, tracking and reporting on specific work from a lakewide perspective. Implementation will take place, to the extent feasible, by agencies with mandates to undertake work in these areas. Not all of the agencies that make up the Lake Superior Partnership will be involved in implementing all of the projects. At the same time, contributions to these projects will not be limited to the agencies listed.

Table 12. Lake Superior Partnership Projects to Address Other Existing and Emerging Threats

| # | Lake Superior Partnership Projects: 2015-2019 | Agencies Involved |
|---|---|--|
| 1 | Provide oil spill responders with better access to existing and new spatial data (as available) on ecologically-important and sensitive habitats. | Bad River, CORA, Fond du Lac, GLIFWC, MOECC, NOAA, NPS, Parks Canada, USFWS, USGS |
| 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. | 1854 Treaty Authority, Bad River, BMIC, CORA, Fond du Lac, GLIFWC, KBIC, MOECC, NOAA, NPS, Parks Canada, Red Cliff, USEPA, USFWS |
| 3 | Outreach and engage with communities and others at the local scale on the value of water and best water use practices and policies. | Bad River, CORA, Fond du Lac, GLIFWC, KBIC, MDEQ, Red Cliff, USFWS, USGS, WDNR |
| 4 | Map current and proposed mining activities in the Lake Superior basin to support understanding of the potential and cumulative impacts of mining on important habitat sites. Assess impacts due to other stressors, such as climate change. | 1854 Treaty Authority, CORA, Fond du Lac, GLIFWC, MPCA, NPS, USGS |

Activities That Everyone Can Take

The general public is encouraged to help address this issue by undertaking the following actions:

- Promote corporate social responsibility and support businesses with sustainability initiatives;
- Support green infrastructure, including low-impact development to manage stormwater;
- Report possible oil spills immediately;
- Install water-saving devices; and
- Use a rain barrel for watering the garden.

High-quality Habitats: Restore and Protect a System of Representative, High-quality Habitats

Context

As described in Section 4, Lake Superior is in the best overall condition of all the Great Lakes; many of its aquatic habitats, watersheds and coastal wetlands are in good condition. For this reason, Lake Superior provides an unparalleled opportunity for sustaining high environmental quality and providing ecosystem services for the people who live near or visit Lake Superior.

In addition to actions that target specific threats such as aquatic invasive species, site-specific considerations and management actions are needed, especially in areas of high or potentially high ecological value. While Lake Superior's habitats are in relatively good condition overall, they are not uniformly "good" all around the lake. Some areas are in excellent condition and other areas are degraded. Similarly, habitat stressors vary from location to location.

Actions

The following list of actions was developed by the Lake Superior Partnership through stakeholder comment processes and engagement (e.g., development of *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015)). The results of these actions will contribute to several lakewide objectives for Lake Superior (objectives 1, 2-4, 6, 7, found in Section 3). These actions also support the GLWQA General Objective to support healthy and productive wetlands and other habitats to sustain resilient populations of native species.

- Restore or protect wetlands, native riparian forests, and coastal habitats such as rocky shorelines, beaches and dunes;
- Achieve an overall net gain of the productive capacity of habitat supporting fish and wildlife, including coastal wetlands;
- Restore habitats that have been degraded in their ecological capacity to better support fish and wildlife communities, where feasible;
- Develop or refine ecologically-based integrated watershed management plans in priority areas;
- Use special land and water designations to protect important habitat on public property;
- Educate and engage people about restoring or protecting important habitat and related ecosystem services;
- Develop comprehensive inventories of important fish and wildlife habitats;
- Inventory and assess impacts of degraded habitats and communities, including hardened shorelines and other artificial coastal structures;

- Develop and distribute information and/or indicators on ecosystem conditions, trends, stressors and important restoration or protection sites; and
- Maintain and share data through existing and new mechanisms, as appropriate.

