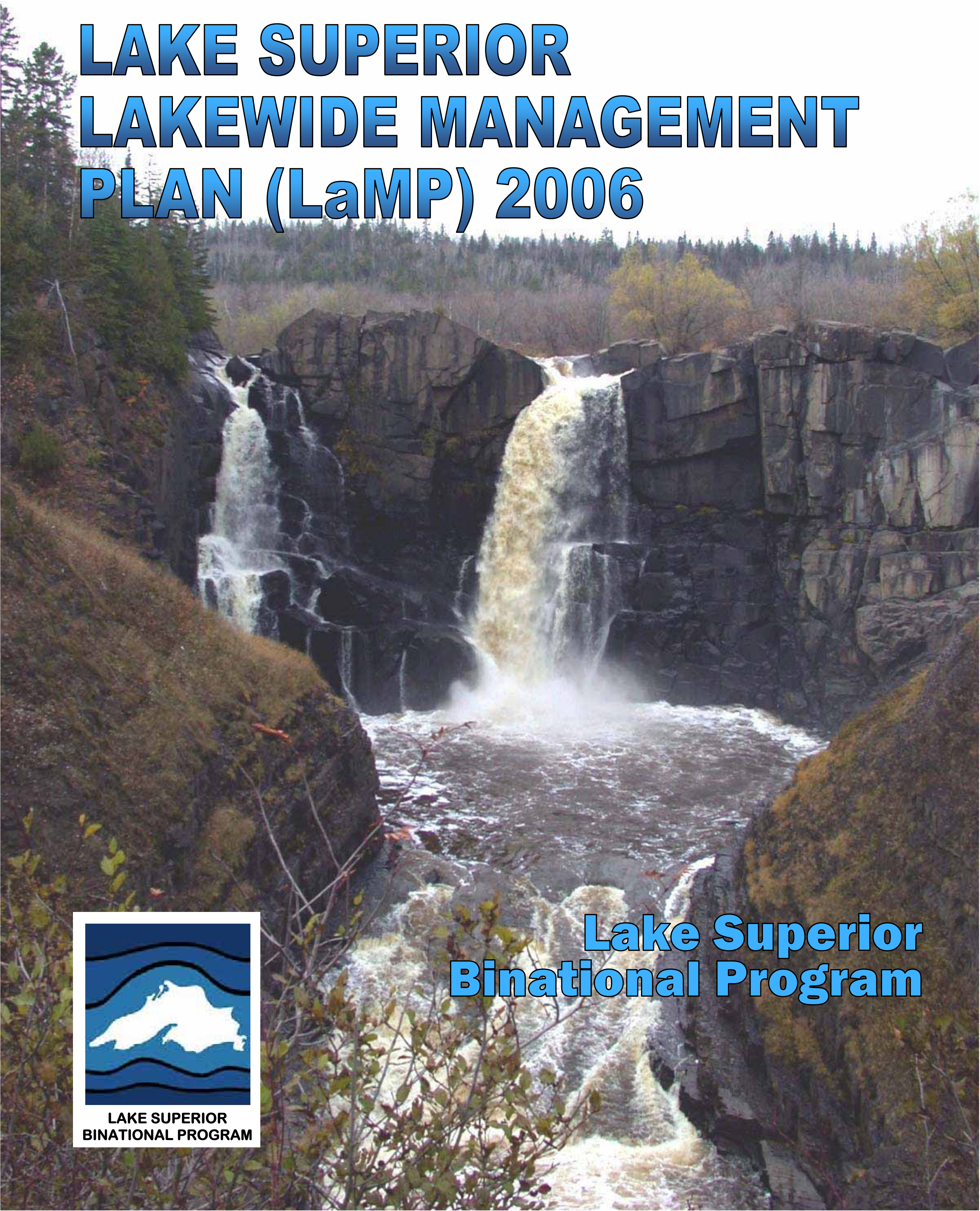
LAKE SUPERIOR LAKEWIDE MANAGEMENT PLAN (LaMP) 2006



Lake Superior Binational Program

LAKE SUPERIOR BINATIONAL PROGRAM

Cover photo: *Grand Portage State Park. Pigeon River (the international boundary: Ontario on the right, Minnesota on the left).* **Photo credit**: *John Marsden, Environment Canada.*

Executive Summary

View of Thunder Bay, Ontario, from Sleeping Giant Provincial Park.
Photo Credit: John Marsden, Environment Canada.

Lake Superior Lakewide Management Plan
2006

Executive Summary

BACKGROUND

One of the most significant environmental agreements in the history of the Great Lakes was put in place with the signing of the Great Lakes Water Quality Agreement of 1978 (GLWQA), between the United States and Canada. This historic Agreement commits the U.S. and Canada (the Parties) to address the water quality issues of the Great Lakes in a coordinated, joint fashion. The purpose of the Agreement is to "restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem" (IJC 1993). The 1987 amendment to the GLWQA requires the development of Lakewide Management Plans (LaMPs) which "shall embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses...they are to serve as an important step toward virtual elimination of persistent toxic substances...". This document represents the current LaMP for Lake Superior.

The Great Lakes Water Quality Agreement specifies that the LaMPs are to be completed in four stages. However, under a streamlined LaMP review and approval process, the LaMPs now treat problem identification, selection of remedial and regulatory measures, and implementation as a concurrent, integrated process rather than a sequential or staged one. In the Lake Superior LaMP, Stages 1 and 2 for critical chemicals were completed before the decision was made to integrate. Stage 3 was merged into LaMP 2000 as the critical chemicals chapter. To date, no other LaMP has a load reduction schedule for critical pollutants as required by the Agreement.

