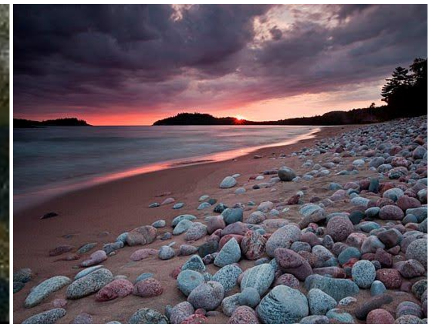
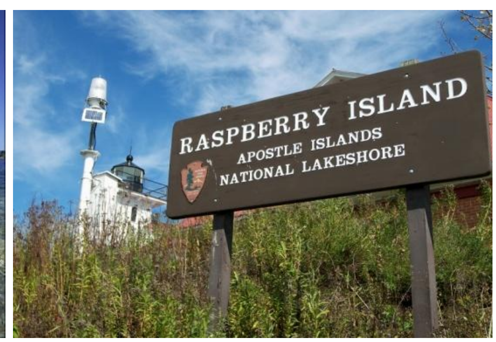




A Biodiversity Conservation Assessment for

Lake Superior





Volume 1: Lakewide Assessment

Prepared by the Superior Work Group of the Lake Superior Lakewide Action and Management Plan

Final Draft: June 2013
Updated: March 2015

Cover photo credits

Clockwise From upper left – *Rainbow Falls Provincial Park* Photo Credit: *Bill Caulfeild-Browne*; *Fall Satellite Image of Lake Superior* Image Credit: *NOAA*; *Sunset over Lake Superior shoreline in Lake Superior Provincial Park* Photo credit: *Ethan Meleg*; *Raspberry Island Lighthouse, Apostle Islands National Lakeshore* Photo Credit: *National Parks Service*; *Sea Kayaks on Lake Superior Shore at Agawa Rock Pictograph Site, Lake Superior Provincial Park, Ontario* Photo Credit: *Ethan Meleg*; *Commercial harvest of Cisco from Lake Superior, date unknown* Photo Credit: *North Shore Commercial Fishing Museum*

Recommended citation

Lake Superior Lakewide Action and Management Plan (LAMP) - Superior Work Group. 2013. Lake Superior Biodiversity Conservation Assessment. 130 pp. (Updated March 2015).

Disclaimer

This report reflects the best efforts of the preparers (Dan Kraus and Megan Ihrig) to accurately represent and interpret the available expertise and information on Lake Superior and the views and opinions of the project participants. Every effort to ensure the accuracy of the information contained in this study has been taken. We welcome suggestions for improvements.

Volume 2: Regional Summaries

Please note that this report includes two volumes. Volume 2 contains regional summaries and maps that are referred to in this document. It is recognized that many regions contain additional information and mapping on biodiversity and threats that could not be fully reflected in this report. Wherever possible, regional and local data and spatial information on biodiversity targets and threats has been noted in the text.

Acknowledgements

This report has been prepared by a project Steering Committee from the Superior Work Group (SWG) of the Lake Superior Lakewide Action and Management Plan (LAMP) with coordination and support from the Nature Conservancy of Canada. The Steering Committee members included:

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Mapping and spatial analysis was completed by Andrea Hebb and Gary White of the Nature Conservancy of Canada (NCC). Sarah Perkins from Battelle kindly supported collecting expert information in the webinars.

Special thanks to the amazing NCC team that supported the project website and communications with our Lake Superior experts and project administration: Nadia Alam, Christine Beevis-Trickett, Quincin Chan, Wendy Cridland, James Duncan, Craig Easton, Shane Eisenberg, Teva Harrison, Rebecca Hull, Dana Kleniewski, Lynda Kosalle, Chris Maher, Mhairi McFarlane, Laura Mousseau, Luc Thomas & Chuck Van Kempen.

Funding for this project is from Environment Canada and the Nature Conservancy of Canada.

Lake Superior Biodiversity Conservation Assessment Executive Summary

Lake of the Great Waters

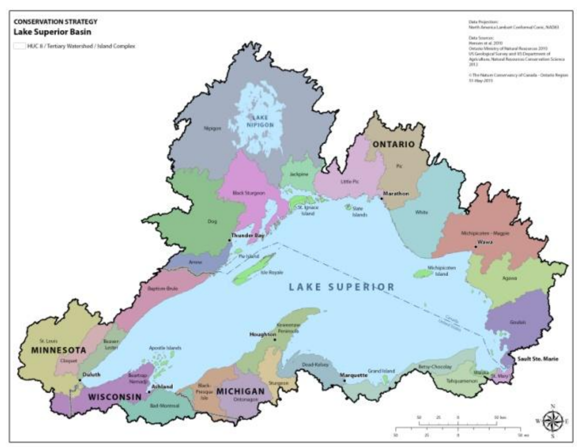
Lake Superior is unique among the world's freshwater lakes. Situated at the top of the chain of the Great Lakes, it is the world's largest freshwater lake by area. It is also the coldest and deepest of the Great Lakes, with a maximum depth of 406 metres. Because of its massive size, Lake Superior has a retention period of 191 years. Despite its northern location, the lake rarely completely freezes over due to the enormous mass of water, even in the coldest winters. It is also a lake of extraordinary biodiversity, supporting endemic and disjunct fishes, a unique deepwater form of Lake Trout (*Salvelinus namaycush*), diverse coastal wetlands, extensive sandy beaches and the cool coastlines and islands harbor arctic-alpine plants and Woodland Caribou (*Rangifer tarandus caribou*).

Lake Superior Coast (Photo by Ethan Meleg)

Developing a Biodiversity Conservation Assessment for Lake Superior

Developing the Lake Superior Biodiversity Conservation Assessment was identified by the binational Lake Superior Lakewide Action and Management Plan (LAMP) as an important tool to better integrate biodiversity objectives into current lake management, and to support implementation of the Great Lakes Water Quality Agreement (GLWQA). This assessment project will support the development of a conservation strategy for Lake Superior

A project team from the Lake Superior LAMP first developed a draft report based on a review of existing information. The assessment of biodiversity target health and the ranking of threats were done through the Conservation Action Planning framework. This framework has also been used to develop biodiversity conservation strategies for Lake Ontario (2009), Lake Huron (2010), Lake Michigan (2012) and Lake Erie (2012).



The project scope includes the open waters of the lake, islands, coastal areas and the watersheds of tributaries with a focus on how they affect the biodiversity of the lake.

The draft biodiversity conservation assessment (biodiversity targets, threats, regional summaries) was shared with experts for their review and comment. This included webinars that provided an introduction to the project, and a series of webinars based on the biodiversity targets and regional summaries. Over 80 Lake Superior experts reviewed and contributed to the document. Key changes resulting from expert review included updates to the viability and threats analysis and the addition of key information to the regional summaries.

The Health of Lake Superior

Seven conservation targets were selected that encompass the biodiversity of Lake Superior. These include aquatic, coastal, and watershed targets that have many species and habitats nested within them. The health of these biodiversity targets was assessed based on SOLEC indicators, with some modifications. The overall viability assessment for Lake Superior is "good" - the lake is in a state of health that is within the natural range of variation, but some management intervention may be required for some elements. The biodiversity conservation target that had the lowest viability was watersheds and tributaries. While nearshore and embayments are in "good" health, they are approaching the threshold for "fair". For many of the coastal habitats (aquatic and terrestrial) and watersheds, there is a high degree of regional variation in target condition. To better illustrate these regional differences, stress/condition indices were mapped for watersheds (Great Lakes Environmental Indicators [GLEI] 2013), lake waters (Great Lakes Environmental Assessment and Mapping [GLEAM] 2012; Allan et al. 2013) and coastal areas (analysis completed for this project). Information on biodiversity health, threats and important habitat areas is also provided for 20 regional units around the lake.

Summary of Biodiversity Conservation Targets and Health for Lake Superior	**Overall Health**
Deepwater and Offshore Waters: Benthic and pelagic waters that are >80 m in depth.	GOOD
Nearshore Zone and Reefs: Coastal areas that are between 15-80 m in depth, and shallow reefs.	GOOD
Embayments and Inshore: Embayments and the inshore zone at depths of 0-15m.	GOOD
Coastal Wetlands: Wetlands within 2 km 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.	GOOD
Islands: All land masses that are surrounded by water, including both natural and artificial islands.	GOOD
Coastal Terrestrial Habitats: Habitats within 2 km from the coast or to the extent of delineation.	GOOD
Tributaries and Watersheds: All rivers, streams and inland lakes that flow into Lake Superior and their associated watersheds.	FAIR

Threats and Conservation Issues

The overall threat rank for Lake Superior is "high". This is driven by a high rating for climate change, aquatic invasive species, and dams and barriers. These threats rank the highest because they impact many targets over a wide area and, in some cases, are very difficult to reverse. These high ranking threats generally reflect SOLEC "pressure" indicators that have been assessed as poor and declining including climate change (i.e., ice duration) and aquatic invasive species.

The biodiversity conservation targets with the highest threat ratings are: the nearshore zone and reefs, embayments and inshore, coastal wetlands, and tributaries and watersheds. These systems generally have the highest numbers of threats and are susceptible to aquatic invasive species, climate change and the continued habitat impacts of dams and barriers.

Ranked Threats to Lake Superior's Biodiversity

Aquatic Invasive Species	**High**
Climate Change	**High**
Dams and Barriers	**High**
Atmospheric Deposition	**Medium**
Coastal Development	**Medium**
Incompatible Forestry	**Medium**
Mining	**Medium**
Non-point Source Pollution	**Medium**
Terrestrial Invasive Species	**Medium**

Next Steps

This biodiversity conservation assessment is intended to summarize the best available information on Lake Superior's biodiversity and provide an analysis on health and threats. This information will be used by the Lake Superior LAMP in the development of a biodiversity conservation strategy in 2014.

Table of Contents

1. Introduction

1.1 Gichigammi[1] - Lake of the Great Waters

Lake Superior is unique among the world's freshwater lakes. Situated at the top of the chain of the Great Lakes, it is the world's largest freshwater lake by area and is rich in natural and human history (see Box 1.1). It is the coldest and deepest of the Great Lakes, with an average depth of 147 meters and a maximum depth of 406 metres. Because of its massive size, Lake Superior has a retention period of 191 years, the longest of all the Great Lakes. Despite its northern location, the enormous mass of water in Lake Superior rarely completely freezes over, even in the coldest winters. It is also a lake of extraordinary biodiversity, supporting endemic and disjunct fishes, a unique deepwater form of Lake Trout (*Salvelinus namaycush*), diverse coastal wetlands, extensive sandy beaches and the cool coastlines and islands harbor arctic-alpine plants and Woodland Caribou (*Rangifer tarandus caribou*). While several areas and features of the lake have been altered by human activities, Lake Superior is the least impacted of all the Great Lakes, and many of its aquatic habitats, watersheds and coast remain healthy and intact (Table 1.1, Figure 1.1).

Box 1.1: Ten Lake Superior Facts Everyone Should Know

1. Gichigammi is the Ojibwe (also known as Chippewa or Anishinaabe) name for Lake Superior meaning "Great Waters" or "Great Lake".
2. Lake Superior is the largest freshwater lake in the world by area.
3. Lake Superior contains 10% of the world's surface freshwater. This is more water than all the other Great Lakes combined, and enough to flood all of North America under 30 cm of water.
4. Lake Superior has over 2,500 islands, including Caribou Island, the most isolated freshwater island in the world. Some of these islands support colonies of the American White Pelican (*Pelecanus erythrorhynchos*).
5. Lake Superior has 6,479 km of coastline. This is longer than the distance between St. John's, Newfoundland and Victoria, British Columbia.
6. Lake Superior's coast and islands support one of North America's southern-most populations of Woodland Caribou.
7. Lake Superior's deep waters support a unique deep-bodied form of Lake Trout called "Siscowet" (*Salvelinus namaycush siscowet*).
8. Some coastal areas of Lake Superior remain so cool through the summer that they support populations of arctic-alpine plants.
9. The Lake Superior National Marine Conservation Area, established in 2007, is the largest freshwater protected area in the world.
10. Waves on Lake Superior can reach over 10 m in height. A phenomenon known as the "Three Sisters", when a series of three successive large waves form, was implicated in the sinking of the SS Edmund Fitzgerald in November 1975.

The management and conservation of Lake Superior is unique in the Great Lakes. The lake has large areas of public and protected lands, and First Nations and Tribes play an important role in managing the lake (Table 1.2, Figures 1.2 and 1.3).

While several large protected areas have been established and much of the Lake Superior basin and coast is undeveloped, many coastal areas, particularly in the U.S., are in private ownership and facing increasing development pressures. Many watersheds have high housing and road density as a result of urban areas, second homes and forestry (Figure 1.4) which can result in habitat loss and declining water quality. The lake also has a number of legacy impacts including dams and toxic sites. Dams have reduced access to river habitats for some migratory fishes, and some contaminants have persisted in the aquatic environment because of Lake Superior's cold waters and slow growth rate of fishes. Other key issues include aquatic invasive species, mining and climate change.

Despite these challenges, Lake Superior remains the most pristine of all the Great Lakes and provides an unparalleled global opportunity for binational conservation and maintaining biological reference sites in the world's largest freshwater ecosystem. This report provides a summary of the health and threats to the biodiversity of Lake Superior, and is intended to provide a starting-point to develop effective lakewide and place-based conservation strategies.

[1] Also spelled "Kitchi-gummi "

Figure 1.1: Land and Water Cover in the Lake Superior Basin
Most of the Lake Superior basin is characterized by forests and inland waters, with less than 2% in urban and agricultural land use. The Lake Superior basin has at least double the amount of natural cover compared to any of the other four Great Lakes (based on percentage cover). Urban areas are mainly associated with Duluth and Thunder Bay, and agricultural land use occurs mainly in Wisconsin in the southern portion of the basin. Some additional agricultural land use may be associated with the "grass/brush" category (which also includes recently cut-over areas of forest).

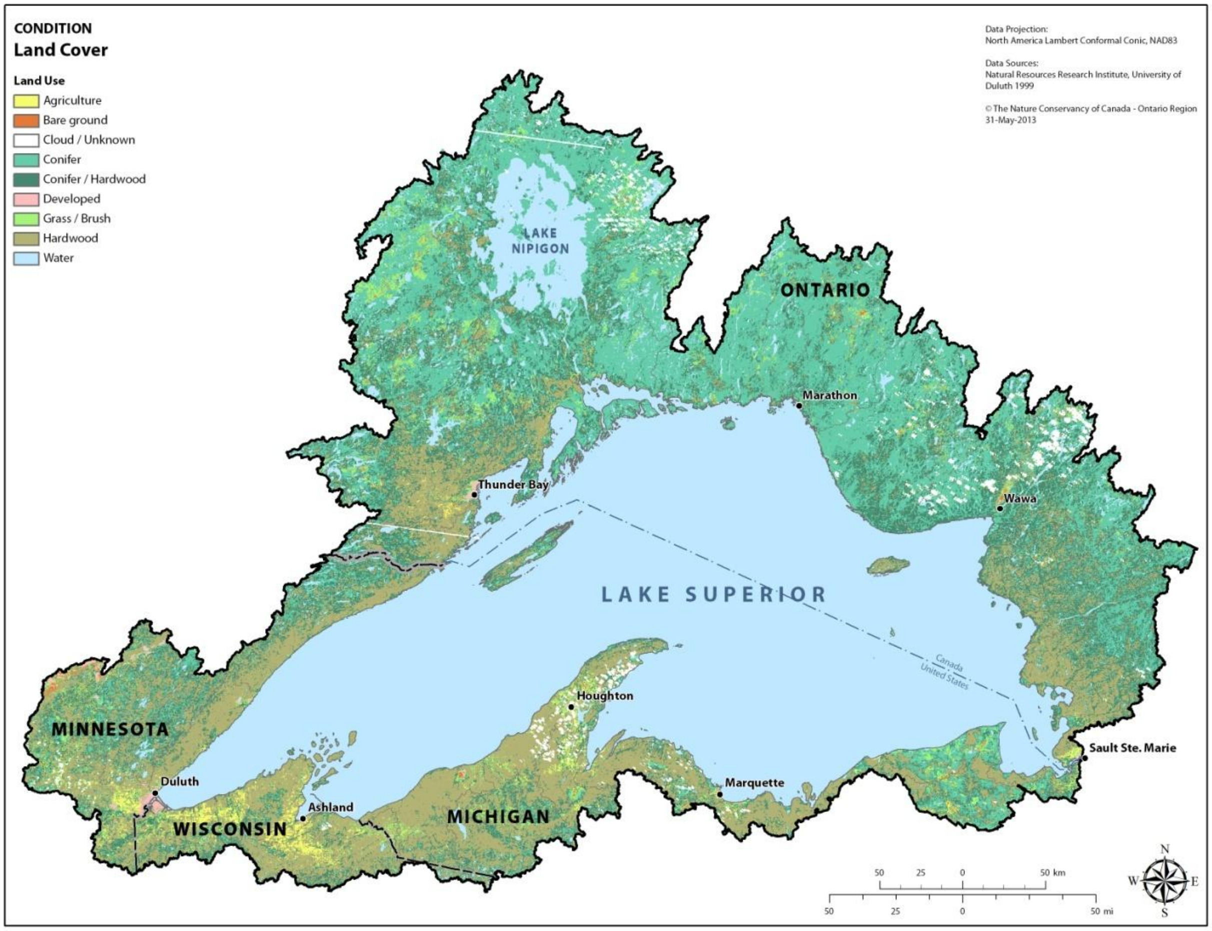


Table 1.1: Land and Water Cover in the Lake Superior Basin

Cover Type	Area (square km)	Percentage of Basin & Lake	Percentage of Basin (Land only)
Agriculture	1,285	0.68%	1.12%
Bare ground	554	0.29%	0.48%
Cloud shadow	2,454	1.31%	2.14%
Conifer	40,340	21.46%	35.22%
Conifer/hardwood	25,940	13.80%	22.65%
Developed	348	0.19%	0.30%
Grass/brush	4,751	2.53%	4.15%
Hardwood	30,326	16.13%	26.48%
Water	8,540	4.54%	7.46%
Lake Superior	73,435	39.07%	NA
Total	**187,972**	**100%**	**100%**

Figure 1.2: Land Protection and Management in the Lake Superior Basin.
Lake Superior has the largest coastal protected areas in the Great Lakes basin including Pukaskwa National Park, Lake Superior Provincial Park, Lake Superior Archipelago Conservation Reserve and Isle Royale National Park. Over 10% of the basin and 30% of the coast is included in parks with strict protection.

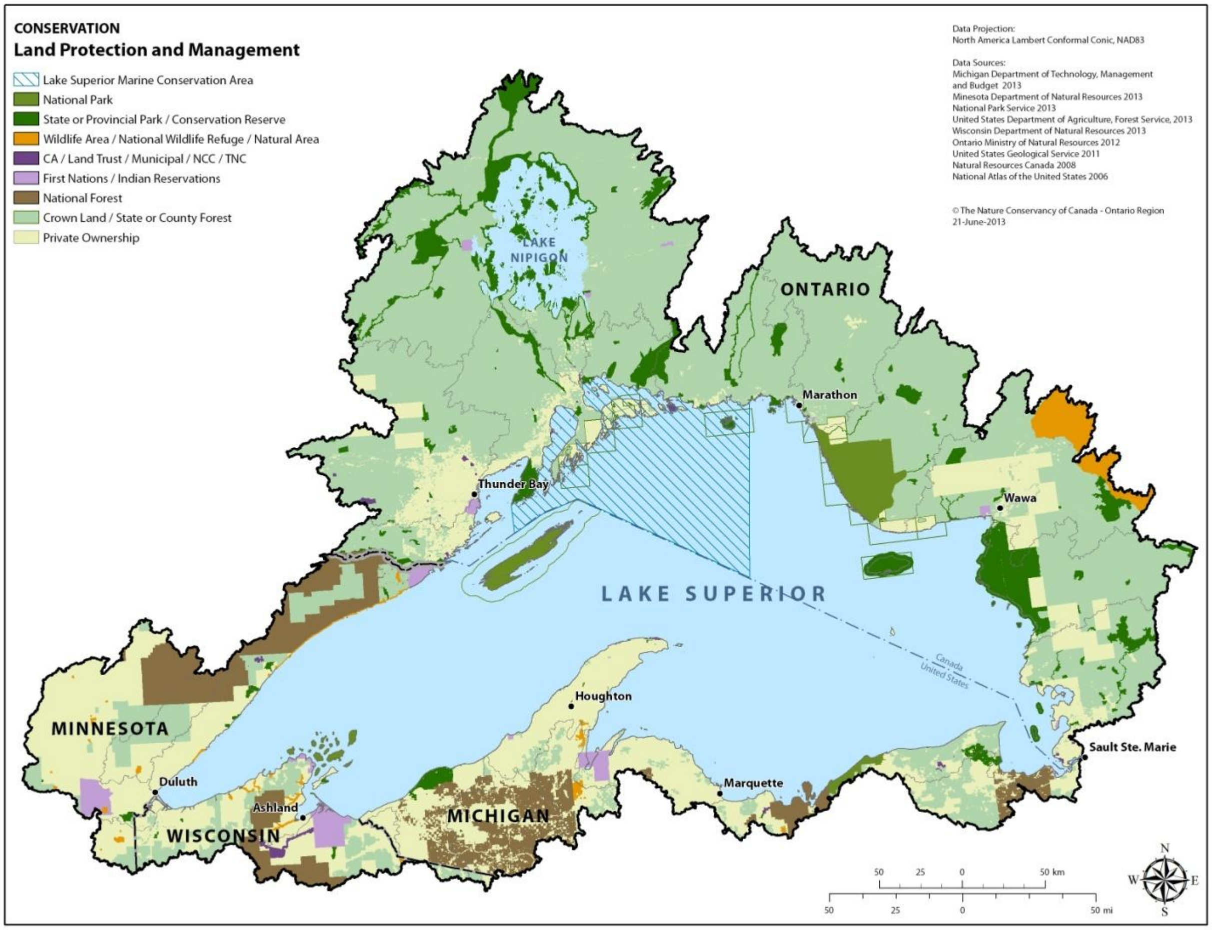


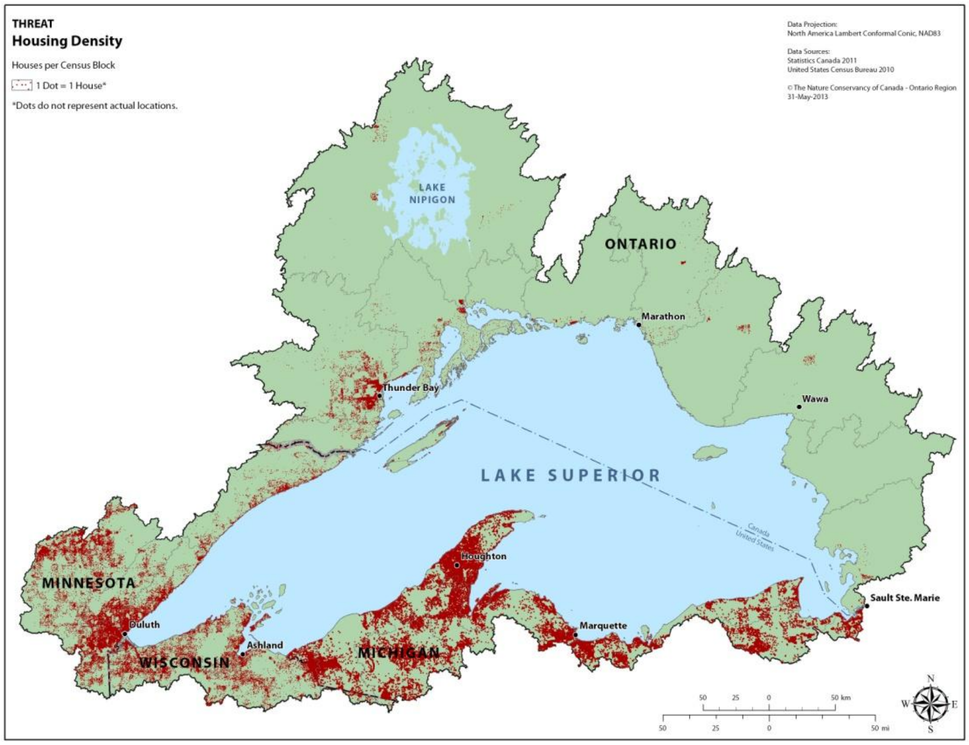
Table 1.2: Summary of Protected Areas in the Lake Superior Basin

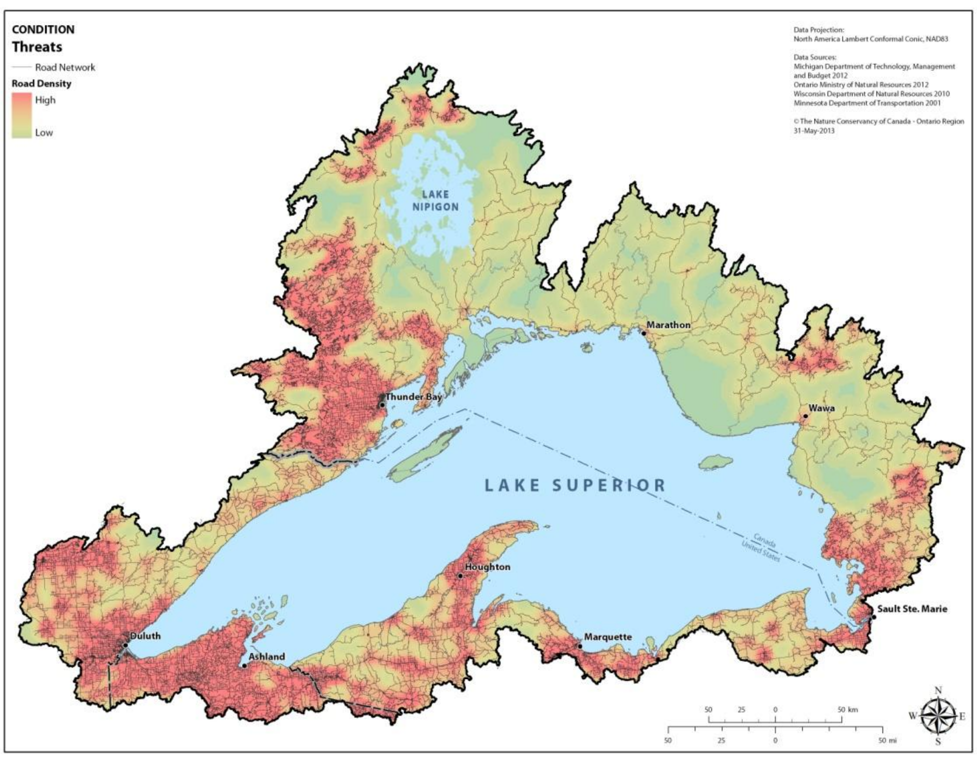
Protected Area	Area (km^2)
National Park	2,661
State or Provincial Park / Conservation Reserve	8,448
Conservation Authority/Non-Government Organization/ Land Trust/Municipal Park/ Wildlife Refuge/Wildlife Area[2]	1,800

[2] Database incomplete

Figure 1.3: First Nations and Tribal Lands and Territories in the Lake Superior Basin
First Nations and Tribes are very important and active contributors to the management of Lake Superior. This includes significant involvement in the Lake Superior Binational Program, the management of many areas of important cultural and natural heritage, in-the-field science and resource management, partnering in various restoration and protection initiatives, and being the source of Traditional Ecological Knowledge.

Figure 1.4: Housing and Road Density in the Lake Superior Basin
Housing density (red dots) and road density (red shading depicts high density, green shading lower density) are generally higher in the U.S. than Ontario. Some regions of Ontario have high road density from forestry operations. Isle Royale National Park, Black Bay Peninsula and the Pukaskwa National Park region all stand out for the near absence of houses and roads.





1.2 Objectives and Project Scope

Objectives

Efforts to conserve and restore Lake Superior's biodiversity by the Lake Superior Lakewide Action and Management Plan[3] (LAMP) have been ongoing for over 20 years. The LAMP includes over 20 organizations and provides a binational management framework to maintain and restore the physical, chemical and biological integrity of the lake. *A Vision for Lake Superior* expresses the commitment and common desire of the Lake Superior community: *"to foster a healthy, clean, and safe Lake Superior ecosystem - where diverse life forms exist in harmony; where wild shorelines and islands are maintained; and where development is well planned and biologically sound"*.

The Lake Superior LAMP has always had a very strong focus on biodiversity (LaMP 2006). Building on this experience, the objectives of the Lake Superior Biodiversity Conservation Assessment are:

1. To present, in a single document, relevant information and planning tools related to Lake Superior's biodiversity and conservation.
2. To provide a more in-depth assessment of the lake's biodiversity status and challenges at both lakewide and regional geographical scales.
3. To support a common approach to biodiversity conservation planning among the Great Lakes by following a concept similar to the biodiversity conservation plans for the other Great Lakes (Lake Ontario Biodiversity Strategy Working Group 2009; Franks Taylor et al. 2010; Pearsall, Carton de Grammont, Cavalieri, Chu et al. 2012; Pearsall, Carton de Grammont, Cavalieri, Doran et al. 2012), while meeting the needs of the Lake Superior LAMP.

This Lake Superior Biodiversity Conservation Assessment is the first phase of a larger project. Information synthesized and reviewed by experts during this phase, on the health of biodiversity, threats, and regional priorities, will form the basis for the second phase, which will include the development of strategic actions. This second phase is expected to be developed immediately after the conclusion of this phase. Together, these two phases will constitute a lakewide project similar to the biodiversity conservation strategies that have already been completed for the other Great Lakes.

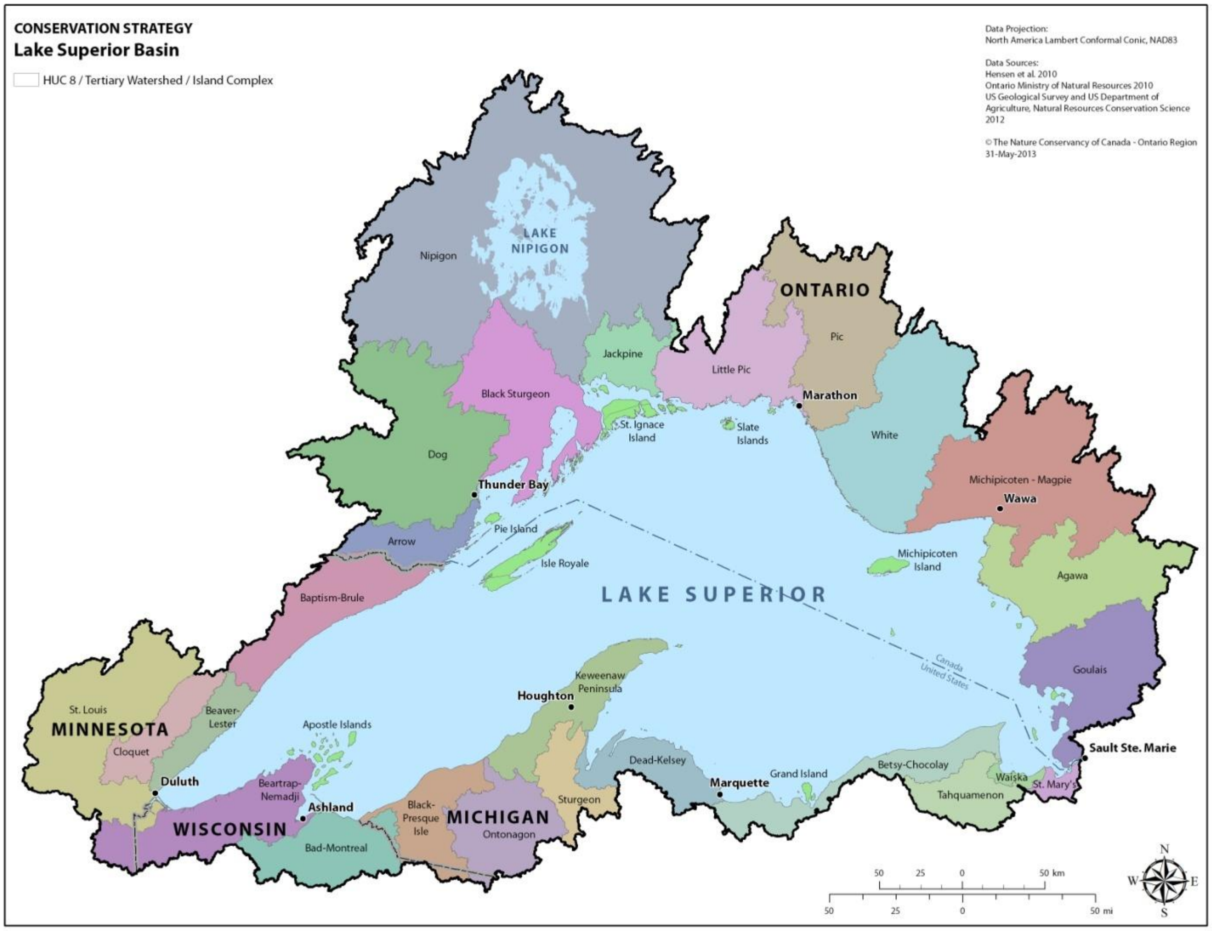
The results of this project support several of the Annexes of the 2012 Great Lakes Water Quality Agreement (GLWQA). This includes establishing baseline and assessment information that will inform future monitoring and ecosystem objectives, identifying areas of high ecological value and the development of lakewide habitat and species protection and restoration conservation strategies. This document also supports initiatives outlined in the U.S. Great Lakes Restoration Initiative (GLRI) and the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem, and the resulting strategy will be used to help identify priority actions and priority areas.

[3] The Lake Superior LAMP was established by the Lake Superior Binational Program. The name of the LAMP was officially changed from the Lakewide Management Plan (LaMP) to the Lakewide Action and Management Plan (LAMP) in 2013 when the amended Great Lakes Water Quality Agreement (GLWQA) formally came into effect.

Project Scope

Since the focus of this project is to foster binational action to conserve and restore the biodiversity of Lake Superior, the scope will include the open waters of the lake (to the head of the St. Marys River), islands, coastal areas (roughly 2 km inland from the shoreline) and the watersheds of tributaries with a focus on how they affect the biodiversity of the lake (Figure 1.5).

Figure 1.5: Project Scope – Lake Superior Basin with major watersheds.



1.3 Approach and Methods

This report was developed based on the existing information on the biodiversity of Lake Superior and draws heavily from the biodiversity information previously developed by the LAMP (e.g., Important Habitat Sites and Areas in the Lake Superior Basin), the Great Lakes Fishery Commission's Fish-Community Objectives for Lake Superior, and the State of the Lakes Ecosystem Conference (SOLEC). The Biodiversity Conservation Strategies recently prepared for the other Great Lakes were also reviewed (Lake Ontario Biodiversity Strategy Working Group 2009; Franks Taylor et al. 2010; Pearsall, Carton de Grammont, Cavalieri, Chu et al. 2012; Pearsall, Carton de Grammont, Cavalieri, Doran et al. 2012). In addition, literature on Lake Superior was identified through a search of journal databases (e.g., Web of Knowledge, JSTOR) and information searches on the internet were also incorporated into an annotated bibliography. As Lake Superior was the last lake to have a Biodiversity Conservation Assessment completed, the project team also contacted several individuals involved in those projects to identify lessons-learned and recommended approaches.

A project team from the Lake Superior LAMP first developed a draft report based on this review of existing information. The assessment of biodiversity target health and the ranking of threats were done through the Conservation Action Planning (CAP) framework (The Nature Conservancy [TNC] 2007). CAP is a proven technique for planning, implementing and measuring success for conservation projects (Figure 1.6). The CAP process helps focus conservation strategies on clearly defined biodiversity targets and links threats to these biodiversity targets. While this project is just focussed on identifying biodiversity targets and threats, CAP leads to creating conservation strategies and measures within an adaptive management framework (TNC 2007). Details on how the CAP process was used to assess biodiversity target viability and rank threats are presented in these respective sections of the report.

Figure 1.6: Conservation Action Planning Framework

Mapping and spatial analysis was based upon existing information where possible. In some cases, GIS analyses were conducted where information was absent, or out of date. Appendix A provides a data catalogue and an outline of spatial analysis methods that were used for this project. In addition to a lakewide assessment, this project also described biodiversity conditions and issues within 20 regional units. These units were developed by the project team based on quaternary watersheds and coastal environments/SOLEC coastal units, with input from the Aquatic Communities Committee/ Lake Superior Technical Committee. This regional information is presented in a separate report (Volume Two).

The draft Biodiversity Conservation Assessment was shared with experts for their review. This process included webinars that introduced the project, and a series of webinars based on biodiversity targets and the regional summaries. In total, over 400 Lake Superior experts were contacted about the project and provided with an opportunity to review the draft information. Expert feedback was received in emails, in comments during the webinars, in direct comments on the draft report and in a review form that was distributed with the draft report. In total, feedback was received and incorporated into the report from over 80 experts. In some cases, the project team evaluated expertise of the experts, weighing more heavily the responses of those with demonstrated or self-identified expertise on a subject or region. This approach incorporates, in part, recommendations of Burgman et al. (2011) for expert elicitation.

2.0 Biodiversity Conservation Targets

Lake Superior contains a rich and diverse array of species, communities and ecosystems that include aquatic, terrestrial and wetland biomes. Following the Conservation Action Planning Framework, this project identified seven biodiversity conservation targets for Lake Superior (Table 2.1).

Table 2.1 Summary of Biodiversity Conservation Targets

Biodiversity Conservation Targets	**Definition**
Deepwater and Offshore Waters	>80 m depth
Nearshore Zone and Reefs	15-80 m depth
Embayments and Inshore	<15 m depth
Coastal Wetlands	Wetlands within 2 km of the coast
Islands	Natural and artificial islands
Coastal Terrestrial Habitats	Natural habitats within 2 km of the coast
Tributaries and Watersheds	Entire drainage area of Lake Superior including all tributaries and inland waters

These biodiversity targets represent and encompass the full array of biodiversity found in Lake Superior and are based on the major habitat types of the lake. Each of these biodiversity targets includes a suite of integrated and nested species and communities with similar conservation needs. By effectively conserving the major habitat types selected as biodiversity targets, these nested species and communities will also be conserved. For example, by conserving tributaries and watersheds, the needs of migratory fishes will also be met.

These biodiversity conservation targets were selected based on targets used by the Great Lakes conservation strategies (Lake Ontario Biodiversity Strategy Working Group 2009; Franks Taylor et al. 2010; Pearsall, Carton de Grammont, Cavalieri, Chu et al. 2012; Pearsall, Carton de Grammont, Cavalieri, Doran et al. 2012) and the Lake Superior LaMP 2006 (Lake Superior Binational Program [LSBP] 2006a). Information describing these targets, nested species and habitats, their extent and health is provided in this section. Maps depicting the distribution and health of these biodiversity targets and key nested features have been developed where data exists. Appendix A provides a summary of the spatial data layers used for this mapping.

Viability Assessment

To assess viability or health of each biodiversity target, all available indicators from the 2011 State of the Lakes Ecosystem Conference (SOLEC) reports for Lake Superior were summarized and linked to the biodiversity targets (see Appendix B). For each biodiversity target, the linked SOLEC indicators were translated into a Conservation Action Planning (CAP) viability category (i.e., good, fair and poor) based on the current status and trends of that indicator for Lake Superior. Each indicator was then scored and averaged using CAP methods to provide an overall assessment of the health of the biodiversity target (see Box 2.1). This approach to assessing target viability is consistent with the approach used for the Great Lakes biodiversity conservation strategies for the other lakes.

Box 2.1: Aggregation Rules for Viability Assessment (TNC 2007)
A numeric value is given to each graded indicator:
Very Good = 4.0[4]
Good = 3.5
Fair = 2.5
Poor = 1.0

The grade for the target is derived from the average of these numeric values using the following ranges:
Poor: 1.0 - 1.745
Fair: 1.75 - 2.995
Good: 3.0 - 3.745
Very Good: 3.75 - 4.0

Very Good	*Ecologically desirable status; requires little intervention for maintenance*
Good	*Within acceptable range of variation; may require some intervention for maintenance.*
Fair	*Outside of the range of acceptable variation and requires management. If unchecked, the biodiversity target may be vulnerable to serious degradation.*
Poor	*Allowing the biodiversity target to remain in this condition for an extended period will make restoration or preventing extirpation practically impossible.*

Some of these indicators were weighted to reflect their importance in assessing the viability of the biodiversity targets. SOLEC currently uses 18 indicators to represent overall conditions and trends of *aquatic dependent-life* in the Great Lakes. These indicators represent the different levels of the food-web and varied locations. These indicators include: Lake Trout, prey fish, diporeia, phytoplankton, coastal wetland fish, Lake Sturgeon (*Acipenser fulvescens*), and Walleye (*Sander vitreus*). Because this group of indicators are a direct representation of biotic health, they are weighted double in the viability assessment.