Addressing the Issue

To address this issue across the Great Lakes, a number of binational efforts are being taken under the GLWQA 2012 (i.e., Annex 2 Lakewide Management, and Annex 7 Habitat and Species). These efforts include: developing a nearshore framework to identify areas that are, or may become, subject to high stress, and areas that are of high ecological value; developing a baseline survey of the existing habitat against which to establish a Great Lakes Basin Ecosystem target of net habitat gain; and developing a binational framework for prioritizing habitat conservation activities.

In addition, domestic efforts in both Canada and the United States are underway across the Great Lakes. Many of these commitments are listed in the *Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health* and the U.S. Great Lakes Restoration Initiative Action Plan II.

Lake Superior Partnership Projects: 2015-2019

The Lake Superior Partnership identified a specific set of projects and agencies involved in implementing them (Table 13, following page). The selection of these projects originated from Lake Superior management experts who comprise the various binational committees of the Lake Superior Partnership. The projects were selected in consideration of the list of actions identified above, accomplishments to date, related work underway, current state of the issue on Lake Superior, benefits of a high-degree of coordinated action, contribution to achieving lakewide objectives, and achievability over the next five years. These projects have been vetted through the larger Lake Superior Partnership, and have undergone broader internal and public reviews.

The projects will help further focus coordination, tracking and reporting on specific projects from a lakewide perspective. Implementation will take place, to the extent feasible, by agencies with mandates to undertake work in these areas. Not all of the agencies that make up the Lake Superior Partnership will be involved in implementing all of the projects. At the same time, contributions to these projects will not be limited to the agencies listed.

Table 13. Lake Superior Partnership Projects to Protect and Restore High-Quality Habitats

| # | Lake Superior Partnership Projects: 2015-2019 | Agencies Involved |
|---|--|--|
| 1 | Investigate, evaluate, and if feasible, implement dredging solutions or other habitat restoration efforts at Buffalo Reef, Michigan. | GLIFWC, NOAA, USACE, USEPA |
| 2 | Improve the mapping and quantification of important spawning, nursery and foraging habitat for key fish species to support protection and restoration decision-making. | 1854 Treaty Authority, GLIFWC, MNRF, NPS, Parks Canada, Red Cliff, USEPA, WDNR |
| 3 | Promote and support local and regional implementation of <i>A Biodiversity Conservation Strategy for Lake Superior, 2015</i> and corresponding Regional Plans. | 1854 Treaty Authority, Bad River, BMIC, CORA, ECCC, Fond du Lac, GLIFWC, Grand Portage, KBIC, MDEQ, MNDNR, MNRF, NOAA, NPS, Parks Canada, Red Cliff, USFS, USFWS, WDNR |
| 4 | Formally establish the Lake Superior National Marine Conservation Area in Canada, and Federal-Provincial harmonization committee to develop and implement management priorities for the area. | MNRF, Parks Canada |
| 5 | Integrate spatial data standards, methodologies and geomatic products to help identify and prioritize sites for habitat protection and rehabilitation. | GLIFWC, MNDNR, NOAA, NPS, USEPA, USFWS, USGS |
| 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. | 1854 Treaty Authority, Bad River, Fond du Lac, GLIFWC, KBIC, MNDNR, NOAA, NPS, Red Cliff, USEPA, USFS, USFWS, USGS, WDNR |

Activities That Everyone Can Take

The general public is encouraged to help address this issue by undertaking the following actions:

- Reduce, reuse, repair, and recycle;
- Stay on established trails to minimize impacts on such sensitive coastal habitat as rocky shorelines, beaches, and dunes;
- Riparian property owners are encouraged to contact federal, state or provincial, tribal, or local natural resource professionals for information, advice, and permits (where applicable) when considering restoring their shoreline;
- Support stewardship events and efforts that promote how people can protect habitats; and
- Work with community groups and local authorities to develop watershed management plans.

Diverse, Healthy and Self-sustaining Native Species Populations: Manage Plants and Animals in a Manner that Ensures Diverse, Healthy and Self-sustaining Populations

Context

Lake Superior has unique fauna, containing species and subspecies found nowhere else on the planet, such as Siscowet, a large deep water form of Lake Trout, and 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. Lake Superior is the only Great Lake with a food web still dominated by native species with largely self-sustaining populations.