The LaMPs go beyond the GLWQA requirement to address critical pollutants by using an ecosystem approach to integrate habitat, terrestrial wildlife and aquatic ecosystem components. This integration allows for the development of both environmental protection and natural resource management strategies.

The Lake Superior LaMP is unique because of an additional agreement between the federal governments, states and province surrounding Lake Superior. Announced in 1991, the agreement, called the "Binational Program to Restore and Protect the Lake Superior Basin," established a Zero Discharge Demonstration Program for critical pollutants and a broader ecosystem approach.

LaMP progress is now reported on every two years. Adaptive management is used to allow the process to change as needed by building upon successes, accepting new information and drawing from public involvement and input. The LaMP therefore, can be adjusted over time to respond to the most pertinent issues facing the lake ecosystem. Additional details on the process can be found in Chapter 1.

The LaMP/Lake Superior Binational Program contains funded and proposed (non-funded) actions for restoration and protection to bring about improvement in the ecosystem. Actions include commitments by the government partners as well as suggested voluntary actions that could be taken by non-governmental partners. LaMP 2000 identified these actions in six ecosystem themes: critical pollutants, aquatic communities, terrestrial wildlife communities, habitat, human health and developing sustainability. The 2002 LaMP update reported on the success of those actions, and identified challenges remaining to achieve established goals and ecosystem objectives. LaMP 2004 reported accomplishments from 2002-2004, challenges to achieving goals and objectives, and next steps.

LaMP 2006

LaMP 2006 builds on the previous LaMP documents. Many of the original LaMP 2000 chapters have been revised, replaced and updated, although the Human Health and Critical Pollutants chapters remain the same as in the LaMP 2000. The Critical Pollutants chapter will be replaced in LaMP 2008 by a "Chemical Milestones" report scheduled for release in Summer 2006. The LaMP 2006 chapters contain a 2004-2006 progress report, presenting an accomplishment summary of the 1) actions completed or underway to improve the lake, 2) challenges, and 3) next steps or changes to ongoing management actions.

Highlights of LaMP 2006 include: an integrated and consolidated ecosystem chapter combining terrestrial wildlife, habitat and aquatic communities activities (Chapter 6); an expanded description of ecosystem goals, objectives and indicators (Chapter 3); community sustainability projects (Chapter 7); public outreach and education brochures and newspaper inserts (Chapter 2); and actions and projects targeted at critical pollutants reduction (Chapter 4). A chapter on coordination with other Great Lakes programs (Chapter 8), including the Great Lakes Regional Collaboration, is also presented. Updates on progress to restore Areas of Concern are contained in Appendix A, and a description of a successful Lake Superior Legacy Act Project (Hog Island) is highlighted in Chapter 1. A holistic, comprehensive look at the "state of lake superior" (the highlights report from the 2004 State of the Lakes Ecosystem Conference) can be found in Addendum A of the Executive Summary. LaMP 2006 also identifies data gaps and next steps for LaMP 2008.

LaMP 2006 is available on a CD-ROM, and is designed to be printed in a loose-leaf format that can be inserted into a three-ringed binder. This format allows for easy updates, additions of new material and removal of outdated information. A description of how to update the LaMP 2004 binder with the 2006 material is presented in the Preface. The LaMP 2006 will also be available on the web at www.epa.gov/glnpo.

This Lakewide Management Plan Report 2006 is not intended to be circulated extensively to the public; the agencies plan to produce a separate document to inform the public on Binational Program activities. Citizens of the basin, as partners and stakeholders in the Binational Program, are strongly encouraged to become actively involved. The Lake Superior Binational Forum can be reached at 1-888-301-LAKE (1-888-301-5253).

ACCOMPLISHMENT AND NEXT STEPS: HIGHLIGHTS 2004 TO 2006

The Lake Superior Binational Forum

The Lake Superior Binational Forum, the citizen's group associated with the government agencies responsible for carrying out the Binational Program, has been key to establishing an effective multi-stakeholder process. The Forum has held many workshops over the years for the purpose of acquiring necessary background information to help develop recommendations and proposals for sustainable development, human health and reducing the Lake Superior nine critical pollutants. They have also held very successful public input sessions and published many documents on key issues relating to the LaMP.

Accomplishments include:

- Initiating and conducting an annual Lake Superior Environmental Stewardship Awards Program;
- Developing, expanding, and promoting an annual Lake Superior Day celebration held on the third Sunday in July around the basin;
- Publishing, producing, and distributing an educational four-page color newspaper supplement that highlights Lake Superior "good news" stories around the basin;
- Holding public input sessions on a variety of topics including watershed planning and management, mining trends and issues, and impacts of aquatic nuisance species.

Next Steps include:

- Establishing a mercury-mentoring program to work with the shipping industry, other targeted industries, and municipalities to identify and reduce mercury sources;
- Participating with the Work Group in an effort to identify the monitoring efforts of private, corporate, municipal, non-profit, and tribal entities so that a more complete Lake Superior monitoring inventory can be obtained.
- Seeking to involve more youth in Lake Superior leadership activities, with a focus on university and college students.

The Lake Superior Binational Program Partners

The activities below represent accomplishments by the various partners represented on committees of the Lake Superior Binational Program. Additional details can be found in the relevant chapters of LaMP 2006.