SOLEC indicators for *water quality*, *landscapes and natural processes* and *pressures* represent habitat conditions in which aquatic-life depend or, are impacted by, and are fully weighed in the assessment. Examples of these indicators include: water chemistry, aquatic habitat connectivity and aquatic non-native species. While *pressure* indicators represent stresses or threats to the biodiversity targets, many of these indicators are also inverse measures of health (e g. hardened shorelines) and were included in the biodiversity conservation strategies for the other lakes.

Some SOLEC indicators were only half-weighted, or not used in the viability assessment. SOLEC *impact* indicators (e.g., beach advisories, drinking water quality, botulism outbreaks) were half-weighted in the viability assessment. While these indicators are very important in assessing impaired human uses of the Great Lakes, their link to the health of biodiversity is not as direct as other SOLEC indicator categories.

The viability assessment did not include any SOLEC *response* indicators (e.g., treating waste water) as these indicators are not linked to target health.

Some SOLEC indicators that are still in development or are currently undetermined for Lake Superior were populated with recent information that informs their status (e.g., surface water temperatures are based on GLEAM (2012) data). These are: ice duration, land cover, terrestrial non-native species, surface water temperature, artificial coastal structures and hardened shorelines (see Appendix B for details on these indicators and their status).

[4] Only CAP categories of good, fair or poor were assigned to SOLEC indicators.

In addition to SOLEC indicators, a few selected additional indicators were added for some targets. These are published indicators that may not have wide application to the entire Great Lakes (and hence are not SOLEC indicators), but are good measures of target health for Lake Superior. Indicators were also added for targets that only had a few applicable SOLEC indicators (e.g., islands). "Lake Superior Indicators" that were added to the viability assessment are:

1. *Mysis relicta*. This freshwater shrimp supports nearshore and offshore fishes, and plays a pivotal role in the structure and function of the Lake Superior fish community (Isaac et al. 2012).
2. *Island Condition Class*. Based on the threats analysis for islands in Henson et al. (2010). Mean island threat class was assigned to all ten coastal environments from Lake Superior. This threat index is based on a number of factors including building density, land use, mining claims, boat launches and access for vehicles.
3. *Coastal Stress Index*. A condition index developed for this report based on artificial shores, building density and road density. This index was applied to the coastal wetlands and coastal terrestrial habitats (see Figure 2.1b and Appendix F).

Level of Confidence
For each target, a level of confidence was applied to the overall assessment of viability. This is based on the number and applicability of SOLEC indicators, and other published information. The following categories were applied:

Higher: There are many SOLEC indicators that are directly linked to target health. A large amount of current information is available. The viability ranking has a very high probability of reflecting the overall health of the target in Lake Superior.

Medium: There are some SOLEC indicators that are directly linked to target health. A fair amount of current information is available. The viability ranking has a good probability of reflecting the overall health of the target in Lake Superior.

Lower: There are only a few SOLEC indicators that are directly linked to target health. Limited or outdated information was available. There is uncertainty in viability ranking reflecting the overall health of the target in Lake Superior.

For each target, the number of potential SOLEC indicators that are under development is indicated. Application of some of these indicators may improve both the status and level of confidence of the viability rankings in the future.

Regional Variability of Biodiversity Health
The purpose of both SOLEC indicators and this CAP viability assessment is to provide a lakewide summary of the health of Lake Superior. For many biodiversity targets, health varies greatly between different occurrences and different regions of the lake. Lakewide assessment and reporting are very important for highlighting overall status, trends and issues and informing lakewide actions, but may not be applicable (or even useful) to every region. For each biodiversity target, the amount of regional variability for the overall biodiversity assessment is indicated based on information in the literature and expert review.

While SOLEC indicators cannot be applied to every region around Lake Superior to provide a more local assessment of biodiversity health, there have recently been a number of reports that have generated indices of condition or stress including Great Lakes Cumulative Stress (GLEAM 2012; Allan et al. 2013) and Watershed Stress Index (GLEI 2013). Linking these indices to the viability of the biodiversity targets can provide a tool to validate the lakewide assessment using SOLEC indicators, and provide greater regional resolution on biodiversity health. Table 2.2 provides a summary of these condition/stress indices and how they can be linked to the health of the biodiversity targets. Information from these indices has been used to help identify the health of biodiversity targets in different regions of Lake Superior (see Section 4 of this report on regional summaries). Basin-wide maps of these indices are shown in Figures 2.1a-c.

Table 2.2: Biodiversity Targets and Associated Indices of Health

Biodiversity Target	**Linked Condition/Stress Index** **Reference**
Deepwater and Offshore Waters	Great Lakes Cumulative Stress (GLEAM 2012; Allan et al. 2013)
Nearshore Zone and Reefs	Great Lakes Cumulative Stress (GLEAM 2012; Allan et al. 2013)
Embayments and Inshore	Great Lakes Cumulative Stress (GLEAM 2012; Allan et al. 2013) Watershed Stress Index (GLEI 2013)
Coastal Wetlands	Watershed Stress Index (GLEI 2013) Coastal Condition Index (developed for this report) Great Lakes Cumulative Stress (GLEAM 2012; Allan et al. 2013)
Islands	Coastal Condition Index (developed for this report) Island Condition Score (Henson et al. 2010)[5]
Coastal Terrestrial Habitats	Coastal Condition Index (developed for this report)
Tributaries and Watersheds	Watershed Stress Index (GLEI 2013)

[5] The Island Condition Score (Henson et al. 2010) was also used to assess the health of islands (see this section), but was not mapped. The Coastal Stress Index provides similar results and provides a common measure for the coastal areas of islands and the mainland.

Figure 2.1: Indices of Biodiversity Health for Lake Superior (3 figures)

Figure 2.1a: Watershed Stress Index

Developed by the Great Lakes Environmental Indicators (GLEI) project in 2013 for all of the Great Lakes (GLEI 2013). The original GLEI stress gradient, developed for the U.S. side of the Great Lakes basin was based on 207 variables from 19 sources (Danz et al. 2007; L. Johnson, pers. comm., March 25 2013). When mapping was extended to the Canadian side of the basin the data content, Sum-Rel (Host et al. 2011), was simplified to relative scores for 5 data layers which reflect human-derived stresses to ecological condition:

- Agricultural land use
- Percent developed
- Road density
- Point sources of pollution
- Human population density

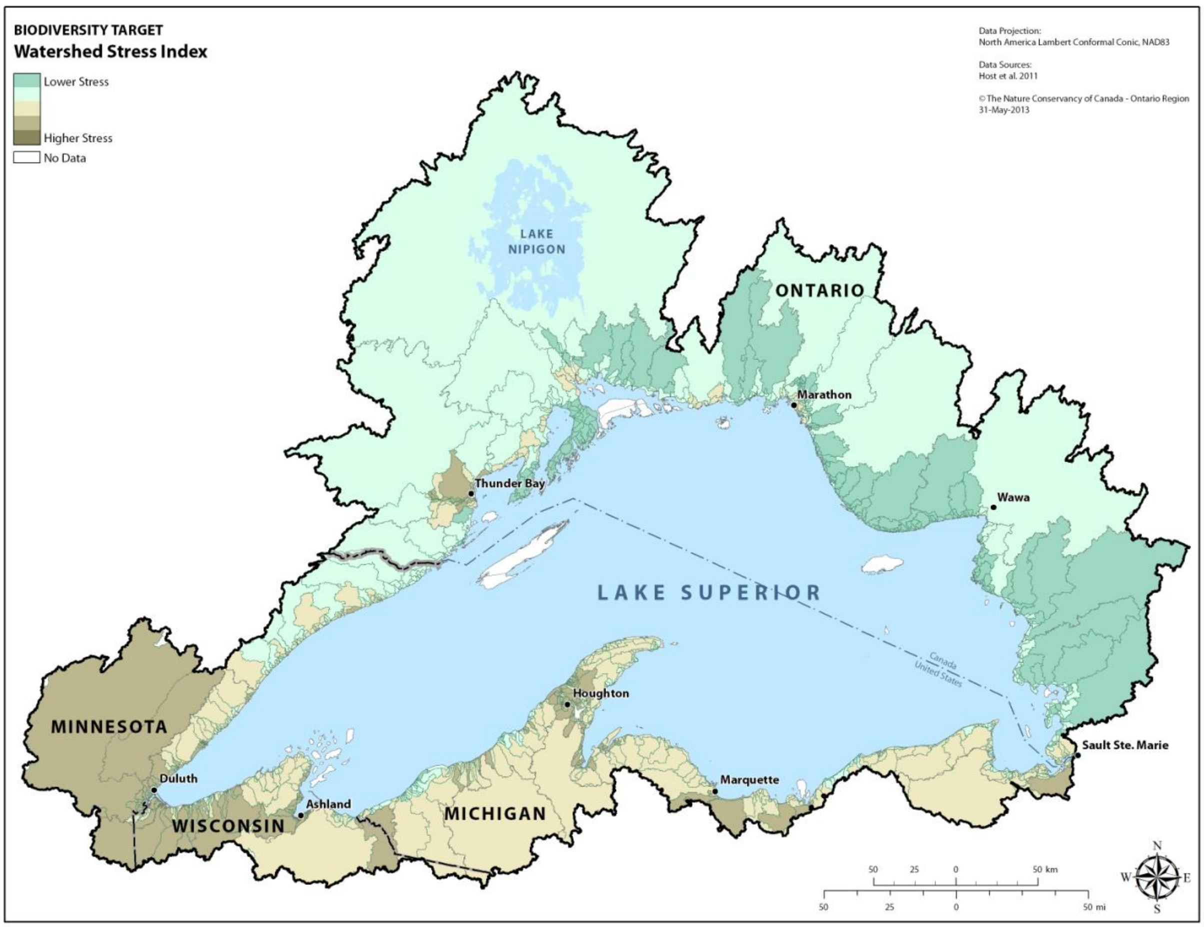


Figure 2.1b: Coastal Stress Index

The **Coastal Stress Index** for Lake Superior was developed for this project and is based on similar units and criteria used for the biodiversity conservation strategies for the other Great Lakes. Coastal units are based on the intersection of the quaternary watershed and coast, and a 2 km inland buffer. Criteria used are:

- Artificial shoreline
- Road density
- Building density
- Natural land cover on the coast
- Natural land cover in the watershed

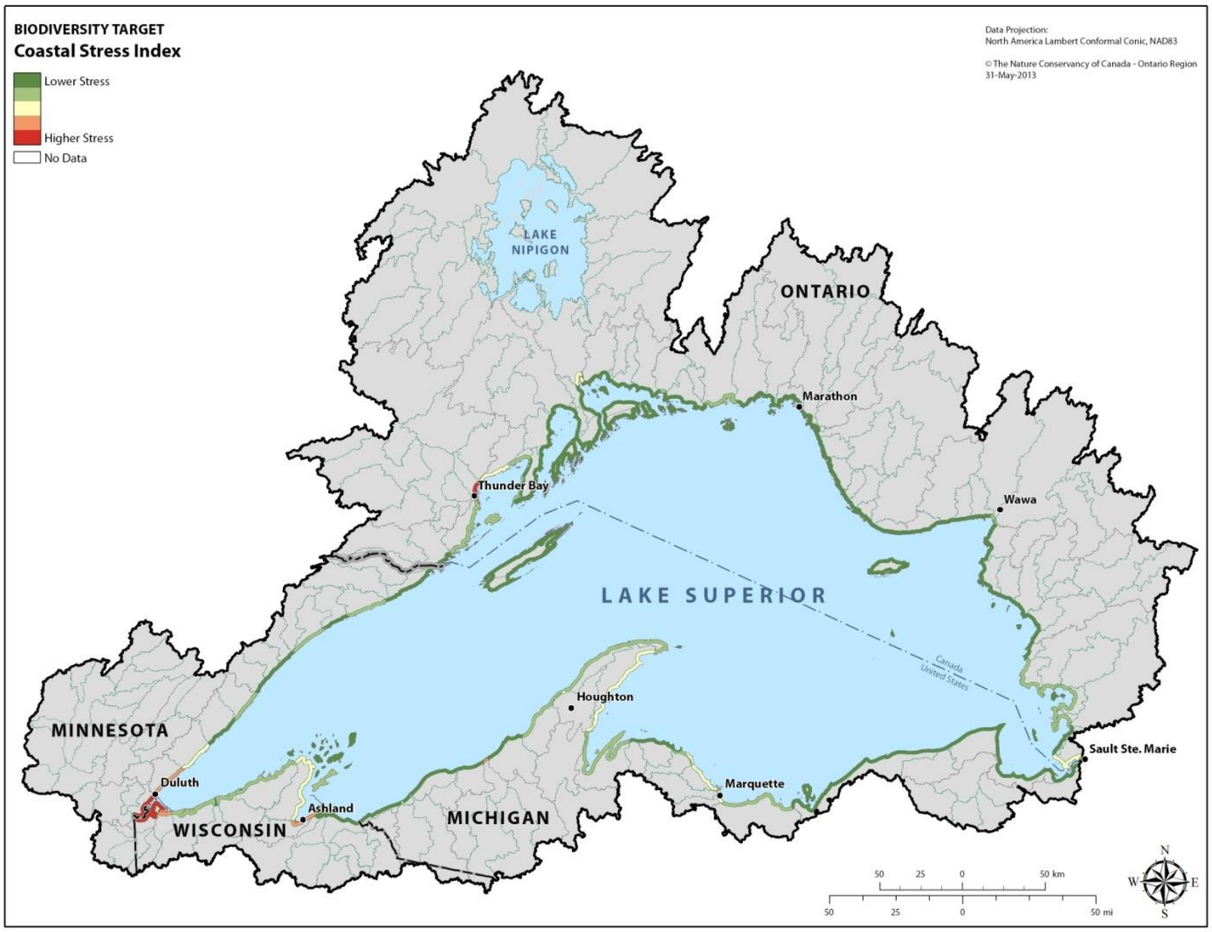
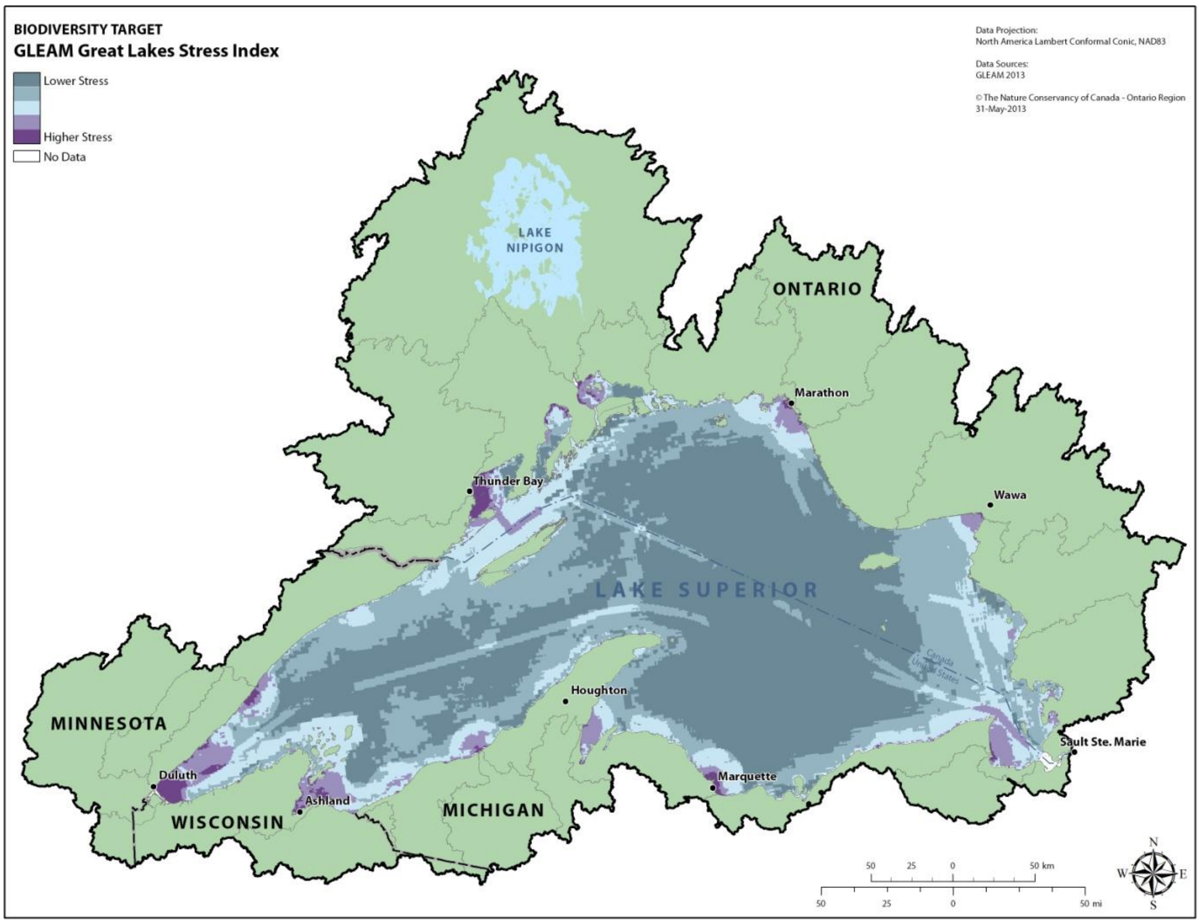


Figure 2.1c: Great Lakes Stress Index

The **Great Lakes Stress Index** was developed by the Great Lakes Assessment and Mapping (GLEAM) project in 2012 for all of the Great Lakes (GLEAM 2012; Allan et al. 2013). The **Great Lakes Stress Index** is based on 34 stressors in seven categories:

- Aquatic habitat alterations
- Climate change
- Coastal development
- Fisheries management
- Invasive species
- Non-point source pollution
- Toxic chemical pollution



Overall Viability Assessment of Lake Superior

Based on the health of the seven biodiversity conservation targets, the overall viability assessment for Lake Superior is "good" (Table 2.3) – the lake is in a state of health that is within the natural range of variation, but some management intervention may be required for some elements.

The only biodiversity target with a "fair" ranking is tributaries and watersheds. This target falls below the CAP threshold for good because several of the indicators are ranked as fair, including the status of some migratory fishes such as Lake Sturgeon, and the lack of aquatic habitat connectivity. The nearshore zone and reefs, and embayments and inshore biodiversity targets were both assessed as "good", but are near the threshold for fair. This is also driven by "fair" rankings for some nearshore fish species, and a large number of landscape drivers and pressures.

Table 2.3 Summary of Biodiversity Conservation Targets

Biodiversity Conservation Targets	**Overall Viability**
Deepwater and Offshore Waters	GOOD
Nearshore Zone and Reefs	GOOD (near FAIR)
Embayments and Inshore	GOOD (near FAIR)
Coastal Wetlands	GOOD
Islands	GOOD
Coastal Terrestrial Habitats	GOOD
Tributaries and Watersheds	FAIR

Very Good	*Ecologically desirable status; requires little intervention for maintenance.*
Good	*Within acceptable range of variation; may require some intervention for maintenance.*
Fair	*Outside of the range of acceptable variation and requires management. If unchecked, the biodiversity target may be vulnerable to serious degradation.*
Poor	*Allowing the biodiversity target to remain in this condition for an extended period will make restoration or preventing extirpation practically impossible.*

The following section provides detail on each of the biodiversity targets, the indicators used to assess them, and their viability assessments.

Lake Superior Biodiversity Conservation Target
2.1 Deepwater and Offshore Waters

Description and Distribution

This biodiversity target includes the offshore waters of Lake Superior that are >80 m in depth and includes both benthic and pelagic (bottom and open water) habitats. Approximately 77% of Lake Superior is characterized by these deep, cold waters (Figure 2.2). The deepest areas occur in the central portion of the lake and along the coast in the western basin.

Lake Trout are an important species for the commercial and recreational fishery in Lake Superior. A study by Minnesota Sea Grant found that recreational fishing in Lake Superior has an estimated economic impact of $12.67M-17.54M annually for that state alone.
Image: http://samcook.areavoices.com/samcook/images

The offshore waters of Lake Superior provides habitat for a number of native fishes, and the offshore fish community is predominately made up of native fish species, including siscowet Lake Trout (*Salvelinus namaycush siscowet*), Cisco (*Coregonus artedi*), Deepwater Sculpin (*Myoxocephalus thompsonii*), Kiyi (*Coregonus kiyi*) and Burbot (*Lota lota*), as well as Bloater (*Coregonus hoyi*) and Shortjaw Cisco (*Coregonus zenithicus*) (Stockwell et al. 2010b).

Lake Trout are the top predator in this deepwater ecosystem, and nearly all of Lake Superior provides important habitat. Lake Trout were historically adapted to a wide range of depths in Lake Superior. Siscowet Lake Trout were historically common throughout the offshore waters, while Humper Lake Trout are present on offshore shoals or banks surrounded by deepwater habitat. Recent work by Muir et al. (2014) has demonstrated quantitative evidence of another Lake Trout morph, the “redfin”, in the waters off Isle Royale. In typical offshore fish communities, deepwater ciscoes (Kiyi and Bloater) and deepwater sculpin were the main prey of these deepwater Lake Trout (Horns et al. 2003). The offshore fish community is supported by Mysis shrimp. Mysis exhibit diurnal vertical migration to find zooplankton and avoid predation. Deepwater ciscoes track the Mysis, and are in turn followed by Lake Trout. In this way, energy and nutrients are transferred vertically between the benthic and pelagic zones of this ecosystem (Gorman et al. 2012a).

Deepwater ciscoes and Lake Trout reproduce and grow slowly, but represent a large amount of the energy and biomass in this ecosystem (Horns et al. 2003). For several fish species, including deepwater Lake Trout forms, ciscoes and sculpins, this offshore habitat encompasses nearly their entire spawning and feeding habitat. For some offshore fish species, their life cycle and habitats remain largely unknown (Horns et al. 2003).

Nested Species and Habitat Targets

- Bloater
- Burbot
- Cisco
- Siscowet Lake Trout
- Humper Lake Trout
- Deepwater Sculpin
- Kiyi
- Shortjaw Cisco
- phytoplankton and zooplankton
- benthic invertebrates
- forage fishes

Viability Assessment

The overall health of the deepwater and offshore ecosystem is "good". This assessment is starting to approach the threshold for "fair" and there are several indicators that are fair or even poor (see Table 2.5). The viability assessment is driven by the good health of Lake Trout and lower food chain species (e.g., Diporeia, Mysis, phytoplankton). Indicators of greatest concern include decreasing ice cover and rising air and water temperatures, and toxic chemicals which could impact this ecosystem. A high level of confidence was assigned to the viability assessment because most indicators are currently available. Regional variability is ranked as lower since the offshore ecosystem is highly connected.

Table 2.4 Overall Viability Assessment of Deepwater and Offshore Waters

OVERALL VIABILITY ASSESSMENT	GOOD (3.13)
CONFIDENCE	HIGHER
REGIONAL VARIABILITY	LOWER
Number of Indicators/ Total Score	17/75
Number of Lake Superior Indicators Used	1
Number of Weighted Indicators (x2)	7
Number of Weighted Indicators (x0.5)	0
Number of Potential SOLEC Indicators in Development	3

Of all the aquatic habitat zones in Lake Superior, the offshore zone has been reported as the least impacted (Gorman et al. 2010b), although it has been altered by human activities. From the time of early European settlement to the 1960s deepwater fishes were in decline, with the 1960s described as the "period of maximum degradation" (Horns et al. 2003, p. 12). Commercial fishing of Lake Trout, Lake Sturgeon, Cisco, Lake Whitefish (*Coregonus clupeaformis*) and deepwater ciscoes caused some of these species to become rare (Horns et al. 2003). The introduction of non-native species also affected offshore fish distributions and food webs. Sea Lamprey (*Petromyzon marinus*) had a significant impact on Lake Trout populations. Rainbow Smelt (*Osmerus mordax*) colonized Lake Superior, and by the 1950s they had largely replaced Cisco and whitefish as the major prey item for Lake Trout. The smelt remained in nearshore areas, as opposed to the more wide-ranging Cisco, and as a result offshore predators lost a significant portion of their prey and changed their behaviour and distribution (Horns et al. 2003).

The fish community in Lake Superior has recovered in the last few decades and is now closer to the preferred community, with the recovery of Lake Trout and ciscoes. An offshore fish community with Lake Trout as the dominant top predator is identified in *Fish-Community Objectives for Lake Superior* and the deepwater and offshore zone likely contains enough high-quality habitat to meet these fish community objectives if Sea Lamprey can continue to be controlled (Horns et al. 2003).

This habitat zone has received less attention than some other zones, largely due to the fact that a relatively small amount of data was available until recently (Stockwell et al. 2010a).

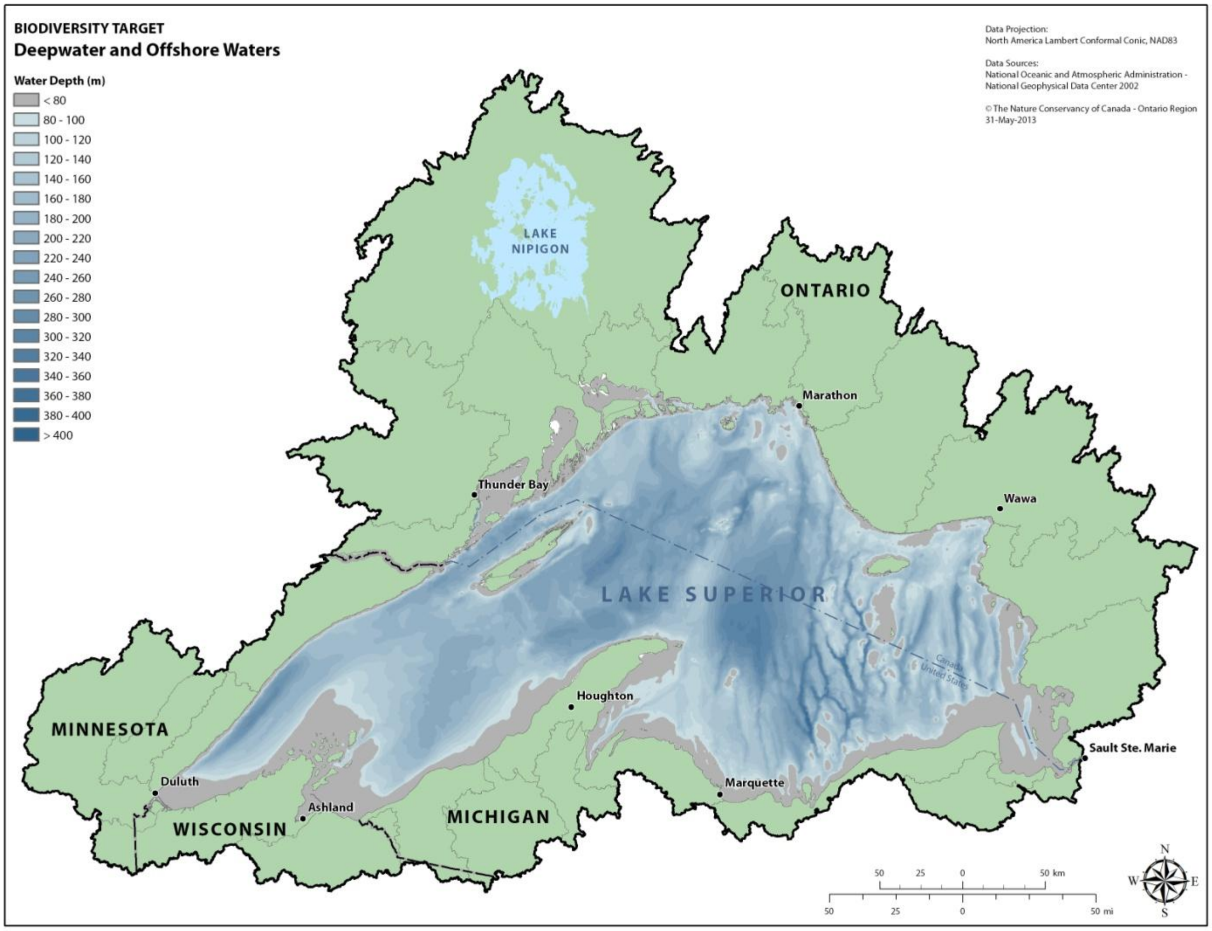
Table 2.5: Ecosystem Indicators for the Health of Deepwater and Offshore Waters
SOLEC Status and Trends for Lake Superior Indicators

Indicator (Weighting)	**Lake Superior** **Status and Trend**
Atmospheric Deposition (x1)	Fair/ Improving (for polycyclic aromatic hydrocarbons [PAHs], organochlorine pesticides, dioxins and furans) / Unchanging or slightly improving (for polychlorinated biphenyls [PCBs] and mercury) Overall assessment only
Benthos (Freshwater Oligochaete) Diversity and Abundance (x2)	Good/ Unchanging
Contaminants in Whole fish (x1)	Fair/ Deteriorating
Diporeia (x2)	Good/ Unchanging
Fish Habitat (x1)	To be developed for SOLEC 2016 See2006 LaMP report This indicator is being developed with the support of the *Great Lakes Basin Fish Habitat Partnership*
Ice Duration (x1)	Poor/ In preparation Overall, the spatial extent of Great Lakes ice cover has decreased by 71% in the past 40 years. These changes have been significant on Lake Superior (Wang et al. 2012).
Lake Trout (x2)	Good/ Improving
Land Cover (x1)	Good/ In preparation Land cover in the Lake Superior basin is dominated by natural cover
Major Ions (x1)	To be developed for SOLEC 2016
Mysis Density (x2)	Good Lake Superior indicator (see Appendix B)
Nutrients in Lakes (x1)	Good/ Unchanging
Phytoplankton (x2)	Good/ Unchanging
Preyfish Populations (x2)	Fair/ Improving
Sea Lamprey (x1)	Fair/ Improving
Sediment Coastal Nourishment (x1)	To be developed for SOLEC 2016
Surface Water Temperature (x1)	Fair/ Undetermined Increasing
Toxic Chemicals in Offshore Waters (x1)	Fair/ Undetermined
Water Chemistry (x1)	*Specific Conductance:* Increasing *Total Chloride:* No Change *pH:* No Change *Total Alkalinity:* No Change *Turbidity:* Increasing
Water Clarity (x1)	Good /Undetermined/ Mostly improving
Zooplankton Biomass (x2)	Good/ Unchanging

Viability Rankings of SOLEC Indicators

Very Good	*Ecologically desirable status; requires little intervention for maintenance*
Good	*Within acceptable range of variation; may require some intervention for maintenance.*
Fair	*Outside of the range of acceptable variation and requires management. If unchecked, the biodiversity target may be vulnerable to serious degradation.*
Poor	*Allowing the biodiversity target to remain in this condition for an extended period will make restoration or preventing extirpation practically impossible.*

Figure 2.2: Deepwater and Offshore Waters. Blue shades depict regions of Lake Superior with water depths greater than 80 metres. Grey shade depicts regions of Lake Superior with less than 80 metres of water depth.



Lake Superior Biodiversity Conservation Target
2.2 Nearshore Zone and Reefs

Description and Distribution

The nearshore zone is defined by a water depth of 15 to 80 metres including the lakebed and water column. Reefs may have more shallow waters (See Figure 2.3).

Nearshore habitat is most extensive at the east and west ends of Lake Superior (Lake Superior Binational Program [LSBP] 2000). The waters surrounding islands, such as Isle Royale and Michipicoten Island, are another important location of nearshore habitat. Areas of shallow water in the offshore also provide nearshore habitat including the Superior Shoal and the Caribou Island Reef Complex (LSBP 2000). The nearshore zone accounts for approximately 16% of Lake Superior's surface area. Lake Superior's major sport and commercial fisheries are located in the nearshore zone (Horns et al. 2003).

The Pygmy Whitefish (Prosopium coulterii) occurs in northwestern North America and Siberia, with a unique disjunct population in Lake Superior. This fish reaches a size of only 16 cm and occurs primarily in nearshore waters at depths of 18-89 m in Lake Superior (NatureServe 2013).
Image: http://www.seattle.gov/util/Environment Conservation/

Though much smaller than the offshore zone, nearshore waters are very important. These warmer waters have a greater diversity of substrate types, and aquatic vegetation is only found in nearshore and inshore habitats (LSBP 2000). The nearshore zone is highly productive and supports waterfowl staging and feeding areas. Most of the fishes in Lake Superior use the nearshore zone during some part of their life cycle (LSBP 2000), including as critical spawning habitat for lean Lake Trout, Cisco, and Lake Whitefish (Horns et al. 2003) (Figure 2.4). Lean Lake Trout and siscowet Lake Trout are the dominant predators in the nearshore community, as well as in shallow offshore reefs (Horns et al. 2003). Recent evidence of another Lake Trout morph, the "redfin" in the waters off Isle Royale has been described by Muir et al. (2014). The extent of redfin Lake Trout distribution in Lake Superior has yet to be determined. Some of the fish species that are found in nearshore habitats may also spend some of their life in tributaries (e.g., Lake Sturgeon and Walleye) (Horns et al. 2003).

Nested Species and Habitat Targets

- Walleye
- Lake Sturgeon
- Brook Trout (*Salvelinus fontinalis*)
- Siscowet Lake Trout
- Humper Lake Trout
- Lean Lake Trout
- Burbot
- Cisco
- Lake Whitefish
- Round Whitefish (*Prosopium cylindraceum*)
- Ninespine Stickleback (*Pungitius pungitius*)
- Trout-perch (*Percopsis omiscomaycus*)
- Pygmy Whitefish
- Slimy Sculpin (*Cottus cognatus*)
- Deepwater Sculpin
- Longnose Sucker (*Catostomus catostomus*)
- White Sucker (*Catostomus commersonii*)
- Shorebirds
- Waterfowl
- Benthic macroinvertebrates
- Native mussels
- Forage fishes
- Spawning habitat for deepwater fishes (e.g., deepwater ciscoes and sculpins)

Viability Assessment

The overall health of the nearshore and reef ecosystem is "good", although this assessment is approaching the threshold for "fair" and there are several indicators that are fair and poor (see Table 2.7). The viability assessment is driven by the good health of Lake Trout and lower food chain species (e.g., Diporeia, Mysis, phytoplankton), and the adjacent coastal areas and watersheds. Indicators of greatest concern include decreasing ice cover and aquatic invasive species which could impact this ecosystem. Both the level of confidence and regional variability were assigned a medium category. Approximately 50% of the indicators are not currently available, and there will be some variation in the conditions between nearshore areas.

Table 2.6: Overall Viability Assessment of Nearshore Zone and Reefs

OVERALL VIABILITY ASSESSMENT	GOOD (3.00)
CONFIDENCE	MEDIUM
REGIONAL VARIABILITY	MEDIUM
Number of Indicators/ Total Score	27/103.25
Number of Lake Superior Indicators Used	1
Number of Weighted Indicators (x2)	9
Number of Weighted Indicators (x0.5)	3
Number of Potential SOLEC Indicators in Development	12

Although generally in good health, the nearshore zone of Lake Superior is generally impacted more than the offshore zone, as the proximity to the shore and to human populations increases the number of stressors. Rainbow Smelt became abundant in Lake Superior from the 1930s through the 1950s, and became the main component of the nearshore prey community until a significant decline took place in the early 1980s (Horns et al. 2003). They remain a large portion of the nearshore food web, despite lower numbers.

Many nearshore fish species have been impacted by a decrease in habitat quality. Brook Trout (*Salvelinus fontinalis*) were easily caught by sport anglers in nearshore waters, and this contributed to their early and rapid decline (Horns et al. 2003; Newman et al. 2003). Lean Lake Trout were nearly wiped out by the combination of fishing and the aquatic invasive Sea Lamprey (Horns et al. 2003). Nearshore populations of Lake Sturgeon, Walleye and Brook Trout remain lower than historical levels (Gorman et al. 2010b, Horns et al. 2003). However, in some areas progress towards their rehabilitation is underway. For example, Lake Sturgeon abundance may be increasing in some areas along the south shore of Lake Superior (D. Caroffino, pers. comm., March 20 2013; Gorman et al. 2010b).

In the nearshore zone there is probably sufficient habitat to achieve lakewide fish community objectives; however in some regions the remaining suitable habitat is not sufficient[6] (Horns et al. 2003). Protection and rehabilitation of the nearshore zone is recognized as an important objective for protecting the diversity of fish species in Lake Superior (Horns et al. 2003).

[6] See embayments target

Table 2.7: Ecosystem Indicators for the Health of Nearshore Zone and Reefs
SOLEC Status and Trends for Lake Superior Indicators

Indicator (Weighting)	**Lake Superior** **Status and Trend**
Aquatic Non-Native Species (x1)	Poor/ Deteriorating
Atmospheric Deposition (x1)	Fair/ Improving (for PAHs, organochlorine pesticides, dioxins and furans) / Unchanging or slightly improving (for PCBs and mercury) Overall assessment only
Bacterial Loadings from Tributaries	To be developed for SOLEC 2016
Bald Eagles (x2)	To be developed for SOLEC 2016
Benthos (Freshwater Oligochaete) Diversity and Abundance (x2)	Good/ Unchanging
Botulism Outbreaks (x0.5)	Undetermined/ No Change
Contaminants in Waterbirds (x1)	Good/ Improving
Contaminants in Whole fish (x1)	Fair/ Deteriorating
Contamination in Sediment (x1)	Good/ Unchanging
Diporeia (x2)	Good/ Unchanging
Dreissenid Mussels (x1)	Good/ Unchanging
Endocrine Disruption (x0.5)	To be developed for SOLEC 2016
Fish Consumption Restrictions (x0.5)	Fair/ Undetermined
Fish Disease Occurrences (x0.5)	To be developed for SOLEC 2016
Fish Habitat (x1)	To be developed for SOLEC 2016 See2006 LaMP report This indicator is being developed with the support of the *Great Lakes Basin Fish Habitat Partnership*
Forest Cover (x1)	Component 1: Percent of forested lands within a watershed Good/ Improving Component 2: Percent of forested lands within riparian zones Good/ TDB
Groundwater Quality (x1)	To be developed for SOLEC 2016
Harmful Algal Blooms (x0.5)	Good/ Undetermined
Ice Duration (x1)	Poor/ In preparation Overall, the spatial extent of Great Lakes ice cover has decreased by 71% in the past 40 years. These changes have been significant on Lake Superior (Wang et al. 2012).
Industrial Loadings (x1)	To be developed for SOLEC 2016
Lake Sturgeon (x2)	Fair/ Improving
Lake Trout (x2)	Good/ Improving
Land Cover (x1)	Good/ In preparation Land cover in the Lake Superior basin is dominated by natural cover
Major Ions (x1)	To be developed for SOLEC 2016
Municipal Wastewater Loadings (x1)	To be developed for SOLEC 2016
Mysis Density (x2)	Good Lake Superior indicator (see Appendix B)
Nutrients in Lakes (x1)	Good/ Unchanging
Phytoplankton (x2)	Good/ Unchanging
Precipitation Events (x1)	Undetermined/ Increasing Overall assessment only.
Preyfish Populations (x2)	Fair/ Improving
Sediment Coastal Nourishment (x1)	To be developed for SOLEC 2016
Surface Water Temperature (x1)	Undetermined/ Increasing
Threatened Species (x2)	To be developed for SOLEC 2016
Tributary Flashiness (x1)	St. Louis River (Lake Superior Basin) Good/ Improving
Walleye (x2)	Fair/ Undetermined

Indicator (Weighting)	**Lake Superior** **Status and Trend**
Water Chemistry (x1)	*Specific Conductance:* Increasing *Total Chloride:* No Change *pH:* No Change *Total Alkalinity:* No Change *Turbidity:* Increasing
Water Clarity (x1)	Good/Undetermined/ Mostly improving
Watershed Stressor Index (x1)	Fair In preparation – status of fair assigned based on average basin-wide index of 63/100
Zooplankton Biomass (x2)	Good/ Unchanging

Viability Rankings of SOLEC Indicators

Very Good	*Ecologically desirable status; requires little intervention for maintenance*
Good	*Within acceptable range of variation; may require some intervention for maintenance.*
Fair	*Outside of the range of acceptable variation and requires management. If unchecked, the biodiversity target may be vulnerable to serious degradation.*
Poor	*Allowing the biodiversity target to remain in this condition for an extended period will make restoration or preventing extirpation practically impossible.*

Figure 2.3: Nearshore Zone and Reefs. Blue shades depict regions of Lake Superior of the nearshore zone, with water depths of 15 to 80 metres. Several reef locations are also identified.