In addition to addressing specific lakewide threats, management of targeted species is needed to maintain diverse, healthy and self-sustaining populations, especially species which are most vulnerable to stress, are regularly harvested, or are of special importance. Often, the results of work to improve one targeted species (e.g., Lake Sturgeon) benefits the overall ecosystem and helps to achieve lakewide objectives (e.g., maintain tributaries in good ecological condition).

Actions

The following list of actions was developed by the Lake Superior Partnership through stakeholder comment processes and engagement (e.g., development of *A Biodiversity Conservation Strategy for Lake Superior* (LSBP, 2015)). The results of these actions will contribute to several lakewide objectives for Lake Superior (objectives 1-7, found in Section 3). These actions also support the GLWQA General Objective to support healthy and productive wetlands and other habitats to sustain resilient populations of native species.

- Develop and implement plans to detect and prevent disease outbreaks;
- Use local native species, to the extent possible, in restoration projects and other natural resource management initiatives, supported by the development or maintenance of lists of native species, use standards, sources, and seed zones;
- Implement native fish and wildlife species restoration, protection or rehabilitation plans, as appropriate;
- Manage the harvest of fish, wildlife and plants, as feasible, to ensure their health, long-term sustainability and balance in the ecosystem;
- Manage over-abundant populations of species where there is strong evidence of sustained detrimental effects on habitats and/or species diversity;
- Educate citizens about the importance and appropriate use of local native plants in restoration and landscaping projects;

- Undertake comprehensive biological surveys to identify species of conservation interest and remaining natural communities;
- Catalogue Lake Superior basin's genetic diversity; and
- Develop and distribute information and/or indicators on species conditions, trends, stressors and potential rehabilitation locations.

Addressing the Issue

The Great Lakes Fishery Commission facilitates cooperative fishery management among the state, provincial, tribal, and federal management agencies, and works to achieve Fish Community Objectives in Lake Superior. These efforts are an important component of lakewide management, and are reflected in the LAMP.

In addition, to address the issue across the Great Lakes, a number of binational efforts are being taken under the GLWQA 2012 (i.e., Annex 7 Habitat and Species). These efforts include assessing gaps in current binational and domestic programs and initiatives to conserve, protect, maintain, restore and enhance native species and habitat as a first step toward the development of a binational framework for prioritizing activities; facilitating binational collaborative actions to reduce the loss of native species and habitat, recover populations of native species at risk, and restore degraded habitat; renewing and strengthening binational collaborative actions to conserve, protect, maintain, restore and enhance native species and habitat by identifying protected areas, conservation easements and other conservation mechanisms to recover populations of species at risk and to achieve the target of net habitat gain; and increasing awareness of native species and the methods to conserve them.

Furthermore, domestic efforts in both Canada and the United States are underway across the Great Lakes. Many of these commitments are listed in the *Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health* and the U.S. Great Lakes Restoration Initiative Action Plan II.

Lake Superior Partnership Projects: 2015-2019

The Lake Superior Partnership identified a specific set of projects and agencies involved in implementing them (Table 14). The selection of these projects originated from Lake Superior management experts who comprise the various binational committees of the Lake Superior Partnership. The projects were selected in consideration of the list of actions identified above, accomplishments to date, related work underway, current state of the issue on Lake Superior, benefits of a high-degree of coordinated action, contribution to achieving lakewide objectives, and achievability over the next five years. These projects have been vetted through the larger Lake Superior Partnership, and have undergone internal and public review.

The projects will help further focus coordination, tracking and reporting on specific projects from a lakewide perspective. Implementation will take place, to the extent feasible, by agencies

with mandates to undertake work in these areas. Not all of the agencies that make up the Lake Superior Partnership will be involved in implementing all of the projects. At the same time, contributions to these projects will not be limited to the agencies listed.