Critical Pollutants

Accomplishments include:

- Mercury pollution prevention and awareness (e.g., progress in dental sector, school mercury removal, collection of thermostats, fluorescent tubes, auto switches, and thermometers);
- PCB phase-out from utility transformers;
- Hazardous and electronic waste collections and pesticide clean sweeps programs;

- Residential garbage burning awareness campaigns;
- Progress on contaminated sediment assessment and cleanup;

Next Steps include:

- Continued implementation of LaMP 2000 priority activities;
- Continued effort to update chemical inventories;
- Completion of a Chemical Milestones Report in Summer 2006; report will review current milestones and update reduction strategies;
- Continuation of sediment remediation in both countries; and
- Continuation of Stormwater Management to prevent pollutant loadings.

Ecosystem (Habitat, Aquatic, Terrestrial Wildlife)

Accomplishments include:

- Initiation of a landscape-scale invasive free zone;
- Restoration and enhancement of wildlife habitat;
- Initiation of a basinwide herptile monitoring program;
- Completion of a peregrine falcon survey;
- Continuation of National Lynx Detection surveys;
- Establishment of a National Marine Conservation Area;
- Establishment of a Watercourse Stewardship Project;
- Progress on watershed habitat rehabilitation;
- Continued development of a hydroacoustic-based pelagic prey fish monitoring program;
- Mapping and quantification of critical fish habitat;
- Initiation of a lower trophic level monitoring effort;
- Removal of structures that limit fish passage and fragment aquatic habitat; and
- Consolidation of various ecosystem components of LaMP 2000 into a single chapter.

Next Steps include:

- Map and describe additional areas of critical fish habitat;
- Continue management and research to prevent introductions and limit the spread of aquatic nuisance species;
- Continue basinwide herptile monitoring program;
- Finalize and implement the hydroacoustic-based prey fish monitoring program;
- Continue development of a Lake Superior Decisions Support System;
- Continue lower trophic monitoring efforts;
- Evaluate and initiate monitoring techniques for medium-sized carnivores;
- Update information in the public kiosk network;
- Continue to rehabilitate coaster brook trout, walleye, and sturgeon populations and manage a sustainable lake trout fishery;
- Complete a report on lake herring status; and
- Continue invasive free zone planned treatment and monitoring.

Human Health

Accomplishments include:
- Formation of the Canadian Great Lakes Public Health Network;
- Participation in the U.S. Great Lakes Human Health Network;
- Enhanced beach monitoring and outreach efforts; and
- Improved education and outreach on fish consumption advisories.

Next Steps include:
- Integration of the U.S. and Canadian Great Lakes Human Health networks;
- Expansion of membership to the Network;
- Improve integration with children's health issues and programs;
- Increase integration with the LaMP groups to jointly set human health priorities and action steps; and
- Additional and continued outreach on human health concerns and risks to Great Lakes human health officials.

Sustainability

Accomplishments include:
- Completion of Phase I of the Community Awareness Review and Development (CARD) project;
- Completion of a riparian buffer demonstration project; and
- Coordination on local sustainability projects with Lake Superior communities.

Next Steps include:
- Possible continuation of the CARD project;
- Recruitment of additional Sustainability Committee members;
- Integration with other ongoing sustainability efforts around the Basin;
- Promoting water conservation, marketing waste reduction and energy efficiency, understanding sprawl; and
- Promoting sustainability workshops.

CHALLENGES OF THE BINATIONAL PROGRAM

In general, the next steps for the Binational Program are to:
- continue to implement projects and priorities identified in the LaMP;
- advocate the benefits to decision makers and the public to ensure continued support for toxic chemical reduction activities;
- continue communication and outreach activities that will achieve measurable progress toward the Binational Program goals;
- continue with priority ecosystem monitoring, mapping, research and restoration efforts;
- prepare various internal and public reports, including the biennial LaMP updates;
- build capacity in the Binational Program by recruiting additional partners; and

- seek additional funding for LaMP implementation from a wide variety of sources.

Future accomplishments will be dependent upon commitments by governments, NGOs, and individuals to support the science, resource management, and legislative activities that will protect and restore the basin.

Ecosystem challenges include:

- protecting critical lake and tributary habitats;
- continuing rehabilitation plans for sturgeon, walleye, lake and brook trout;
- preventing invasion and transport of non-native species within the basin;
- ensuring the maintenance of healthy aquatic communities on rivers with hydropower;
- establishing long-term monitoring programs of biological communities;
- establishing monitoring programs for invasive species and fish community changes and status;
- ongoing support and maintenance of the geographic database and projects associated with the Lake Superior Decision Support System;
- closing information gaps on the status and trends of habitat conditions;
- developing land use change models; and
- educating the public on important habitat and ecological resources in the Lake Superior basin by expanding the use of interactive information kiosks.

Even though the idea of sustainability has long provided a foundation for the Lake Superior Binational Program, it is challenging to facilitate sustainable practices “on the ground”. To promote practices that provide for sustainable outcomes requires consideration of a variety of issues that go beyond the prevention of pollution. To produce a truly sustainable society, we must grapple with issues that are more general in scope than those associated with other aspects of the LaMP. Though progress has been made, we are still a long way from promoting a full range of social and economic initiatives that will make for a sustainable future.

ADDENDUM A

STATE OF THE GREAT LAKES 2005

Lake Superior

Assessment: The status of the Lake Superior ecosystem is *mixed.*

Bald eagles, gray wolf and cormorants have recovered and forest cover has increased. Fisheries recovery indicators are also good. Some trends in contaminant loadings are showing declines while others remain constant. Invasive species continue to be a problem and remain a threat to the recovering fish population. Stresses on the system include shoreline development, habitat loss, land use change and invasive species.