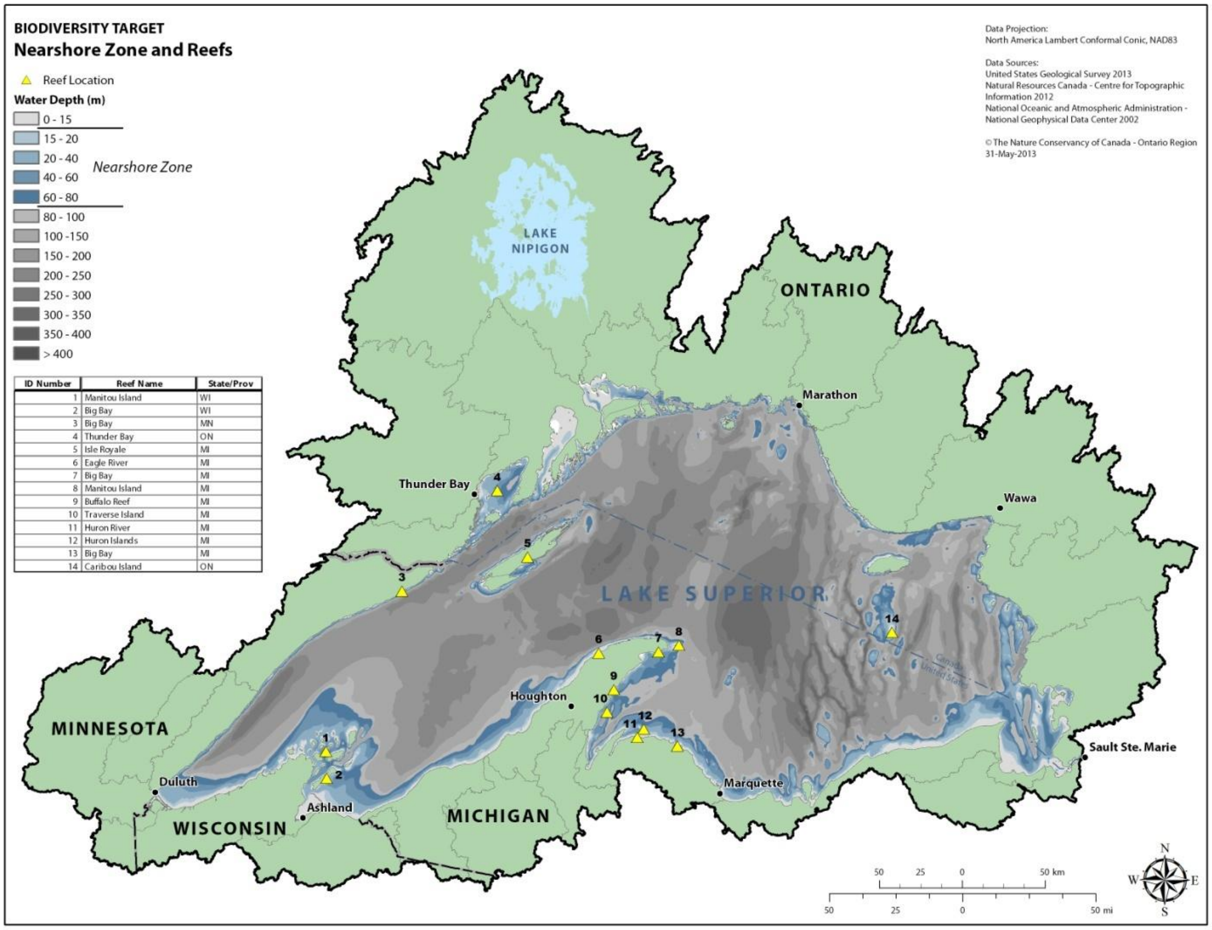
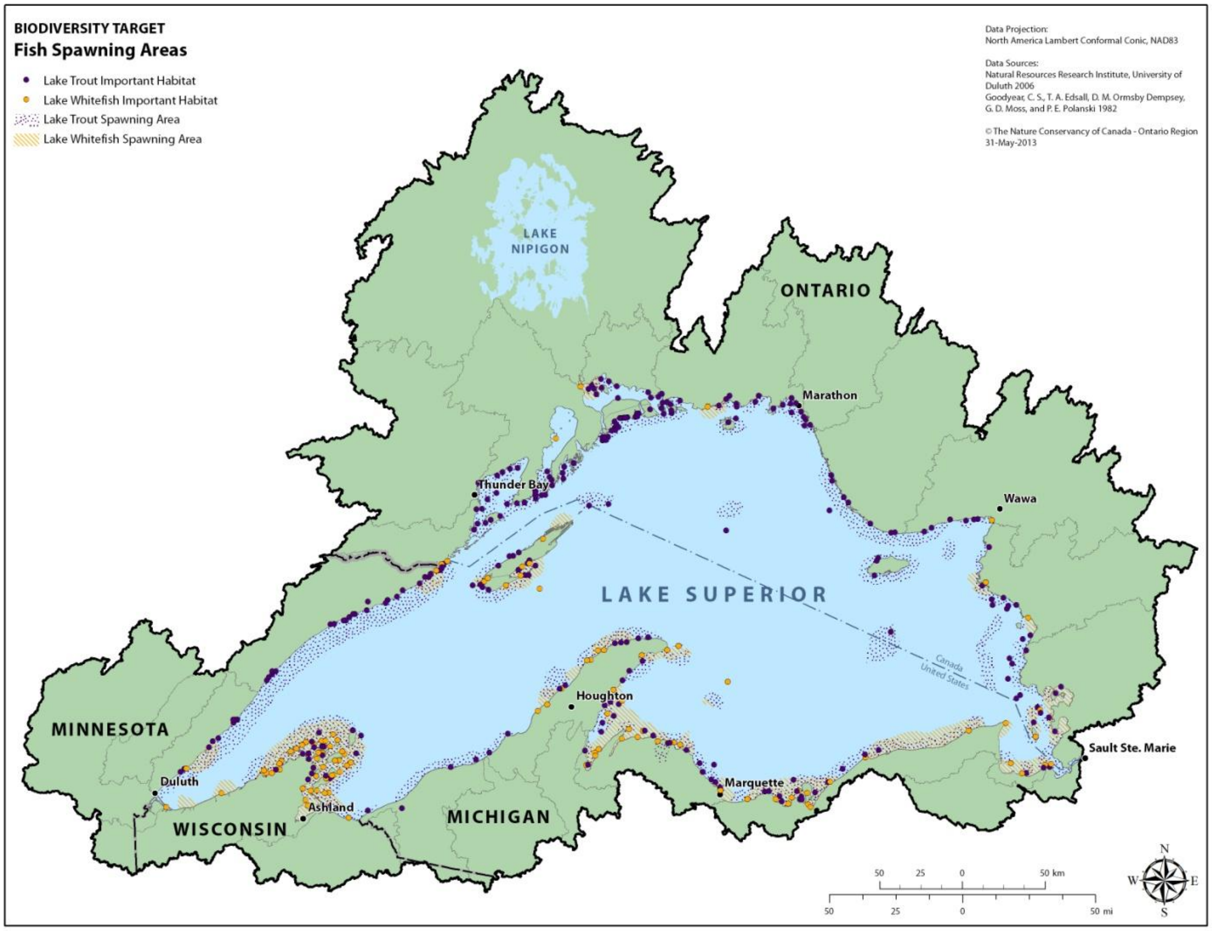


Figure 2.4: Lake Trout and Lake Whitefish Spawning Areas. Shaded areas denote current and historic spawning areas for these fishes. The point data generally reflect more accurate locations of current spawning areas.



Lake Superior Biodiversity Conservation Target
2.3 Embayments and Inshore

Description and Distribution

Embayments and the inshore zone occur at depths of 0 to 15 metres. Embayments are connected to Lake Superior, but have unique physical properties because they are partially protected by land from some of the physical dynamics that occur in Lake Superior.

Inshore areas and embayments account for approximately 7% of the area of Lake Superior. Major embayments include Black Bay, Nipigon Bay, Thunder Bay, Batchawana Bay, Keweenaw Bay and Chequamegon Bay (LSBP 2000) (Figure 2.5).

Nipigon Bay is located along the northern coast of Lake Superior. Embayments are warmer and shallower than most of the lake, and more susceptible to pollution. Most of Lake Superior's Areas of Concern are in embayments.
Image: http://www.northshorerap.ca/

Embayments include natural bays and harbours, as well as estuaries (Gorman et al. 2010a; Gorman et al. 2010b). Although the combined size of inshore areas and embayments is small when compared to the overall size of Lake Superior, these habitats are critical for the fish abundance and diversity throughout Lake Superior, since these areas provide spawning and nursery habitat for many nearshore and offshore fish species (Gorman et al. 2010a; Gorman et al. 2010b). Inshore areas are warmer and more productive and diverse than other lake zones. Zooplankton concentrations reach their highest levels in inshore areas, especially in major embayments (LSBP 2000), and embayments often have communities of submerged aquatic plants. Fish communities found in embayments are very diverse and include both warm-water and cool-water species, including Walleye, Smallmouth Bass (*Micropterus dolomieu*), Yellow Perch (*Perca flavescens*), Rock Bass (*Ambloplites rupestris*), Northern Pike (*Esox lucius*), Trout-perch, Lake Sturgeon, Brook Trout, Ninespine Stickleback, Johnny Darter (*Etheostoma nigrum*), Emerald Shiner (*Notropis atherinoides*), Longnose Dace (*Rhinichthys cataractae*), Sand Shiner (*Notropis stramineus*), Black Bullhead (*Ameiurus melas*), Shorthead Redhorse (*Moxostoma macrolepidotum*) and Silver Redhorse (*Moxostoma anisurum*) (Horns et al. 2003). Some fish species, such as Longnose Dace, Rock Bass and Smallmouth Bass use the inshore habitats for all life stages (Gorman et al. 2010b; Pratt et al. 2010). Recent reports on the inshore zone indicate that these fish communities are dominated by stable populations of native species (Gorman et al. 2010a).

Nested Species and Habitat Targets

- Walleye
- Lake Sturgeon
- Brook Trout
- Burbot
- Cisco
- Lake Whitefish
- Round Whitefish
- Ninespine Stickleback
- Pygmy Whitefish
- Longnose Sucker
- White Sucker
- Shorebirds
- Waterfowl
- Benthic macroinvertebrates
- Aquatic plant communities
- Native mussels
- Forage fishes
- Spawning habitat for some deepwater and nearshore fishes (e.g., Lake Whitefish and Lake Trout)

Viability Assessment

The overall health of the embayment and inshore ecosystem is “good”, although this assessment is approaching the threshold for “fair” and there are several indicators that are fair or even poor (see Table 2.9). The viability assessment is driven by the good health of Lake Trout (spawning habitat) and lower food chain species, and the adjacent coastal areas and watersheds. Indicators of greatest concern include decreasing ice cover and aquatic invasive species which could impact this ecosystem. The level of confidence is higher for the overall viability assessment because two-thirds of the indicators are available. Regional variability is assigned a medium category as there is variation in the conditions between inshore and embayment areas, largely due to adjacent land use.

Table 2.8: Overall Viability Assessment of Embayment and Inshore

OVERALL VIABILITY ASSESSMENT	GOOD (3.00)
CONFIDENCE	HIGHER
REGIONAL VARIABILITY	MEDIUM
Number of Indicators/ Total Score	30/106.75
Number of Lake Superior Indicators Used	0
Number of Weighted Indicators (x2)	8
Number of Weighted Indicators (x0.5)	5
Number of Potential SOLEC Indicators in Development	12

Embayments, wetlands and tributaries have historically been the zones with the greatest habitat concerns, owing to their closer proximity to human populations and numerous associated stressors (Horns et al. 2003; Gorman et al. 2010b). Many embayments and the inshore zones have been subject to environmental stresses which have impacted fish communities (e.g., removal of aquatic vegetation from Batchawana Bay affecting Yellow Perch, Smallmouth Bass and cyprinids; and mercury contamination from a pulp mill in Peninsula Harbor affecting all species) (Horns et al. 2003). In many bays the loss of coastal wetlands has negatively affected species such as Yellow Perch, Walleye and Northern Pike (Horns et al. 2003). A number of Areas of Concern (AOCs) in Lake Superior are located in embayments (See Threats section).

Loss of habitat remains an issue in embayment areas (Horns et al. 2003). In the larger nearshore zone there is probably sufficient habitat to achieve the fish community objectives; however for the embayment target there may not be sufficient suitable habitat remaining (Horns et al. 2003). The embayment habitat of Lake Superior is subject to dredging, break walls, discharges from vessels and industry, and filling of wetlands (Horns et al. 2003).

Table 2.9: Ecosystem Indicators for the Health of Embayments and Inshore
SOLEC Status and Trends for Lake Superior Indicators

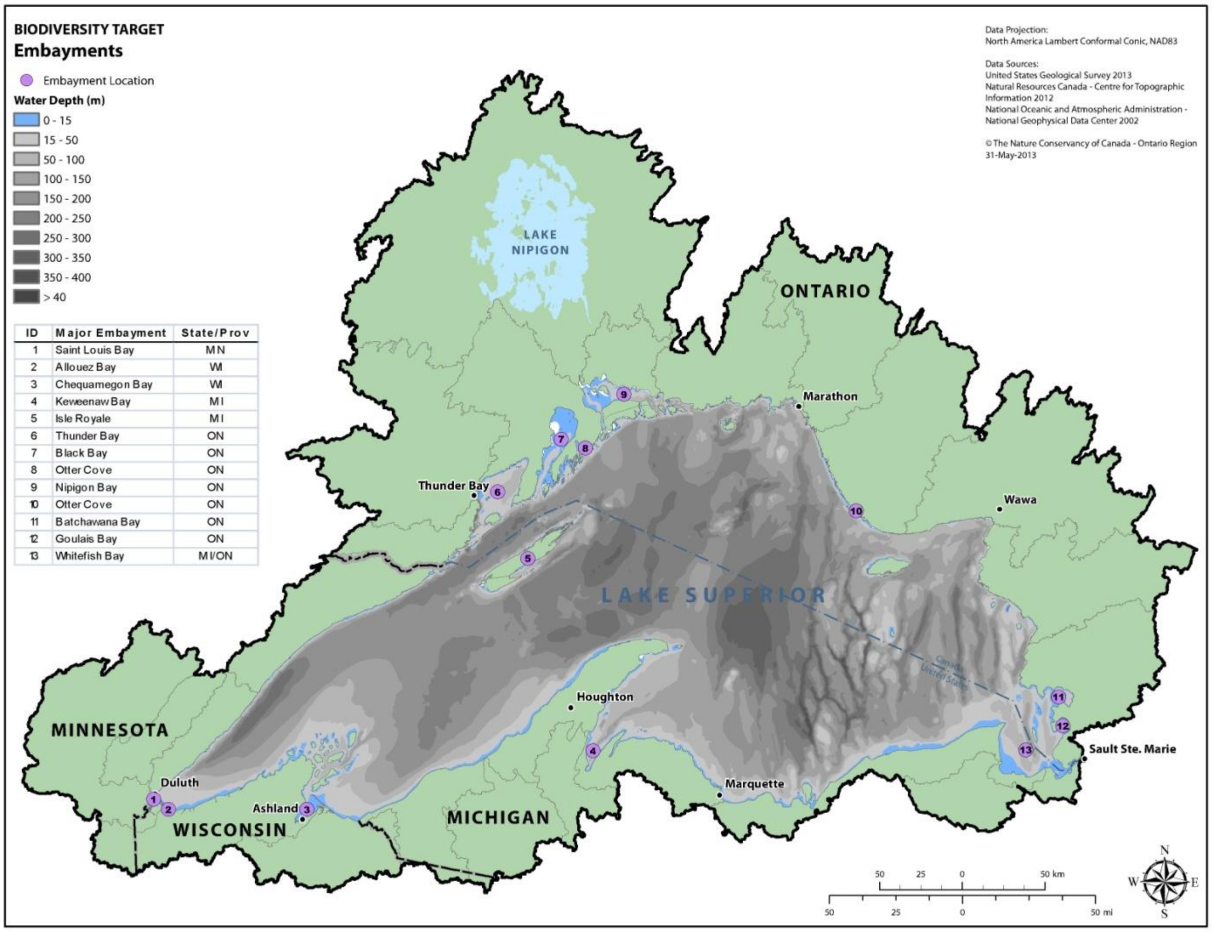
Indicator	**Lake Superior** **Status and Trend**
Aquatic Non-Native Species (x1)	Poor/ Deteriorating
Artificial Coastal Structures (x1)	Good/ To be developed for SOLEC 2016 Lake Superior has relatively few artificial coastal structures.
Atmospheric Deposition (x1)	Fair/ Improving (for PAHs, organochlorine pesticides, dioxins and furans) / Unchanging or slightly improving (for PCBs and mercury) Overall assessment only.
Bacterial Loadings from Tributaries (x1)	To be developed for SOLEC 2016
Bald Eagles (x2)	To be developed for SOLEC 2016
Beach Advisories (x0.5)	Good/ U.S.: Unchanging, Canada: Deteriorating
Benthos (Freshwater Oligochaete) Diversity and Abundance (x2)	Good/ Unchanging
Botulism Outbreaks (x0.5)	Undetermined/ No Change
Cladophora (x0.5)	Good/ Unchanging
Contaminants in Waterbirds (x1)	Good/ Improving
Contaminants in Whole fish (x1)	Fair/ Deteriorating
Contamination in Sediment (x1)	Good/ Unchanging
Diporeia (x2)	Good/ Unchanging
Dreissenid Mussels (x1)	Good/ Unchanging
Endocrine Disruption (x0.5)	To be developed for SOLEC 2016
Fish Consumption Restrictions (x0.5)	Fair/ Undetermined
Fish Disease Occurrences (x0.5)	To be developed for SOLEC 2016
Fish Habitat (x1)	To be developed for SOLEC 2016 See2006 LaMP report This indicator is being developed with the support of the *Great Lakes Basin Fish Habitat Partnership.*
Forest Cover (x1)	Component 1: Percent of forested lands within a watershed Good/ Improving Component 2: Percent of forested lands within riparian zones Good/ TDB
Forest Disturbance (x1)	To be developed for SOLEC 2016
Groundwater Quality (x1)	To be developed for SOLEC 2016
Hardened Shorelines (x1)	Good Undetermined/Undetermined >90% of Lake Superior's shorelines are natural.
Harmful Algal Blooms (x0.5)	Good/ Undetermined
Ice Duration (x1)	Poor/ In preparation Overall, the spatial extent of Great Lakes ice cover has decreased by 71% in the past 40 years. These changes have been significant on Lake Superior (Wang et al. 2012).
Industrial Loadings (x1)	To be developed for SOLEC 2016
Lake Sturgeon (x2)	Fair/ Improving
Lake Trout (x2)	Good/ Improving
Land Cover (x1)	Good/ In preparation Land cover in the Lake Superior basin is dominated by natural cover.
Major Ions (x1)	To be developed for SOLEC 2016
Municipal Wastewater Loadings (x1)	To be developed for SOLEC 2016
Nutrients in Lakes (x1)	Good/ Unchanging
Phytoplankton (x2)	Good/ Unchanging
Precipitation Events (x1)	Undetermined/ Increasing Overall assessment only.
Preyfish Populations (x2)	Fair/ Improving
Sediment Coastal Nourishment (x1)	To be developed for SOLEC 2016

Indicator	**Lake Superior** **Status and Trend**
Surface Water Temperature (x1)	Undetermined/ Increasing
Threatened Species (x2)	To be developed for SOLEC 2016
Tributary Flashiness (x1)	St. Louis River (Lake Superior Basin) Good/ Improving
Walleye (x2)	Fair/ Undetermined
Water Chemistry (x1)	*Specific Conductance:* Increasing *Total Chloride:* No Change *pH:* No Change *Total Alkalinity:* No Change *Turbidity:* Increasing
Water Clarity (x1)	Undetermined/ Mostly improving
Water Levels (x1)	The level of Lake Superior has been below average on an annual basis since 1998. TBD
Watershed Stressor Index (x1)	Fair In preparation – status of fair assigned based on average basin-wide index of 63/100
Zooplankton Biomass (x2)	Good/ Unchanging

Viability Rankings of SOLEC Indicators

Very Good	*Ecologically desirable status; requires little intervention for maintenance*
Good	*Within acceptable range of variation; may require some intervention for maintenance.*
Fair	*Outside of the range of acceptable variation and requires management. If unchecked, the biodiversity target may be vulnerable to serious degradation.*
Poor	*Allowing the biodiversity target to remain in this condition for an extended period will make restoration or preventing extirpation practically impossible.*

Figure 2.5: Embayments and Inshore. Light blue shading depicts areas of inshore waters, with depths of 0 to 15 metres. The locations of several embayments are also shown. Whitefish Bay (MI/ON) refers to the shallow waters along the southern coast of Lake Superior.



Lake Superior Biodiversity Conservation Target
2.4 Coastal Wetlands

Description and Distribution

Coastal wetlands include all wetlands within approximately 2 kilometres of Lake Superior's coast, with an emphasis on wetlands that have historic and current hydrologic connectivity to the lake, and which are directly influenced by the lake.

Coastal wetlands are a critical interface between the land and the lake, providing key ecological services such as water purification and habitat for waterfowl and fishes. There are 26,626 hectares of coastal wetlands documented from Lake Superior and they occur along approximately 10% of the coast (Ingram et al. 2004)[7] (Figure 2.6). Mapping and estimates of the extent of coastal wetlands is incomplete in some areas (Rodriguez and Holmes 2009).

The Kakagon-Bad River Sloughs located just east of Ashland WI have been described as the "Everglades of the north". This 4,000+ ha wetland is owned by the Bad River Band of the Lake Superior Tribe of Chippewa Indians, and was designated as a Ramsar Wetland of International Significance in 2012.
Image: www.wisconsinwetlands.org

Coastal wetlands in Lake Superior have been found to have relatively unique vegetation types compared to the other Great Lake wetlands due to their higher latitude and the physical features of the lake (Sass et al. 2011). The dominant form of wetlands in Lake Superior is barrier protected (>10,000 ha). Other types of coastal wetlands in Lake Superior are: drowned rivermouth, protected embayment, delta and open embayment (Ingram et al. 2004).

Coastal wetlands provide habitat for many fish, amphibian and reptile species at various life stages. Many bird species use coastal wetlands during breeding and migration (LSBP 2006a). For Lake Superior, the status and trend for the wetland amphibians and wetland birds indicators are currently undetermined, as the coverage for these indicators is too sparse for analysis (Tozer 2011a; Tozer 2011b). Coastal wetlands also provide important ecological services for local communities. These functions include protecting shorelines from erosion, storage and cycling of nutrients entering the lake from tributaries, groundwater recharge and biological productivity (LSBP 2006a; Rodriguez and Holmes 2009).

Nested Species and Habitat Targets

- All Coastal Wetland Types
- Spawning and larval fish
- Amphibians
- Breeding and migratory birds
- Invertebrates

[7] An additional 10,790 ha of coastal wetlands are located in St. Marys River (Ingram et al. 2004), approximately 670 ha of which are within the project area. While not all the river's coastal wetlands are within the scope of this project, those which are accessible to native fish may contribute to the health of Lake Superior by providing spawning and nursery habitat. Barriers to fish movement in the river, including rapids and the compensating gates, impact the availability of these wetlands for native fish species.

Table 2.10: Overall Viability Assessment of Coastal Wetlands

OVERALL VIABILITY ASSESSMENT	GOOD (3.23)
CONFIDENCE	LOWER
REGIONAL VARIABILITY	MEDIUM
Number of Indicators/ Total Score	10/35.5
Number of Lake Superior Indicators Used	0
Number of Weighted Indicators (x2)	1
Number of Weighted Indicators (x0.5)	0
Number of Potential SOLEC Indicators in Development	13

The overall health of coastal wetlands is "good" (see Table 2.10, 2.11). The viability assessment is driven by the lack of artificial shorelines and structures, lack of terrestrial invasive species (including wetland species such as Common Reed [*Phragmites australis*]) and high amount of forest cover. Many coastal wetlands in Lake Superior are also subject to relatively low levels of watershed development (Trebitz et al. 2011). Indicators that rank lower are increasing water temperatures and lower lake levels, which are impacting the area of wetlands. A lower level of confidence was assigned to this target because of the large number of indicators that are still under development. A category of medium was assigned for the regional variability because regional differences in the condition of coastal wetlands have been documented; however, some indicators such as lake levels and water temperatures likely impact all coastal wetlands. Coastal wetland plant communities in Lake Superior are generally ranked as "good" condition, however there exists degradation around major areas (Albert and Sass 2011). Wetlands are one of the more impacted zones of Lake Superior, especially in areas near cities (Gorman et al. 2010b).

A ranking of 15 Lake Superior coastal wetlands using a water quality index calculated using 12 water quality parameters led to an overall classification of "good" (Seilheimer and Chow-Fraser 2007, p. 159). Individually, the wetlands ranked from moderately degraded (the lowest ranking given to a Lake Superior wetland) to excellent (the highest ranking given to a Lake Superior wetland, and the highest possible ranking). None of the 15 Lake Superior coastal wetlands ranked were classified as highly degraded or very degraded using this water quality index (Seilheimer and Chow-Fraser 2007).

Many of the factors related to coastal wetlands are inextricably linked to watersheds, tributaries, embayments and the inshore zone. The many stressors which contribute to the loss and degradation of wetlands include shoreline modification, invasive species, adjacent land use, and excessive sediment and nutrient flow from watersheds (Ingram et al. 2004). Additionally, coastal wetland habitat is expected to be lost as a result of climate change (Gorman et al. 2010b). Healthy, densely vegetated coastal wetlands in western Lake Superior were found to provide native fishes with a refuge from competition with the non-native Ruffe (*Gymnocephalus cernua*) (Brazner et al. 1998 as cited in Sass et al. 2011), and degradation of coastal wetlands could allow Ruffe to increase in that region (Sass et al. 2011).

A number of initiatives to monitor, protect and restore coastal wetland habitat exist. These include the protection and restoration of over 5,000 acres of coastal and inland wetland communities in Wisconsin through the Lake Superior Coastal Wetland Initiative. Other initiatives include the development of a long-term monitoring program for coastal wetlands by the Great Lakes Coastal Wetland Consortium and the Great Lakes Environmental Indicators (GLEI) research project, which developed indicators for ecological condition and causes of degradation for coastal and wetland habitat of Lake Superior (Gorman et al. 2010b; Great Lakes Coastal Wetlands Consortium 2008).

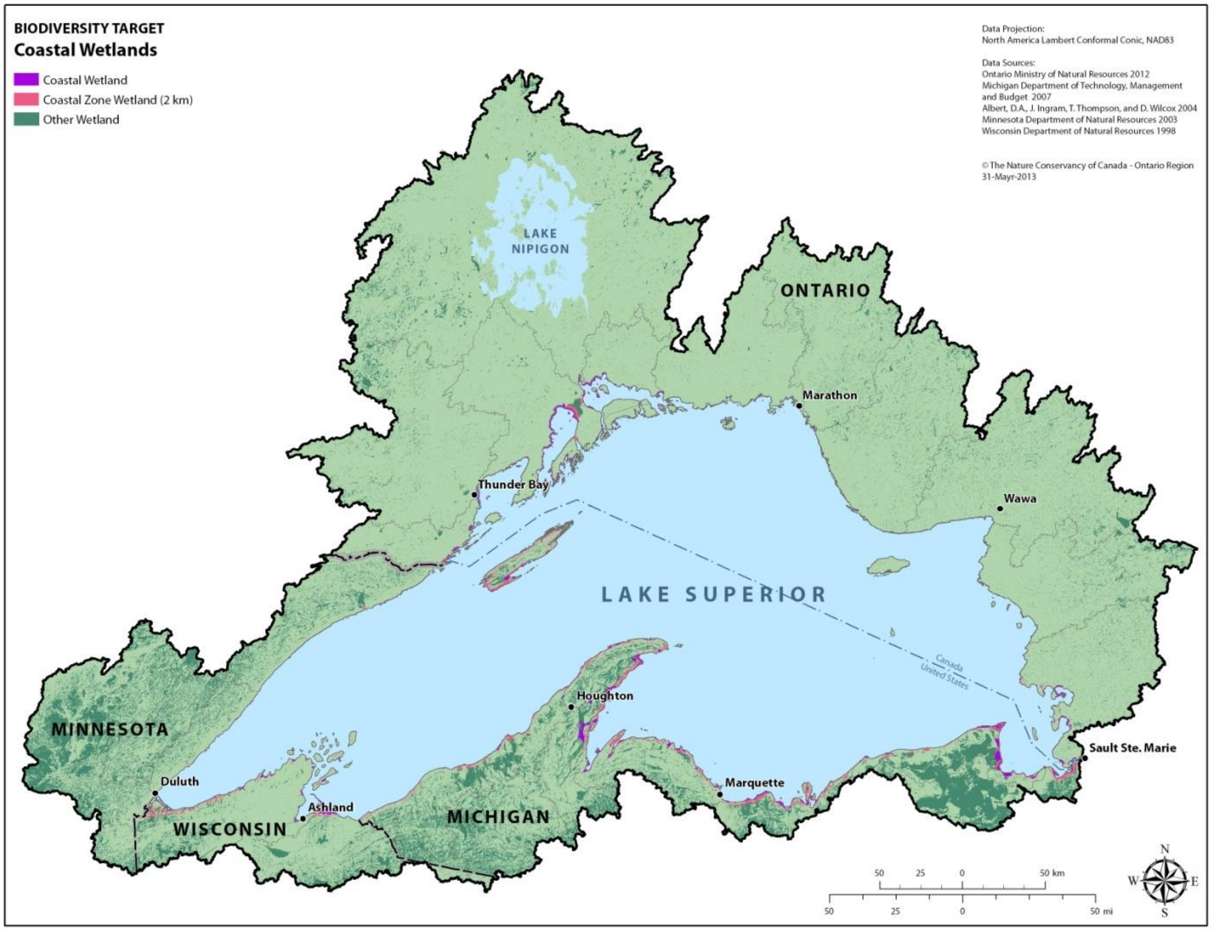
Table 2.11: Ecosystem Indicators for the Health of Coastal Wetlands SOLEC Status and Trends for Lake Superior Indicators

Indicator	Lake Superior Status and Trend
Artificial Coastal Structures (x1)	Good/ To be developed for SOLEC 2016 Lake Superior has relatively few artificial coastal structures.
Coastal Stress Index (x1)	Good Developed for this report
Coastal Wetland Amphibians (x2)	Undetermined/ Undetermined
Coastal Wetland Bird Communities (x2)	Undetermined/ Undetermined
Coastal Wetland Fish Communities (x2)	Not assessed/ Undetermined
Coastal Wetland Invertebrates (x2)	Not assessed Undetermined
Coastal Wetland Landscape Extent and Composition (x1)	To be developed for SOLEC 2016
Coastal Wetland Plants (x2)	Mixed/ Undetermined
Fish Habitat (x1)	To be developed for SOLEC 2016 See 2006 LaMP report (LSBP 2006a) This indicator is being developed with the support of the *Great Lakes Basin Fish Habitat Partnership.*
Forest Cover (x1)	Component 1: Percent of forested lands within a watershed Good/ Improving Component 2: Percent of forested lands within riparian zones Good/ TDB
Groundwater Quality (x1)	To be developed for SOLEC 2016
Hardened Shorelines (x1)	Good Undetermined/Undetermined >90% of Lake Superior's shorelines are natural.
Land Cover (x1)	Good/ In preparation Land cover in the Lake Superior basin is dominated by natural cover.
Surface Water Temperature (x1)	Undetermined/ Increasing
Terrestrial Non-Native Species (x1)	Good Undetermined/Undetermined Lake Superior coastal areas have relatively few invasive plants, including Common Reed.
Threatened Species (x2)	To be developed for SOLEC 2016
Tributary Flashiness (x1)	St. Louis River (Lake Superior Basin) Good/ Improving
Water Levels (x1)	The level of Lake Superior has been below average on an annual basis since 1998. TBD
Watershed Stressor Index (x1)	Fair In preparation – status of fair assigned based on average basin-wide index of 63/100

Viability Rankings of SOLEC Indicators

Very Good	*Ecologically desirable status; requires little intervention for maintenance*
Good	*Within acceptable range of variation; may require some intervention for maintenance.*
Fair	*Outside of the range of acceptable variation and requires management. If unchecked, the biodiversity target may be vulnerable to serious degradation.*
Poor	*Allowing the biodiversity target to remain in this condition for an extended period will make restoration or preventing extirpation practically impossible.*

Figure 2.6: Coastal Wetlands. Purple shading depicts coastal wetlands of Lake Superior that intersect the shore. Pink shading depicts coastal wetlands within 2 kilometres of the shore, and green shading depicts coastal wetlands greater than 2 kilometres from the shore.

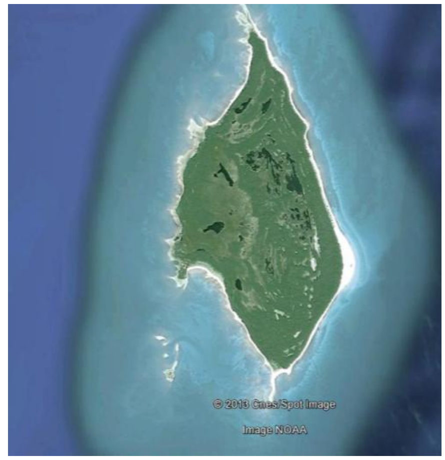


Lake Superior Biodiversity Conservation Target
2.5 Islands

Description and Distribution

Islands include all land masses within Lake Superior that are surrounded by water, including both natural and artificial islands.

There are 2,591 documented islands from Lake Superior (Figure 2.7) with a total coastline of over 2,400 kilometres. Most islands are less than one hectare. The three largest islands (Isle Royale, St. Ignace Island, and Michipicoten Island) comprise more than half the total island area (LSBP 2006a; Henson et al. 2010). Lake Superior has many of the largest and most isolated islands on the Great Lakes. Several offshore islands support unique plant and animal communities.



Caribou Island, located in the eastern part of Lake Superior, is the most isolated freshwater island in the world. In some early maps it is labelled "Isle of the Golden Sands".

Along the northern shore of Lake Superior the Precambrian islands are largely composed of basalt and granite, while the islands along the southern shore are Precambrian and Cambrian sandstones (Henson et al. 2010). Shifting islands of unconsolidated sediments also form in Lake Superior as the result of cobbles accumulating on reefs (Henson et al. 2010). Some Lake Superior islands provide unique opportunities to study population and predator-prey dynamics, such as the Gray Wolf (*Canis lupus*) and Moose (*Alces americanus*) study that has been ongoing on Isle Royale since 1958, and the population crashes of Woodland Caribou that have occurred on some northern islands.

The islands of Lake Superior provide habitats which are distinct from mainland sites (LSBP 2006a) and contribute to basinwide biodiversity, particularly for colonial nesting waterbirds (Figure 2.8). The numbers and composition of some waterbird colonies have been changing due to increasing numbers of some gulls, which may be linked to changes in land use. Populations of some waterbird colonies have also been decreasing due to recovery and increased predation by Bald Eagles (*Haliaeetus leucocephalus*). Many Lake Superior islands are also important sites for fish spawning and nursery areas, arctic and alpine disjuncts, neotropical migrant songbirds and endemic plants, among other features (Cuthbert et al. 2008). Over 60 islands and island complexes have been identified as significant sites for biodiversity conservation including Pie Island, St. Ignace Island, Ile Parisienne, Patterson Island and Isle Royale (Henson et al. 2010) (Figure 2.9).

Nested Species and Habitat Targets

- Migratory birds and stopover habitat
- Colonial nesting waterbirds
- Arctic-alpine disjunct communities and plants
- Landbirds (songbirds and raptors)
- Shorebirds
- Waterfowl
- Aerial migrants (e.g., migratory insects, bats)
- Ring-billed Gull (*Larus delawarensis*)
- Herring Gull (*Larus argentatus*)
- Common Tern (*Sterna hirundo*)
- Caspian Tern (*Hydroprogne caspia*)
- American White Pelican
- Unique plant and animal communities (e.g., populations of Beaver (*Castor canadensis*) and Woodland Caribou in predator-free environments)

Table 2.12: Overall Viability Assessment of Islands

OVERALL VIABILITY ASSESSMENT	GOOD (3.5)
CONFIDENCE	HIGHER
REGIONAL VARIABILITY	MEDIUM
Number of Indicators/ Total Score	8/28
Number of Lake Superior Indicators Used	1
Number of Weighted Indicators (x2)	1
Number of Weighted Indicators (x0.5)	0
Number of Potential SOLEC Indicators in Development	1

The overall health of islands is “good” (see Table 2.12, 2.13). This is consistent with Henson et al. (2010), who report that most Lake Superior islands are in natural cover and have few threats. Changes in ice cover and rising air temperatures could be impacting some island species and habitats. A higher level of confidence was assigned to this target. While there are only a few SOLEC indicators, the report by Henson et al. (2010) ranked the condition of every island and island complex in Lake Superior and reported overall good condition. Regional variability is ranked as medium. While the overall health of islands is good, some islands are known to be more developed.

Many of Lake Superior’s islands did not have any threats documented in the assessment by Henson et al. (2010), including most of the islands along the north shore. Threats that were documented included limited buildings for recreation (i.e., cottages, hunting and fishing cabins) and lighthouses. Madeline Island (part of the Apostle Islands National Lakeshore) and Barker Island and Hog Island (near Duluth) are the most developed islands in Lake Superior.

Several of the large islands along Lake Superior’s north coast are protected by various parks and protected area designations. These include islands within the Lake Superior National Marine Conservation Area, Isle Royale National Park, Michipicoten Island Provincial Park, Slate Islands Provincial Park and Sleeping Giant Provincial Park (Henson et al. 2010). The Apostle Islands National Lakeshore protects 21 islands along the south shore of Lake Superior (National Parks Service 2013).

Table 2.13: Ecosystem Indicators for the Health of Islands

Indicator	**Lake Superior** **Status and Trend**
Air Temperature (x1)	Fair/ Undetermined Increasing Overall assessment only.
Artificial Coastal Structures (x1)	Good/ To be developed for SOLEC 2016 Lake Superior has relatively few artificial coastal structures.
Contaminants in Waterbirds (x1)	Good/ Improving
Hardened Shorelines (x1)	Good Undetermined/Undetermined >90% of Lake Superior's shorelines are natural.
Ice Duration (x1)	Poor/ In preparation Overall, the spatial extent of Great Lakes ice cover has decreased by 71% in the past 40 years. These changes have been significant on Lake Superior (Wang et al. 2012).
Island Condition Class (x2)	Good
Land Cover (x1)	Good/ In preparation Land cover in the Lake Superior basin is dominated by natural cover.
Terrestrial Non-Native Species (x1)	Good Undetermined/Undetermined Lake Superior coastal areas have relatively few invasive plants, including Common Reed.
Threatened Species (x2)	To be developed for SOLEC 2016

Viability Rankings of SOLEC Indicators

Very Good	*Ecologically desirable status; requires little intervention for maintenance*
Good	*Within acceptable range of variation; may require some intervention for maintenance.*
Fair	*Outside of the range of acceptable variation and requires management. If unchecked, the biodiversity target may be vulnerable to serious degradation.*
Poor	*Allowing the biodiversity target to remain in this condition for an extended period will make restoration or preventing extirpation practically impossible.*

Figure 2.7 Lake Superior Islands. The orange shading depicts islands and island complexes from Lake Superior (from Henson et al. 2010).