Table 14. Lake Superior Partnership Projects to Manage Diverse, Healthy and Self-Sustaining Native Species Populations

| # | Lake Superior Partnership Projects: 2015-2019 | Agencies Involved |
|---|---|--|
| 1 | Develop and update stock assessment models to improve management of self-sustaining commercial and sport fisheries for Lake Trout, Cisco, and Lake Whitefish. | Bad River, BMIC, CORA, GLIFWC, Grand Portage, MNRF, NPS, Red Cliff, USFWS, USGS, WDNR |
| 2 | Rehabilitate populations of indigenous aquatic species (e.g., Brook Trout, Lake Sturgeon, Muskellunge, Walleye, etc.). | Bad River, CORA, DFO, Grand Portage, KBIC, MNRF, NPS, Red Cliff, USFWS, WDNR |
| 3 | Update the Ecopath with Ecosim (EwE) ecological model (www.ecopath.org) 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. | CORA, GLIFWC, Grand Portage, MNRF, USEPA, USFWS, USGS |
| 4 | Develop and implement improved monitoring approaches for inshore, embayment, and tributary fish populations. | 1854 Treaty Authority, BMIC, CORA, Fond du Lac, GLIFWC, Grand Portage, NPS, Red Cliff, USFWS, USGS |

Activities That Everyone Can Take

The general public is encouraged to help address this issue by undertaking the following actions:

- Adhere to harvest limits and guidelines;
- Use proper catch and release practices for protecting species such as Brook Trout, Lake Sturgeon, and Muskellunge; and
- Report suspicious fish die-offs immediately to federal, state or provincial, tribal or Sea Grant authorities.

9.2 Areas of Concern

Remedial Action Plans (RAPs) are strategic plans designed to restore impaired “beneficial uses” in degraded areas, known as Areas of Concern (AOC). Refer to Section 4, to see the status of Lake Superior’s AOCs.

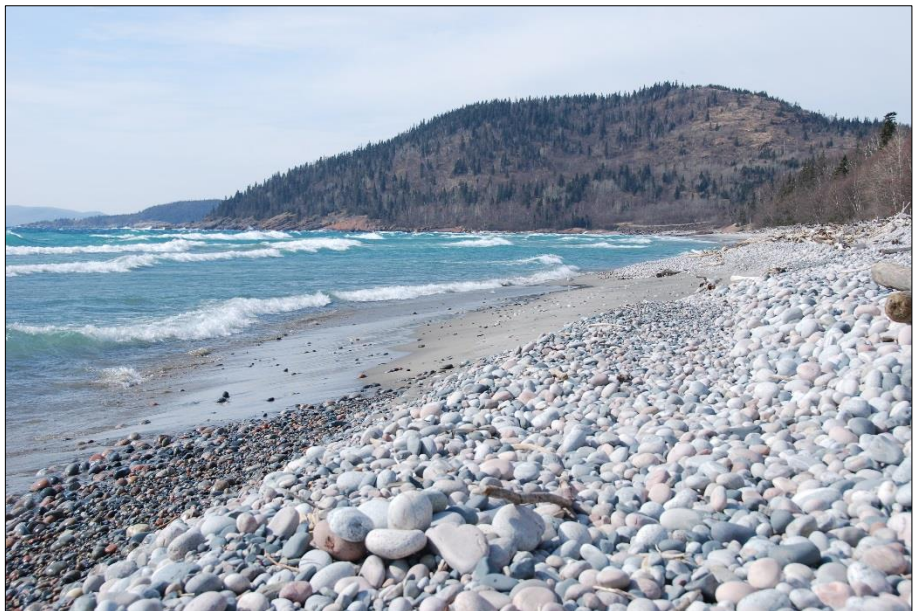
Pursuant to the GLWQA, RAPs have been developed for each AOC, with a team of federal, state, provincial, tribal, First Nation and Métis partners, along with local stakeholders, cooperating to restore the AOC.

Maintaining a strong relationship between the LAMPs and the RAPs is essential to restoring and protecting Lake Superior. AOCs by definition can hinder the achievement of lakewide objectives. Conversely, actions completed in AOCs, such as those to remediate contaminated sediment or restore fish and wildlife habitat, greatly contribute to the achievement of lakewide objectives.