Summary of the State of Lake Superior

Lake Superior is the largest freshwater lake in the world by area and third largest by volume; it averages 147 metres in depth, with a maximum depth of 406 metres. The total watershed area is 228,000 km² including Lake Nipigon and two major diversions. Water transparency can reach a depth of 23 metres. Lake Superior has the lowest summer surface temperature (13 degrees Celsius) and mean annual water temperature (3.6 degrees Celsius) of the Great Lakes. The watershed contains many globally rare vegetation types, including arctic alpine communities, sand dunes, and pine barrens. The three principal industries are forestry, mining and tourism. The retention time for Lake Superior is 173 years; what goes into the lake affects it for several generations. Lake Superior has eight Areas of Concern (AOCs) as shown on the map (Figure 1).

CHEMICAL CONTAMINANTS

Over the last 30 years, concentrations of nearly all measured contaminants in fish and the water column, with the exception of toxaphene, have declined in Lake Superior. Because of its remote location, limited industrial activity and large surface to

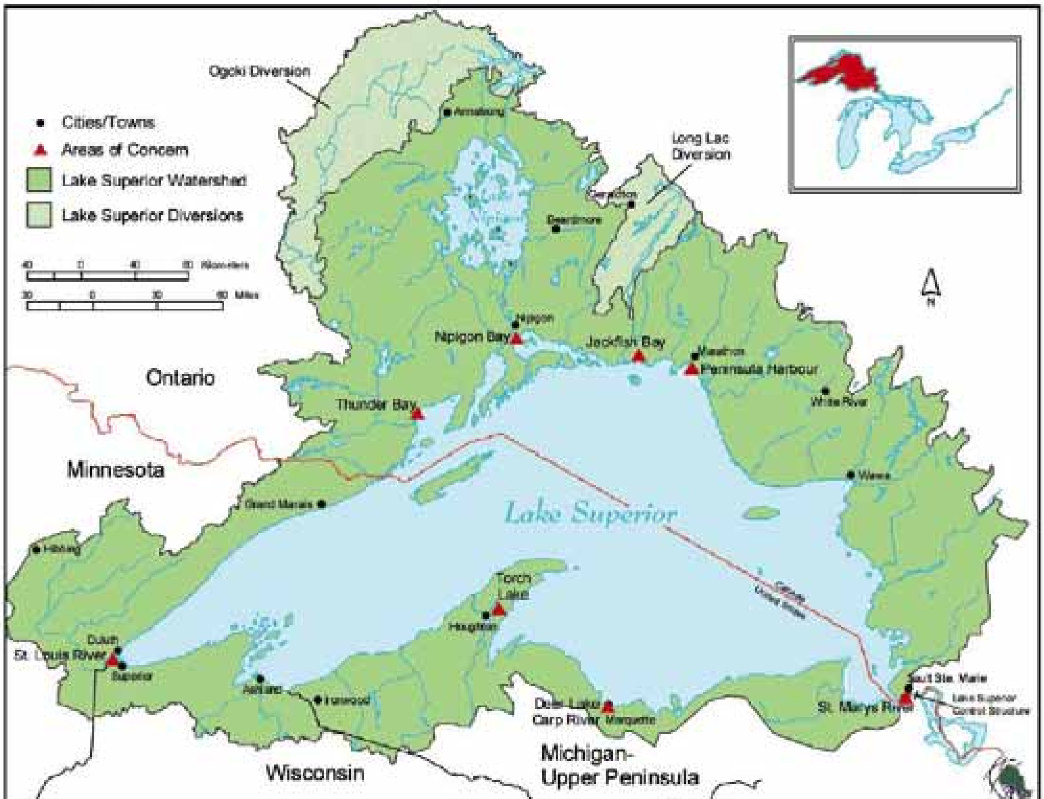


Figure 1. Lake Superior drainage basin map.
Source: Environment Canada

watershed ratio, Lake Superior receives the majority of its loading via atmospheric deposition, especially with regard to PCBs, mercury and toxaphene.

Figure 2 shows the mercury emission decreases that have occurred between 1990 and 2000. While significant reductions have occurred in products and mining, emissions from fuel combustion are virtually unchanged.

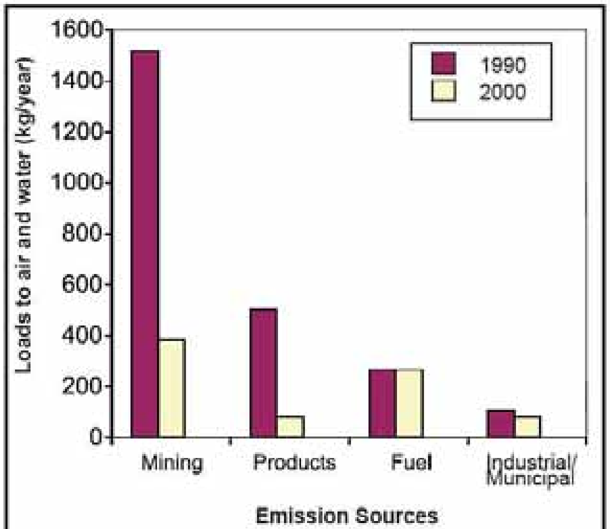


Figure 2. Mercury emissions from various sources within the Lake Superior basin.
Source: Lake Superior LaMP Chemical Committee, 2003

Water Column
Concentrations of a suite of toxic organic contaminants in water including the Lake Superior critical and lakewide remediation pollutants declined more than 50% between 1986 and 1997. Nevertheless, of the nine critical pollutants, dieldrin, mercury, PCBs and toxaphene concentrations in Lake Superior continue to exceed the most stringent water quality standards.