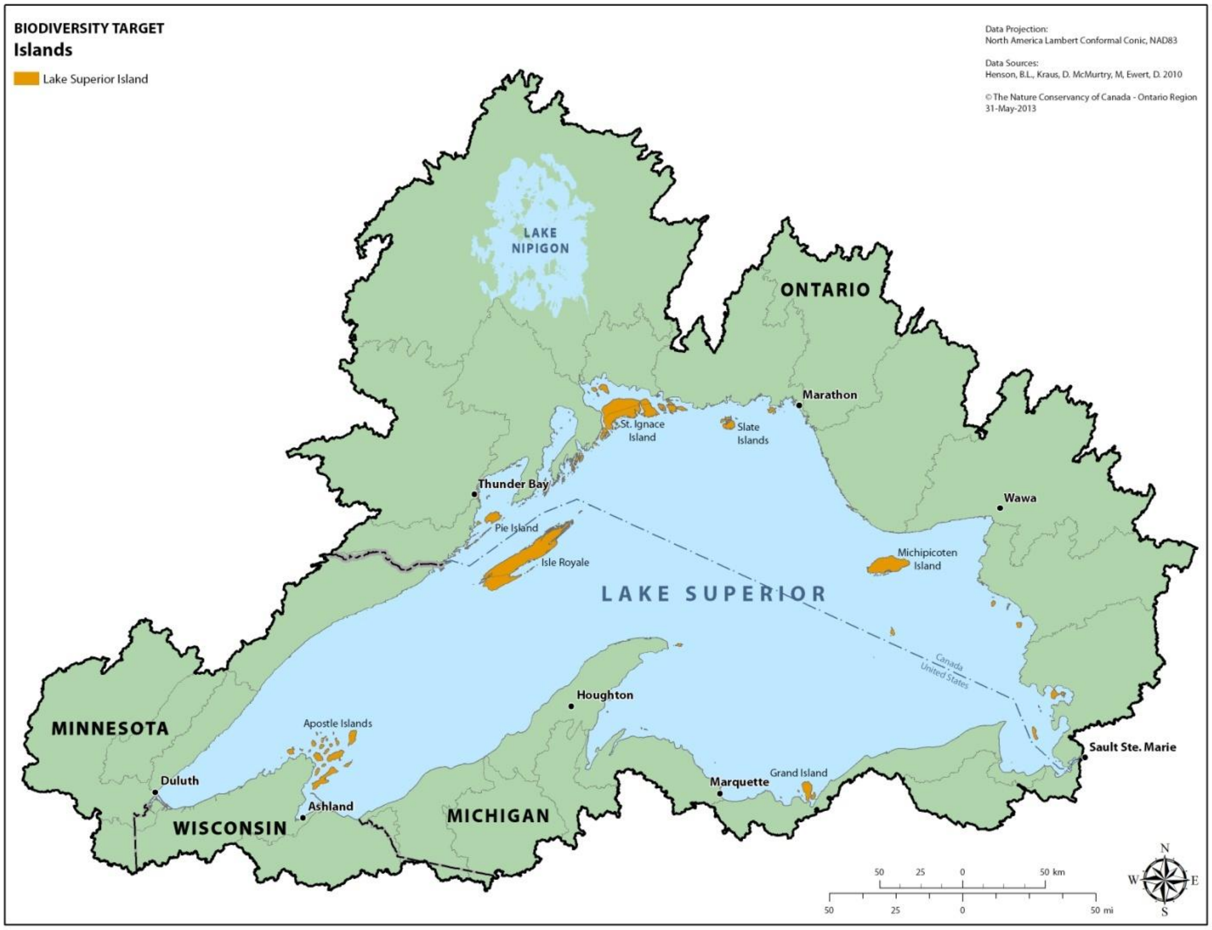


Figure 2.8: Colonial Nesting Waterbirds. The yellow dots depict colonial waterbird nesting sites. Data from Environment Canada and Linda Wires (University of Minnesota).

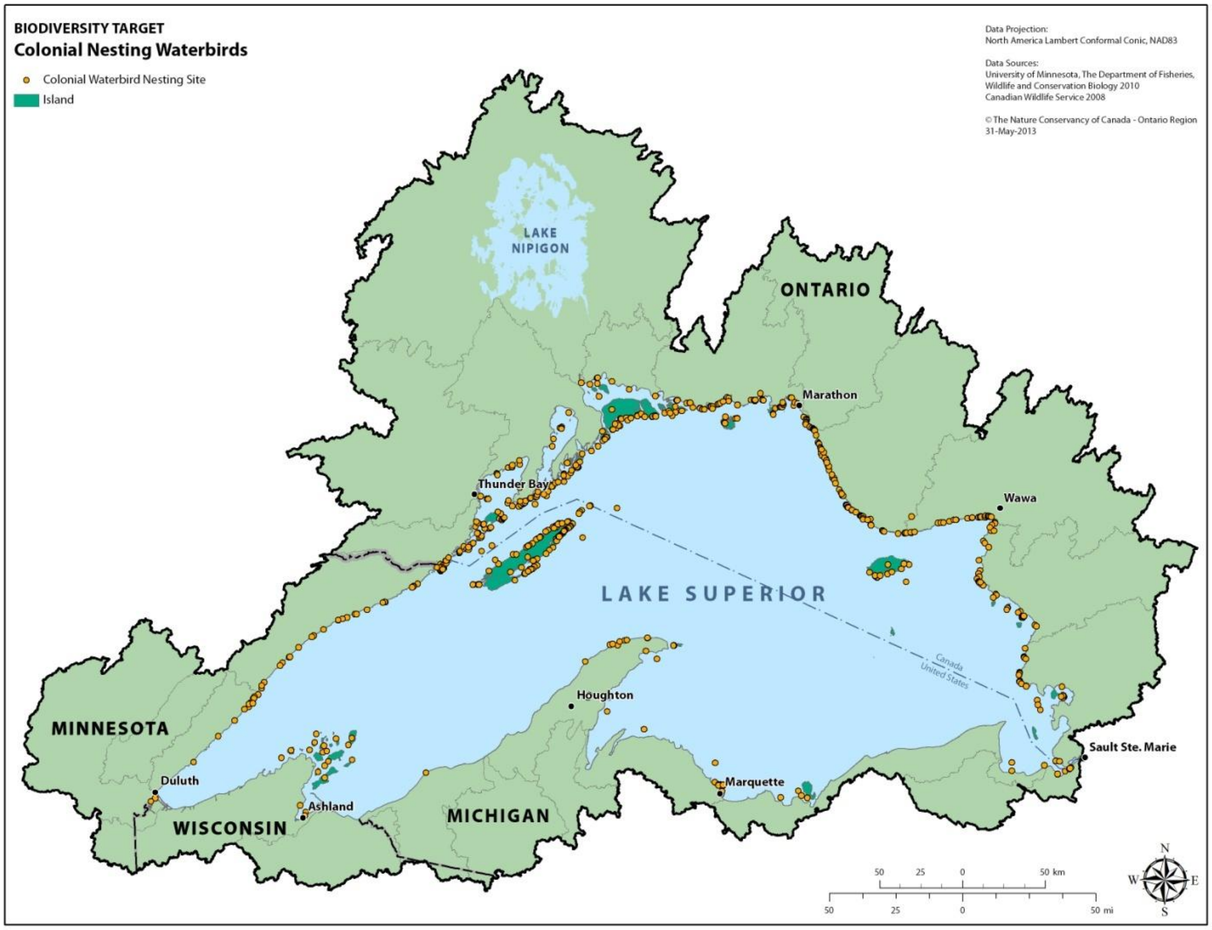
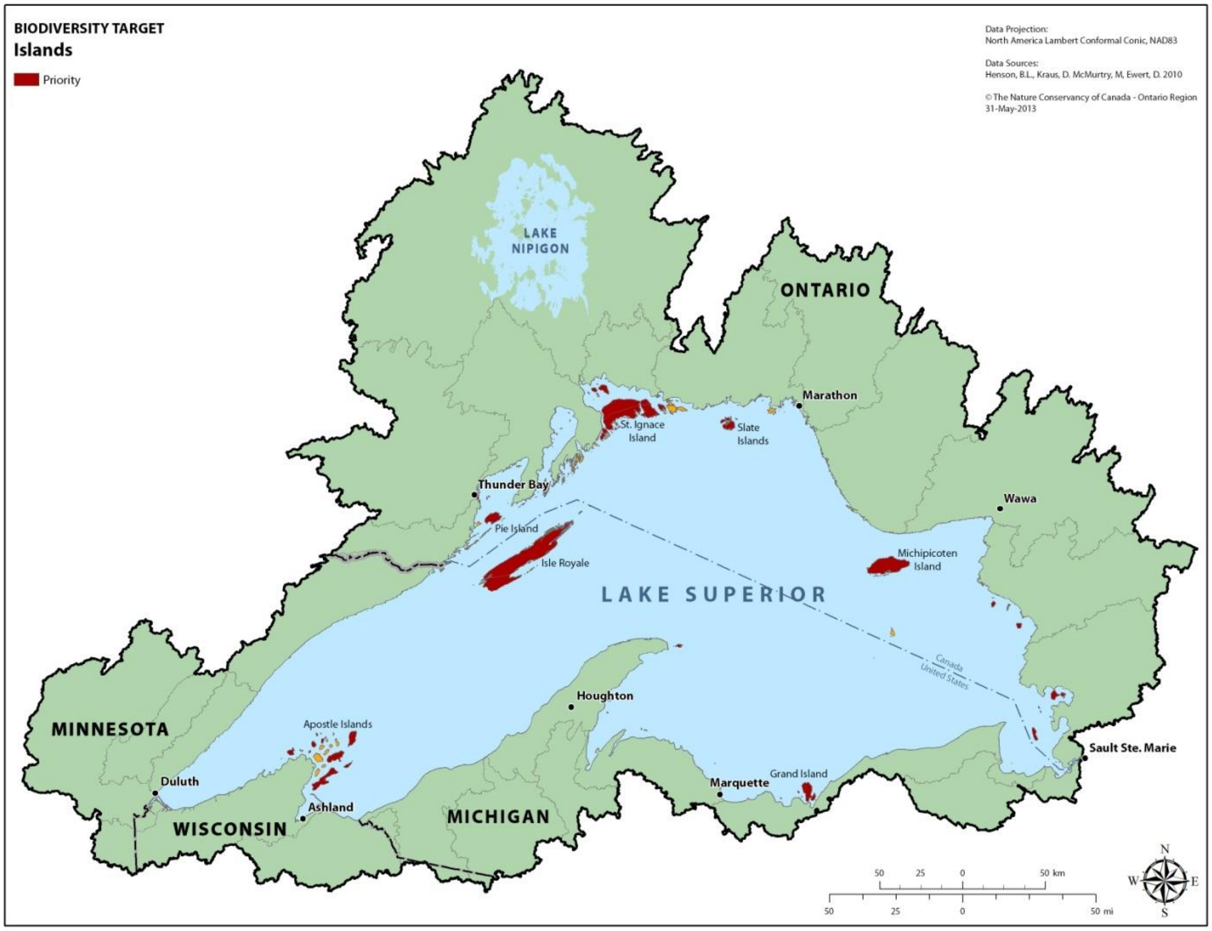


Figure 2.9: Islands with Higher Biodiversity Values. The red shading depicts priority islands. The orange shading depicts other islands (from Henson et al. 2010). Priority islands are those islands or island complexes identified through an ecologically-based analysis as the highest priority for conservation action.



Lake Superior Biodiversity Conservation Target
2.6 Coastal Terrestrial Habitats

Description and Distribution

Coastal terrestrial habitats extend from the shoreline up to 2 kilometres inland or to the extent of the delineated Great Lake coastal communities.

Lake Superior's coast is dominated by rocky shores and cliffs (50%) with cobble beaches (14%) and sand beaches (10%) (Figure 2.10). Coastal terrestrial habitats also include sand dunes, raised cobble beaches and coastal forests. The vast size of Lake Superior creates a microclimate, directly influencing the habitats and species found within this coastal area (Horns et al. 2003).

Lake Superior has a wide variety of coastal types including this sand beach and shoreline cliff at Lake Superior Provincial Park in Ontario. This habitat diversity is reflected in the wildlife of the region. The southern and northwestern shores of Lake Superior have some of the highest species richness in North America for breeding birds (LSBP 2006a).

Image: Courtesy Ethan Meleg, with permission.

The coastal band of Lake Superior includes globally rare ecosystems along with endemic and disjunct species, which contribute to the high regional species diversity (Kraus and White 2009). Unique species and habitats found in the coastal terrestrial environment include arctic-alpine disjuncts and coastal forests. Coastal forests are influenced by their proximity to the cold waters, constant winds and other micro-climate factors of the lake. Some communities include stunted "krumholtz" forests and stands with a high abundance of mosses and lichens. These coastal forests support migrating songbirds and a coastal herd of Woodland Caribou. A summary of documented coastal terrestrial species and habitats is provided in Appendix C.

Relatively large numbers of migratory birds follow the eastern and western shores during migration. Migratory raptors prefer to migrate around Lake Superior as opposed to over water, and tend to concentrate in coastal areas (LSBP 2006a). The Keweenaw Peninsula is especially favoured by migrating species. On the south shore, nine sites have been identified as potential Important Bird Areas, many for their migration staging and stopover characteristics (LSBP 2006a) (Figure 2.11a), but almost any coastal areas likely provide high quality stop-over habitat (Figure 2.11b). It is believed that large numbers of migratory bats use the coast as a migratory route, but migratory movements of bats are poorly understood in the Lake Superior region (Kruger and Peterson 2008).

Nested Species and Habitat Targets

- Sand beaches and dunes
- Cobble beaches
- Shoreline cliffs
- Rocky shores
- Bluffs
- Arctic-alpine disjunct species
- Coastal forests
- Lake Huron Tansy (*Tanacetum bipinnatum*)
- Houghton's Goldenrod (*Oligoneuron houghtonii*)
- Dune Thistle (*Cirsium pitcheri*)
- Piping Plover (*Charadrius melodus*)
- Peregrine Falcon (*Falco peregrinus*)
- Bald Eagle
- Woodland Caribou
- Wide-ranging mammals (e.g., Lynx [*Lynx canadensis*])
- Endemic coastal insects and migratory insects
- Landbirds (songbirds and raptors)
- Shorebirds, waterfowl and waterbirds
- Migratory bats

Table 2.14: Overall Viability Assessment of Coastal Terrestrial Habitats

OVERALL VIABILITY ASSESSMENT	GOOD (3.21)
CONFIDENCE	MEDIUM
REGIONAL VARIABILITY	HIGHER
Number of Indicators/ Total Score	7/22.5
Number of Lake Superior Indicators Used	0
Number of Weighted Indicators (x2)	0
Number of Weighted Indicators (x0.5)	0
Number of Potential SOLEC Indicators in Development	5

The overall viability for the Coastal Terrestrial Habitats target is ranked as “good” (see Table 2.14, 2.15). All the indicators are ranked as good, except for air temperature. A medium level of confidence was assigned to this target. While many SOLEC indicators are not available, the Coastal Stress Index analysis completed for this project indicates that coastal condition is good in most regions of the lake. Regional variability is ranked as higher. While the overall health of the coastal terrestrial target is good, the Coastal Stress Index analysis illustrates that there are regions that are more impacted, such as the coastal areas of Thunder Bay and Duluth. The coastal areas of Isle Royale, Black Bay Peninsula, Michipicoten Island and Pukaskwa National Park area are the least disturbed coastal areas in Lake Superior, and probably represent the last remaining true wilderness coasts on the Great Lakes.

Approximately 26.8% of Lake Superior’s coast is protected, including many high quality ecosystems and habitat types. For example, high quality occurrences of the Great Lakes forested dunes, barrens and swales vegetation communities are protected in Apostle Islands National Lakeshore. Effective management plans are needed to help identify and mitigate threats to coastal terrestrial habitats in protected areas (Kraus and White 2009).

Table 2.15: Ecosystem Indicators for the Health of Coastal Terrestrial Habitats

Indicator	Lake Superior Status and Trend
Air Temperature (x1)	Fair/ Undetermined Increasing Overall assessment only.
Artificial Coastal Structures (x1)	Good/ To be developed for SOLEC 2016 Lake Superior has relatively few artificial coastal structures.
Bald Eagles (x2)	To be developed for SOLEC 2016
Coastal Stress Index (x1)	Good Developed for this report
Forest Cover (x1)	Component 1: Percent of forested lands within a watershed Good/ Improving Component 2: Percent of forested lands within riparian zones Good/ TDB
Forest Disturbance (x1)	To be developed for SOLEC 2016
Hardened Shorelines (x1)	Good Undetermined/Undetermined >90% of Lake Superior's shorelines are natural.
Piping Plover (x2)	To be developed for SOLEC 2016
Terrestrial Non-Native Species (x1)	Good Undetermined/Undetermined Lake Superior coastal areas have relatively few invasive plants, including Common Reed.
Threatened Species (x2)	To be developed for SOLEC 2016
Watershed Stressor Index (x1)	Fair In preparation – status of fair assigned based on average basin-wide index of 63/100

Viability Rankings of SOLEC Indicators

Very Good	*Ecologically desirable status; requires little intervention for maintenance*
Good	*Within acceptable range of variation; may require some intervention for maintenance.*
Fair	*Outside of the range of acceptable variation and requires management. If unchecked, the biodiversity target may be vulnerable to serious degradation.*
Poor	*Allowing the biodiversity target to remain in this condition for an extended period will make restoration or preventing extirpation practically impossible.*

Figure 2.10: Major Coastal Terrestrial Systems. The shading depicts different major coastal types. Purple shading represents sand beaches, orange shading represents coarse beaches and green shading represents rocky shores or bluffs.

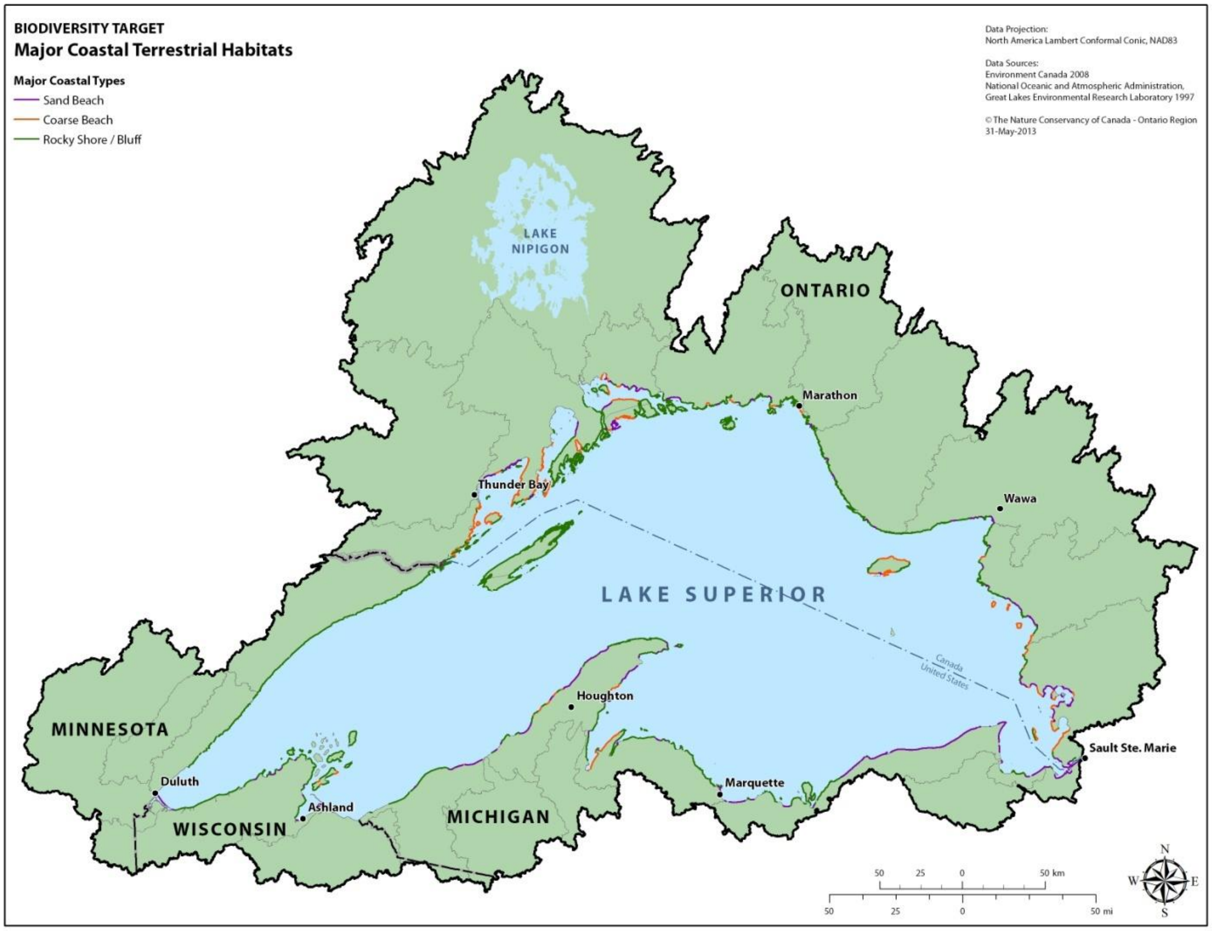


Figure 2.11a-b: Migratory Birds. Coastal areas are critical for migrating landbirds, shorebirds and waterfowl.

Figure 2.11a Important Bird Areas. This figure depicts Important Bird Areas (IBAs) for the basin; no IBAs have been identified on the Ontario coast of Lake Superior.

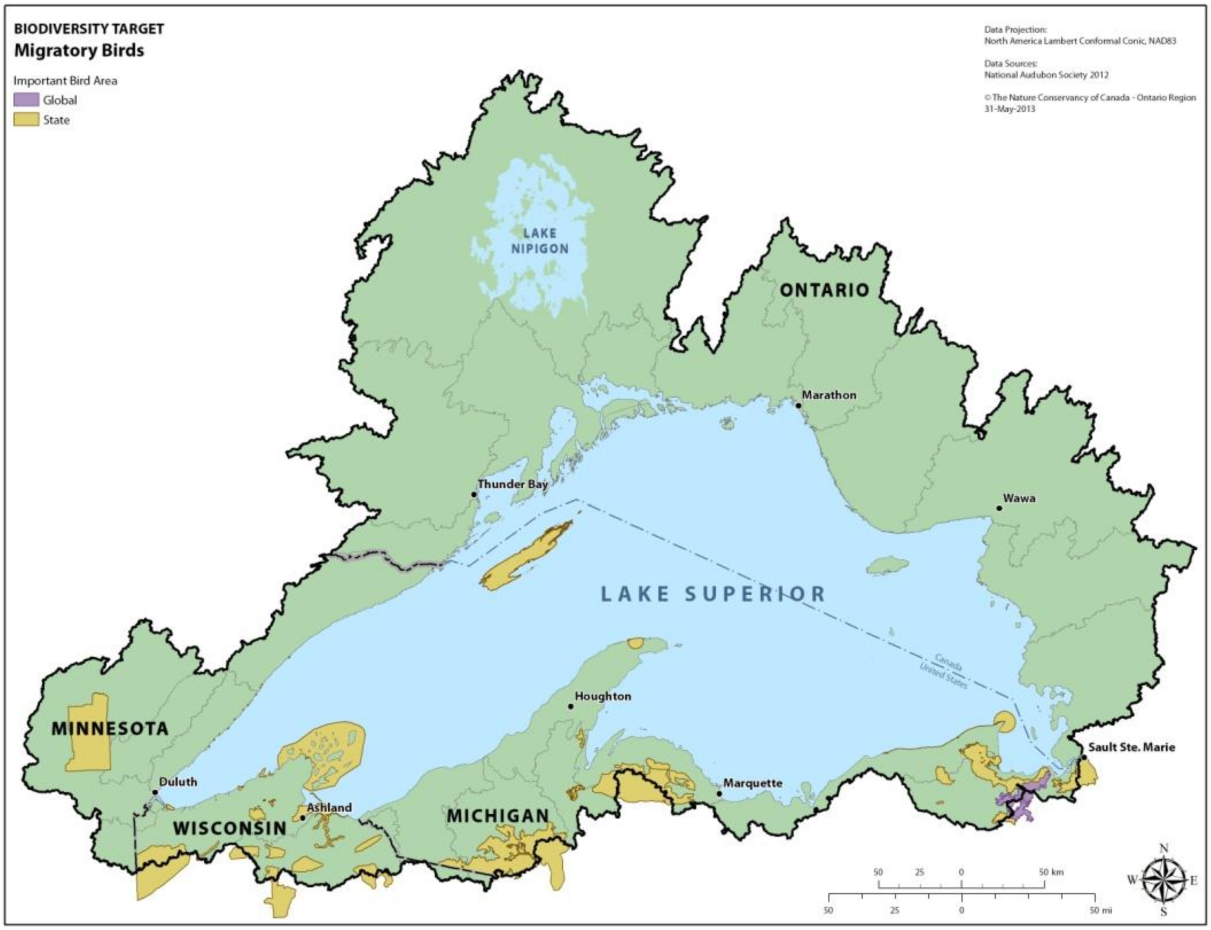
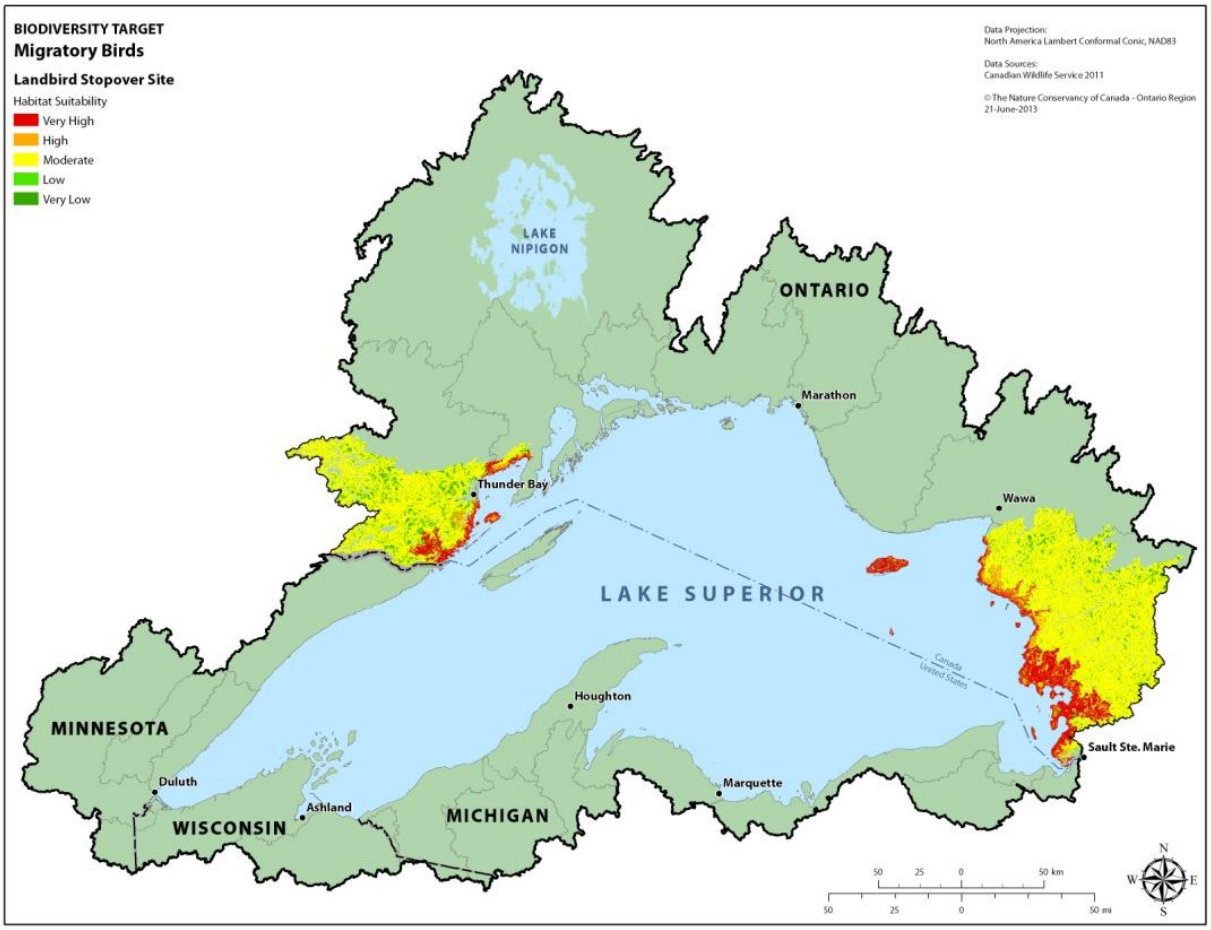


Figure 2.11b Landbird Stopover Sites. This partial analysis for Lake Superior indicates the degree of habitat suitability for landbird stopover sites. The red shading indicates areas of very high habitat suitability. Habitat suitability declines as the shading moves from red to dark green (based on model developed by Dave Ewert of The Nature Conservancy). While this mapping has not been completed for the entire basin, higher habitat suitability is clearly associated with any coastal area with natural cover.



Lake Superior Biodiversity Conservation Target
2.7 Tributaries and Watersheds

Description and Distribution

Tributaries include all rivers, streams and inland lakes that flow into Lake Superior and their associated watersheds (Figure 2.12).

There are 25 tertiary (HUC-6) and 1,546 quaternary (HUC-8) watersheds in the Lake Superior basin. Lakes, rivers and streams in the basin are influenced by land use, which can affect water quality in Lake Superior. Native Lake Superior fishes that migrate to and depend on tributaries as part of their natural life cycle are nested targets of the tributary and watershed target.

Lake Superior supports Brook Trout. These unique fishes migrate between the nearshore waters and tributaries of Lake Superior.
Image: http://www.fws.gov/Midwest/Fisheries

Tributaries and watersheds are critical components of Lake Superior's aquatic ecosystem. They provide important habitats for fish and wildlife, and transport nutrients and sediments into embayments and the nearshore. The estimated 1,500+ tributaries of Lake Superior vary from large rivers (including the Nipigon, St. Louis, Kaministiquia and Pic rivers) to intermittent streams (LSBP 2006a), and provide approximately 3,300 km of tributary habitat to migratory fishes (Horns et al. 2003; LSBP 2006a). The total drainage area of the tertiary watersheds is over 209,000 km^2.

Migratory fishes are a key group nested in this target and include Lake Superior fishes that use tributaries for part of their natural life cycle, usually for spawning, but sometimes for foraging or refugia (e.g., thermal, predation). While many migratory fishes spawn almost exclusively in rivers, some spawn in both lake and riverine habitats (including Lake Trout and Lake Whitefish on occasion). Key migratory fishes that use Lake Superior and its tributaries are Lake Sturgeon, Walleye, Brook Trout, suckers and many species of minnows (Horns et al. 2003). Figure 2.13 depicts historic and current riverine spawning habitats used by Lake Sturgeon.

Nested Species and Habitat Targets

- Nutrient and sediment processes
- Watershed characteristics and health
- Migratory fishes
- Lake Sturgeon
- Brook Trout
- River spawning Lake Trout
- White Sucker
- Longnose Sucker
- Silver Redhorse
- Shorthead Redhorse
- Walleye
- Northern Wild Rice

Table 2.16: Overall Viability Assessment of Tributaries and Watersheds

OVERALL VIABILITY ASSESSMENT	FAIR (2.69)
CONFIDENCE	HIGHER
REGIONAL VARIABILITY	HIGHER
Number of Indicators/ Total Score	11/35
Number of Lake Superior Indicators Used	0
Number of Weighted Indicators (x2)	2
Number of Weighted Indicators (x0.5)	0
Number of Potential SOLEC Indicators in Development	9

The overall viability for the Tributaries and Watersheds target is assessed as “fair”. A higher level of confidence was assigned to this target because there are a larger number of SOLEC indicators, and many indicators apply to this target across its range (e.g., Walleye). In addition, the Watershed Stress Index (GLEI 2013) provides a regional snapshot of the condition of Lake Superior watersheds. While the northern part of the basin generally has fewer stresses, other regions are experiencing higher levels of stress. Regional variability was also assigned a category of higher because of clear differences in the health of different watersheds.

Tributaries have been identified as the most vulnerable component of the Lake Superior aquatic ecosystem (LSBP 2006a). Issues impacting the health of tributary habitats are hydroelectric facilities, barrier dams, water crossings, loss of wetlands, land-use practices, exotic species, inappropriate or poorly managed timber harvesting, mining, agricultural practices, urban development, industrial effluents and sedimentation (LSBP 2006a). Historically, a number of factors contributed to the degradation of tributaries, including woody debris from sawmill operations and dams that blocked and changed flows. In addition, logging caused erosion, sedimentation and more variable flows. Agriculture and mining also contributed to degradation in some tributary streams (Horns et al. 2003). Horns et al. (2003) noted that habitat protection and restoration in Lake Superior is especially needed in tributary, embayment and nearshore habitats.

Fishes that use tributaries are more likely to be limited by habitat quantity and quality (Horns et al. 2003; Gorman et al. 2010b). Brook Trout previously inhabited at least 118 tributaries of Lake Superior – today only a few remote streams support viable populations, including those on Isle Royale (Horns et al. 2003). Historical records indicate that there were 21 tributaries where Lake Sturgeon spawned (Lake Superior Lake Sturgeon Work Group 2012, unpublished data). Due to pollution, direct and indirect fishing mortality, hydroelectric dams, industrial developments and other factors, Lake Sturgeon now occur in only half of these historic sites, and few of the Lake Superior Lake Sturgeon populations are self-sustaining (Lake Superior Lake Sturgeon Work Group 2012, unpublished data), as defined in the Lake Sturgeon Rehabilitation Plan for Lake Superior (Auer 2003). Habitat degradation and fishing-induced mortality have also affected Walleye in every major bay and tributary in Lake Superior, and remain impediments to achieving goals for Walleye populations (Horns et al. 2003). Similarly, the recovery of Brook Trout populations cannot be achieved without the restoration and protection of tributary habitat (Horns et al. 2003). Arctic Grayling (*Thymallus arcticus*) was once present in the tributaries of Lake Superior; it is now extirpated from the entire watershed (Horns et al. 2003).

Further adding to the complexity of tributary habitat management is that several non-indigenous species of salmon and trout use tributary habitat for reproduction and development. The non-indigenous, naturalized species are managed for sustainability if they are compatible with the native fish community objectives (Horns et al. 2003).

Table 2.17: Ecosystem Indicators for the Health of Tributaries and Watersheds

Indicator	**Lake Superior Status and Trend**
Aquatic Habitat Connectivity (x1)	Fair/ Improving
Aquatic Non-Native Species (x1)	Poor/ Deteriorating
Baseflow due to Groundwater Discharge (x1)	Fair/ Undetermined Overall assessment only.
Coastal Wetland Fish Communities (x2)	Not assessed/ Undetermined
Fish Habitat (x1)	To be developed for SOLEC 2016 See2006 LaMP report (LSBP 2006a) This indicator is being developed with the support of the *Great Lakes Basin Fish Habitat Partnership.*
Forest Cover (x1)	Component 1: Percent of forested lands within a watershed Good/ Improving Component 2: Percent of forested lands within riparian zones Good/ TDB
Forest Disturbance (x1)	To be developed for SOLEC 2016
Groundwater Quality (x1)	To be developed for SOLEC 2016
Inland Water Quality Index (x1)	Good/ Undetermined
Lake Sturgeon (x2)	Fair/ Improving or Undetermined
Land Cover (x1)	Good/ In preparation Land cover in the Lake Superior basin is dominated by natural cover.
Nutrients in Tributaries (x1)	To be developed for SOLEC 2016
Pesticides in Tributaries (x1)	To be developed for SOLEC 2016
Sea Lamprey (x1)	Fair/ Improving
Sediment Coastal Nourishment (x1)	To be developed for SOLEC 2016
Terrestrial Non-Native Species (x1)	Good/ Undetermined/Undetermined Lake Superior coastal areas have relatively few invasive plants, including Common Reed.
Threatened Species (x2)	To be developed for SOLEC 2016
Tributary Flashiness (x1)	St. Louis River (Lake Superior Basin) Good/ Improving
Walleye (x2)	Fair/ Undetermined
Watershed Stressor Index (x1)	Fair In preparation – status of fair assigned based on average basin-wide index of 63/100

Viability Rankings of SOLEC Indicators

Very Good	*Ecologically desirable status; requires little intervention for maintenance*
Good	*Within acceptable range of variation; may require some intervention for maintenance.*
Fair	*Outside of the range of acceptable variation and requires management. If unchecked, the biodiversity target may be vulnerable to serious degradation.*
Poor	*Allowing the biodiversity target to remain in this condition for an extended period will make restoration or preventing extirpation practically impossible.*

Figure 2.12: Tributaries. Depicts the rivers, streams and lakes of the Lake Superior watershed.

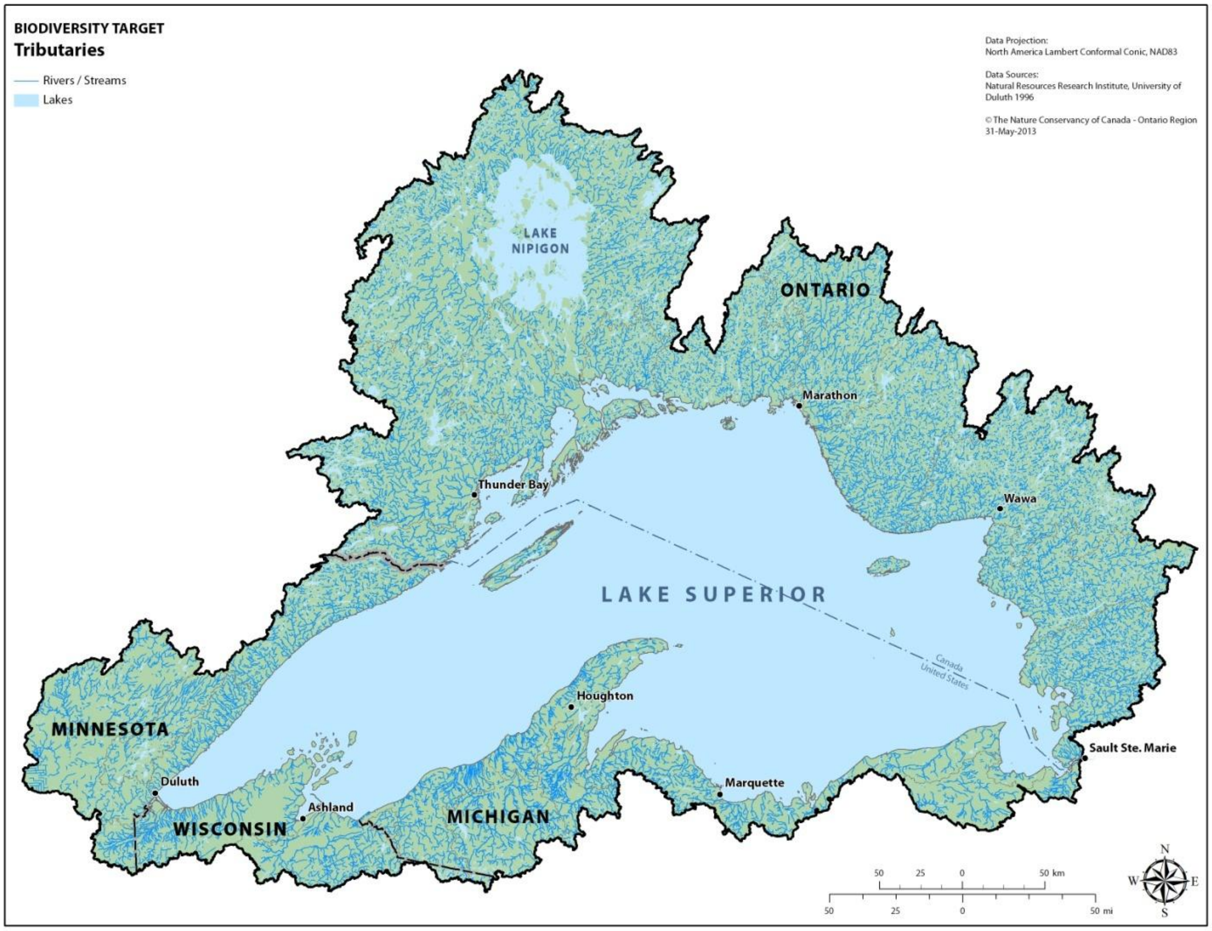


Figure 2.13: Lake Sturgeon Spawning Rivers. The shaded circles depict the population information for Lake Sturgeon. The left half of the circle shows the population status and the right half of the circle depicts population trajectory. There is some uncertainty if the Harmony and Stokely Rivers ever supported spawning sturgeon as both rivers are shallow and flashy. This identification may have been perpetuated in the literature and because of a naming error in the chart for this area that calls the Chippewa River the Harmony. This map includes new information on Lake Sturgeon populations from the Lake Superior Lake Sturgeon Work Group and the Anishinabek/Ontario Fisheries Resource Centre (Ecclestone 2013).

3.0 Issues Impacting the Health of Lake Superior

Threats to Lake Superior were assessed based on their potential impact to the biodiversity targets over the next ten years. A list of draft threats was developed from previous biodiversity conservation strategies (Lake Ontario Biodiversity Strategy Working Group 2009; Franks Taylor et al. 2010; Pearsall, Carton de Grammont, Cavalieri, Chu et al. 2012; Pearsall, Carton de Grammont, Cavalieri, Doran et al. 2012), regional and local plans, reports from SOLEC and the Lake Superior LAMP. The initial threat ranking was reviewed by the project Steering Committee and then updated based on expert review comments.

This information was assessed using the CAP process. It was entered into *Miradi* which calculates threat ratings using a rule-based system that combines Scope, Severity and Irreversibility criteria (Box 3.1). It then produces an overall threat-to-target rank and calculates ratings for threats across all targets and overall threat ratings for each target. This is the same method that was used to rank threats for the recent biodiversity conservation strategies for the other Great Lakes.