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 Lake Superior Partnership members continue to work collaboratively to achieve common goals, especially since much of the restoration expertise, as well as land use control and watershed planning, resides at the local level.

Cooperation between the two efforts is essential to removing both lakewide and site-specific impairments.

Once an AOC is delisted, the area will come under the purview of the Lake Superior Partnership. Local watershed groups can continue to be engaged in lakewide management to build on the positive efforts completed as part of the RAP.



Peninsula Harbour AOC in Ontario. Credit: Environment and Climate Change Canada.

9.3 Implementation and Accountability

As demonstrated by the agency commitments in Section 9.1, Lake Superior Partnership organizations commit to incorporating, to the extent feasible, LAMP objectives and projects 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 and as new threats are identified;
- Coordination – actions will be coordinated across jurisdictions and stakeholder agencies, where possible;
- Prevention – anticipating and preventing pollution and other threats to the quality of the waters of the Great Lakes to reduce overall risks to the environment and human health;
- Public engagement – incorporating public opinion and advice, as appropriate, and providing information and opportunities for the public to participate in activities that contribute to the achievement of the objectives of the GLWQA; and
- Science-based management – implementing management decisions, policies, and programs that are based on best available science, research and knowledge, as well as traditional ecological knowledge, when available.

Implementation of projects will remain one of the highest priorities of the individual organizations that make up the Lake Superior Partnership. Organizations identified in Section 9.1 will take action, to the extent feasible, given budget constraints and domestic policy considerations.

Internal agency work planning and reporting will help track commitment progress and provide an accountability mechanism for the results of each individual organization. Internal Lake Superior Partnership committee workplans will help track implementation at a higher level to support coordination between organizations and in the engagement of others, as well as to support lakewide reporting on LAMP implementation (e.g., annual updates to the public on the LAMP).



10.0 REFERENCES

- Allan, J.D., McIntyre, P.B., Smith, S.D.P, Halpern, B.S., Boyer, G.L. Buchsbaum, A., Steinman, A.D. 2013. Joint analysis of stressors and ecosystem services to enhance restoration effectiveness. *Proceedings of the National Academy of Sciences of the United States of America* 110(1): 372-377. DOI:10.1073/pnas.1213841110. Image available at: greatlakesmapping.org/great_lake_stressors/5/warming-water-temperatures.
- Austin, J., and Colman, S. 2008. A century of temperature variability in Lake Superior. *Limnology and Oceanography*, 53(6), 2724-2730.
- Backus et al. 2010. Integrating multi-media monitoring of PBDEs in the Canadian environment. [http://refhub.elsevier.com/S0160-4120\(14\)00011-7/rf0915](http://refhub.elsevier.com/S0160-4120(14)00011-7/rf0915).
- 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/>.
- Canada and United States. 2012. Protocol Amending the Agreement Between Canada and the United States of America on Great Lakes Water Quality, 1978. Available at <http://binational.net/glwqa-aqegl/>.
- 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.J.H., G.E. Host, T.A. Brown, P. Meysembourg and L.B. Johnson. 2011. Linking Land to the Lakes: the linkages between land-based stresses and conditions of the Great Lakes. Background Technical Paper prepared for Environment Canada in support of the 2011 State of the Lakes Ecosystem Conference (SOLEC), Erie, PA. 47 p + Appendixes.
- deSolla, S.R., Weseloh, D.V.C., Hughes, K.D., Moore, D.J. *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>.

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 USEPA. 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 and Minnesota Department of Health (MDH). 2014. Community Report for Cadmium, Lead, and Mercury. Retrieved from <http://www.fdlrez.com/humanservices/biomonitoring.htm>.

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. October 2015 Draft available at http://binational.net/2015/12/03/groundwater-science/?utm_source=epa-gl-list&utm_medium=email&utm_content=Jan2015&utm_campaign=gw-report-draft.

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 (GLC). 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 Emissions Reduction Strategy.

Gronewold, A.D. and C.A. Stow, 2014. Water Loss from the Great Lakes. *Science*, Vol. 343 No. 6175, pp. 1084-1085.