Gull Eggs
Herring Gull eggs have been collected and analyzed annually from the same two Lake Superior sites, Granite Island and Agawa Rocks, since 1974 for selected contaminants. Overall contaminant levels have declined. For the period 1974 to 2002, 64% of Lake Superior contaminant–colony comparisons declined as fast as or faster than they did earlier in the study, while 29% declined more slowly in recent years.

Data from 1974 to 2002 illustrates the decline in dieldrin in herring gull eggs at the Agawa rocks monitoring site. For most compounds, this site, which is in eastern Lake Superior, ranked low compared to other locations. The Granite Island site in western Lake Superior, however, ranked 3rd overall in the Great Lakes. For dieldrin and heptachlor epoxide, the two Lake Superior sites ranked the 4th and 3rd most contaminated of 15 sites studied, respectively, on the Great Lakes. For more information on contaminants in herring gull eggs, refer to the Great Lakes indicator report #115, Contaminants in Colonial Nesting Waterbirds, found later in this report.

Fish Contaminants
DDT data for lake trout collected by the U.S. Environmental Protection Agency–Great Lakes National Program Office (GLNPO) and Canada Department of Fisheries and Ocean (DFO) display a general fluctuation in concentrations from year–to–year with a recent increase in concentration. It is likely that this increase is due to a change in the sampling location rather than to an actual increase in contaminant concentration.

Concentrations of toxaphene have declined dramatically in lake trout across all Great Lakes except for Lake Superior. Lower productivity, colder temperatures and large surface area are likely responsible for higher Superior levels. Seventy–80% of Ontario's sport fish consumption advisories are due to toxaphene.

GLNPO lake trout collections show PCBs are fluctuating, although levels have dropped since 1980. The DFO lake trout data show very little recent change in mean PCB concentrations. Lake trout concentrations remain above the GLWQA criteria.

DFO smelt data continue to show a steady decline in mercury concentrations through 2002. While mercury levels are below GLWQA criteria, the trend data show continuing improvement in mercury levels for smelt. At every site monitored, mercury levels in lamprey were significantly greater than those detected in their primary prey. These data also demonstrate the significantly elevated mercury levels in lamprey from the Lake Superior system compared to other Great Lakes.

Figure 3 shows the trends for four of the Lake Superior critical chemicals. Dieldrin and chlordane appear to be leveling off. DDT appears to be increasing slightly and PCBs are fluctuating, as noted above. The number and geographic extent of sport fish consumption advisories in Lake Superior is expected to decrease as contaminant concentrations decline. However, the ecosystem requires decades to purify itself, and agencies will likely continue to issue sport fish advisories for some time.

Atmospheric Deposition
Data from the Great Lakes Integrated Atmospheric Deposition

STATE OF THE GREAT LAKES 2005

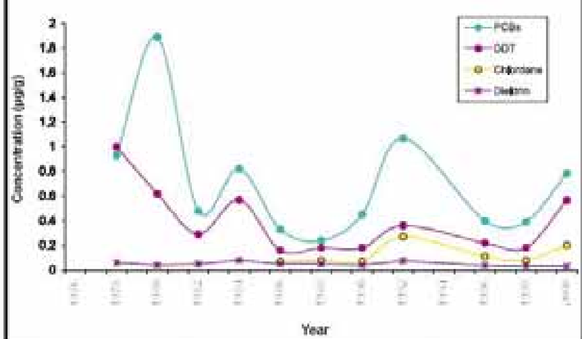


Figure 3. Apostle Island lake trout contamination trends, 1978-2000.
Source: Murphy, 2004

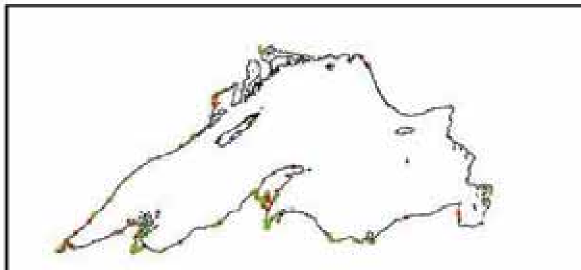


Figure 4. Man-made shorelines in the Lake Superior basin. Red circles represent riprap, sheet piling and other anthropogenic changes to the shoreline.
Source: U.S. Environmental Protection Agency, 1994 and Environment Canada, 1993

Network (IADN) indicate that levels of PCBs and banned organochlorine pesticides are declining at all master stations. For Lake Superior, the Duluth/Superior area appears to have some influence on PAHs and possibly HCB deposition to the lake. There is no apparent effect of this urban area on PCB deposition.

IADN data also suggest that the Canadian Prairie Provinces and the southern U.S. are sources of lindane to Lake Superior. PCB behavior in Lake Superior is unique with little storage in the sediments. Also there is little organic matter in the ecosystem to affect PCB levels. PCBs deposited into the lake are recycled into the food web via the plankton and also volatilized back into the atmosphere. Only 2–5% accumulates in bottom sediments.

Over many years, net volatilization of PCBs has released 26,000 kilograms to the atmosphere. Lake Superior was considered a PCB source but is now is at equilibrium with the atmosphere.

WILDLIFE AND HABITAT

Shoreline Development and Hardening

Shoreline development is one of the most pressing issues facing the Lake Superior basin today. The Keweenaw Peninsula on Michigan's Upper Peninsula has seen unprecedented housing growth in the past 20 years, mainly in recreational homes; over 50% of the homes in Keweenaw County are now classified as second homes. Population growth is greatest in the Duluth/Superior areas, Grand Marais and the Bayfield Peninsula. In Ontario, this population trend is greatest along the shorelines east and west of Thunder Bay and north of Sault Ste. Marie.