The overall threat rank for Lake Superior is *high* (Table 3.1). This is driven by a high rating for climate change, aquatic invasive species and dams and barriers. These threats rank the highest because they impact many targets over a wide area and, in some cases, are very difficult to reverse. These high ranking threats generally reflect SOLEC pressure indicators that are poor and declining including climate change (i.e., ice duration) and aquatic invasive species. Climate changes and aquatic invasive species are also based on predictions of future impacts (vs. dams and barriers which reflects a current condition that will also largely exist in the future), and have a higher degree of uncertainty around scope and severity.

The biodiversity conservation targets with the highest threat ratings are: nearshore zones and reefs, inshore and embayments, coastal wetlands and tributaries and watersheds. These systems generally have the most threats including invasive species, climate change and dams and barriers. The other biodiversity conservation targets have a medium threat rating. All of the threats that are ranked high and medium are detailed in this section. Appendix E provides more detail on the threat rankings, including how scope, severity and irreversibility of each threats was applied to each target.

Box 3.1: Direct threats rating criteria used in the CAP process

Scope - Most commonly defined spatially as the proportion of the target that can reasonably be expected to be affected by the threat within ten years given the continuation of current circumstances and trends.
For ecosystems and ecological communities, measured as the proportion of the target's occurrence.
For species, measured as the proportion of the target's population.

- Very High: The threat is likely to be pervasive in its scope, affecting the target across all or most (71-100%) of its occurrence/population.
- High: The threat is likely to be widespread in its scope, affecting the target across much (31-70%) of its occurrence/population.
- Medium: The threat is likely to be restricted in its scope, affecting the target across some (11-30%) of its occurrence/population.
- Low: The threat is likely to be very narrow in its scope, affecting the target across a small proportion (1-10%) of its occurrence/population.

Severity - Within the scope, the level of damage to the target from the threat that can reasonably be expected given the continuation of current circumstances and trends.
For ecosystems and ecological communities, typically measured as the degree of destruction or degradation of the target within the scope.
For species, usually measured as the degree of reduction of the target population within the scope.

- Very High: Within the scope, the threat is likely to destroy or eliminate the target, or reduce its population by 71-100% within ten years or three generations.
- High: Within the scope, the threat is likely to seriously degrade/reduce the target or reduce its population by 31-70% within ten years or three generations.
- Medium: Within the scope, the threat is likely to moderately degrade/reduce the target or reduce its population by 11-30% within ten years or three generations.
- Low: Within the scope, the threat is likely to only slightly degrade/reduce the target or reduce its population by 1-10% within ten years or three generations.

Irreversibility (Permanence) - The degree to which the effects of a threat can be reversed and the target affected by the threat restored.

- Very High: The effects of the threat cannot be reversed and it is very unlikely the target can be restored, and/or it would take more than 100 years to achieve this (e.g., wetlands converted to a shopping center).
- High: The effects of the threat can technically be reversed and the target restored, but it is not practically affordable and/or it would take 21-100 years to achieve this (e.g., wetland converted to agriculture).
- Medium: The effects of the threat can be reversed and the target restored with a reasonable commitment of resources and/or within 6-20 years (e.g., ditching and draining of wetland).
- Low: The effects of the threat are easily reversible and the target can be easily restored at a relatively low cost and/or within 0-5 years (e.g., off-road vehicles trespassing in wetland).

Table 3.1 Summary of Biodiversity Conservation Threat Rankings for Lake Superior

Threats \ Targets	**Embayments and Inshore**	**Nearshore Zone and Reefs**	**Islands**	**Deepwater and Offshore Waters**	**Coastal Wetlands**	**Tributaries and Watersheds**	**Coastal Terrestrial Habitats**	**Summary Threat Rating**
Aquatic Invasive Species	High	High		High	High	High		**High**
Climate Change	High	Medium	High	Medium	High	Medium	High	**High**
Dams and Barriers	High	High			Low	High		**High**
Atmospheric Deposition	Medium	Medium		Medium	Medium			**Medium**
Coastal Development	High	Medium	Medium		Medium		Medium	**Medium**
Incompatible Forestry						Medium	Medium	**Medium**
Mining	Medium	Medium	Low		Low	High	Low	**Medium**
Non-point Source Pollution	Medium	Medium			Medium	Medium		**Medium**
Terrestrial Invasive Species			Medium		Medium	Medium	Medium	**Medium**
Incompatible Fisheries Management	Low	Medium		Low				**Low**
Oil Spills from Shipping and Refining	Low	Low	Low		Low	Low	Low	**Low**
Point Source Pollution	Medium	Low		Low	Low	Low		**Low**
Wind Energy Development	Low	Low				Low	Low	**Low**
Summary Target Ratings:	**High**	**High**	**Medium**	**Medium**	**High**	**High**	**Medium**	**High**

Very High	The threat is likely to *destroy or eliminate* the biodiversity target.
High	The threat is likely to *seriously degrade* the biodiversity target.
Medium	The threat is likely to *moderately degrade* the biodiversity target.
Low	The threat is likely to *only slightly impair* the biodiversity target.

Lake Superior Threats to Biodiversity Heath
3.1 Aquatic Invasive Species

Overall Rating: HIGH
Biodiversity Targets Impacted:

- Deepwater and Offshore Waters (*High*)
- Nearshore Zone and Reefs (*High*)
- Embayments and Inshore (*High*)
- Coastal Wetlands (*High*)
- Tributaries and Watersheds (*High*)

*Zebra Mussels (*Dreissena polymorpha*) and Quagga Mussels (*Dreissena bugensis*) are only found in some areas of Lake Superior, including in the harbors of Duluth and Thunder Bay. There is a risk that aquatic invasive species may spread to other embayments.*
Image: http://www.portofthunderbay.com

Aquatic invasive species (AIS) were identified as a high threat to the biodiversity of Lake Superior because they impact many of the targets throughout most of their range, can seriously degrade habitats and are difficult to reverse. Once aquatic invasive species are established and abundant, ecosystems are likely to experience instability and unpredictability, and a loss of biotic community diversity (Horns et al. 2003).

In the Lake Superior watershed, 97 non-native aquatic species have been found, including fish species, aquatic invertebrates, diseases and parasites, algae and plants (Minnesota Sea Grant 2012a). A further 53 species have been identified as "watch-list species" for the Great Lakes basin (United States Geological Survey [USGS] 2012) (see Appendix D). Of the five Great Lakes, Lake Superior has the highest ratio of non-native to native fish species (Environment Canada [EC] and the U.S. Environmental Protection Agency [US EPA] 2005), with a ratio of 20 non-native species to 68 native species (Minnesota Sea Grant 2012b). When non-native species become established in an ecosystem, spreading widely and causing harm, they are considered invasive (Lake Superior Work Group 2010). Due to Lake Superior's low temperature and productivity, non-native species do not reproduce and spread as quickly as in other Great Lakes. Lake Superior still has the fewest overall number of aquatic invasive species of any of the Great Lakes (Dupre 2011).

The mechanisms or pathways for introduction of aquatic invasive species are varied (Lake Superior Work Group 2010). Most non-indigenous species were introduced through unintentional release or in the ballast water of ships (Horns et al. 2003; LSBP 2006a). Lake Superior receives a disproportionate amount of deballasting activities, which could serve to facilitate introductions of aquatic invasive species (Grigorovich et al. 2003). Salmon and some species of trout were introduced for sport fishing and to control Rainbow Smelt (Horns et al. 2003; Minnesota Sea Grant 2012b). In some cases, the introduction mechanism for non-native species is not entirely clear. Viral Hemorrhagic Septicemia (VHS, *Novihabdovirus* sp.) is believed to have been introduced by commercial ships or recreational boats from the lower Great Lakes (Lake Superior Work Group 2010).

Lake Superior is the only lake to have an aquatic invasive species prevention plan. Efforts to reduce the introduction of new aquatic invasive species into the Great Lakes appear to be reducing the rate of invasions and no new species have been recorded since 2006. Future impacts of aquatic invasive species in Lake Superior may occur from extant species moving to new locations. Further spread could be facilitated by climate change resulting in warmer water temperatures and increased recreational use.

One of the most serious aquatic invasive species to have become established in Lake Superior is Sea Lamprey. Sea Lamprey have significantly altered the fish community, and the combined cost of suppression efforts and the economic effect on fisheries ranges into the hundreds of millions of dollars (Horns et al. 2003). Sea Lamprey are currently managed in the basin through the application of lampricide in key rivers where they spawn. Existing dams and barriers also prevent Sea Lamprey from accessing some spawning areas. The ecosystem effects of more recently introduced species including Ruffe and Round Goby (*Neogobius melanostomus*) are not fully known. For a number of non-native fishes (including Ruffe, Alewife [*Alosa pseudoharengus*], and Fourspine Stickleback [*Apeltes quadracus*]) the period from 2001 to 2005 recorded stable or declining population trends (Pratt et al. 2010).

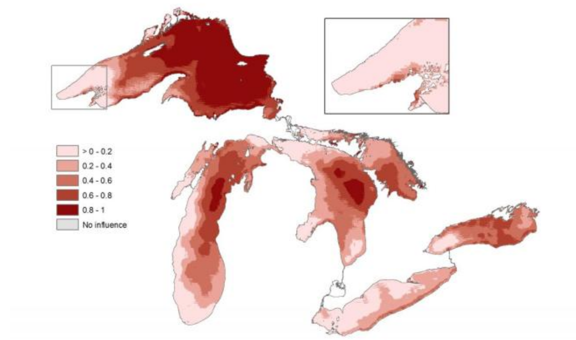
Asian carps (Bighead Carp [*Hypophthalmichthys nobilis*], Silver Carp [*Hypophthalmichthys molitrix*], Grass Carp [*Ctenopharyngodon idella*] and Black Carp [*Mylopharyngodon piceus*]) have been identified as one of the most serious potential invaders to the Great Lakes ecosystem. The risk of Asian carp invasion and establishment in Lake Superior is rated as moderate in the next ten years (Cudmore et al. 2012). Modelling predicts that if the entry point of Asian carp into the Great Lakes is through the Chicago canal, then very few individuals would make it to Lake Superior in 20 years. Those that do migrate into the lake would likely become established in the northern embayments, including Black Bay and Thunder Bay and the St. Louis estuary. If Asian carp became established in western Lake Superior (through the release of live fish), they are likely to remain in the estuary, but would also likely start to move into nearshore and inshore waters at Black Bay, Thunder Bay and the Keweenaw Peninsula (Cudmore et al. 2012).

Lake Superior Threats to Biodiversity Heath
3.2 Climate Change

Overall Rating: HIGH
Biodiversity Targets Impacted:

- Deepwater and Offshore Waters (*Medium*)
- Nearshore Zone and Reefs (*Medium*)
- Embayments and Inshore (*High*)
- Coastal Wetlands (*High*)
- Islands (*High*)
- Coastal Terrestrial Habitats (*High*)
- Tributaries and Watersheds (*Medium*)

Climate change was identified as a high threat to the biodiversity of Lake Superior over the next ten years because it impacts all of the targets throughout their range, will likely have moderate impacts and the effects cannot be reversed.



While water temperatures are increasing across the Great Lakes, Lake Superior may be the most impacted (GLEAM 2012, Allan et al. 2013)
Image: http://www.greatlakesmapping.org

The Lake Superior Ecosystem Climate Change Adaptation Draft Plan (LSECCAP Draft) (LSBP 2012a) identifies a number of projected changes to the regional climate and effects to ecosystems. Expected changes to climate include: 1) an increase in air temperatures by 3 to 4.5^{o}C by the end of the 21st century, 2) a slight increase in annual precipitation, with seasonal shifts in amounts, 3) an increase in annual average water temperatures of 5 to 7^{o}C throughout the 21st century, 4) a continued decrease in the extent and duration of ice cover through the 21st century, 5) increased wind speeds, 6) an expected decrease in water levels similar to the decreases seen during the past 20 years and, 7) an earlier onset of spring and summer and an increased growing season (LSBP 2012a). Evidence suggests that some of these changes are already underway, including increases in open-water summer temperatures and changes in lake stratification, and reductions in winter ice cover (Austin and Colman 2008).

The projected changes to climate are expected to alter the physical, chemical and biological aspects of Lake Superior (LSBP 2012a). Coastal wetlands could shrink, negatively impacting fish and wildlife populations. Lower water levels would be favourable to the invasive Common Reed, while higher water temperatures may favour aquatic invasive species such as Sea Lamprey (LSBP 2012a). Deciduous forests may shift northward due to warmer air temperatures and changes in precipitation. Forest pests may also spread widely due to higher air temperatures (LSBP 2012a). Disjunct and boreal species that are dependent on cooler temperatures and microclimates may experience a reduction in suitable habitat due to increased air temperature and lower lake water levels (LSBP 2012a). Shorelines may be more vulnerable to erosion, due to lower water levels and higher wave energy. Warmer waters would impact a number of species, from altering the plankton communities with potential implications for the entire food web, to creating conditions that are unfavourable to coldwater fish communities. Climate change may also cause increased concentrations of toxic pollutants through increased precipitation, or the exposure of previously submerged toxic sediments through lower water levels (LSBP 2012a). Water quality changes that could be brought about by climate change include lower dissolved oxygen levels due to warmer waters and an increased duration of summer stratification and an increase in algal blooms (LSBP 2012a). Climate change could also alter human uses and potential impacts on the lake. Longer shipping and boating seasons could increase the risk for introduction of aquatic invasive species.

Lake Superior Threats to Biodiversity Heath
3.3 Dams and Barriers

Overall Rating: HIGH
Biodiversity Targets Impacted:

- Nearshore Zone and Reefs (*High*)
- Embayments and Inshore (*High*)
- Coastal Wetlands (*Low*)
- Tributaries and Watersheds (*High*)

Dams and barriers were identified as a high threat to the biodiversity of Lake Superior because they impact many of the aquatic targets throughout most of their range and can seriously degrade habitats for migratory fishes. The impacts of any dams and barriers can however, be reasonably reversed.


Options to improve fish passage at the Camp 43 dam on the Black Sturgeon River are currently being explored by the Ontario Ministry of Natural Resources.
Image: Ontario Ministry of Natural Resources

Dams and barriers disrupt connectivity for aquatic (and sometimes terrestrial) organisms and the movement of woody debris, sediment and nutrients. Dams and barriers include structures like dams, weirs and poorly installed road-stream crossings. When improperly installed, culverts can become "perched", resulting in a barrier to fish moving upstream. This is more common in headwater areas with smaller streams. Over 23,600 dams and potential barriers have been documented from the Lake Superior watershed (Januchowski-Hartley et al. 2013) (Figure 3.1).

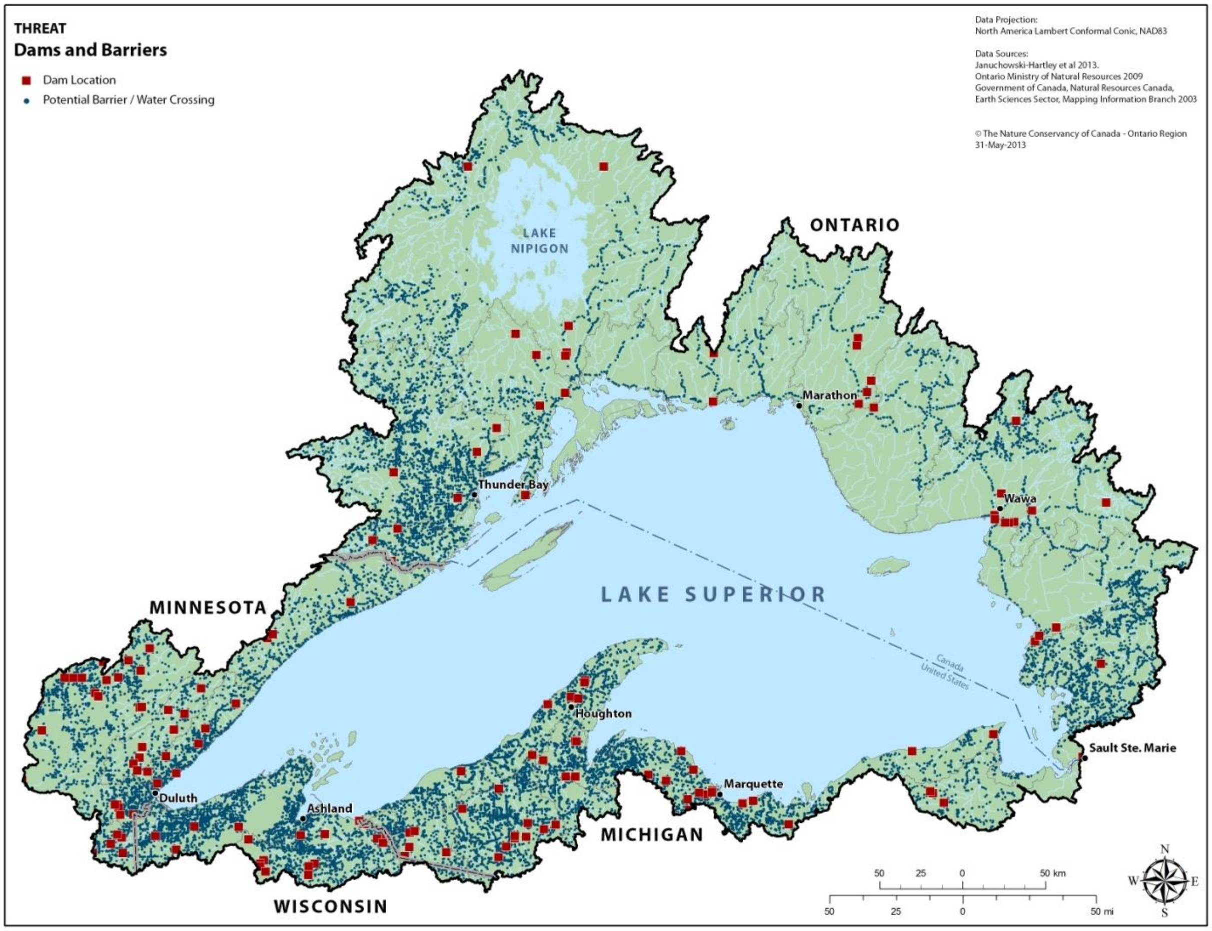
Dams are identified as one of the principal stresses to aquatic habitat in Lake Superior because they can prevent some migratory fishes from reaching spawning grounds in tributary streams and are considered an impediment to the fish community objective for tributary spawning Lake Sturgeon (Horns et al. 2003). Dams are major contributing factors to population collapses of some Lake Superior fish stocks. For example, the Black Sturgeon Dam on the Black Sturgeon River is thought to be partially responsible for the Black Bay Walleye population collapse in 1966, and for the inability of this population to recover. Although the spawning and nursery habitat still exists, it is inaccessible (Gorman et al. 2010b).

Many dams in the basin are now more than 50 years old and are deteriorating. Faced with aging infrastructure and the availability of funding for habitat restoration projects, the removal of dams and barriers has been increasing (Kraus 2011). In some cases the impacts of dams and barriers can be reduced without complete removal. The Nipigon River Water Management Plan has resulted in a more natural cycle of river flow in the Nipigon River watershed (LSBP 2008).

Most new dams will have fewer impacts than existing, legacy dams. In Ontario, land uses on crown land, including hydropower, are governed by land use designations. Where land use designations permit the potential development of hydropower, proposals for development are considered on a site specific basis through environmental assessment processes. These processes are designed to assess potential impacts to the environment, including aquatic species and habitat, as well as identify any appropriate avoidance and mitigation measures.

Dam removal is a complex issue in the Great Lakes. While dams prevent migratory fishes from accessing tributary habitats, they also prevent Sea Lamprey from accessing spawning areas, and some dams and barriers may need to be used as management tools to limit the spread of aquatic invasive species.

Figure 3.1: Dams & barriers in the Lake Superior Basin. Red dots depict documented dam locations. Smaller dots are road-stream crossings. Some of these crossings may present a barrier to migratory fishes (e.g., at sites with perched culverts). These crossings need to be assessed on a case-by-case basis. Data from Januchowski-Hartley et al. (2013).



Lake Superior Threats to Biodiversity Heath
3.4 Atmospheric Deposition

Overall Rating: MEDIUM
Biodiversity Targets Impacted:

- Deepwater and Offshore Waters (*Medium*)
- Nearshore Zone and Reefs (*Medium*)
- Embayments and Inshore (*Medium*)
- Coastal Wetlands (*Medium*)

Atmospheric deposition was identified as a medium threat to the biodiversity of Lake Superior because it impacts many of the aquatic targets throughout their range. While actions to reduce emissions will need to occur at a scale beyond the basin, recent studies have shown that aquatic ecosystems can recover quickly once inputs such as mercury are reduced.

Coal-fired power plants are a major source of mercury deposition. In 2013, Canada and the U.S. signed the Minamata Convention on Mercury to reduce emissions.
Image: http://sierraclubgreatlakes.blogspot.ca

Atmospheric deposition is the primary means through which a number of persistent bioaccumulative toxic chemicals enter the Lake Superior basin (LSBP 2000). Atmospheric deposition is identified as a principal stressor to the aquatic community of Lake Superior resulting in some degradation to all habitat zones (LSBP 2006a). Chemicals from atmospheric deposition affect the lake in the form of contaminated offshore waters, sediments, and fish and waterbirds.

Mercury is one of the most serious chemicals that enters the lake through atmospheric deposition. Coal-fired power plants are the largest source of mercury air emissions (Integrated Atmospheric Deposition Network [IADN] Steering Committee 2011). While the levels of mercury and other persistent bioaccumulative toxic chemicals in the air are lowest over Lake Superior, the large surface area allows for atmospheric deposition to be a large source of chemical input (IADN Steering Committee 2011). The Lake Superior ecosystem also has unique physical, thermal and biological characteristics which retain chemical contaminants, including cold waters and a long retention period (LSBP 2012b), and unique microbial food web (Guildford et al. 2008).

While there has been a decrease in the release of several chemical contaminants over the past 30 years, a consistent decline in these chemicals in Lake Superior sediments has not been observed. Since the first measurements of PCBs (Polychlorinated Biphenyls), DDT (dichloro-diphenyl-trichloroethane) and mercury were taken in the 1960s they have only declined slightly (Gewurtz et al. 2008 as cited in LSBP 2012b). Despite an 80% reduction in mercury discharges and emissions in the Lake Superior basin from 1990 to 2010, mercury levels in fish are increasing and are higher than in any other Great Lake (LSBP 2012b), resulting in some advisories against fish consumption (LSBP 2012b, IADN Steering Committee 2011). Atmospheric deposition of nutrients such as nitrogen also has the potential to change the productivity of some ecosystems, and may be linked to the spread of Common Reed (Rickey and Anderson 2004). The atmospheric deposition of chemicals of emerging concern has been identified as an additional potential stressor for the Great Lakes. Efforts to determine chemicals of emerging concern are underway and brominated flame retardants have emerged as one key group (IADN Steering Committee 2011).

Lake Superior Threats to Biodiversity Heath
3.5 Coastal Development

Overall Rating: MEDIUM
Biodiversity Targets Impacted:
- Nearshore Zone and Reefs (*Medium*)
- Embayments and Inshore (*High*)
- Coastal Wetlands (*Medium*)
- Islands (*Medium*)
- Coastal Terrestrial Habitats (*Medium*)

Coastal development and shoreline changes can remove and fragment habitats and disrupt coastal processes.
Image: neebing.estatesincanada.com

Coastal development was identified as a medium threat to the biodiversity of Lake Superior because it impacts many of the coastal and aquatic targets in a limited part of their range. Where incompatible development does occur it can seriously degrade habitats and is very difficult to mitigate or reverse.

Coastal development included roads, residential, commercial and industrial development, in addition to shoreline structures such as rip rap, bulkheads, jetties, groins, piers, gabions and seawalls. Coastal development directly destroys habitats, including the loss of coastal forests and beaches and the filling of wetlands. Fragmentation of habitats reduces the capacity of coastal species to migrate along the shoreline. Loss of wetlands in numerous sites around Lake Superior has negatively impacted Yellow Perch, and in some locations Walleye, Northern Pike, and other species have also been affected (Horns et al. 2003). Modifications to and development of shorelines may even facilitate invasions by aquatic invasive species by disrupting populations of native species (Meadows et al. 2005).

Shoreline structures and hardening can constrain shifts of coastal habitats in response to changes in lake levels. Structures that are constructed to protect shoreline properties can also alter sediment transport processes along the coast and impact beaches and wetlands. In parts of Lake Superior, beaches have been lost through the installation of jetties, breakwater and hardened shorelines which capture sand up-current (Kraus and White 2009). Artificial shorelines replace natural habitat, such as coastal wetlands, and are often found near the mouths of larger rivers, where urban areas are located (LSBP 2006a).

Artificial structures presently account for less than five percent of the Lake Superior shoreline (Figure 3.2), and Lake Superior's shoreline remains in a largely natural state compared to other Great Lakes (LSBP 2006a). However, while Lake Superior has many areas of public ownership and protected areas along significant stretches of shoreline, the shoreline is becoming increasingly developed (LSBP 2006a). Areas of human habitation are already concentrated in estuaries and embayments (Figure 3.3).

In urban communities, reclamation of former industrial lands for public waterfront access, or restoration of green space along the shore is a positive shoreline trend that may continue with reduced industrial demand for shoreline (LSBP 2006a).

Figure 3.2: Artificial Shoreline. Red areas depict artificial shoreline.

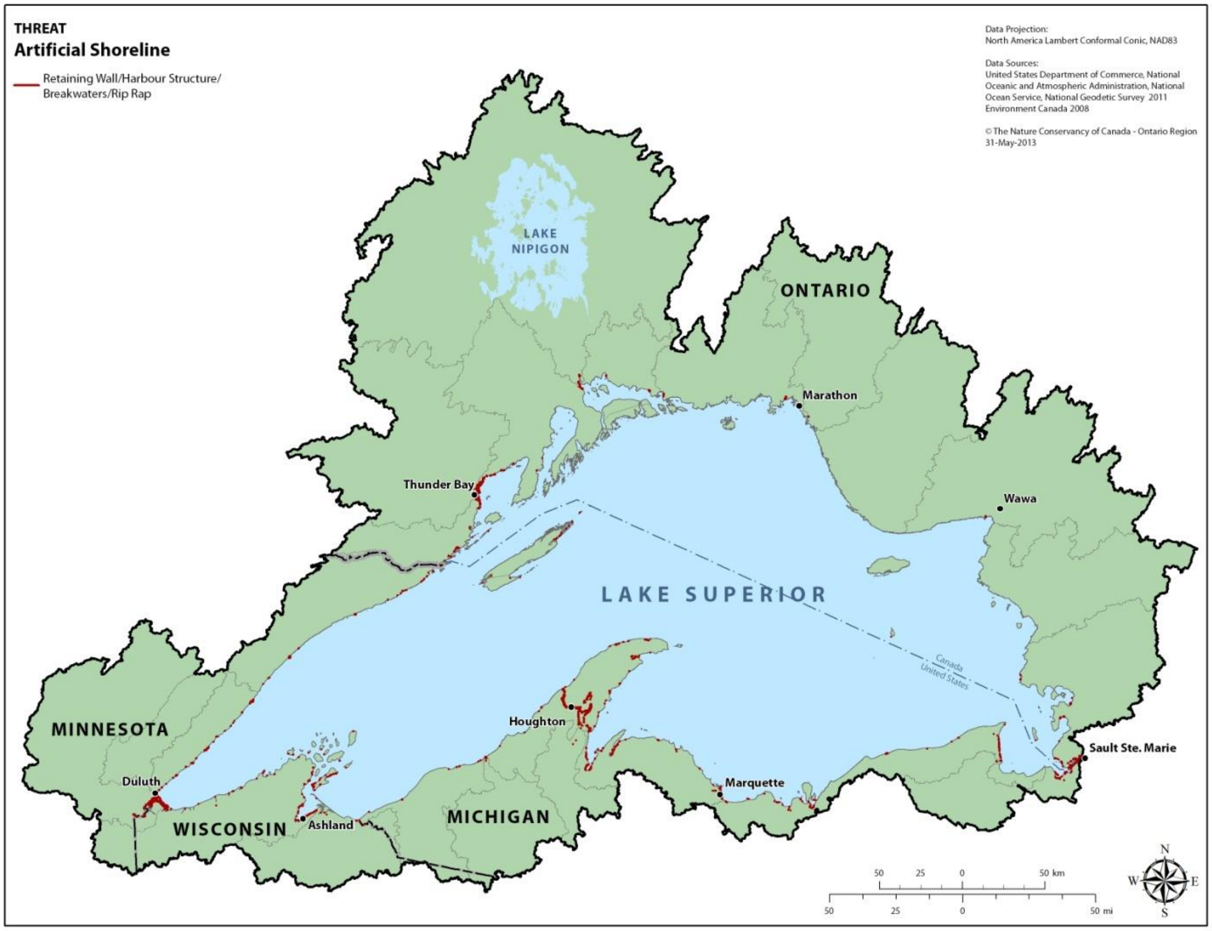
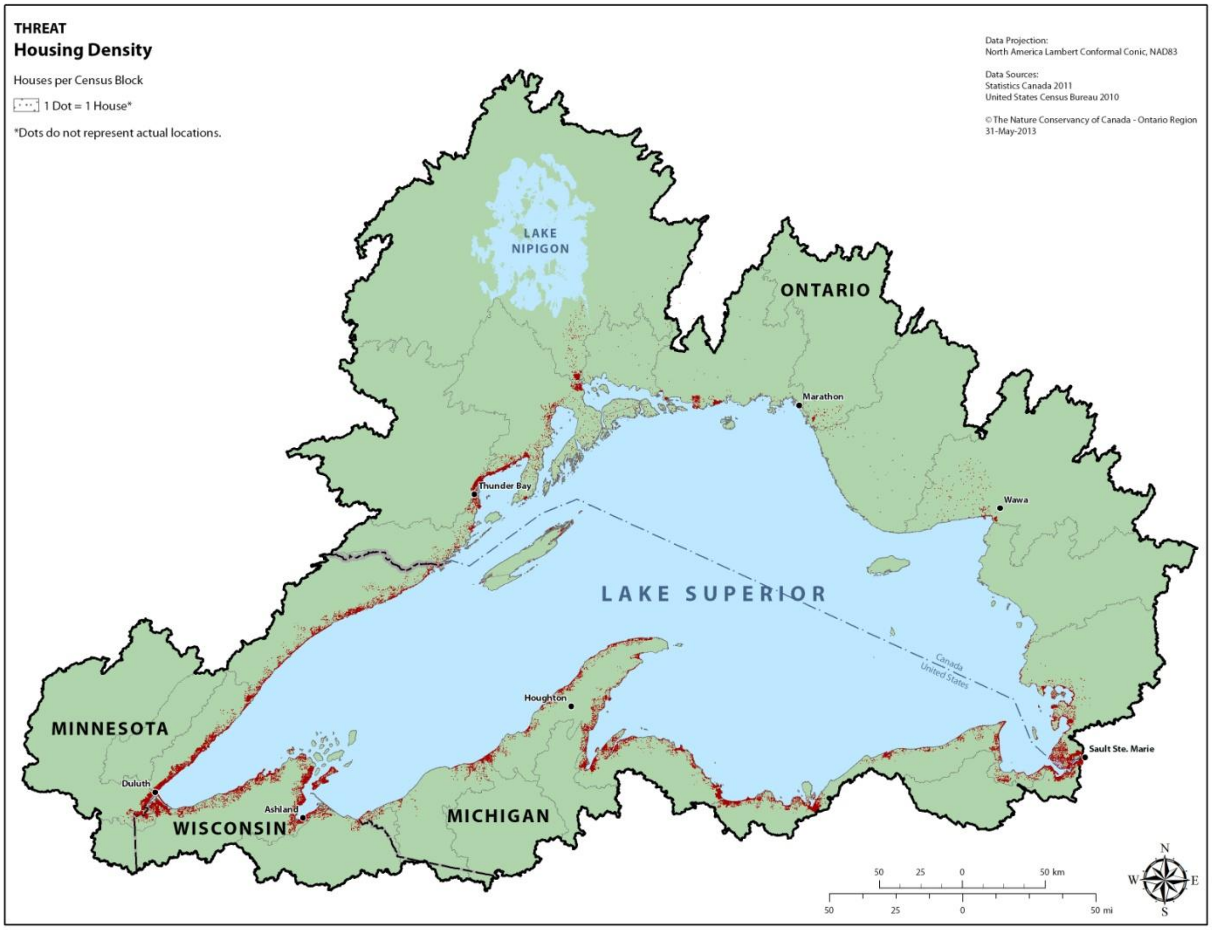


Figure 3.3: Housing density along the Lake Superior coast. Concentrations of red (dots) denote areas with higher levels of coastal development.



Lake Superior Threats to Biodiversity Heath
3.6 Incompatible Forestry

Overall Rating: MEDIUM
Biodiversity Targets Impacted:
- Coastal Terrestrial Habitats (*Medium*)
- Tributaries and Watersheds (*Medium*)

Incompatible forestry was identified as a medium threat to the biodiversity of Lake Superior because it impacts coastal habitats and watersheds in part of their range and can moderately degrade these habitats. However, it is possible to reverse the impacts.

Most of Lake Superior's forests are managed sustainably. Incompatible forestry can result in habitat loss and degradation to tributaries.
Image: landsalelistings.com

Forestry is one of the three principal industries of the Lake Superior basin, along with mining and tourism (National Wildlife Federation [NWF] 1993 as cited in LSBP 2006a). Incompatible forestry includes practices that result in significant soil exposure or compaction, which leads to increased sedimentation and runoff into tributaries. This can result in sedimentation of fish spawning grounds and an increase in nutrients to nearshore waters (see Section 3.8). Examples of incompatible forestry include large clearcuts, significant forest clearing in or near riparian areas, excessive soil disturbance through heavy equipment operation or dragging of logs on slopes or in riparian areas, and poorly designed stream crossings.

A number of forestry practices have historically been incompatible, and have consequently degraded fish habitat. Log drives, the logging of stream banks, and erosion from stream crossings are problems that have occurred in all of the major Lake Superior watersheds in Ontario (LSBP 2006a).

In the Ontario portion of the Lake Superior basin, 75% of land ownership is Crown Land, and administration of forestry is through the Ontario Ministry of Natural Resources and Forestry (OMNRF). Sustainable forest licenses are used to ensure sustainable management of commercial forestry, reducing practices of incompatible forestry (LSBP 2006a). In the U.S. portion of the basin, 47% of forests are owned by various levels of government; public involvement in planning is being more integrated at all levels (LSBP 2006a). Many of the public and a growing numbers of private lands are currently certified for sustainable forestry practices. Under these practices, timber harvesting is designed to mimic natural disturbances, retain wildlife habitat features and protect riparian areas (LSBP 2006a).

A recent analysis of land use change in the basin detected a decrease in the amount of coniferous forest and a corresponding increase in deciduous and mixed forest that is likely related to forestry practices (Hollenhorst et al. 2011). Fire suppression in the basin may also have some impact on nutrient flows into Lake Superior (S. Greenwood, pers. comm., 2013).

Lake Superior Threats to Biodiversity Heath
3.7 Mining

Overall Rating: **MEDIUM**
Biodiversity Targets Impacted:

- Embayments and Inshore (*Medium*)
- Nearshore Zone and Reefs (*Medium*)
- Coastal Wetlands (*Low*)
- Islands (*Low*)
- Coastal Terrestrial Habitats (*Low*)
- Tributaries and Watersheds (*High*)

Mining was identified as a medium threat to the biodiversity of Lake Superior because it impacts many of the targets in a limited part of their range, but can have major impacts that cannot be easily reversed. The impacts of new mines will likely not be as severe as historic mines due to better environmental regulations, but the number of mining applications in the basin is growing rapidly.

The 15 km^2 Hull-Rust Mahoning Iron Mine near Hibbing MN at the headwaters of the St. Louis River.
Image: http://www.superiorforum.org

Mining remains a major land use in the Lake Superior basin, and interest in mining is increasing (LSBP 2006a). Mining activities in the Lake Superior basin have extracted gold, silver, copper, platinum, palladium, nickel, zinc, diamond, lead, iron-ore and taconite, as well as quarried brownstone (LSBP 2006a; Kerfoot et al. 2009). Many of these operations are open-pit mines (Kerfoot et al. 2009).

Mines in the Lake Superior basin were at one time global leaders in the production of silver and copper (LSBP 2006a). The Keweenaw Peninsula area in Michigan was the second largest global copper producer for over 75 years (Kerfoot et al. 2012), and Minnesota still produces 75% of the iron ore in the United States (LSBP 2006a). In addition to these existing mines, there has been a recent increase in exploration and claims in the basin. A recent map by the Lake Superior Ad Hoc Mining Committee (2011) shows the locations of operating mines, sites of mineral exploration, and areas of mineral leases and mining claims (Figure 3.4). Aggregate quarries have also been proposed along the Ontario coast, and an increase in mining in Ontario's northern "Ring of Fire" may increase the number of smelting and shipping facilities on Lake Superior. Many Lake Superior watersheds are shown to have mining activity and a number of mineral leases and mining claims extend to coastal areas (Figure 3.4).

Mining can contribute to impaired water quality, especially in the nearshore, embayments and tributaries (Horns et al. 2003). In areas of Minnesota and Michigan, the nearshore habitat has been locally degraded due to the discharge of mine chemicals and tailings (Horns et al. 2003). Mining sediments in the nearshore, embayments and river mouths may cover and degrade spawning habitats (Chiriboga and Mattes 2008; Kerfoot et al. 2012). Mining can also result in direct habitat impacts to coastal species and habitats, and degradation of tributaries.

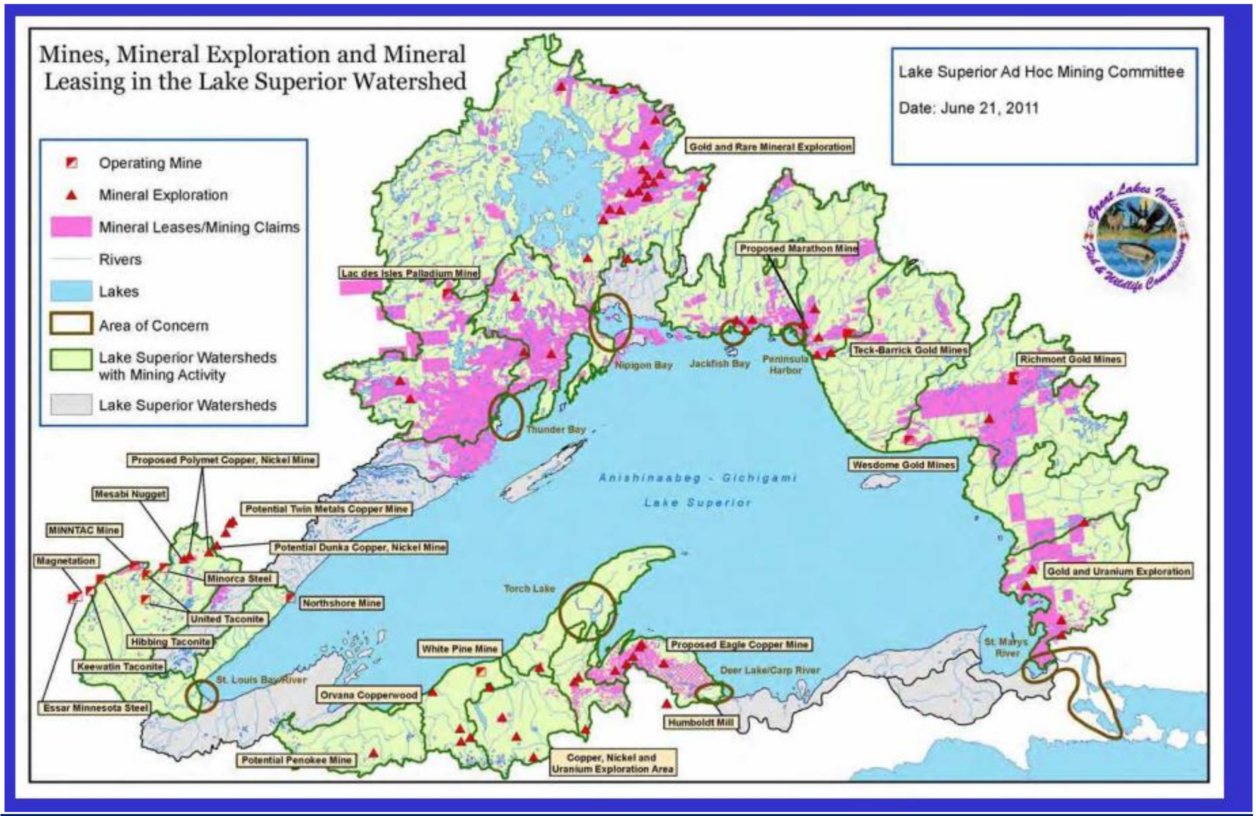
Some early mining operations (e.g., on the Keweenaw Peninsula) discharged tailings directly into Lake Superior (Kerfoot et al. 2009). Some evidence from Keweenaw Bay suggests that while metal concentrations are declining and recovery is occurring, the continued erosion of tailing piles into Lake Superior contributes metals to the nearshore areas (Kerfoot et al. 2009).