Guide to Eating Ontario Fish, 2015. Queen's Printer for Ontario, PIBS# 590b17. Available at <https://www.ontario.ca/document/guide-eating-ontario-fish>.

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, J. F., S.P. Cox, C.J. Harvey, T.B. Johnson, D.M. Mason, K.K. Schoen, K. Aydin, C. Bronte, M. Ebener, M. Hansen, M. Hoff, S. Schram, D. Schreiner, and C.J. Walters. 2000. Sustainability of the Lake Superior Fish Community: Interactions in a Food Web Context. *Ecosystems*, 3 (6): 545-560. www.jstor.org/stable/3658774.

Lake Superior Binational Program (LSBP). 2015. *A Biodiversity Conservation Strategy for Lake Superior*. Accessed at <http://binational.net/2015/02/23/biodiversity-strategies/>.

Lake Superior Binational Program (LSBP). 2014. Lake Superior Aquatic Invasive Species Complete Prevention Plan. January 2014. Available at www.epa.gov/greatlakes/lake-superior-aquatic-invasive-species-complete-prevention-plan.

Lake Superior Binational Program (LSBP). 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.

Lepak, R.F., Runsheng, Y., Krabbenhoft, D.P., Ogorek, J.M., DeWild, J.F., Holsen, T.M., Hurley, J.P. 2015. Use of Stable Isotope Signatures to Determine Mercury Sources in the Great Lakes. *Environ. Sci. Technol. Lett.* Available at <http://pubs.acs.org/doi/abs/10.1021/acs.estlett.5b00277>.

Liu, L. Y.; Salamova, A.; Venier, M.; Hites, R. A. 2016. Trends in the levels of halogenated flame retardants in the Great Lakes atmosphere over the period 2005-2013. *Environment International*, submitted 8 February 2016.

Minnesota Department of Health (MDH). 2013. Beaches and Recreational Waters in Minnesota. Accessed at <http://www.health.state.mn.us/divs/eh/beaches/howSAFE.html>.

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. *Aquatic Invasive Species*. Website. Accessed at <http://www.seagrant.umn.edu/ais/index>.

McGoldrick, D.J. and E.W. Murphy. 2015. Concentration and distribution of contaminants in Lake Trout and Walleye from the Laurentian Great Lakes (2008 – 2012). D.J. Environmental Pollution, <http://dx.doi.org/10.1016/j.envpol.2015.12.019>.

National Oceanic and Atmospheric Administration (NOAA), Office for Coastal Management Coastal Change Analysis Program. Land Cover 2010.

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

Ontario MOECC, unpublished.

Parks Canada. 2015. *Lake Superior National Marine Conservation Area Receives Highest Level of Federal Protection*. Press release, June 24, 2015. 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.

Ruge, Z., Muir, D., Helm, P., Lohmann, R. 2015. Concentrations, trends, and air-water exchange of PAHs and PBDEs derived from passive samplers in Lake Superior in 2011. Environmental Science and Technology, 49(23):13777-86.

Salamova, A. Venier, M. Hites, R. A. 2015. Revised temporal trends of persistent organic pollutant concentrations in air around the Great Lakes. Environmental Science and Technology Letters, 2: 20-25.

Trebitz, A.S., J.C. Brazner, D.K. Tanner, and R. Meyer. 2011. Interacting watershed size and landcover influences on habitat and biota of Lake Superior coastal wetlands. Aquatic Ecosystem Health & Management, 14 (4): 443-455. DOI:10.1080/14634988.2011.635901.

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

Wisconsin Department of Natural Resources and Apostle Islands National Lakeshore. 2012. *Blue-green Algae Observed in Lake Superior*. Joint Press Release.

Zhang, Y, Jacob, DJ, Horowitz, HM, Chen, L, Amos, HM, Krabbenhoft, DP, Slemr, F, St. Louis, VL, Sunderland, EM. 2016. Observed Decrease in Atmospheric Mercury Explained by Global Decline in Anthropogenic Emissions, Proceedings of the National Academy of Sciences, vol. 113 no. 3 526–531, doi: 10.1073/pnas.1516312113.