Shoreline hardening, which consists of sheet piling, riprap or other anthropogenic changes, is an increasing problem for Lake Superior. Although Lake Superior has the lowest percentage of shoreline hardening, the trend is increasing due to rapid growth of population in the areas previously mentioned (Figure 4).

Forest

Forest fragmentation and changes in forest composition are two of the seminal changes to the Lake Superior basin since settlement times. Beginning in the 1880s, U.S. forests were almost entirely clear–cut. Aspen, birch, fir and poplar have increased since logging began while spruce and pines have been severely reduced. Forest cover is anticipated to remain the same or slightly increase in the future. Forest fragmentation of hardwoods will continue to increase due to development and including road construction. The Great Lakes Forestry Alliance reported in 1995 that timber growth in Michigan, Minnesota, and Wisconsin exceeded harvest by 90% and timber volume increased from about 700 million m^3 (25 billion ft^3) in 1952 to more than 14 billion m^3 (50 billion ft^2) in 1992.

Wetlands

About 15% of the U.S. Lake Superior basin and 6–25% of the Canadian basin are wetlands (Figure 5). The greatest threats to Lake Superior's wetlands are wetland draining and filling, toxic contamination, water level regulation and site–specific stresses such as shoreline development. Other threats include invasive species and diminished water quality. Although there have been many wetland restoration success stories, it is not possible to determine if there has been a net loss or gain of wetlands because of limitations on, and lack of coordination among, current monitoring efforts. Monitoring, use of Best Management Practices and remedial actions are necessary to completely address the wetland issue.

Loss of wetland habitat has been small in some counties but most of the St. Louis River estuary wetlands at Duluth have been lost since the early 1900s. The wetlands of the Apostle Islands, Bad River and Kakagon Slough are largely intact.

There are no comprehensive estimates of coastal wetland losses for Lake Superior. Wetland loss in Ontario is low (0–25%) for most of the basin, but locally, wetland losses have been reported in the Thunder Bay and St. Marys River AOCs due to shoreline modification and urban encroachment. Wetland area around Thunder Bay has declined by over 30% since European settlement.

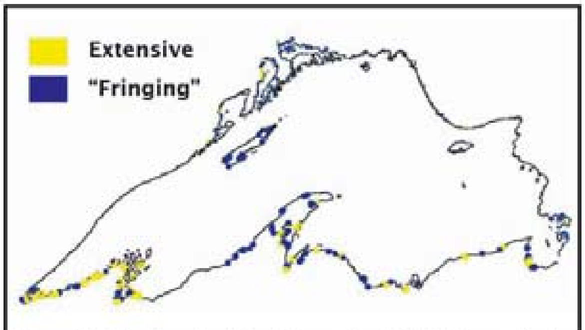


Figure 5. Lake Superior shoreline wetlands. Fringing wetlands are marsh communities, characteristically found in shallow water coves protected from wind and waves. They closely border the shore to form a narrow belt of aquatic vegetation. Extensive wetlands are larger (up to 1 to 2 km long) and occupy shallow coves with stream outlets.
Source: U.S. Environmental Protection Agency, 1994 and Environment Canada, 1993

Lake Superior shoreline wetlands are a particular concern in Ontario, given their scarcity and proximity to developed areas. The potential for further development at Cloud Bay, Sturgeon Bay and Pine Bay threatens wetlands.

Wildlife

Habitat changes on the landscape, as well as harvest and management of select species, have created some dramatic changes in wildlife communities over the past 150 years. Ungulates, wolves and furbearers were hunted to near extinction but are now rebounding.

Successful reintroduction of peregrine falcons is also underway within the basin. Cormorants and herring gulls are recovering after being decimated by toxic contaminants in the 1970s.

Caribou in Canada and Canada lynx in the U.S. are still scarce although recovery planning is underway for these and a number of other species at risk in the basin, i.e. piping plover and wood turtle.

Eighteen animal species found in the Lake Superior watershed, including mammals, birds, insects and herptiles, are listed by Canada and/or the U.S. as endangered. In addition, there are 400 species in the basin listed by provincial or state jurisdictions as endangered, threatened, or of special concern. Of the 400 species, nearly 300 are plants. The preparation of recovery plans or conservation strategies is underway for 26 species.

Little work has been done to monitor and classify the status of amphibians and reptiles in comparison to other vertebrates, although the planning of a basin–wide monitoring program for herptiles is underway. Thirty–seven species of reptiles and amphibians have been documented including seven salamanders, 12 frogs, six turtles, two lizards and one snake. As with many vertebrates, the widespread changes in habitat cover across the landscape have had a dramatic effect on the community composition of amphibians and reptiles. However, local population declines of many amphibians (Table 1) are becoming a concern worldwide. Many possible reasons exist for these declines; monitoring programs are being initiated to document trends.

Species	Relatively Stable	Increasing	Decreasing	State Endangered	Special Concern	No Trend Data Available
Wood frog	●	■				
Northern leopard frog	●		●■			
Pickerel frog			■			
Mink frog						●■
Green frog	●■					
Chorus frog	■					
Northern spring peeper	●		■			
Eastern gray treefrog	●■					
Cope's gray treefrog			■			
Blanchard's cricket frog					●	
American toad	●■					
Blue-spotted salamander	●■					
Eastern tiger salamander			●			
Spotted salamander	■					
Four-toed salamander					■	
Redback salamander	●					
Mudpuppy						●■

■ Wisconsin ● Minnesota

Table 1. Status of amphibian species found in the Lake Superior basin in the states of Minnesota and Wisconsin.
Source: Casper, 1998, Moriarty 1998, and Mossman *et al.*, 1998

Aquatic Communities

The fish community of Lake Superior is generally good and remains relatively intact compared to the other Great Lakes. Through rehabilitation, lake trout stocks have increased substantially and may be approaching ancestral states. Although the siscowet shows high levels of toxic contaminants, this has not interfered with reproduction (Figure 6). There are more naturally reproducing lake trout in Lake Superior than there are in all the other Great Lakes combined. These trout are reproducing on their own with very little management needed. There are good stocks of whitefish and herring.