Mine wastes from historical iron mining in the Lake Superior basin have remained potential sources for contaminants and environmental impairments, decades after the closure of mine operations (LSBF 2011). Some Lake Superior Areas of Concern (AOCs), including Deer Lake (MI) (delisted as an AOC in 2014) and Torch Lake (MI), were listed as AOCs due to the negative effects of mining activities (LSBP 2008). Despite the closure of some of these mines over 50 years ago, adverse environmental effects are still evident. It is estimated that it may be 800 years before concentrations of copper in water and sediment at Torch Lake return to background conditions (Kerfoot et al. 2009).

Mining is closely linked to mercury emissions. In 2010, although the total mercury emissions declined from 2005 levels (from 333 kg/yr to 261 kg/yr), mining and metals production still accounted for 63% of the mercury emissions. Taconite mining (a form of iron) accounted for 98.5% of the mercury emissions from mining (LSBP 2012b). Existing taconite mining and new or expanded mining are identified as emissions sources which present reduction challenges (LSBP 2008, 2012b). Minnesota's statewide goals for Total Maximum Daily Loads (TMDL) of mercury emissions cannot be met without reductions from the mining sector (LSBP 2008).

The contribution of some mining sectors to harmful air emissions has also been identified in Canada's Regulatory Framework for Air Emissions (LSBP 2008). The historic release of harmful emissions continues to impact some regions in the basin. The processing of iron ore in Wawa from 1939 to 1998 caused a plume containing sulfur and arsenic to be released, which in turn deforested an area 40 km away and large enough to be seen on satellite surveys (Kerfoot et al. 2009). However, the closure of mining facilities does lead to reductions in chemical outputs. Many of the reductions of nine Zero Discharge Demonstration Program (ZDDP) chemicals between 1990 and 2000 were primarily the result of the closure of two mining facilities in Michigan and Ontario (LSBP 2006b).

Figure 3.4: Mining in the Lake Superior Basin



Lake Superior Threats to Biodiversity Heath
3.8 Non-point Source Pollution

Overall Rating: MEDIUM

Biodiversity Targets Impacted:

- Embayments and Inshore (*Medium*)
- Nearshore Zone and Reefs (*Medium*)
- Coastal Wetlands (*Medium*)
- Tributaries and Watersheds (*Medium*)

Non-point source pollution was identified as a medium threat to the biodiversity of Lake Superior because it impacts four of the targets in part of their range, and can have moderate impacts that can be reversed with reasonable commitment.

Heavy rains in June 2012 resulted in significant run-off into the western part of Lake Superior.
Image: NOAA; http://www.seagrant.umn.edu

Non-point source pollution results from diffuse movement of rainwater and snowmelt across the landscape into surface waters. As water moves across the landscape, nutrients, sediment, and other pollutants are dissolved or suspended by the water and carried into tributaries and the waters of Lake Superior. This form of pollution cannot be traced to a specific point. It contains sediment, chemical or nutrient contaminants that exceed natural baseline levels and, as a result, degrades water quality and associated biological communities. Human activities such as agriculture, urban development and forestry have increased water runoff and the amount of pollutants in runoff. Phosphorus and sediments are the most serious non-point source pollutants in Lake Superior, and are generally only an issue in embayments that have high levels of watershed development. Phosphorus runoff is considered one of the most important drivers of eutrophication and the proliferation of nuisance algae because phosphorus often limits algal growth in freshwater ecosystems. Sediments exported from rivers cause turbidity, which can interfere with aquatic plant growth and prey location by visual predators, and alter benthic habitat conditions.

Non-point source pollution from atmospheric deposition is treated separately in this report.

Lake Superior Threats to Biodiversity Heath
3.9 Terrestrial Invasive Species

Overall Rating: MEDIUM
Biodiversity Targets Impacted:

- Coastal Wetlands (*Medium*)
- Islands (*Medium*)
- Coastal Terrestrial Habitats (*Medium*)
- Tributaries and Watersheds (*Medium*)

Terrestrial invasive species were identified as a medium threat to the biodiversity of Lake Superior because they impact all of the terrestrial and wetland targets in part of their range, and can have moderate to severe impacts that can be reversed with reasonable commitment.

Common Reed is spreading in the southern Great Lakes and has scattered occurrences along the Lake Superior coast including the Bayview Beach-Sioux River Slough, WI and Batchawana Bay, ON.
Image: http://www.torontozoo.com/

Terrestrial invasive species could directly impact coastal habitats by displacing native species and altering the composition and function of these ecosystems. Compared to the other Great Lakes, terrestrial invasive species are rare in the Lake Superior basin (see Appendix D), presenting an opportunity for early detection and eradication before they become problematic.

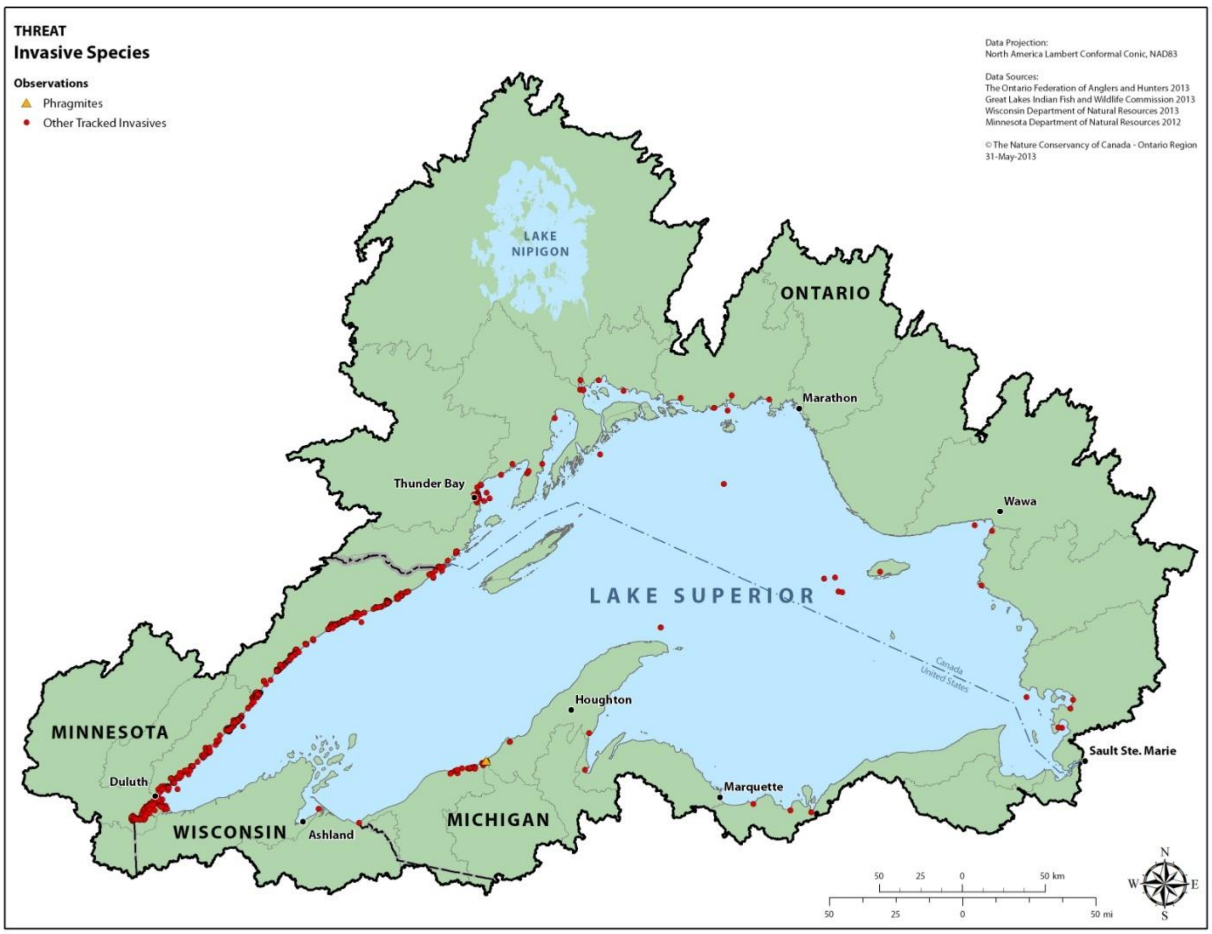
Common Reed[8] is one of the most serious coastal invaders in other regions of the Great Lakes. It is distributed sporadically along the southern shore of Lake Superior, as well as on Isle Royale (Michigan Tech Research Institute [MTRI] no date; Midwest Invasive Species Information Network [MISIN] 2013). It is also found in scattered occurrences in Ontario (Invasives Tracking System 2012), and in the coastal marshes of Batchawana Island (Noble 1982b as cited in Henson et al. 2010). Purple Loosestrife (*Lythrum salicaria*) is identified as another high impact invasive species (Liva 2011). In Ontario, Purple Loosestrife is now found in several locations in the basin (Invading Tracking System 2012). It is also found at numerous locations throughout Wisconsin, Minnesota and Michigan (MISIN 2013; Great Lakes Early Detection Network [GLEDN] 2012). Other terrestrial invasive species are Common Buckthorn (*Rhamnus cathartica)*, Honeysuckle (*Lonicera sp*.) and Garlic Mustard (*Alliaria petiolata*) (Liva 2011). Exotic buckthorns (Common Buckthorn and Glossy False Buckthorn [*Frangula alnus*]) are established in Duluth (MN), Michigan and Wisconsin, but not in the Ontario portion of the basin. Tatarian Honeysuckle (*Lonicera tatarica*) is established in Duluth (MN), Michigan, and near settlements in Ontario. Garlic Mustard is known to occur in the Lake Superior basin, and has it has been verified in Wisconsin, as well as a number of locations in counties in Michigan (MISIN 2013). Leafy spurge (*Euphorbia esula*) is widespread in the basin, but restricted to roadsides and disturbed sites (LSBP 2006a). Spotted Star-thistle (or Spotted Knapweed [*Centaurea biebersteinii]*) is known from Isle Royale and Grand Sable Dunes in Michigan and in northern Wisconsin. It has also been reported to be in the east side of the Lake Superior basin in Ontario (LSBP 2006a). Other non-native species which affect Lake Superior's watersheds include the Gypsy Moth (*Lymantria dispar*) and the Emerald Ash Borer (*Agrilus planipennis*), which has been found in the Upper Peninsula of Michigan (LSBP 2008) as well as in Sault Ste. Marie Ontario (Canadian Food Inspection Agency [CFIA] 2012). Recent reported locations of a number of invasive species in the U.S. portion of the Lake Superior basin can be viewed using the Midwest Invasive

[8] Common Reed is also treated as an aquatic invasive species (AIS) by some agencies and in some reports because it often occurs in wetlands.

Species Information Network mapping tool (MISIN 2013). Figure 3.5 depicts the location of some invasive species along the coast.

The *Lake Superior Aquatic Invasive Species Complete Prevention Plan* recognizes that the same methods recommended to prevent the spread of AIS can be used as tools to prevent the spread of terrestrial invasive species (Lake Superior Work Group 2010).

Figure 3.5: Coastal Terrestrial Invasive Species. The red dots depict tracked invasive species from various state and provincial databases. Common Reed is shown in orange. These databases are not complete and there are projects to improve tracking and mapping of terrestrial invasive species in many regions of Lake Superior. Note that the Ontario database includes aquatic species (i.e., locations in the lake).



3.10 Other Threats and Emerging Issues

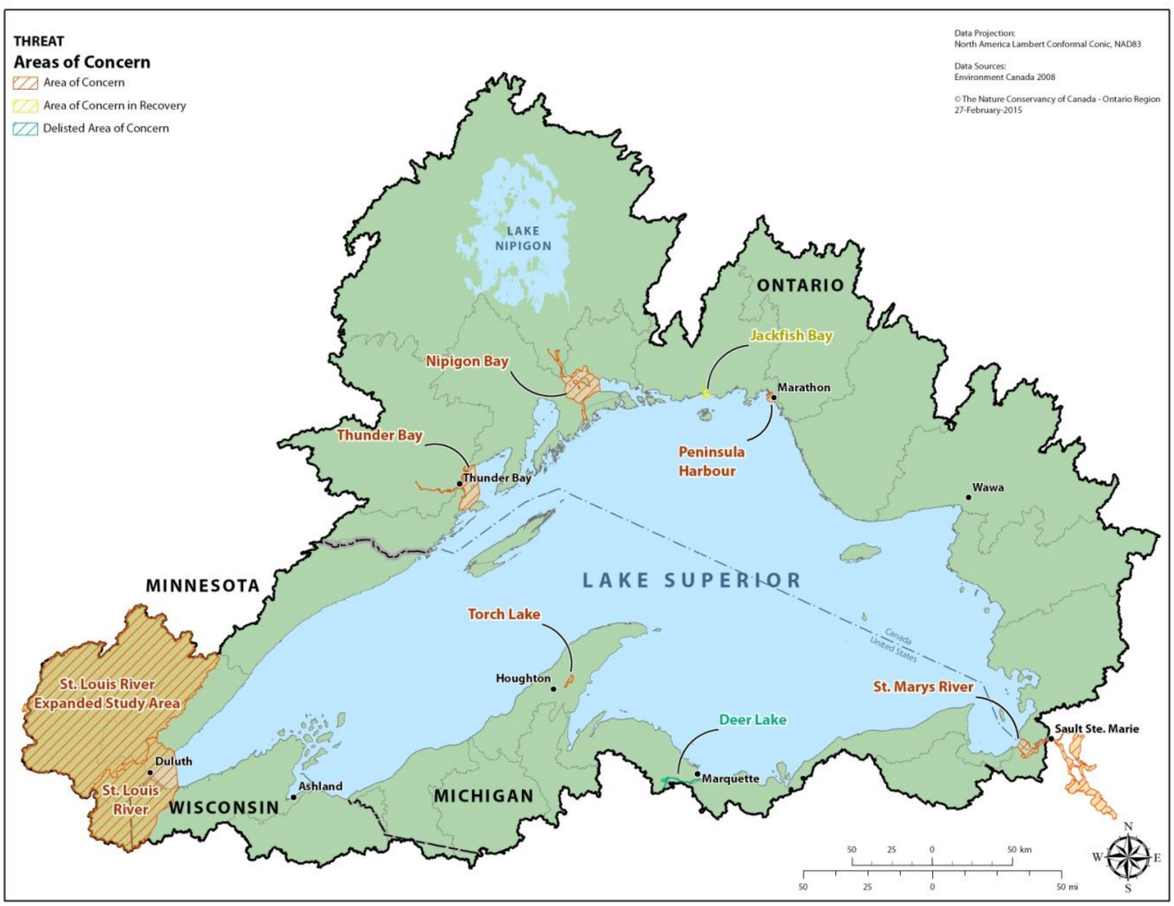
Several lower ranking threats were identified in the assessment. These threats generally have limited scope and/or severity, or there is some information that their intensity could increase in the future. Some of these threats may be very important regional issues, but generally have limited lakewide impacts to the health of biodiversity compared to the other threats that have been identified.

Point Source Pollution

Point source industrial effluents and waste have been major habitat stressors in Lake Superior (Horns et al. 2003), and the legacy of this pollution still impacts biodiversity in some areas. Remediation of these polluted sites in the Great Lakes has been a major focus of the Great Lakes Water Quality Agreement. In Lake Superior, eight Areas of Concern (AOCs) have been identified: Thunder Bay, Nipigon Bay, Jackfish Bay (Area of Concern in Recovery), Peninsula Harbour, St. Marys River, Deer Lake (delisted in 2014), Torch Lake and the lower St. Louis River (Figure 3.6).

The Ontario Ministry of the Environment uses 37 streams to monitor and assess the impacts of point source pollution, including the mouths of major tributaries (LSBP 2006a).

Figure 3.6: Lake Superior Areas of Concern.

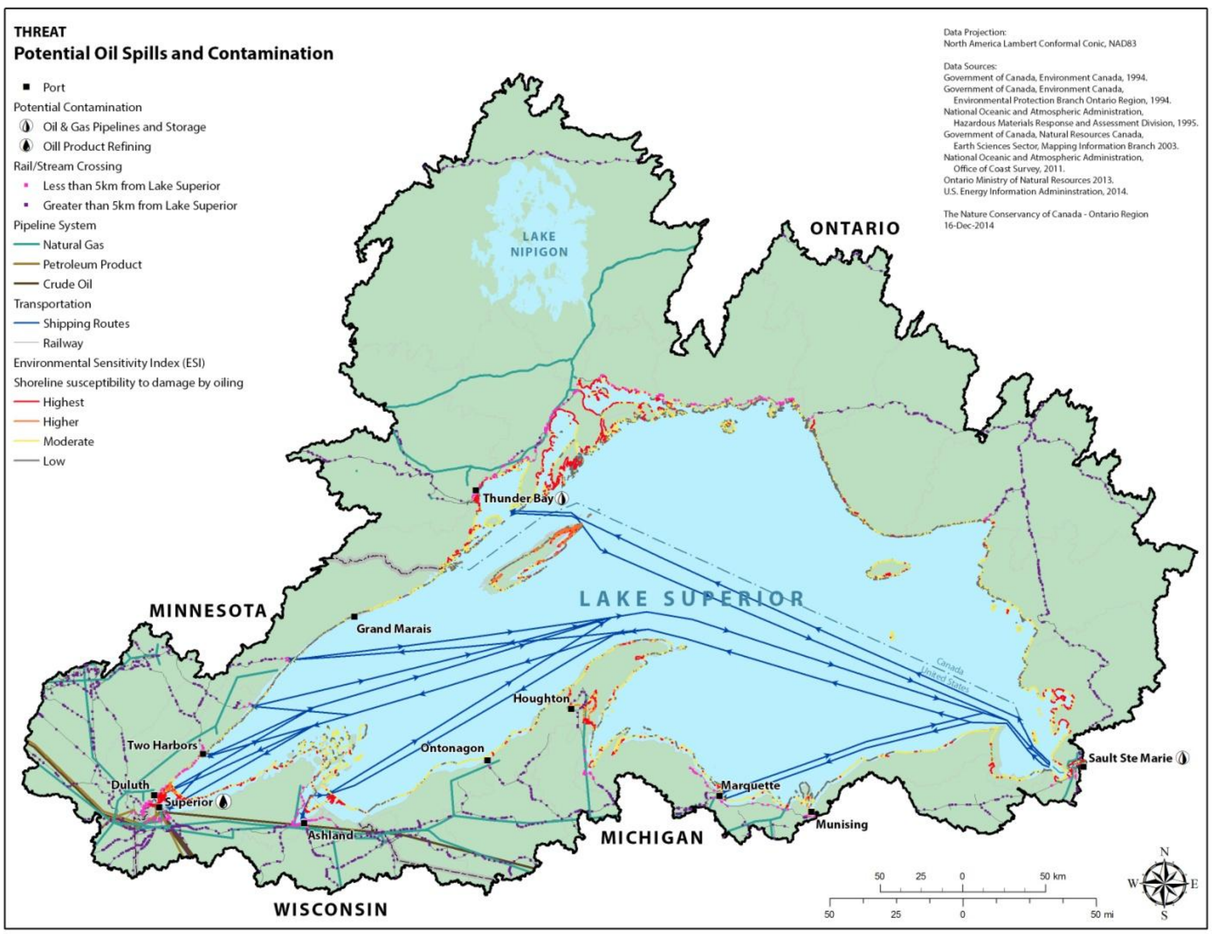


Oil Spills from Shipping and Refining

Although oil spills were ranked as a low threat from a lake wide perspective, it is difficult to predict the scope and severity of potential spills. There are several new proposals which could increase the amount of oil being refined and transported in the Lake Superior basin. This includes increased volumes of oil transported through existing pipelines that run through the basin, increased shipping of oil on rail, and a proposed expansion of the refinery in Superior, Wisconsin that proposes to load up to 13 million barrels of crude oil a year onto barges for shipping to other refineries in the lower Great Lakes. While expansion of refinery and docking facilities could have regional impacts, shipping of crude oil on Lake Superior could have significant impacts on coastal, inshore and nearshore species and habitats in the event of a spill.

Figure 3.7 illustrates the regions of Lake Superior that are potentially more sensitive to marine oil spills. This figure also depicts road and rail stream crossings, and pipelines where accidents could impact tributaries or nearshore areas.

Figure 3.7: Oil and Gas Infrastructure and Shoreline Sensitivity



Incompatible Fisheries Management

Effective fisheries management has been an important tool in restoring the populations of many of Lake Superior fishes, and harvest rates are currently sustainable. There has been some recent discussion on establishing a regulated fishery for siscowet Lake Trout for omega 3 fatty acids. Some biologists are concerned that the lake could not support this commercial harvest.

Other future changes in stocking or catch limits could also cause issues for fish populations. The rehabilitation of lean Lake Trout and Lake Whitefish in the nearshore waters of the east end of the lake has not progressed to the same extent as the remainder of the lake. Ensuring that the unregulated fish harvests in the region are at levels that maintain sustainable populations will provide for the opportunity to resume cooperative rehabilitative fish stocking efforts.

Wind Energy Development

Several wind farms have been developed on and near the eastern coast of Lake Superior in Ontario, and Minnesota's north shore is actively being explored. Many coastal areas of Lake Superior have high potential wind power and have access to existing regional power grids that have been established for hydro-electric power. Wind energy development could fragment some coastal areas and, if improperly sited, can impact migrating birds and bats.

4.0 Regional Summaries

In order to support place-based conservation in Lake Superior, the basin and waters were divided into 20 regional units (Table 4.1). These units are based on quaternary watershed boundaries that were grouped based on coastal environments identified from Lake Superior. In addition to the watershed and coast, each regional unit includes the associated inshore and nearshore waters. In some regions, offshore waters were also incorporated to include islands. One unit that encompasses all of the Lake Superior offshore waters was also included. Maintaining the open waters as a single unit was recommended by the Aquatic Community Committee/Lake Superior Technical Committee. These units are shown on Figure 4.1.

Volume Two of this report includes summaries for each regional unit. Information in the regional summaries was based on a review of the literature and expert input. Spatial information was calculated for this project using the data sources outlined in the data catalogue (Appendix A). It is recognized that many regions contain additional information and mapping on biodiversity and threats that could not be fully reflected in this report. Wherever possible, regional and local data and spatial information on biodiversity targets and threats has been included in the text.

These summaries also include the scoring of biodiversity target viability/condition at a regional-scale based on stress/condition indices (see Section 2). The grades provided in the report card, and conditions and trend table are intended to denote relative condition/health and stresses for each biodiversity target in the region based on available condition and stress indices (see below). **These grades are intended to help highlight where the biodiversity targets are likely in better or worse health than the lakewide average, and to inform discussion about priority areas for conservation and restoration.** This automated assignment on the relative regional health of biodiversity targets was subject to expert review, and in cases where the experts felt the grade did not reflect actual conditions, the results were overridden with this expert input.

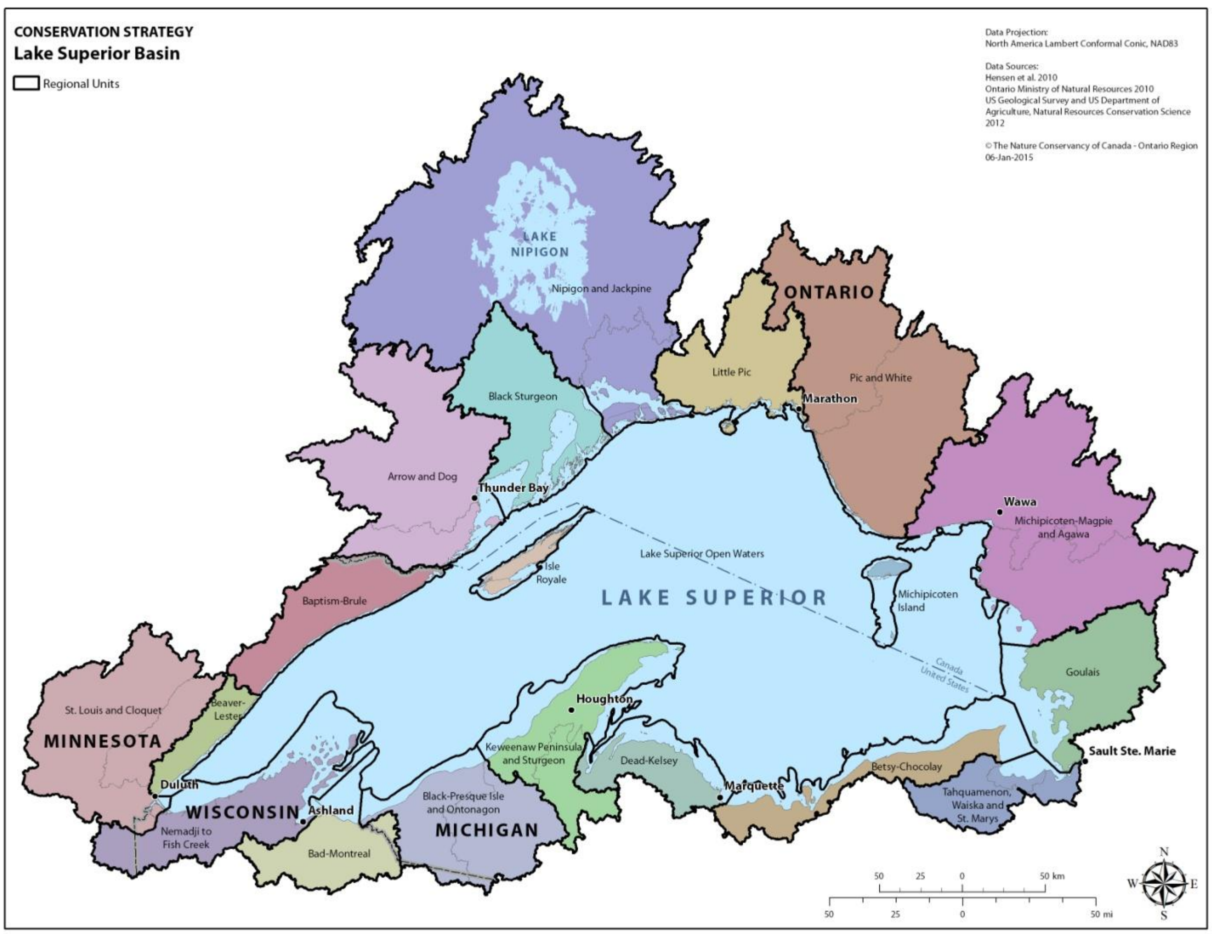
For each regional unit, a regional average of all stress/condition indices was calculated based on the individual scores of each sub-unit within the region (Appendix F). For example in Regional Unit 1 (Goulais), each of the 92 quaternary watersheds has a watershed stress index value (in this case ranging from 0 to 0.754, max=1). The regional score is based on an average of these sub-units. For the Watershed Stress Index and Great Lakes Cumulative Stress, the average was subtracted from 1. For the Coastal Condition Index, the average was subtracted from the maximum possible score. These regional average values were then applied to the biodiversity targets. For some targets only one average index was used (e.g., the average value of the watershed stress index was used for the tributary and watershed target). For other targets, the condition/stress is likely reflected by a combination of the indices (e.g., embayment health), and the average of multiple indices was applied (Table F.1 in Appendix F). The final score/grade is an average of the score for all targets.

Priority areas for conservation are based on the 264 important habitat areas have been mapped by the Lake Superior LAMP (LSBP Habitat Committee 2006). These are based on the important habitat map, most recently updated in 2006, developed in recognition that to restore and maintain the whole ecosystem, key biological features require special attention. Box 4.1 provides the criteria that were used to select these sites. Conserving or restoring these system components are of highest priority to maintaining Lake Superior biodiversity, recognizing that other important habitat areas inevitably exist, most notably in remote expanses of Lake Superior's east and north shores where habitats are largely undisturbed.

Table 4.1: Regional Units

1. Goulais
2. Michipicoten-Magpie and Agawa
3. Pic and White
4. Michipicoten Island
5. Little Pic
6. Nipigon and Jackpine
7. Black Sturgeon
8. Arrow and Dog
9. Baptism-Brule
10. Isle Royale
11. Beaver-Lester
12. St. Louis and Cloquet
13. Nemadji to Fish Creek
14. Bad-Montreal
15. Black-Presque Isle and Ontonagon
16. Keweenaw Peninsula and Sturgeon
17. Dead-Kelsey
18. Betsy-Chocolay
19. Tahquamenon, Waiska and St. Marys
20. Lake Superior Open Waters

Figure 4.1: Regional Units



Box 4.1: Criteria for the Identification of Biodiversity Features in the Lake Superior Watershed

Ecosystems

1. Large, relatively unfragmented areas most representative of the Lake Superior basin ecosystem that support natural community assemblages where ecosystem dynamics are intact or can be restored.
2. Nationally significant ecosystems. Areas that have wildlife and plant habitat values that go beyond local values in that they provide substantial benefits that extend beyond the basin.
3. Old Growth Forest. Tracts of varying size supporting native old growth forest. Tracts that with restoration and proper management could support high quality, native old growth forest.
4. Coastal shore or coastal wetland ecosystems. Sites that have, or with restoration could develop, high quality, diverse ecosystems that are representative of the interacting communities unique to the Lake Superior shoreline.
5. Areas that support high biological and ecological diversity. Sites that support, or with restoration could support the compositional, functional, and structural elements associated with diverse ecosystems.
6. Habitats that contribute to, or with restoration could contribute to maintaining ecosystem integrity on a landscape scale. These areas could include buffering communities around currently protected ecosystems, core areas within a managed area, or may be connecting corridors between important habitat sites.

Communities

1. Rare communities. Communities that are of high quality, or have high restoration potential, or are critically endangered. Examples include: calcareous fens, beach dunes, interdunal wetlands, red clay wetland complexes, bedrock beaches and cliffs.
2. Plant and wildlife habitats that are rare in the Lake Superior basin, or are rare globally.
3. Plant and wildlife habitats that occur only in the Great Lakes basin.
4. Communities that are, or that with restoration could be, outstanding representatives of the natural (i.e., pre-settlement) ecosystem.

Species

1. Sites (large or small) that serve as habitat for vulnerable, endangered, threatened or special concern species (or candidate species) during any stage of their life cycle. Currently occupied habitats and sites with potential for future colonization or reintroduction are included. Prioritization of potential sites depends on status of the species (i.e., rarity at global, sub-national, and basin scales), likelihood of occupation and the quality (or restoration potential) of the site.
2. Sites that serve, or with restoration may serve, vital functions in the life cycle of species named in appropriate planning documents (e.g., Lake Superior Ecosystem Objectives, Fish-Community Objectives for Lake Superior, Tribal resource plans, etc.)
3. Habitats required for the conservation of migratory wildlife (e.g., neotropical migrant birds, migratory fish, etc.), including staging areas, migration corridors and routes.
4. Spawning and nursery grounds for reptiles, amphibians, fish, or aquatic invertebrates. Colonial water bird nesting sites.
5. Habitats that can contribute to the conservation of species most likely to be at risk from human activity.
6. Habitats that support species that provides important ecological functions (e.g., nutrient cycling or chemical detoxification.)

5.0 Next Steps

This Biodiversity Conservation Assessment is the first step of a process to develop a strategy that will ensure the long-term conservation and restoration of Lake Superior. The assembly, synthesis and review of this information are intended to provide a platform to link strategies to the current health of biodiversity targets and the most critical threats. This report also provides baseline information on biodiversity targets and threats that can be used to help set lakewide ecosystem objectives and inform future SOLEC reporting.

This first phase in development of a Biodiversity Conservation Strategy for Lake Superior included a focus on collecting and presenting information from all regions of Lake Superior. This was done based on recommendations from participants in the previous biodiversity conservation strategies, recognizing that while some actions will need to be implemented at the lakewide scale, many of the most important actions to conserve and restore Lake Superior will need to occur within local communities. The regional information presented in this report can be used to put local actions into a lakewide context and to help set regional ecosystem objectives and measures. While Areas of Concern and Remedial Action Planning (RAP) have served as an important model to restore degraded areas in the Great Lakes, this regional information can be used to develop implementation plans that also aim to maintain the high quality waters, coasts and watersheds that exist in so many parts of the basin. The regional summaries also include examples of important and effective conservation work that is already happening at the local level that should serve as a model of best practices, and as inspiration to conserve and restore Lake Superior.

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Appendix A: Spatial Data Catalogue and Methods

Dataset	Vintage	Scale/ Resolution	Source	Notes
BIODIVERSITY TARGETS				
Deepwater and Offshore Waters				
Bathymetry of Lake Superior	1999	-	Publisher: National Geophysical Data Center Originator: National Geophysical Data Center NOAA Great Lakes Environmental Research Lab NOAA National Ocean Service Canadian Hydrographic Service	http://www.ngdc.noaa.gov/mgg/greatlakes/superior.html
Lake Superior Bathymetry	1998	1000 m	Natural Resource Research Institute	http://www.nrri.umn.edu/lsgis2/ - Generated 5-m contours from model for mapping bathymetry on maps
Computerized Bathymetry and Shorelines of the Great Lakes	1980 Revised 1996	2 km	Great Lakes Environmental Research Laboratory	http://www.glerl.noaa.gov/ftp/publications/tech_reports/glerl-016/dr-016.html http://www.glerl.noaa.gov/data/char/glshoreline.html
Lake Superior Bathymetry	2007	Unknown (20-m intervals)	Great Lakes Information Network (GLIN)	http://gis.glin.net/ogc/metadata/publish/lake_superior_bathymetry.html
Nearshore Zone and Reefs				
Reefs	 2012 2013	 1:250,000 1:24,000	List provided by committee Canadian Geographical Names Geographic Names Information System	 http://www.geobase.ca/geobase/en/search.do?produit=cgn&decoupage=province&language=en http://geonames.usgs.gov/domestic/download_data.htm
Atlas of the Spawning and Nursery Areas of Great Lakes Fishes	1982	-	Goodyear, C. S., T. A. Edsall, D. M. Ormsby Dempsey, G. D. Moss, and P. E. Polanski	Digitized the maps in report for Lake Trout and Lake Whitefish http://www.glsc.usgs.gov/main.php?content=products_publications_atlas&title=Publications0&menu=products
Coastal Wetlands				
Wetland Units (Ontario)	2012	1:10,000-1:50,000	Ontario Ministry of Natural Resources	Version also identifies whether evaluated and provincial/other significance

Dataset	Vintage	Scale/ Resolution	Source	Notes
Great Lakes Coastal Wetland Inventory	2004	1:10,000	Publisher: Great Lakes Wetland Consortium Originator: Environment Canada US Geological Service Michigan Natural Features Inventory Ontario Ministry of Natural Resources	Albert, D.A., J. Ingram, T. Thompson, and D. Wilcox http://www.glc.org/wetlands/inventory.html
National Wetlands Inventory Polygons (US)	2003	1:24,000	DNR Minnesota	http://deli.dnr.state.mn.us/metadata.html?id=L260000162101
DNR 100k Wetlands	2002	1:100,000	DNR Minnesota	http://deli.dnr.state.mn.us
Final Wetland Inventory (US)	2007	1:24,000	DNR Michigan/Michigan Department of Technology, Management and Budget	http://www.mcgi.state.mi.us/mgdl/?rel=thext&action=thmname&cid=3&cat=Final%5FWetland%5FInventory Available by County, assembled together
Wetlands	1994	1:24,000	DNR Wisconsin	Available by County, assembled together
Land Use / Land Cover	1999	200 m	Natural Resources Research Institute, University of Minnesota Duluth	Covers entire basin. Used for analysis. http://www.nrri.umn.edu/lsgis2/data/landuse.html Subset from classified Landsat MSS of Great Lakes Basin by Peter Wolter. US land cover was derived from the National Land Cover Database (Vogelmann *et al.* 1998) and Canadian land cover from the Ontario Land Cover Database (Spectranalysis 2004). Both of these land cover datasets were derived from 30 m Landsat Thematic Mapper satellite data, and use similar land classification schemes
Islands				
Great Lakes Island Biodiversity Project	2010	-	Henson, B.L., Kraus, D. McMurtry, M, Ewert, D.	
Colonial Waterbird Nesting Sites (Ontario)	2008	-	Canadian Wildlife Service	
Colonial Waterbird Nesting Sites (US)	2010	-	University of Minnesota, The Department of Fisheries, Wildlife and Conservation Biology	Table provided by Linda Wires.
Coastal Terrestrial Habitats				
SOLEC Shoreline Data (CAN)	2008	-	Environment Canada	Used for Ontario. Also used for Artificial Shoreline (Threat).
Great Lakes and St. Lawrence River Medium Resolution Vector Shoreline Data	1997	-	Great Lakes Environmental Research Laboratory, NOAA	Used for the United States. Also used for Artificial Shoreline (Threat).

Dataset	Vintage	Scale/ Resolution	Source	Notes
Provincial Land Cover (CAN)	1998, 2002	25 m	Ontario Ministry of Natural Resources	
Land Use / Land Cover	1999	200 m	Natural Resources Research Institute, University of Minnesota Duluth	Covers entire basin. Used for analysis. http://www.nrri.umn.edu/lsgis2/data/landuse.html [accessed 25/09/2012] Subset of classified Landsat MSS of Great Lakes Basin by Peter Wolter
Important Bird Areas	2004	≥ 1:50,000	Bird Studies Canada Canadian Nature Federation	None within basin.
Migratory Landbird Stopover Sites	2011	-	Canadian Wildlife Service	Modelled by NCC but only for an area covering Bird Conservation Region 12 in Ontario. Based on model by Ewert 2006.
Tributaries				
WRIP Water Flow Network (CAN)	2005	1:10,000	Ontario Ministry of Natural Resources	
DNR 24K Streams (Minnesota)	2003	1:24,000	DNR Minnesota	http://deli.dnr.state.mn.us/metadata.html?id=L260000072102 Not used for tributary map. May be needed for detailed analysis
Geographic Framework Hydrography Lines (Michigan)	2012	1:24,000	DNR Michigan/Michigan Department of Technology, Management and Budget	http://www.mcgi.state.mi.us/mgdl/framework/statewide/hydro_mi.zip Not used for tributary map. May be needed for detailed analysis Version 12b.
Hydrography – Flowlines (Wisconsin)	2011	1:24,000	DNR Wisconsin	ftp://dnrftp01.wi.gov/geodata/hydro_24k Not used for tributary map. May be needed for detailed analysis.
Lake Sturgeon Population Status and Trajectory	2008	-	Pratt 2008	Digitized from Table 2 “Recovery Strategy for Lake Sturgeon in Ontario” http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@species/documents/document/stdprod_086034.pdf
	2008	-	US Fish and Wildlife	Digitized from Page 1 “Lake Sturgeon Status by Lake Basin” http://www.fws.gov/midwest/sturgeon/documents/2008-coord-mttg-basin-tables-figures.pdf
Important Bird Areas	2012		Bird Studies Canada Audubon Society	
THREATS				
Roads	2011	1:10,000	Ontario Ministry of Natural Resources	Ontario Road Network
	2001	1:24,000	MN Department of Transportation	DOT Basemap Roads - All Types
	2012	1:24,000	Michigan Center for Geographic Information	MI Geographic Framework All Roads (v12b)
	2010	1:24,000	DNR Wisconsin	WI Roads 2010 (TIGER Lines)
Hydro Corridors	2011	-	Ontario Ministry of Natural Resources	

Dataset	Vintage	Scale/ Resolution	Source	Notes
Pipelines	2011	-	Ontario Ministry of Natural Resources	
Buildings/Population	2010	-	US Census Bureau	2010 Census Population & Housing Unit Counts – Blocks http://www.census.gov/geo/maps-data/data/tiger-data.html
	2011	-	Statistics Canada	2011 Census - Boundary files (Cartographic version) http://www12.statcan.gc.ca/census-recensement/2011/geo/bound-limit/bound-limit-2011-eng.cfm Geographic Attribute Table http://www5.statcan.gc.ca/bsolc/olc-cel/olc-cel?catno=92-151-XBB&lang=eng
Mines	2011	-	Ontario Ministry of Natural Resources	
Invasive Species	2013	-	Great Lakes Indian Fish and Wildlife Commission	
	2013	-	The Ontario Federation of Anglers and Hunters	
	2012	-	Minnesota Department of Natural Resources	
	2013	-	Wisconsin Department of Natural Resources	
Land Use / Land Cover	-	200 m	Peter Wolter	Covers entire basin. Used for analysis. http://www.nrri.umn.edu/lsgis2/data/landuse.html Subset from classified Landsat MSS of Great Lakes Basin by Peter Wolter. US land cover was derived from the National Land Cover Database (Vogelmann *et al.* 1998) and Canadian land cover from the Ontario Land Cover Database (Spectranalysis 2004). Both of these land cover datasets were derived from 30 m Landsat Thematic Mapper satellite data, and use similar land classification schemes
Areas of Concern	2008	1:5,000-1:10,000	Environment Canada	
Dams	2012		US Army Corp Engineers NID	USGS National Hydrological Data ftp://nhdftp.usgs.gov/DataSets/National
	2009	1:10,000	Ontario Ministry of Natural Resources	Dams and Barriers (Provincially owned/managed for Ontario)
	2008	1:1,000,000	Geogratis Atlas of Canada Framework	Hydrology – Dams (Ontario)
	2013		Januchowski-Hartley et al 2013.	In press in Frontiers in Ecology & Environment. Dams and road-stream crossings
Conservation / Protected Areas				
Federal Marine Conservation Areas (Ontario)	2010	50,000	Parks Canada	
National Parks (Ontario)	2003	1:50,000	Ontario Ministry of Natural Resources	

Dataset	Vintage	Scale/ Resolution	Source	Notes
National Parks (US)	2013		National Park Service - US Department of the Interior	https://irma.nps.gov/App/Portal/Home/FeaturedContent
National Wildlife Areas	2002	~1:50,000	Canadian Wildlife Service	
Crown Game Preserves	-	-	Ontario Ministry of Natural Resources	
Provincial Parks	2011	1:10,000	Ontario Ministry of Natural Resources	
Recommended Provincial Parks	2007	1:10,000	Ontario Parks	
Conservation Reserves	2007	1:10,000	Ontario Parks	
Conservation Authority Properties	2006 – 2012	1:10,000	Ontario Ministry of Natural Resources with supplemental information added by NCC	Dataset is not regularly maintained by MNR. Some areas have been manually added by NCC
NCC Properties	2012		Nature Conservancy of Canada	
NGO	2006		Ontario Ministry of Natural Resources	Dataset is not regularly maintained by MNR. Some areas have been manually added by NCC
Municipal Park	2006		Ontario Ministry of Natural Resources	Dataset is not regularly maintained by MNR.
ANSI	2011	1:10,000-1:50,000	Ontario Ministry of Natural Resources	
Conservation and Recreation Lands (Michigan)	2008		Ducks Unlimited and The Nature Conservancy	Michigan
Protected Areas Database of the United States (US)	2011	1:24,000-1:100,000	USGS	Version 1.2 - http://www.protectedlands.net/padus/preview.php Public land ownership, management and conservation lands nationally, including voluntarily provided privately protected areas
DNR Managed Lands	2012		Wisconsin Department of Natural Resources	Data provided by DNR
GAP Land Stewardship Coverage	2001		Michigan Department of Natural Resources	Downloaded from http://www.dnr.state.mi.us/spatialdatalibrary/sdl/ownership/land_stewardship_GAP/gap_stewardship_lp.exe

Dataset	Vintage	Scale/ Resolution	Source	Notes
• State Forest Boundaries • State Park Statutory Boundaries • Wildlife Private Lands Specialist Support Areas • Wildlife Refuge Inventory • State Wildlife Management Area Boundaries - Publicly Accessible • GAP Stewardship 2008 - Private Conservancy Lands	2012		Minnesota Department of Natural Resources	http://deli.dnr.state.mn.us/
US National Forests (Proclaimed)	2013		US Department of Agriculture – Forest Service	http://fsgeodata.fs.fed.us/vector/lsrs.php
CONDITION / STRESS				
Cumulative Stress, Laurentian Great Lakes, 2000-2009	2013	921 m	Dr. J.D. Allan, School of Natural Resources and Environment, University of Michigan	Great Lakes Environmental Assessment and Mapping (GLEAM) Project http://www.greatlakesmapping.org Scientific Manuscript: Allan et al. 2013
Watershed Stress Index	2011	-	Host et al. 2011, Natural Resources Research Institute, University of Minnesota Duluth	Great Lakes Environmental Indicators (GLEI) Project
UNITS				
Watersheds / Hydrologic Units	2010	1:10,000 – 1:250,000	Ontario Ministry of Natural Resources	Tertiary and Quaternary Watershed for Ontario
	2012	1:24,000	US Geological Survey US Department of Agriculture, Natural Resources Conservation Service	HUC8, HUC10 and HUC 12 Watersheds for US http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset
BASE				
Great Lakes	2010	1:10,000	Ontario Ministry of Natural Resources	

Dataset	Vintage	Scale/ Resolution	Source	Notes
International Boundaries	2010	1:5,000	International Boundary Commission via Geobase.ca	Canadian Geopolitical Boundaries
State Boundaries	2008	1:1,000,000	National Atlas of the United States - Unites States Geological Survey	
Populated Places			List provided by committee	
	2012	1:250,000	Canadian Geographical Names	http://www.geobase.ca/geobase/en/search.do?produit=cgn&decoupage=province&language=en
	2013	1:24,000	Geographic Names Information System	http://geonames.usgs.gov/domestic/download_data.htm
Provincial Boundary	2010	1:10,000	Ontario Ministry of Natural Resources	

Appendix B: Lake Superior Indicators

The following tables provide a summary of the indicators that were used to measures the health of the seven biodiversity targets in Section 2 of the report.

Table B.1 SOLEC Indicators. SOLEC indicators are based on 2011 State of the Great Lakes Highlight Report (EC and USEPA 2011). SOLEC indicators are categorized as 1) driving forces, 2) pressures, 3) state, 4) impacts, 5) response. Response indicators (i.e., remediating contaminated sediment, stocking native fish, etc.) are not used in the assessment of target health. These are listed at the bottom of the table. Some of the state indicators are weighed more heavily for some targets (see main report).

Indicator	**Category** **DPSIR Framework**	**Lake Superior Status and Trend**	**Rationale**
Contaminants in Waterbirds	Water Quality STATE	Good Improving	Significant decline for most legacy contaminants in long term (1974-2009) and short term (2000-2009). Some legacy and some new contaminants show no significant change in the short term. The traditional legacy contaminants, DDE, SUM PCBs and TCDD, have declined significantly both since the 1970s and in the last decade. Hg has declined significantly in the long term but neither it, nor SUM BDE, has declined significantly in the short term.
Contaminants in Whole fish	Water Quality STATE	Fair Deteriorating	Concentrations of PCBs and pentaBDEs are above guidelines in Lake Trout in Lake Superior and declining. Total Hg concentrations, although still below the target of 0.5 µg/g ww, have returned to levels observed in the 1980s and appear to be increasing.
Groundwater Quality	Water Quality STATE	To be developed for SOLEC 2016	
Nutrients in Lakes	Water Quality STATE	Good Unchanging	Targets have consistently been met, and offshore total phosphorus concentrations are similar to historic values, indicating acceptable conditions. There is no trend over time.
Major Ions	Water Quality STATE	To be developed for SOLEC 2016	
Toxic Chemicals in Offshore Waters	Water Quality STATE	Fair Undetermined	Concentrations of some compounds are lowest in Lake Superior, but several persistent compounds that are delivered to Lake Superior by atmospheric deposition are found at higher concentrations compared to the other Great Lakes. The temporal changes are subtle and the overall trend is unchanging.
Water Clarity	Water Quality STATE	Undetermined Mostly improving	Unchanging to moderate improvement in offshore waters with some deterioration in near-shore zones such as Thunder Bay and Duluth.

Indicator	**Category** **DPSIR Framework**	**Lake Superior Status and Trend**	**Rationale**
Water Chemistry	Water Quality STATE	*Specific Conductance* Increasing *Total Chloride* No Change *pH* No Change *Total Alkalinity* No Change *Turbidity* Increasing	*Specific Conductance* Spring lakewide median values from 1992 through 2008 exhibited a statistically significant ($P<0.05$, $\rho = 0.57$) positive Spearman's Rank Correlation. The median rate of change was 0.10 µmhos·cm-1·yr-1. *Total Chloride* Spring lakewide median values from 1992 through 2008 did not exhibit a statistically significant ($P>0.05$, $\rho = -0.10$) negative Spearman's Rank Correlation. *pH* Spring lakewide median values from 1992 through 2008 did not exhibit a statistically significant ($P>0.05$, $\rho = 0.13$) positive Spearman's Rank Correlation. *Total Alkalinity* Spring lakewide median values from 1992 through 2008 did not exhibit a statistically significant ($P>0.05$, $\rho = 0.43$) positive Spearman's Rank Correlation. *Turbidity* Spring lakewide median values from 1992 through 2008 exhibited a statistically significant ($P<0.001$, $\rho = 0.76$) positive Spearman's Rank Correlation. The median rate of change was 0.013 NTU·yr-1.
Bald Eagles	Aquatic Dependent Life STATE	To be developed for SOLEC 2016	
Benthos (Freshwater Oligochaete) Diversity and Abundance	Aquatic Dependent Life STATE	Good Unchanging	All sites in Lake Superior were classified as oligotrophic based on the oligochaete community index since 1997.
Coastal Wetland Amphibians	Aquatic Dependent Life STATE	Undetermined Undetermined	
Coastal Wetland Bird Communities	Aquatic Dependent Life STATE	Undetermined Undetermined	
Coastal Wetland Fish Communities	Aquatic Dependent Life STATE	Not assessed Undetermined	Progress Report only.

Indicator	**Category** **DPSIR Framework**	**Lake Superior Status and Trend**	**Rationale**
Coastal Wetland Invertebrates	Aquatic Dependent Life STATE	Not assessed Undetermined	Progress Report only.
Coastal Wetland Plants	Aquatic Dependent Life STATE	Mixed Undetermined	Degradation around major urban areas. Coastal wetlands plants in Lake Superior generally have a good status.
Diporeia	Aquatic Dependent Life STATE	Good Unchanging	Long- term monitoring of populations in deeper regions of the lake indicate that, although substantial interannual variability can occur, there are not directional trends in abundances of *Diporeia* in the lake. Other studies have shown abundances in shallower regions remain high.
Lake Sturgeon	Aquatic Dependent Life STATE	Fair Improving	Lake Sturgeon abundance shows an increasing trend in a few remnant populations and where stocked in the Ontonagon and St. Louis rivers. Lake Sturgeon currently reproduce in approximately half (10 of 21) of known historic spawning locations (Lake Superior Lake Sturgeon Work Group 2012, unpublished data).
Lake Trout **(weighted indicator: x2)**	Aquatic Dependent Life STATE	Good Improving	Natural reproduction of both nearshore (lean) and offshore (siscowet) populations is widespread and supports all populations. Most stocking has been discontinued and fisheries are well managed. Sea Lamprey mortality has been increasing. All agencies committed to further restoration and conservation.
Phytoplankton	Aquatic Dependent Life STATE	Good Unchanging	Changes in phytoplankton community size or seasonality, as measured by satellite-estimated chlorophyll a, have not been detected in Lake Superior. Current communities are indicative of an oligotrophic system.
Piping Plover	Aquatic Dependent Life STATE	To be developed for SOLEC 2016	
Preyfish Populations	Aquatic Dependent Life STATE	Fair Improving	Abundance of preyfish populations, dominated by native coregonids, continues to fluctuate with a downward trend that sharply steepened in 2009. The decline in preyfish populations since the early 1990s is attributed to recruitment variation and predation by recovered Lake Trout populations. Non-native Rainbow Smelt remains as a principal component of preyfish assemblage. Round gobies are present though rare in western Lake Superior and Eurasian Ruffe, though uncommon, continues to colonize inshore waters and embayments.
Threatened Species	Aquatic Dependent Life STATE	To be developed for SOLEC 2016	

Indicator	**Category** **DPSIR Framework**	**Lake Superior Status and Trend**	**Rationale**
Walleye	Aquatic Dependent Life STATE	Fair Undetermined	Walleye abundance in all areas of Lake Superior, with the possible exception of the St. Louis River, is still below historical levels. Walleye in the St. Louis River (MN, WI) area contain the only healthy, self-sustaining Walleye population in Lake Superior, while other populations in Black, Nipigon, and Thunder Bays (ON), Chequamegon Bay and Bad River (WI), have low populations due to habitat loss and predation issues. Rehabilitation efforts of the Walleye population in Black Bay (ON) are ongoing, but competing fish community objectives for Walleye and Sea Lamprey in the Black Sturgeon River, a Black Bay tributary, will complicate rehabilitation plans. Fish Community Objectives for Walleye abundance and harvest are only being met in the St. Louis River. Rehabilitation strategies are developing with agencies and tribes addressing habitat loss, periodic stocking programs, and harvest control with highly-managed fisheries. Impediments to Walleye rehabilitation in Lake Superior remain including: slow Walleye growth, highly variable recruitment, habitat loss, variable stocking success, continued need for basin-wide long-term assessment, and predation on juvenile and adult Walleye.
Zooplankton Biomass	Aquatic Dependent Life STATE	Good Unchanging	Stable summer zooplankton community is dominated by large calanoid copepods.
Aquatic Habitat Connectivity	Landscapes and Natural Processes STATE	Fair Improving	A comprehensive assessment of barriers to aquatic connectivity has not been completed for Lake Superior.
Baseflow due to Groundwater Discharge	Landscapes and Natural Processes STATE	Fair Undetermined Overall assessment only.	Human activities are estimated to have detrimentally impacted groundwater discharge on at least a local scale in some areas of the Great Lakes basin; although discharge in other areas of the basin has not been significantly impaired. Trends in baseflow with time have not been analyzed for the basin.
Coastal Wetland Landscape Extent and Composition	Landscapes and Natural Processes STATE	To be developed for SOLEC 2016	
Fish Habitat	Landscapes and Natural Processes STATE	To be developed for SOLEC 2016	To be developed for SOLEC 2016 See2006 LaMP report (LSBP 2006a) This indicator is being developed with the support of the *Great Lakes Basin Fish Habitat Partnership.*

Indicator	**Category** **DPSIR Framework**	**Lake Superior Status and Trend**	**Rationale**
Forest Cover	Landscapes and Natural Processes STATE	Component 1: Percent of forested lands within a watershed Good Improving Component 2: Percent of forested lands within riparian zones Good TBD	Component 1: Percent of forested lands within a watershed The Lake Superior basin has a high forest cover (85%) and low rates of agriculture and development (3.2%). These data suggest that there is unlikely to be long-term impairment of water quality. Component 2: Percent of forested lands within riparian zones With 96% of the riparian zones of water bodies in the Lake Superior basin having forest cover, these waters are likely to be well protected. Insufficient data is available to assess trends.
Ice Duration	Landscapes and Natural Processes STATE	In preparation **Ranking of POOR used for this report**	The Great Lakes have lost 71% of their ice cover since 1973, according to a study by the Great Lakes Environmental Research Laboratory (GLERL) http://www.glerl.noaa.gov. There have been severa; recent winters when all the lakes, including Lake Superior, were virtually ice free with as little as 5% ice coverage.. It is not clear what the long term impacts of this will be. Overall, the spatial extent of Great Lakes ice cover has decreased by 71% in the past 40 years. These changes have been most significant on Lake Superior (Wang et al. 2012).
Land Cover	Landscapes and Natural Processes STATE	In preparation **Ranking of GOOD used for this report**	Natural land cover in Lake Superior is 85%+ natural cover.
Sediment Coastal Nourishment	Landscapes and Natural Processes STATE	To be developed for SOLEC 2016	
Tributary Flashiness	Landscapes and Natural Processes STATE	St. Louis River (Lake Superior Basin) Good Improving	Long-term trend is toward lower R-B Index (p=0.0153). The average for the most recent ten-year period is lower than that for the previous period.

Indicator	Category DPSIR Framework	Lake Superior Status and Trend	Rationale
Water Levels	Landscapes and Natural Processes STATE	The level of Lake Superior has been below average on an annual basis since 1998. TBD	The level of Lake Superior has been below average on an annual basis since 1998, and all but three months on a monthly basis since May 1998. It had a new period of record low for the months of August and September in 2007, but has remained within historical record since then. There has been a low water period on Lake Superior for the past 12 years; however, this is not yet of sufficient duration to suggest a long-term trend or shift in climate. There is no certainty (and no method to determine) as to whether these low water levels will continue or wetter conditions may occur again and cause water levels to rise. Water level regimes are the product of short- and long-term climate variability and Lake Superior's water level is influenced by the regulation of its outflow. The water levels have remained within historical records since August and September 2007 when they did reach a period of record monthly low. Evaporation from the lake has been increasing, probably due to a reduction in ice cover, and it is likely that evaporation will continue to increase for the foreseeable future (International Upper Great Lakes Study [IUGLS] 2012). Unlike the other Great Lakes, this increase in evaporation has not been offset by an increase in precipitation. A new regulation plan was proposed for Lake Superior by the IUGLS Board in March 2012. Future trends are not expected to be influenced by the implementation of a revised regulation plan for the outflows of Lake Superior as regulation has significant limitations in addressing extremes. Glacial isostatic adjustment, or the gradual rebound of the land over time following the retreat of the glaciers, does have the effect of causing the water to gradually get shallower along the northeast shoreline and get deeper along the southwest shoreline over time.
Economic Prosperity	Economic and Social Drivers DRIVING FORCES	Undetermined Undetermined Overall assessment only.	Between 1976 and 2010, the overall unemployment rate fluctuated in response to socio-economic conditions, therefore identifying an expected but "undetermined" long-term trend. The short-term trend (2005 to 2010) is an increasing unemployment rate. Throughout the 35 year bracket, with the exception of 2008-2009 where it experienced a 3.0% increase, the annual rate of change has consistently remained within an approximate 2.0% difference.
Energy Consumption	Economic and Social Drivers DRIVING FORCES	Undetermined Increasing Overall assessment only.	The trend of total energy consumption in the eight Great Lakes States and Ontario has increased over the 18 year examined period. Between 1990 and 2008 energy consumption has increased 10.0%. However, the short-term trend assessment of energy consumption from 2005-2008 illustrates that the total energy usage has decreased (a drop of 3.0% from 2005).
Greenhouse Gas Emissions	Economic and Social Drivers DRIVING FORCES	Undetermined Undetermined Overall assessment only.	Between 1990 and 2008, the long-term trend of greenhouse gas emissions in the Great Lakes region was increasing. In 2009, however, the region experienced its largest annual drop in emissions, resulting in the region's lowest greenhouse gas emission in 19 years.
Human Population	Economic and Social Drivers DRIVING FORCES	Undetermined Decreasing	Human population around Lake Superior has decreased by 5.0% over the long-term. The short-term trend indicates a continued decline; specifically, from 2001 to 2006, Lake Superior's population decreased 1.3%.
Value of Great Lakes	Economic and Social Drivers DRIVING FORCES	To be developed for SOLEC 2016	

Indicator	**Category** **DPSIR Framework**	**Lake Superior Status and Trend**	**Rationale**
Beach Advisories	Human Impacts IMPACTS	Good U.S.: Unchanging Canada: Deteriorating	During 2008 through 2010, on average, 97% of monitored Lake Superior beaches were open and safe for swimming in the U.S. In addition, efforts to identify and remediate sources of contamination are being conducted at several Lake Superior beaches. In Canada, during 2008 through 2010, 88% of Lake Superior beaches were open and safe for swimming during the swimming season. The trend shows deteriorating conditions, from 96% in 2006-2007; however, there was an increase in 30% more beaches being monitored from the last reporting cycle.
Cladophora	Human Impacts IMPACTS	Good Unchanging	Shore fouling by *Cladophora* has not historically been an issue in Lake Superior. There is no observational evidence that the occurrence of *Cladophora* has changed in recent years.
Drinking Water Quality	Human Impacts IMPACTS	Good Unchanging Overall assessment only.	The overall quality of source and finished drinking water in the Great Lakes basin can be considered good. The potential risk of human exposure to the noted chemical and/or microbiological contents, and any associated health effect, is generally low.
Fish Consumption Restrictions	Human Impacts IMPACTS	Fair Undetermined	U.S. Lake Average Score - 2.67 Ontario MOE Lake Average Score - 2.81 The U.S. States of Minnesota, Wisconsin and Michigan and the Province of Ontario issue consumption advice for fish from the waters of Lake Superior. Advisories in Lake Superior are driven by PCBs, dioxin, mercury, chlordane, and toxaphene with PCBs continuing to be the largest contributor. Lake Superior fish consumption advisories for Lake Trout range between unrestricted or 1 meal per week for some small fish, to do not eat for some large fish.
Harmful Algal Blooms (HABs)	Human Impacts IMPACTS	Good Undetermined	There is very little quantitative current information on HABs in Lake Superior. To our knowledge, severe HABs outbreaks have not been documented recently in this lake. Algal biomass remains mostly at low levels, although there may be some local impairment near shoreline development
Botulism Outbreaks	Fish and Wildlife Impacts IMPACTS	Undetermined No Change	Avian mortality estimates due to Clostridium botulinum type E are infrequent and small in scale.
Endocrine Disruption	Fish and Wildlife Impacts IMPACTS	To be developed for SOLEC 2016	
Fish Disease Occurrences	Fish and Wildlife Impacts IMPACTS	To be developed for SOLEC 2016	

Indicator	Category DPSIR Framework	Lake Superior Status and Trend	Rationale
Atmospheric Deposition	Pollution and Nutrients PRESSURES	Fair Improving (for PAHs, organochlorine pesticides, dioxins and furans) / Unchanging or slightly improving (for PCBs and mercury) Overall assessment only.	Fair because different chemical groups have different trends and rates of decline over time. Levels of toxic chemicals in urban areas can be much higher than in rural areas. Levels of persistent bioaccumulative toxic (PBT) chemicals in air tend to be lowest over Lake Superior, Lake Huron, and northern Lake Michigan, but their surface area is larger, resulting in a greater importance of atmospheric inputs (Strachan and Eisenreich 1990; Kreis 2005). Connecting channels inputs dominate for Lake Erie and Lake Ontario, which have smaller surface areas. While concentrations of some toxic chemicals are very low at rural sites, they may be much higher in "hotspots" such as urban areas. Lake Michigan, Lake Erie, and Lake Ontario have greater inputs from urban areas. The Lake Erie station tends to have higher levels than the other remote masters stations, most likely since it is located closer to an urban area (Buffalo, NY) than the other master stations. It may also receive some influence from the East Coast of the U.S. Atmospheric deposition of chemicals of emerging concern, such as brominated flame retardants and other compounds that may currently be under the radar, could be future stressors to the Great Lakes. Efforts are being made to screen for other chemicals of potential concern.
Bacterial Loadings from Tributaries	Pollution and Nutrients PRESSURES	To be developed for SOLEC 2016	
Contamination in Sediment	Pollution and Nutrients PRESSURES	Good Unchanging	Lake Superior is the largest, coldest and deepest of the Great Lakes; as a result, rates of decreases in concentrations of legacy contaminants are slow. However, typical offshore sediment contaminant concentrations are very low as atmospheric deposition is the primary source. Concentrations of some metals exceed the strictest sediment quality guidelines due to the nature of the watershed (pre-Cambrian shield) and historical regional sources associated with mining and smelting.
Industrial Loadings	Pollution and Nutrients PRESSURES	To be developed for SOLEC 2016	
Inland Water Quality Index	Pollution and Nutrients PRESSURES	Good Undetermined	Average WQI value for 9 tributaries was 80/100 (Ontario only).
Municipal Wastewater Loadings	Pollution and Nutrients PRESSURES	To be developed for SOLEC 2016	
Nutrients in Tributaries	Pollution and Nutrients PRESSURES	To be developed for SOLEC 2016	

Indicator	**Category** **DPSIR Framework**	**Lake Superior Status and Trend**	**Rationale**
Pesticides in Tributaries	Pollution and Nutrients PRESSURES	To be developed for SOLEC 2016	
Aquatic Non-Native Species (ANS)	Invasive Species PRESSURES	Poor Deteriorating	Lake Superior is the site of greatest ballast water discharge in the Great Lakes, but this pathway has led to comparatively fewer ANS establishments. Intrabasin movement of ANS is likely to be of greater consequence, as in the case of recent establishment of Viral Hemorrhagic Septicemia (VHS).
Dreissenid Mussels	Invasive Species PRESSURES	Good Unchanging	Zebra Mussels were first found in Duluth-Superior Harbor in 1989, and Quagga Mussels were found in the same area in 2005. Since then, spread and population growth of both dreissenid species has been minimal. Both species are most abundant confined in the harbor area or in the immediate vicinity of nearshore Lake Superior. Some Zebra Mussels, however, were found in 2009 in a bay of Isle Royale, and were also present in Thunder Bay harbor in 2001. Overall, population growth and spread of both species has been slow. It is believed that calcium concentrations in Lake Superior are too low to support high abundances.
Sea Lamprey	Invasive Species PRESSURES	Fair Improving	Sea Lamprey abundance has declined since 2005, reaching the target range and holding there since 2009. The Lake Trout wounding rate is above target and has been increasing since 1999. Lake Trout relative abundance has been increasing since 2003.
Terrestrial Non-Native Species	Invasive Species PRESSURES	Undetermined Undetermined Overall assessment only. **Ranking of GOOD used for this report**	At this time, there is no comprehensive measure of terrestrial non-native species. Terrestrial non-native species are pervasive in the Great Lakes basin. Although not all introductions have an adverse affect on native habitats, those that do pose a considerable ecological, social, and economic burden. Historically, the Great Lakes basin has been particularly vulnerable to non-native invasive species (NIS). Conditions that make the basin vulnerable to introductions include high population, industrialization, and volume of transboundary movement of goods and people. There are currently very few invasive species in coastal areas. Common Reed remains restricted in occurrences.
Air Temperature	Resource Use and Physical Stressors PRESSURES	Undetermined Increasing Overall assessment only.	Based on the analysis of data from the National Climate Data Center (1985-2001) and the Midwest Climate Center (1900-2000) of the Great Lakes region, over the last thirty years, temperatures have hovered near or slightly above long-term averages. The data also suggests a recent shift in temperature. In the last four years the annual average temperatures have ranged from 2 to 4˚F (1 to 2˚C) warmer than the long-term average with up to a 7˚F (4˚C) increase above average in the winter. It is important to note, however, that this warming is comparable in magnitude to warm periods experienced during the 1930s and 1950s. Furthermore, the hottest months in history have occurred in the past two decades and most years have been characterized by a decrease in cold waves (Kling et al. 2003). Based on the predictions of climate models, temperature in the region are expected to warm by 5 to 12 ˚F (3 to 7˚C) in the winter months and by 5 to 20 ˚F (3 to 11˚C) in the summer months. Examining the data at a finer resolution, models also suggest a larger increase in night-time temperatures than daytime temperatures and an increase in extreme heat events (Kling et al. 2003).

Indicator	**Category** **DPSIR Framework**	**Lake Superior Status and Trend**	**Rationale**
Artificial Coastal Structures	Resource Use and Physical Stressors PRESSURES	To be developed for SOLEC 2016 **Ranking of GOOD used for this report**	There are relatively few artificial structures.
Precipitation Events	Resource Use and Physical Stressors PRESSURES	Undetermined Increasing Overall assessment only.	In recent decades the Great Lakes region has seen pattern of above average precipitation in both summer and winter months (Kling et al. 2003). From 1915 to 2004, total annual precipitation increased by 4.5 inches (Hodgkins et al. 2007). Although trends indicate increases in total precipitation, precipitation has not increased uniformly over the last one hundred years. For example, over the last 90, 70, and 50 years respectively, precipitation in March and February declined. Conversely, precipitation in April, May and July through December, over the same time periods, increased (Hodgkins et al. 2007). These finding highlight the seasonal shift in precipitation patterns.
Forest Disturbance	Resource Use and Physical Stressors PRESSURES	To be developed for SOLEC 2016	
Hardened Shorelines	Resource Use and Physical Stressors PRESSURES	**Ranked as GOOD.** 90% of Lake Superior shoreline is natural. Undetermined Undetermined	Available information does not allow a direct comparison to previous hardened shoreline indicator status. See table – 90% shoreline is natural
Surface Water Temperature	Resource Use and Physical Stressors PRESSURES	Undetermined Increasing	The date of the onset of summer stratification in Lake Superior is occurring earlier at a rate of roughly 0.5+/-0.3 days per year. This rate is consistent between three NOAA NDBC buoys.
Watershed Stressor Index	Resource Use and Physical Stressors PRESSURES	In preparation	GLEI (2013) and Sum-Rel (Host et al. 2011) information used

Table B.2 Lake Superior Indicators
These indicators are not included in SOLEC, but are important measures of the health of Lake Superior.

Indicator	Category	Target	Lake Superior Status and Trend	Rationale
Mysis density	Aquatic Dependent Life STATE		Good	This freshwater shrimp supports nearshore and offshore fishes, and plays a pivotal role in the structure and function of the Lake Superior fish community.
Island Condition Class	Resource Use and Physical Stressors PRESSURES	Islands	Good	Based on the threats analysis for islands in Henson et al. (2010). Mean Island threat class was assigned to all ten coastal environments from Lake Superior. This threat index is based on a number of factors including building density, land use, mining claims, boat launches and access for vehicles.
Coastal Stress Index	Resource Use and Physical Stressors PRESSURES	Coastal Wetlands Coastal Terrestrial	Good	Developed for this report and applied to coastal units. This stress index is based on a number of factors including building density, land use and artificial shoreline.

Table B.3 Response SOLEC Indicators
These indicators were not used to assess the health of the biodiversity targets.

Indicator	Category	Target	Lake Superior Status and Trend	Rationale
Conserving and Protecting Forest Land	Restoration and Protection RESPONSE		In preparation	See draft report and map from SC Likely to be Good, good mgt: ON-78%, MN-45%, Mi-45%, WI-95%
Educating Great Lakes Basin Residents	Restoration and Protection RESPONSE		To be developed for SOLEC 2016	
Enhancing Wildlife and Conserving Soil and Water on Agricultural Lands	Restoration and Protection RESPONSE		Canada Undetermined Undetermined U.S. Undetermined Increasing	Canada Small proportion of agricultural land in the Ontario portion of this lakeshed. U.S The area of land removed from previous agricultural production has increased. The area of agricultural land affected by best management practices aimed at conserving soil, improving water quality and enhancing wildlife habitat has increased.

Indicator	Category	Target	Lake Superior Status and Trend	Rationale
Implementing Industrial Efficiency Measures	Restoration and Protection RESPONSE		To be developed for SOLEC 2016	
Remediating Contaminated Sediment	Restoration and Protection RESPONSE		Undetermined Increasing Overall assessment only.	Between 1997 and 2010, U.S. EPA and its partners have remediated approximately 7 million cubic yards of contaminated sediment in Great Lakes AOCs. As of 2010, over 200,000 cubic meters of contaminated sediment have been managed in the Canadian Great Lakes AOCs.
Protecting and Restoring of Habitats and Species	Restoration and Protection RESPONSE		To be developed for SOLEC 2016	
Protecting Special Lakeshore Areas	Restoration and Protection RESPONSE		To be developed for SOLEC 2016	
Stocking Native Fish	Restoration and Protection RESPONSE		To be developed for SOLEC 2016	
Treating Wastewater	Restoration and Protection RESPONSE		Undetermined Increasing	In the Canadian portion of the Lake Superior basin, the percent of the population served secondary wastewater treatment or higher increased from 4% in 2004 to 98% in 2006 and 99% in 2009. Based on the graph in the report it looks like most US wastewater is also treated.
Withdrawing Water Sustainably	Restoration and Protection RESPONSE		Mixed Unchanging Overall assessment only.	The amount of water withdrawn from the Great Lakes continues to slowly decrease in large part due to shutdown of nuclear power facilities, advances in water efficiency in the industrial sector, and growing public awareness of resource conservation. Limiting withdrawal from the Great Lakes will protect the ecosystem of the entire basin.

Appendix C: Coastal Terrestrial Habitats and Species

Data included in Appendix C were provided by the Conservation Data Centres for each state or province, and were current as of 2014. These data are not based on an exhaustive inventory of the state or province. The lack of data for any geographic area shall not be construed to mean that no significant features are present.

Lake Superior Coastal Terrestrial Habitats

Name	***Ecological System*** *Vegetation Community (Common Name) – from state/provincial Conservation Data Centers*	***Great Lakes State/ Provincial Classification***	***Notes***
Great Lakes Sand Beaches	**Great Lakes Dune** Great Lakes Beach Northern Great Lakes Dune Grassland	Sand /Gravel Beach (MI) Sand Beach (MN) Lake Beach – Sand Subtype (MN) Sea Rocket Open Mineral Shoreline Type (ON) Great Lakes Beach (WI)	Primary sand beach below high water mark.
Great Lakes Foredunes	**Great Lakes Dune** Great Lakes Beachgrass Dune Cottonwood Dune Sand Cherry Dune Shrubland Great Lakes Juniper Dune Shrubland Northern Great Lakes Dune Grassland Shrub Dune Sparse Vegetation	Open Dunes (MI) Great Lakes Dune (MI) Beachgrass Dune (MN) Juniper Dune Shrubland (MN) Little Bluestem-Switch Grass-Beachgrass Open Dune Type (ON) Little Bluestem-Long-leaved Reed Grass-Great Lakes Wheatgrass Open Dune Type (ON) Sand Dropseed - Flat Stemmed Bluegrass Open Sand Dune Type (ON) Sand Cherry Shrub Sand Dune Type (ON) Great Lakes Dune (WI)	Herbaceous and shrub dominated dunes above high water mark.
Coastal Back Dune Complexes	**Great Lakes Dune and Swale** **Northern Great Lakes Interdunal Wetland** Great Lakes Wooded Dune and Swale Complex Great Lakes Dune Pine Forest Great Lakes Pine Barrens Interdunal Wetland	Interdunal Wetland (MI) Wooded Dune and Swale Complex (MI) Great Lakes Barrens (MI) Beach Ridge Shrubland (Lake Superior) (MN) Great Lakes Barrens (WI) Great Lakes Ridges and Swale (WI) Great Lakes Barrens (WI) Interdunal Wetland (WI)	Defined by stabilized back dunes and includes a complex of upland and wetland communities. Modified from 1996 report to include all communities that occur in complex.
Bedrock Shores	**Great Lakes Alkaline Rocky Shore and Cliff** Great Lakes Limestone - Dolostone Bedrock Shore Great Lakes Basalt - Conglomerate Bedrock Shore **Great Lakes Acidic Rocky Shore and Cliff** Great Lakes Granite - Metamorphic Bedrock Shore Great Lakes Sandstone Bedrock Shore	Basalt Bedrock Lakeshore (MI) Volcanic Conglomorate Bedrock Lakeshore (MI) Lake Superior Rocky Shore (MN) Dry Bedrock Shore (Lake Superior) (MN) Wet Rocky Shore (Lake Superior) (MN) Lake Beach (Lake Superior) Bedrock Subtype (MN) Sandstone Bedrock Beach/ Bar Ecosite (ON) Granite Bedrock Beach/ Bar Ecosite (ON) Great Lakes Alkaline Rockshore (WI) Bedrock Shore (WI)	Typically bedrock that occurs below high water mark or storm surges. Modified from 1996 report (cobble and bedrock split) because of significant differences in vegetation communities. Two major sub-types can generally be defined by coastal unit.
Cobble Beaches	**Great Lakes Alkaline Rocky Shore and Cliff** Great Lakes Basalt – Diabase Cobble – Gravel Shore **Great Lakes Acidic Rocky Shore and Cliff** Great Lakes Non-alkaline Cobble – Gravel Shore Great Lakes Sandstone Bedrock Shore	Sandstone Cobble Shore (MI) Cobble Beach (MI) Gravel/ Cobble Beach (Lake Superior) (MN) Wet Rocky Shore (Lake Superior) Cobble Subtype (MN) Lake Beach (Lake Superior) Gravel-Cobble Subtype (MN) Wormwood Gravel Open Beach Type (ON) Willow Gravel Shrub Beach Type (ON)	Typically cobble/ gravel that occurs below high water mark or storm surges. Modified from 1996 report (cobble and bedrock split) because of significant differences in vegetation communities. Cobble beaches were treated separately by SOLEC in 1998. Two major sub-types can generally be defined by coastal unit.

Name	***Ecological System*** *Vegetation Community (Common Name) – from state/provincial Conservation Data Centers*	***Great Lakes State/ Provincial Classification***	***Notes***
Shoreline Cliffs	**Great Lakes Alkaline Rocky Shore and Cliff** Great Lakes Shore Basalt – Diabase Cliff **Great Lakes Acidic Rocky Shore and Cliff** Great Lakes Shore Granite - Metamorphic Cliff Great Lakes Shore Sandstone Cliff	Sandstone Lakeshore Cliff (MI) Basalt Lakeshore Cliff (MI) Volcanic Conglomerate Lakeshore Cliff (MI) Dry Non-acid Cliff (MI) Moist Non-acid Cliff (MI) Moist Acid Cliff (MI) Dry Cliff (MN) Moist Cliff (MN) Exposed Mafic Cliff (Lake Superior) (MN) Sheltered Mafic Cliff (Lake Superior) (MN) Exposed Felsic Cliff (Lake Superior) (MN) Calcareous Cliff Community (NY) Moist Cliff (WI) Moist Cliff (WI)	Ontario has over 20 cliff/ talus communities. None of these are classified as coastal Modified from 1996 report to include all coastal cliff types that had been documented. Two major sub-types can generally be defined by coastal unit.
Shoreline Bluffs	**none** Clay Seeps (GNR)	Clay Seepage Bluff (WI)	*Clay Slopes Sparsely Vegetated Alliance* **Unconsolidated material sparse vegetation**
Arctic-Alpine Disjunct Communities	**Great Lakes Alkaline Rocky Shore and Cliff**	Great Lakes Arctic-Alpine Basic Open Bedrock Shoreline Type (ON)	Also nested with non-alkaline bedrock shores (basalt), but treated separately due to special features.
Rich Coastal Fens	**Great Lakes Alkaline Rocky Shore and Cliff** Shrubby-cinquefoil – Sweetgale Rich Shore Fen Great Lakes Sedge Rich Shore Fen	Graminoid Coastal Meadow Marsh Type (ON) Shrubby Cinquefoil Coastal Meadow Marsh Type (ON) Shore Fen (WI) Calcareous Fen (WI)	Ontario types could also be included as Cobble Beach (alkaline). Wetland/ terrestrial interface. Bluejoint - Little Green Sedge - Twig-rush - Ontario Lobelia Saturated Herbaceous Alliance Perennial graminoid vegetation
Coastal Rock Barrens	**Great Lakes Acidic Rocky Shore and Cliff** **Great Lakes Alkaline Rocky Shore and Cliff** Common Juniper Rocky Krummholz (G3G4) Basalt Bedrock Glade	Northern Bald (MI) Volcanic Conglomerate Bedrock Glade (MI) Basalt Bedrock Glade (MI) Bedrock Shrubland (Lake Superior) (MN) Lake Superior Rocky Shore/ Bedrock Shrubland/ Bedrock Outcrop Complex (MN) Blueberry Granite Shrubland Barren Type (ON)* Oak – Red Maple – Pine Treed Granite Barren Type (ON)* Pitch Pine Treed Granite Barren Type (ON)* Chokeberry Granite Shrubland Barren Type (ON) Common Juniper Granite Shrubland Barren Type (ON) Jack Pine Treed Granite Barren Type (ON) Red Cedar Treed Granite Barren Type (ON) Dry Granite Barren Type (ON) Dry Moss Non-Calcareous Open Rock Barren Type (ON) Non-Calcareous Poverty Oat Grass Rock Barren Meadow Type (ON) Non-Calcareous Tufted Hairgrass Rock Barren Meadow Type (ON) Raspberry Non-Calcareous Shrub Rock Barren Type (ON) Cinquefoil Non-Calcareous. Shrub Rock Barren Type (ON) White Pine - Oak - Red Cedar Non-Calcareous Treed Rock Barren Type (ON) *Ontario community types with documented coastal occurrences.	Modified to include all coastal rocklands (except alvars). Rocklands that are influenced by the coastal environment. Occurs as a narrow band between bedrock shores (non-alkaline) and interior rocklands.

Name	***Ecological System*** *Vegetation Community (Common Name) – from state/provincial Conservation Data Centers*	***Great Lakes State/ Provincial Classification***	***Notes***
Great Lakes Coastal Forests	none Great Lakes Spruce – Fir Basalt Bedrock Shore (GNR)		Forests that occur within 2 km of the coast and are influenced by the coastal environment. Includes Krumholtz.