Natural reproduction supports most salmonid populations. Some

STATE OF THE GREAT LAKES 2005

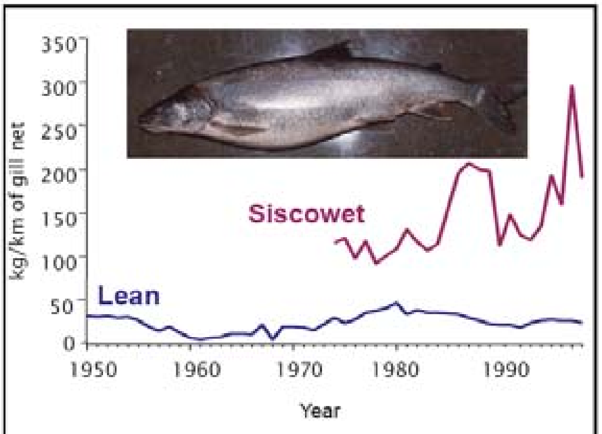


Figure 6. All forms (stocked and non-stocked) of lake trout abundance, 1950-1998.
Source: Great Lakes Fishery Commission

near shore fish populations, especially lake sturgeon, walleye and brook trout, remain below historical levels. Non–native species continue to be introduced to Lake Superior, although the fish community appears to contain enough buffering capacity to withstand and minimize the current levels of non–native species. Sea lampreys still kill thousands of lake trout each year. Round gobies and ruffe have colonized some areas and have the ability to negatively impact the near shore cool–water fish community.

Aquatic Habitat

Nearshore and open water habitat is very good, leading to abundance of trout, and good stocks of whitefish and herring. The problem is mostly in the tributaries and embayments, especially in the Areas of Concern. Lake Superior tributaries have borne the brunt of most of the habitat destruction and loss. These tributaries remain significantly degraded by such stressors as agriculture, mining, hydroelectric dams, industrial effluents and waste, wetland dredging and filling, non–point source pollution, shoreline development and use practices that lead to increased runoff and erosion. There is now naturally reproducing sturgeon, walleye and brook trout. Although the habitat is sufficient to help them increase in abundance, populations are not near historic levels because of past habitat destruction. All three species have active rehabilitation programs and resource management activities.

Invasive Species

Except for sea lamprey, the non–native species in Lake Superior have been manageable up to this point. Lake Superior, however, has the highest ratio of non–native species to native species of all the Great Lakes. Lake Superior represents the dead–end for shipping for many invasive species as it is at the end of the

Lake Superior Statistics	
Elevation[a]	
feet	600
metres	183
Length	
miles	350
kilometres	563
Breadth	
miles	160
kilometres	257
Average Depth[a]	
feet	483
metres	147
Maximum Depth[a]	
feet	1,332
metres	406
Volume[a]	
cu.mi.	2,900
km^3	12,100
Water Area	
sq.mi.	31,700
km^2	82,100
Land Drainage Area	
sq.mi.	49,300
km^2	127,700
Total Area	
sq.mi	81,000
km^2	209,800
Shoreline Length[b]	
miles	2,726
kilometres	4,385
Retention Time	
years	173
Population: USA (2000)[c]	663,606
Population: Canada (2001)	178,656
Totals	842,262
Outlet	St. Marys River

[a] measured at low water datum
[b] including islands
[c] 2000 population census data were calculated based on the total population of each county, either completely or partially, located within the watershed.

Sources:
The Great Lakes: An Environmental Atlas and Resource Book

Statistics Canada, Environment Accounts and Statistics Division, Spatial Environmental Information System and Censuses of Population 2001.

U.S. Census Bureau: State and County QuickFacts. Data derived from Population Estimates, 2000 Census of Population and Housing, 1990 Census of Population and Housing lakes. There is nothing to make us think that Lake Superior will not have its own singular invasive species problem (i.e., such as zebra mussels in the lower lakes) and, unless we do something fairly proactive fairly soon, we could have a significant problem on our hands.

Numerous invasive insect, animal and plant species have been also introduced to the Lake Superior basin. A few examples of species likely to have significant impacts include: gypsy moth, Asian long–horned beetle, rusty crayfish and exotic buckthorns. One of the most potentially devastating invasive species is the emerald ash borer. Now located in Lower Michigan and Ontario, it remains outside the Lake Superior basin for now. There is no known natural control or treatment at this time, so it could potentially devastate inland and coastal wetland ecosystems that may contain large areas of ash trees.

Future and Emerging Management Issues

Lake Superior has many existing pressures on its system which will continue to pose problems now and in the future including: continued degradation of tributary and embayment aquatic habitat, shoreline and other habitat development, continued introduction and impacts of non–native species, and continued release and deposition of critical pollutants.

Positive action is now occurring in the Lake Superior basin. The U.S. and Canadian governments have recently reaffirmed their commitment to the Zero Discharge Demonstration Program. The Lake Superior cooperative monitoring program has been working to develop priorities for the 2005–2006 Lake Superior monitoring year. Many habitat inventory, assessment and monitoring programs are being implemented. Rehabilitation of critical aquatic habitats is underway and several wildlife and fish species have been restored.