Lake Superior Coastal Terrestrial Species (includes species with >70% of their occurrences in the basin restricted to the coast and known to have an affinity for coastal habitats), *Draft*

Allium schoenoprasum	Chives
Ammophila breviligulata ssp. breviligulata	Beach Grass
Antennaria parvifolia	Small-leaved Pussytoes
Arnica cordifolia	Heart-leaved Arnica
Bistorta vivipara	Alpine Bistort
Botrychium acuminatum	Moonwort
Botrychium ascendens	Upswept Moonwort
Botrychium hesperium	Western Moonwort
Botrychium hesperium	Western Moonwort
Botrychium pseudopinnatum	False Northwestern Moonwort
Calamovilfa longifolia var. magna	Sand Reed Grass
Carex atratiformis	Scabrous Black Sedge
Carex loliacea	Ryegrass Sedge
Carex media	Intermediate Sedge
Castilleja septentrionalis	Northern Paintbrush
Cerastium alpinum	Alpine Chickweed
Charadrius melodus	Piping Plover
Cicindela hirticollis rhodensis	Beach-dune Tiger Beetle
Cirsium pitcheri	Dune Thistle
Cystopteris montana	Mountain Bladder Fern
Diplophyllum taxifolium	A Liverwort
Dryas drummondii	Yellow Mountain Avens
Enallagma clausum	Alkali Bluet
Erebia discoidalis	Red-disked Alpine
Euxoa aurulenta	Dune cutworm
Falco peregrinus	Peregrine Falcon
Hudsonia tomentosa	Woolly Beach-heath
Huperzia appressa	Mountain Firmoss
Hydroprogne caspia	Caspian Tern
Hygrohypnum eugyrium	A Moss
Juncus greenei	Greene's Rush
Juncus longistylis	Long-styled Rush
Leymus mollis	Sea Lyme-grass
Malaxis paludosa	Bog Adder's-mouth
Oeneis macounii	Macoun's Arctic

Oplopanax horridus	Devil's Club
Oxytropis splendens	Showy Locoweed
Packera indecora	Elegant Groundsel
Parnassia palustris	Marsh Grass-of-Parnassus
Pellaea atropurpurea	Purple cliff brake
Pinguicula vulgaris	Butterwort
Poa alpina	Alpine bluegrass
Polygonum viviparum	Alpine bistort
Potentilla hippiana	Horse Cinquefoil
Primula mistassinica	Bird's-eye Primrose
Prunus pumila var. pumila	Sand Cherry
Rangifer tarandus caribou	Woodland Caribou
Ranunculus cymbalaria	Seaside Crowfoot
Sagina nodosa	Pearlwort
Sagina nodosa ssp. borealis	Knotty Pearlwort
Salix cordata	Sand Dune Willow
Salix myricoides	Blue-leaved Willow
Saxifraga oppositifolia	Purple Mountain Saxifrage
Saxifraga tricuspidata	Prickly saxifrage
Selaginella selaginoides	Northern Spikemoss
Tanacetum bipinnatum	Floccose Tansy
Tanacetum huronense	Lake Huron tansy
Tofieldia pusilla	Small False Asphodel
Trimerotropis huroniana	Lake Huron locust
Vaccinium ovalifolium	Oval-leaved Bilberry
Vaccinium uliginosum	Alpine Bilberry
Vaccinium vitis-idaea	Mountain cranberry
Zizia aptera	Heart-leaved Alexanders

Potential Lake Superior Coastal Terrestrial Species

List of all tracked species from Ontario, Michigan, Wisconsin and Minnesota with >60% of documented occurrences from within 2 km of the coast. Note that note all species are tracked in every jurisdiction.

Scientific Name	Common Name	Percent Coastal
Aeshna juncea	Sedge Darner	100.0%
Aeshna sitchensis	Zigzag Darner	100.0%
Agropyron spicatum	Bluebunch wheatgrass	100.0%
Ammophila breviligulata ssp. breviligulata	Beach Grass	100.0%
Anaptychia setifera	A Lichen	100.0%
Andreaea crassinervia	A Moss	100.0%
Anguilla rostrata	American Eel	100.0%
Antennaria parvifolia	Small-leaved Pussytoes	100.0%
Aquila chrysaetos	Golden Eagle	100.0%
Arnica cordifolia	Heart-leaved Arnica	100.0%
Arphia conspersa	Speckled Rangeland Grasshopper	100.0%
Asplenium trichomanes-ramosum	Green spleenwort	100.0%
Aster modestus	Great northern aster	100.0%

Astragalus adsurgens	Laxmann's Milk-vetch	100.0%
Beckmannia syzigachne	Slough grass	100.0%
Bedrock shore	Bedrock Shore	100.0%
Bistorta vivipara	Alpine Bistort	100.0%
Braya humilis	Low northern rock cress	100.0%
Bromus pumpellianus	Pumpelly's Brome	100.0%
Bryoria lanestris	Lichen	100.0%
Bryum pallens	A Moss	100.0%
Bucephala clangula	Common Goldeneye	100.0%
Canadanthus modestus	Northwestern Sticky Aster	100.0%
Carex atratiformis	Scabrous Black Sedge	100.0%
Carex capillaris	Hair-like Sedge	100.0%
Carex concinna	Beautiful Sedge	100.0%
Carex davisii	Davis's sedge	100.0%
Carex inops ssp. heliophila	Sun sedge	100.0%
Carex livida var. radicaulis	Livid Sedge	100.0%
Carex loliacea	Ryegrass Sedge	100.0%
Carex pallescens	Pale Sedge	100.0%
Carex prasina	Drooping Sedge	100.0%
Carex richardsonii	Richardson's sedge	100.0%
Carex scirpoidea	Bulrush sedge	100.0%
Carex squarrosa	Sedge	100.0%
Ceanothus sanguineus	Wild lilac	100.0%
Cerastium brachypodum	Shortstalk chickweed	100.0%
Chamaerhodos nuttallii var. keweenawensis	Rock-rose	100.0%
Charadrius melodus	Piping Plover	100.0%
Cicindela hirticollis rhodensis	Beach-dune Tiger Beetle	100.0%
Cincinnatia cincinnatiensis	Campeloma spire snail	100.0%
Cirsium pitcheri	Dune Thistle	100.0%
Coccocarpia palmicola	Salted shell lichen	100.0%
Coregonus hoyi	Bloater	100.0%
Cryptogramma acrostichoides	American rock-brake	100.0%
Cryptogramma stelleri	Slender cliff brake	100.0%
Cystopteris montana	Mountain Bladder Fern	100.0%
Danthonia intermedia	Wild oat grass	100.0%
Dermatocarpon moulinsii	Lichen	100.0%
Draba cana	Hoary Draba	100.0%
Draba glabella	Smooth whitlow grass	100.0%
Draba incana	Twisted whitlow grass	100.0%
Draba norvegica	Norwegian Whitlow-grass	100.0%
Eleocharis compressa	Flat-stemmed Spike-rush	100.0%
Elodea bifoliata	Twoleaf Waterweed	100.0%
Emergent marsh	Emergent Marsh	100.0%
Emergent marsh - wild rice	Emergent Marsh - Wild Rice	100.0%
Empetrum atropurpureum	Purple Crowberry	100.0%
Empetrum nigrum	Black Crowberry	100.0%
Enallagma clausum	Alkali Bluet	100.0%
Epilobium strictum	Downy Willow-herb	100.0%
Equisetum telmateia	Giant horsetail	100.0%
Erebia discoidalis	Red-disked Alpine	100.0%

Erigeron acris	Fleabane	100.0%
Euphrasia hudsoniana	Eyebright	100.0%
Euphrasia nemorosa	Eyebright	100.0%
Euxoa aurulenta	Dune cutworm	100.0%
Fontinalis sphagnifolia	A Moss	100.0%
Frullania inflata	A Liverwort	100.0%
Gymnocarpium jessoense ssp. parvulum	Northern Oak Fern	100.0%
Haploperla orpha	Quadrate Sallfly	100.0%
Hieracium venosum	Rattlesnake Hawkweed	100.0%
Hudsonia tomentosa	Beach-heather	100.0%
Hydroprogne caspia	Caspian Tern	100.0%
Hygrohypnum eugyrium	A Moss	100.0%
Hypotrachyna revoluta	Lichen	100.0%
Ilybius angustior	A Predaceous Diving Beetle	100.0%
Ilybius subaeneus	A Predaceous Diving Beetle	100.0%
Juncus greenei	Greene's Rush	100.0%
Juncus longistylis	Long-styled Rush	100.0%
Lactuca pulchella	Blue lettuce	100.0%
Lampropeltis triangulum	Milksnake	100.0%
Leymus mollis	American dune wild-rye	100.0%
Ligumia nasuta	Eastern pondmussel	100.0%
Listera borealis	Northern Twayblade	100.0%
Lycaena helloides	Purplish Copper	100.0%
Lynx canadensis	Lynx	100.0%
Mannia sibirica	A Liverwort	100.0%
Marsupella sparsifolia	A Liverwort	100.0%
Melanelia substygia	Lichen	100.0%
Melanoplus flavidus	Blue-legged Grasshopper	100.0%
Muhlenbergia cuspidata	Plains muhly	100.0%
Mylia taylorii	A Liverwort	100.0%
Myosotis laxa	Small Forget-me-not	100.0%
Myotis leibii	Eastern Small-footed Myotis	100.0%
Nardia insecta	A Liverwort	100.0%
Nicrophorus americanus	American burying beetle	100.0%
Odontoschisma macounii	A Liverwort	100.0%
Omalotheca sylvatica	Woodland Cudweed	100.0%
Oxytropis splendens	Showy Locoweed	100.0%
Packera obovata	Round-leaved Groundsel	100.0%
Parmelia stictica	A Species of Lichen	100.0%
Pellaea atropurpurea	Purple cliff brake	100.0%
Peltigera collina	A Lichen	100.0%
Phleum alpinum	Mountain timothy	100.0%
Phyciodes batesii	Tawny crescent	100.0%
Physcia phaea	Lichen	100.0%
Pisidium equilaterale	Round Peaclam	100.0%
Placynthium aspratile	Lichen	100.0%
Planorbella multivolvis	Acorn ramshorn	100.0%
Poa canbyi	Canbyi's bluegrass	100.0%
Poa paludigena	Bog bluegrass	100.0%
Poa wolfii	Wolf's Bluegrass	100.0%

Porpidia herteliana	A Lichen	100.0%
Potentilla hippiana	Horse Cinquefoil	100.0%
Potentilla pensylvanica	Prairie cinquefoil	100.0%
Potentilla pulcherrima	Soft Cinquefoil	100.0%
Primula mistassinica	Bird's-eye Primrose	100.0%
Protopannaria pezizoides	Brown-gray Moss-shingle Lichen	100.0%
Prunus pumila var. pumila	Sand Cherry	100.0%
Rallus elegans	King rail	100.0%
Ramalina farinacea	Lichen	100.0%
Ranunculus macounii	Macoun's buttercup	100.0%
Rhizocarpon oederi	A Lichen	100.0%
Rhizomnium gracile	A Moss	100.0%
Sagina nodosa	Pearlwort	100.0%
Sagina nodosa ssp. borealis	Knotty Pearlwort	100.0%
Sagittaria cristata	Crested Arrowhead	100.0%
Salix cordata	Sand Dune Willow	100.0%
Salix myricoides	Blue-leaved Willow	100.0%
Saxifraga oppositifolia	Purple Mountain Saxifrage	100.0%
Saxifraga tricuspidata	Prickly saxifrage	100.0%
Scapania degenii	A Liverwort	100.0%
Scapania gymnostomophila	A Liverwort	100.0%
Schistostega pennata	Luminous Moss	100.0%
Selaginella selaginoides	Northern Spikemoss	100.0%
Sphaerium fabale	River fingernail clam	100.0%
Splachnum luteum	A Moss	100.0%
Stellaria crassifolia	Fleshy stitchwort	100.0%
Stellaria longipes	Stitchwort	100.0%
Sympetrum corruptum	Variegated Meadowhawk	100.0%
Tanacetum bipinnatum	Floccose Tansy	100.0%
Tanacetum huronense	Lake Huron tansy	100.0%
Thalictrum venulosum	Veined Meadowrue	100.0%
Tofieldia pusilla	False asphodel	100.0%
Trimerotropis huroniana	Lake Huron locust	100.0%
Trisetum spicatum	Downy oat-grass	100.0%
Umbilicaria arctica	A Lichen	100.0%
Umbilicaria torrefacta	Lichen	100.0%
Vaccinium uliginosum	Alpine Bilberry	100.0%
Vaccinium vitis-idaea	Mountain cranberry	100.0%
Viola lanceolata var. lanceolata	Lance-leaved Violet	100.0%
Pinguicula vulgaris	Butterwort	96.7%
Castilleja septentrionalis	Northern Paintbrush	96.6%
Senecio indecorus	Northern ragwort	96.2%
Euphrasia hudsoniana var. ramosior	Hudson Bay Eyebright	95.5%
Poa alpina	Alpine bluegrass	95.0%
Listera auriculata	Auricled Twayblade	93.9%
Myriophyllum alterniflorum	Alternate-leaved water-milfoil	93.8%
Juniperus horizontalis	Creeping Juniper	93.3%
Oplopanax horridus	Devil's Club	92.3%
Shore fen	Shore Fen	90.0%
Lonicera involucrata	Black twinberry	88.2%

Viburnum edule	Squashberry or mooseberry	88.2%
Deschampsia flexuosa	Slender Hairgrass	85.7%
Polygonum viviparum	Alpine bistort	85.7%
Prosartes trachycarpa	Northern fairy bells	85.7%
Ribes oxyacanthoides	Canada Gooseberry	85.7%
Falco peregrinus	Peregrine Falcon	84.7%
Carex lenticularis	Shore Sedge	84.6%
Anaptychia crinalis	Hanging fringe lichen	83.3%
Botrychium pseudopinnatum	False Northwestern Moonwort	83.3%
Draba arabisans	Rock whitlow grass	83.3%
Goodyera oblongifolia	Giant Rattlesnake-plantain	83.3%
Malaxis paludosa	Bog Adder's-mouth	83.3%
Oeneis macounii	Macoun's Arctic	83.3%
Ranunculus rhomboideus	Prairie buttercup	83.3%
Senecio eremophilus	Desert Ragwort	83.3%
Zizia aptera	Heart-leaved Alexanders	83.3%
Calypso bulbosa	Calypso or fairy-slipper	81.4%
Osmorhiza berteroi	Chilean Sweet Cicely	80.6%
Amerorchis rotundifolia	Round-leaved Orchis	80.0%
Chlidonias niger	Black Tern	80.0%
Diplophyllum taxifolium	A Liverwort	80.0%
Erigeron acris var. kamtschaticus	Bitter Fleabane	80.0%
Gnaphalium sylvaticum	Woodland everlasting	80.0%
Ranunculus cymbalaria	Seaside Crowfoot	80.0%
Equisetum palustre	Marsh Horsetail	78.9%
Sterna hirundo	Common Tern	78.9%
Dermatocarpon reticulatum	Lichen	75.0%
Perimyotis subflavus	Eastern Pipistrelle	75.0%
Pisidium idahoense	Giant northern pea clam	75.0%
Huperzia appressa	Mountain Firmoss	73.7%
Vaccinium ovalifolium	Oval-leaved Bilberry	72.7%
Peltigera venosa	Fan lichen	71.4%
Allium schoenoprasum	Chives	70.6%
Botrychium hesperium	Western Moonwort	70.0%
Packera indecora	Elegant Groundsel	70.0%
Carex media	Intermediate Sedge	69.7%
Parnassia palustris	Marsh Grass-of-Parnassus	69.2%
Alces americanus	Moose	66.7%
Antennaria rosea	Rosy Pussytoes	66.7%
Armoracia lacustris	Lake cress	66.7%
Bryum blindii	A Moss	66.7%
Calamagrostis lacustris	Marsh Reedgrass	66.7%
Dryas drummondii	Yellow Mountain Avens	66.7%
Euchloe ausonides	Large Marble	66.7%
Falco columbarius	Merlin	66.7%
Galium kamtschaticum	Bedstraw	66.7%
Listera convallarioides	Broad-leaved Twayblade	66.7%
Martes americana	American Marten	66.7%
Myoxocephalus thompsoni	Deepwater Sculpin	66.7%
Planogyra asteriscus	Eastern flat-whorl	66.7%

Triglochin palustris	Marsh Arrow-grass	66.7%
Elymus glaucus	Blue Wild Rye	65.4%
Streptopus amplexifolius	White Mandarin	65.1%
Clematis occidentalis	Purple clematis	64.9%
Drosera anglica	English Sundew	64.7%
Woodsia glabella	Smooth Woodsia	64.3%
Huperzia selago	Fir Clubmoss	64.0%
Cystopteris laurentiana	Laurentian Bladder Fern	63.6%
Myotis septentrionalis	Northern Long-eared Bat	62.5%
Pterospora andromedea	Pine-drops	61.1%
Botrychium acuminatum	Moonwort	60.0%
Deschampsia cespitosa	Tufted Hairgrass	60.0%
Schoenoplectus torreyi	Torrey's Bulrush	60.0%

Appendix D: Aquatic and Terrestrial Invasive Species from Lake Superior

Source: All tables based on Minnesota Sea Grant (2012a) with updates.

Table D1. Reproducing and Non-Reproducing Non-Native Fish

Common Name	Scientific Name	Earliest Record	Earliest Location	Attributed Mechanism(s)
White Perch	*Morone americana*	1986	St. Louis River	Ballast Water
Tubenose Goby	*Proterorhinus marmoratus*	2000	St. Louis River	Ballast Water
Threespine Stickleback	*Gasterosteus aculeatus*	1987	Thunder Bay, ON	Ballast Water
Sea Lamprey	*Petromyzon marinus*	1938	Two Harbors, MN	Canals
Round Goby	*Neogobius melanostomus*	1995	St. Louis River	Ballast Water
Rainbow Trout	*Oncorhynchus mykiss*	1883 or 1895[9]	W. Lake Superior	Stocked
Rainbow Smelt	*Osmerus mordax*	1930	Whitefish Bay, E. Lake Superior	Canals
Pink Salmon	*Oncorhynchus gorbuscha*	1956	Thunder Bay, ON	Stocked
Freshwater Drum[10]	*Aplodinotus grunniens*	18th century; 2007	Lower Michipicoten River; In nearshore waters west of Wawa	Unknown, Stocked (assumed)
Fourspine Stickleback	*Apeltes quadracus*	1986	Thunder Bay, ON	Ballast Water or Live Bait
Ruffe	*Gymnocephalus cernua*	1986	St. Louis River	Ballast Water
Common Carp	*Cyprinus carpio*	1897	Lake Superior, WI	Stocked
Coho Salmon	*Oncorhynchus kisutch*	1966	Lake Superior, MI	Stocked
Chinook Salmon	*Oncorhynchus tshawytscha*	1967	Lake Superior, MI	Stocked
Brown Trout	*Salmo trutta*	1883	Lake Superior, MI	Stocked
Brook Silverside[11]	*Labidesthes sicculus*	2002, 2007	St. Louis River, lower St. Marys River	Unknown
Alewife	*Alosa pseudoharengus*	1953 (or earlier)	E. Lake Superior	Canals
American Eel	*Anguilla rostrata*	1970	Brule River, WI	Canals
Atlantic Salmon	*Salmo salar*	1972	Lake Superior, WI	Stocked

[9] Kerr and Lasenby (2000) note that there is some confusion in the literature about when Rainbow Trout were first stocked into Lake Superior. MacCrimmon and Gots (1972) report they were first introduced into Lake Superior in 1883 near Sault Ste. Marie, while Lawrie and Rahrer (1973) report the first introduction was in Minnesota in 1895 (S. Greenwood, pers. comm., May 23 2013).

[10] Academic review is need as to whether the Freshwater Drum is a native or non-native species. Hudson Bay Company records from the 18th century note the presence of a fish species described as Freshwater Drum in fish food nets in the lower Michipicoten River. This record, reported in Goodier (1984), is disputed by some based on the species description. In 2007 a commercially caught Freshwater Drum was taken 40 kilometres west of Michipicoten Bay and given to the OMNR office in Wawa for identification verification. Freshwater Drum may be native to eastern portions of Lake Superior, but there is not yet clear evidence of a reproducing population. Minnesota Sea Grant (2012b) lists the attributed mechanism for introduction in the western arm of Lake Superior as stocked. At this time the question rests on whether the species is a pan lake native and/or locally introduced (S. Greenwood, pers. comm., May 23 2013).

[11] Academic review is needed as to whether the Brook Silverside is a native species that has previously been missed in fish surveys, or a non-native that has been found in western Lake Superior through human mediated introduction. A 2007 record of the Brook Silverside from the lower St. Marys River and 2013 capture of Brook Silverside from the upper St. Marys River suggests this species may be native to both the lower and upper portions (Superior waters) of the St. Marys River (S. Greenwood, pers. comm., May 23 2013).

Table D2. Non-Native Aquatic Invertebrates

Common Name	Scientific Name	Group	Earliest Record	Earliest Location	Attributed Mechanism(s)
Aquatic oligochaeta	*Paranais frici*	Oligochaeta			
Aquatic oligochaeta	*Pristina acuminata*	Oligochaeta			
Aquatic oligochaeta	*Ripistes parasita*	Oligochaeta	1987	Thunder Bay, ON	Ballast Water
Aquatic oligochaeta	*Vejdovskyella intermedia*	Oligochaeta	1980	Unknown	Ballast Water?
Asian Clam	*Corbicula fluminea*	Bivalve	1999	St. Louis River	Ballast Water
Bosmonid Waterflea	*Eubosmina coregoni*	Zooplankton	1970s		Ballast Water
Calanoid copepod	*Eurytemora affinis*	Zooplankton	1960s		Ballast Water
Caspia hydroid	*Cordylophora caspia*	Zooplankton			
Cyclopoid copepod	*Cyclops strenuous*	Zooplankton			Ballast Water?
Cyclopoid copepod	*Magacyclops virdis*	Zooplankton			
European Fingernail Clam	*Sphaerium corneum*	Bivalve			
European Valve Snail	*Valvata piscinalis*	Snail	1985	St. Louis River	Ballast Water or Aquaria
Gammarid amphipod	*Gammarus fasciatus*	Zooplankton	2001	Widespread	Ballast Water
Gammarid amphipod	*Echinogammarus ischnus*	Zooplankton	2001	Thunder Bay, ON	Ballast Water, Packaging or Other
Greater European Pea Clam	*Pisidium amnicum*	Bivalve	1985?	St. Louis River	Ballast (Solid)?
Henslows Pea Clam	*Pisidium henslowanum*	Bivalve	2005	St. Louis River	Ballast Water?
Hump-backed Pea Clam	*Pisidium supinum*	Bivalve	2005	St. Louis River	Ballast Water?
Lumholtz's Waterflea	*Daphnia lumholtzi*	Zooplankton	2005	St. Louis River	Ballast Water?
New Zealand Mudsnail	*Potamopyrgus antipodarum*	Snail	2001	Thunder Bay, ON	Ballast Water
Pygmy Pea Clam	*Pisidium moitessierianum*	Bivalve	1985?	St. Louis River	Ballast Water?
Quagga Mussel	*Dreissena bugensis*	Bivalve	2005	St. Louis River	Ballast Water
Rusty Crayfish	*Orconectes rusticus*	Crayfish	1991	Thunder Bay, ON	Ballast Water, Live Bait, or Aquaria
Spiny Waterflea	*Bythotrephes longimanus*	Zooplankton	1987	E. Lake Superior, ON	Ballast Water
Testate amoeba	*Psammonobiotus communis*	Zooplankton			
Testate amoeba	*Psammonobiotus dziwnowi*	Zooplankton			
Tiger Sideswimmer	*Gammarus tigrinus*	Zooplankton	1985?	St. Louis River	Ballast Water
Tubificid worm	*Potamothrix bedoti*	Oligochaeta			
Tubificid worm	*Potamothrix moldaviensis*	Oligochaeta			
Tubificid worm	*Potamothrix vejdovskyi*	Oligochaeta			
Zebra Mussel	*Dreissena polymorpha*	Bivalve	1989	St. Louis River	Ballast Water

Table D3. Diseases and Parasites

Common Name	Scientific Name	Group	Earliest Record	Earliest Location	Attributed Mechanism(s)
Bacterial kidney disease	*Corynebacterium ssp.*	Fish disease	1975 (or earlier)		Fish disease
Fluke	*Dactylogirus amphibothrium*	Fish parasite	1986	St. Louis River	Fish parasite
Fluke	*Dactylogirus hemiamphibothrium*	Fish parasite	1986	St. Louis River	Fish parasite
Fluke	*Ichthyocotylurus pileatus*	Fish parasite	1995	St. Louis River	Fish parasite
Fluke	*Timoniella spp.*	Fish parasite			
Fluke, trematode	*Necascus brevicaudatus*	Fish parasite			
Furunculosis, also known as Aeromonas salmonicida		Fish disease			Fish disease
Parasite	*Sphaeromyxa sevastopoli*	Fish parasite	1995	St. Louis River	Fish parasite
Parasite	*Tryponasoma acerinae*	Fish parasite	1986	St. Louis River	Fish parasite
Parasite (microsporidian)	*Glugea herwigi*	Fish parasite	1930s		Fish parasite
Parasitic Copepod	*Salmincola lotae*	Fish parasite			
Viral Hemorrhagic Septicemia	*Novihabdovirus spp.*	Fish virus			
Whirling disease	*Myxobolus cerebralis*	Fish disease			Fish disease
Yellow Perch parasite	*Heterosporis spp.*	Fish parasite			

Table D4. Non-Native Algae

Common Name	Scientific Name	Group	Earliest Record	Earliest Location	Attributed Mechanism(s)
Diatom	*Actinocyclus normanii fs. subsalsa*	Diatom			
Diatom	*Cyclotella atomus*	Diatom			
Diatom	*Cyclotella pseudostelligera*	Diatom			
Diatom	*Skeletonema potamos*	Diatom			
Diatom	*Thalassiosira baltica*	Diatom			
Diatom	*Thalassiosira seissflogii*	Diatom			
Red algae	*Bangia atropurpurea*	Red algae			

Table D5. Non-Native Aquatic and Wetland Plants

Common Name	Scientific Name	Group	Earliest Record	Earliest Location	Attributed Mechanism(s)
Curlyleaf Pondweed	*Potamogeton crispus*		1988, 1996	Knife River Marina, MN; Washburn Harbor, WI	With Fish or Recreational Boats
Eurasian Watermilfoil	*Myriophyllum spicatum*		1996	Chequamegon Bay, WI	Aquaria or Recreational Boats
Water-cress	*Rorippa nasturtium-aquaticum*		1985 (or earlier)	E. Lake Superior, MI	Cultivation
Barnyard Grass	*Echinochloa crusgalli*	Grass	1972 (or earlier)	E. Lake Superior, MI	Cultivation
Bitter Dock	*Rumex obtusifolius*	Flower	1985 (or earlier)	E. Lake Superior, MI	
Bittersweet Nightshade	*Solanum dulcamara*	Flower			
Bur Reed	*Sparganium glomeratum*	Reed	1936	Superior Bay	
Crack Willow	*Salix fragilis*	Woody plant	1985 (or earlier)	E. Lake Superior, MI	Cultivation
Creeping Yellow Cress	*Rorippa sylvestris*	Flower	1985 (or earlier)	E. Lake Superior, MI	Ballast (solid)?
European Brooklime	*Veronica beccabunga*	Flower			
Field Sow Thistle	*Sonchus arvensis*	Flower	1996 (or earlier)	E. Lake Superior, MI	Cultivation
Indian Balsam	*Impatiens glandulifera*	Flower	1984, 1998	Grand Marais, MN, Lake Superior, ON	Cultivation
Lupine	*Lupinus polyphyllus*	Flower	1982	Beaver Bay, MN	Cultivation
Marsh Thistle	*Cirsium palustre*	Flower	1990 (or earlier)	E. Lake Superior, MI	
Narrow-leaved Cattail	*Typha angustifolia*	Cattail	1972 (or earlier)	E. Lake Superior, MI	Canals or Cultivation
Oak-leaved Goose Foot	*Chenopodium glaucum*	Flower	1985 (or earlier)	E. Lake Superior, MI	Railroads or Highways
Purple Loosestrife	*Lythrum salicaria*	Flower	1907	Duluth, MN	Cultivation
Redtop	*Agrostis gigantean*	Grass	1972 (or earlier)	E. Lake Superior, MI	Cultivation
Rough-stalked Meadow Grass	*Poa trivalis*	Grass			
Spotted Knapweed	*Polygonum persicaria*	Flower	1989 (or earlier)	Sugar Loaf, MN	
True Forget-me-not	*Myosotis scorpioides*	Flower	1989 (or earlier)	Widespread	Cultivation
Watermint	*Metha aquatica*	Flower			
Western Water Horehound	*Lycopus asper*	Flower			
White Willow	*Salix alba*	Woody plant			
Yard Dock	*Rumex longifolius*	Flower	1901	Isle Royale, MI	Cultivation
Yellow Iris	*Iris pseudacorus*	Flower			
Yellow Loosestrife	*Lysimachia vulgaris*	Flower			
Common Reed	*Phragmites australis*	Grass	recent		

Appendix E: Threat Rating Details

Embayments and Inshore

Threat	Scope	Severity	Irreversibility	Summary Threat Rating
Oil Spills from Shipping and Refining	Low	High	Medium	Low
Incompatible Fisheries Management	High	Medium	Low	Low
Coastal Development	Medium	Medium	Very High	High
Dams and Barriers	High	High	Medium	High
Point Source Pollution	Medium	Medium	High	Medium
Atmospheric Deposition	Very High	Medium	Medium	Medium
Wind Energy Development	Low	Medium	Medium	Low
Aquatic Invasive Species	High	Medium	Very High	High
Non-point Source Pollution	Medium	Medium	Medium	Medium
Climate Change	Medium	Medium	Very High	High
Mining	High	Medium	High	Medium

Nearshore Zone and Reefs

Threat	Scope	Severity	Irreversibility	Summary Threat Rating
Oil Spills from Shipping and Refining	Low	Medium	Medium	Low
Incompatible Fisheries Management	High	Medium	Medium	Medium
Coastal Development	Low	High	Very High	Medium
Dams and Barriers	High	High	Medium	High
Point Source Pollution	Low	Medium	High	Low
Atmospheric Deposition	Very High	Medium	Medium	Medium
Wind Energy Development	Low	Medium	Medium	Low
Aquatic Invasive Species	High	Medium	Very High	High
Climate Change	Medium	Low	Very High	Medium
Non-point Source Pollution	Medium	Medium	Medium	Medium
Mining	High	Medium	High	Medium

Islands

Threat	Scope	Severity	Irreversibility	Summary Threat Rating
Terrestrial Invasive Species	Medium	Medium	Medium	Medium
Oil Spills from Shipping and Refining	Low	Medium	Medium	Low
Coastal Development	Low	Medium	Very High	Medium
Climate Change	Medium	Medium	Very High	High
Mining	Low	Medium	High	Low

Deepwater and Offshore Waters

Threat	Scope	Severity	Irreversibility	Summary Threat Rating
Incompatible Fisheries Management	High	Medium	Low	Low
Point Source Pollution	Low	Medium	High	Low
Atmospheric Deposition	Very High	Medium	Medium	Medium
Aquatic Invasive Species	High	Medium	Very High	High
Climate Change	Medium	Low	Very High	Medium

Coastal Wetlands

Threat	Scope	Severity	Irreversibility	Summary Threat Rating
Terrestrial Invasive Species	Medium	High	Medium	Medium
Oil Spills from Shipping and Refining	Low	Medium	Medium	Low
Coastal Development	Low	High	Very High	Medium
Dams and Barriers	Low	Medium	Medium	Low
Point Source Pollution	Low	Medium	High	Low
Atmospheric Deposition	Very High	Medium	Medium	Medium
Non-point Source Pollution	Medium	Medium	Medium	Medium
Climate Change	Medium	Medium	Very High	High
Aquatic Invasive Species	High	Medium	Very High	High
Mining	Low	High	Medium	Low

Tributaries and Watersheds

Threat	Scope	Severity	Irreversibility	Summary Threat Rating
Terrestrial Invasive Species	Medium	Medium	Medium	Medium
Oil Spills from Shipping and Refining	Low	Medium	Medium	Low
Dams and Barriers	Very High	High	Medium	High
Point Source Pollution	Low	Medium	High	Low
Incompatible Forestry	Medium	Medium	Medium	Medium
Wind Energy Development	Low	Medium	Medium	Low
Aquatic Invasive Species	High	Medium	Very High	High
Non-point Source Pollution	Medium	Medium	Medium	Medium
Climate Change	High	Medium	High	Medium
Mining	Very High	High	High	High

Coastal Terrestrial Habitats

Threat	Scope	Severity	Irreversibility	Summary Threat Rating
Terrestrial Invasive Species	Medium	Medium	Medium	Medium
Oil Spills from Shipping and Refining	Low	Medium	Medium	Low
Coastal Development	Low	High	Very High	Medium
Incompatible Forestry	Medium	Medium	Medium	Medium
Wind Energy Development	Low	Medium	Medium	Low
Climate Change	Medium	Medium	Very High	High
Mining	Low	High	High	Low

Appendix F: Regional Summaries

Table F.1: Biodiversity Targets and Linked Condition/Stress Indices

Biodiversity Target	**Linked Condition/Stress Index Reference**
Deepwater and Offshore Waters	Great Lakes Cumulative Stress (GLEAM 2012, Allan et al. 2013)
Nearshore Zone and Reefs	Great Lakes Cumulative Stress (GLEAM 2012, Allan et al. 2013)
Embayments and Inshore	Great Lakes Cumulative Stress (GLEAM 2012, Allan et al. 2013)
	Watershed Stress Index (GLEI 2013)
Coastal Wetlands	Watershed Stress Index (GLEI 2013)
	Coastal Condition Index (developed for this report)
	Great Lakes Cumulative Stress (GLEAM 2012, Allan et al. 2013)
Islands	Coastal Condition Index (developed for this report)
	Island Condition Score (Henson et al. 2010)[12]
Coastal Terrestrial Habitats	Coastal Condition Index (developed for this report)
Tributaries and Watersheds	Watershed Stress Index (GLEI 2013)

[12] The Island Condition Score (Henson et al. 2010) was also used to assess the health of islands, but was not mapped. The Coastal Stress Index provides similar results and provides a common measure for the coastal areas of islands and the mainland.

Table F.2 Regional Average Values of the Watershed Stress Index

Regional Unit No	Subwatershed Count	Final Watershed Stress Index Score							
		Min	**Max**	**Mean**	**Sum**	**S. Dev**	**Variance**	Score	Relative Grade
1	92	0.000	0.754	0.2936	27.015	0.1423	0.0202	0.71	B
2	105	0.000	0.421	0.1426	14.973	0.1149	0.0132	0.86	A
3	116	0.000	0.482	0.1448	16.794	0.1139	0.0130	0.86	A
4	0	-	-	-	-	-	-	0.90[13]	A
5	54	0.000	0.626	0.2949	15.922	0.1253	0.0157	0.71	B
6	46	0.000	0.470	0.2419	11.129	0.1032	0.0106	0.76	B
7	100	0.000	0.640	0.1560	15.604	0.1886	0.0356	0.84	A
8	46	0.123	0.762	0.4646	21.370	0.1800	0.0324	0.54	C
9	109	0.130	0.629	0.4313	47.008	0.1138	0.0129	0.57	C
10	0	-	-	-	-	-	-	0.90[14]	A
11	66	0.244	0.805	0.5756	37.992	0.1013	0.0103	0.42	C
12	42	0.109	0.846	0.6269	26.328	0.1501	0.0225	0.37	D
13	138	0.080	0.953	0.5624	77.613	0.1310	0.0171	0.44	C
14	23	0.087	0.632	0.4537	10.434	0.1641	0.0269	0.55	C
15	94	0.000	0.716	0.4044	38.018	0.2013	0.0405	0.60	B
16	223	0.000	0.900	0.5122	114.230	0.1648	0.0272	0.49	C
17	90	0.334	0.893	0.5793	52.140	0.0982	0.0096	0.42	C
18	120	0.147	0.709	0.4825	57.898	0.1187	0.0141	0.52	C
19	62	0.080	0.723	0.4801	29.766	0.1239	0.0154	0.52	C

Categories use to convert numerical value into a grade:

80.0-100 A
60.0-79.9 B
40.0-59.9 C
0-39.9 D

[13] Information not available for islands. High relative value assigned due to high amount of natural cover.

[14] Information not available for islands. High relative value assigned due to high amount of natural cover.

Table F.3 Regional Average Values of the Coastal Stress Index

Regional Unit No	SubUnit Count	Final Coastal Stress Index Score: Min	Max	Mean	Sum	S. Dev	Variance	Score	Relative Grade
1	52	19	42	40.0962	2085	4.6072	21.2259	0.955	A
2	108	36	42	41.7963	4514	0.8176	0.6684	0.995	A+
3	104	41	42	41.9808	4366	0.1380	0.0190	1.000	A+
4	38	39	42	41.9211	1593	0.4867	0.2368	0.998	A+
5	119	33	42	41.8151	4976	0.9564	0.9147	0.996	A+
6	133	32	42	41.8421	5565	1.0649	1.1340	0.996	A+
7	204	31	42	41.7353	8514	1.1987	1.4370	0.994	A+
8	68	12	42	39.6912	2699	6.0650	36.7838	0.945	A
9	37	36	42	41.1351	1522	1.5840	2.5090	0.979	A+
10	110	42	42	42.0000	4620	0.0000	0.0000	1.000	A+
11	15	27	42	39.4000	591	4.5795	20.9714	0.938	A
12	4	13	37	21.0000	84	10.8321	117.3333	0.500	C
13	38	22	42	40.1316	1525	4.5570	20.7660	0.956	A
14	6	37	42	40.8333	245	1.9408	3.7667	0.972	A+
15	5	25	40	33.6000	168	6.3482	40.3000	0.800	A-
16	25	30	42	40.5600	1014	3.1236	9.7567	0.966	A
17	26	21	42	40.1154	1043	4.7860	22.9062	0.955	A
18	8	33	42	39.3750	315	3.2486	10.5536	0.938	A
19	14	15	42	35.2857	494	11.0274	121.6044	0.840	A

Categories use to convert numerical value into a grade:

97.0-100	A+
84.0-96.9	A
80.0-83.9	A-
60.0-79.9	B
40.0-59.9	C
0-39.9	D

Table F.4 Regional Average Values of the Great Lakes Stress Index

Regional Unit No	Point Count	Final Great Lakes Stress Index							
		Min	**Max**	**Mean**	**Sum**	**S. Dev**	**Variance**	Score	Relative Grade
1	1731	0.095	0.821	0.382	661.045	0.131	0.017	0.62	B
2	1118	0.037	0.913	0.383	428.606	0.151	0.023	0.62	B
3	282	0.067	0.851	0.267	75.234	0.199	0.040	0.73	B
4	810	0.000	0.402	0.101	81.745	0.066	0.004	0.90	A
5	344	0.014	0.985	0.478	164.382	0.192	0.037	0.52	C
6	940	0.062	0.942	0.410	384.936	0.209	0.044	0.59	C
7	1817	0.057	0.972	0.415	753.807	0.217	0.047	0.59	C
8	587	0.206	0.997	0.754	442.277	0.192	0.037	0.25	D
9	310	0.085	0.883	0.432	133.765	0.160	0.026	0.57	C
10	585	0.095	0.589	0.392	229.355	0.078	0.006	0.61	B
11	322	0.232	0.998	0.796	256.175	0.170	0.029	0.20	D
12	56	0.927	0.997	0.970	54.323	0.020	0.000	0.03	D
13	3155	0.032	0.992	0.429	1352.652	0.231	0.053	0.57	C
14	884	0.097	0.937	0.511	451.962	0.245	0.060	0.49	C
15	792	0.121	0.953	0.517	409.512	0.139	0.019	0.48	C
16	2390	0.030	0.938	0.345	823.901	0.175	0.031	0.66	B
17	1348	0.063	0.993	0.477	642.445	0.190	0.036	0.52	C
18	3017	0.031	0.932	0.444	1340.053	0.169	0.029	0.56	C
19	434	0.215	0.915	0.592	257.092	0.126	0.016	0.41	C

Categories use to convert numerical value into a grade:

97.0-100	A+
84.0-96.9	A
80.0-83.9	A-
60.0-79.9	B
40.0-59.9	C
0-39.9	D

Table F.5 Coastal Condition Index

The following six measures were calculated and then assembled into a single index to assess the relative condition of each coastal unit.

Indicator	Poor- (0)	Poor+ (1)	Fair- (2)	Fair+ (3)	Good- (4)	Good+ (5)	V. Good- (6)	V. Good+ (7)
Artificial shoreline within 2 km of shoreline	>60%	40-60%	35-40%	30-35%	25-30%	20-25%	10-20%	<10%
Natural land cover within 2 km of shoreline	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
Natural land cover from 2 to 5 km from shoreline	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
Natural land cover within watershed	<20%	20-40%	40-50%	50-60%	60-70%	70-80%	80-90%	>90%
Road density within 2 km of shoreline (m road/ km^2)	>3000	2001-3000	1501-2000	1160-1500	1001-1159	501-1000	251-500	<250
Building density within 500 m of shoreline (number of buildings/km^2)	>400	200-400	150-200	100-150	75-100	50-75	10-50	<10