Global warming, climate change, increasing water temperature, large–scale water export, other chemicals of emerging concern (such as pharmaceuticals and personal health products), and newly proposed or expanded industrial facilities are other critical issues that will require attention now and in the future.

Acknowledgments/Sources of Information

Casper, G.S., Moriarty, J.J., Mossman, M.J., et al. 1998. Status and conservation of midwestern amphibians. In University of Iowa Press, ed. M.J. Lannoo, pp. 507. Iowa City, IA.

Ebener, M.P. (ed.). 2005. The state of Lake Superior in 2000. Great Lakes Fishery Commission Special Publication. http://www.glfc.org/lakecom/lsc/stateofsuperior/index.htm, last accessed June 9, 2005.

Environment Canada. 1993. Environmental Sensitivity Atlas for Lake Superior's Canadian Shoreline, Conservation and Protection Branch.

Lake Superior Lakewide Management Plan (LaMP) Chemical Committee, 2003.

Murphy, Elizabeth. 2004. U.S. Environmental Protection Agency, Great Lakes Fish Monitoring Program, Great Lakes National Program Office. Chicago, IL.

SOLEC 2004 Presentations, Toronto, Ontario. 2004. Lake Superior. http://www.epa.gov/solec/solec_2004/presentations/index.html, last accessed June 8, 2005.

U.S. Environmental Protection Agency. 1994. Inland Spill Response Mapping Project, Digital Database.

U.S. Environmental Protection Agency. 2004. Lake Superior Lakewide Management Plan (LaMP) 2004. http://epa.gov/glnpo/lakesuperior/2004/, last accessed June 8, 2005.

Lake Superior Lakewide Management Plan (LaMP)

2006

Lake Superior Binational Program

Preface
Lakewide Management Plans

One of the most significant environmental agreements in the history of the Great Lakes took place with the signing of the Great Lakes Water Quality Agreement of 1978 (GLWQA), between the United States and Canada. This historic Agreement committed the U.S. and Canada (the Parties) to address the water quality issues of the Great Lakes in a coordinated, joint fashion. The purpose of the Agreement was to "restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem" (IJC 1993).

In the revised GLWQA of 1978, as amended by Protocol signed November 18, 1987, the Parties agreed to develop and implement, in consultation with State and Provincial Governments, Lakewide Management Plans (LaMPs) for open lake waters and Remedial Action Plans (RAPs) for Areas of Concern (AOCs). The LaMPs are intended to identify the critical pollutants that affect the beneficial uses and to develop strategies, recommendations and policy options to restore these beneficial uses. Moreover, the Specific Objectives Supplement to Annex 1 of the GLWQA requires the development of Ecosystem Objectives for the Lakes as the state of knowledge permits. Annex 2 further indicates that the RAPs and LaMPs "shall embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses....they are to serve as an important step toward virtual elimination of persistent toxic substances...".

The Great Lakes Water Quality Agreement specifies that the LaMPs are to be completed in four stages. These stages are: 1) when problem definition has been completed; 2) when the schedule of load reductions has been determined; 3) when remedial measures are selected; and 4) when monitoring indicates that the contribution of the critical pollutants to impairment of beneficial uses has been eliminated. These stage descriptions suggest that the LaMPs are to focus solely on the impact of critical pollutants to the Lakes. However, the group of government agencies designing the LaMPs felt it was also necessary to address other equally important issues in the Lake basin. Therefore, the LaMPs go beyond the requirement of a LaMP for critical pollutants, and use an ecosystem approach, integrating environmental protection and natural resource management.

The Lake Superior LaMP is unique because of an additional agreement, announced in 1991, between the federal governments, states, and province surrounding Lake Superior. Called the Binational Program to Restore and Protect the Lake Superior Basin, the program established a Zero Discharge Demonstration Program and a broader ecosystem approach. The Zero Discharge Demonstration was created in response to citizen and International Joint Commission recommendations to establish Lake Superior as a pilot for zero discharge. Annex 12 of the Great Lakes Water Quality Agreement notes that "the philosophy adopted for control of inputs of persistent toxic substances shall be zero discharge."

The LaMP process has proven to be a resource intensive, long-term effort. In the interest of advancing the rehabilitation of the Great Lakes, and getting more information out to the public in a timely manner, the Binational Executive Committee (BEC) passed a resolution in 1999 to accelerate the LaMP effort. By accelerate, it was meant that there should be an emphasis on taking action and adopting a streamlined LaMP review and approval process. The LaMPs should treat the stages of problem identification, load reduction schedules, selection of remedial and regulatory measures, and implementation and monitoring as a concurrent, integrated process rather than a sequential one. Furthermore, BEC suggested that the LaMPs be based on the current body of knowledge and state what remedial actions can be implemented now. It was recommended that a LaMP be produced for each Lake by April 2000, with updates every two years thereafter.

Consistent with the BEC resolution, the LaMP contains funded and proposed (non-funded) actions for restoration and protection to bring about improvement in the ecosystem. Actions include commitments by the Parties, governments and regulatory programs, as well as suggested voluntary actions that could be taken by non-governmental partners. LaMP 2004 reported on the success of those actions, and identified challenges remaining to achieve established goals and ecosystem objectives.

The concept of adaptive management is being applied to the LaMP process. That is, an iterative approach is being taken with periodic refining based upon the lessons learned, successes, new information, and public input generated. The LaMP will adjust over time to address the most pertinent issues facing the Lake ecosystem.

Some parts of LaMP 2006 are incomplete and identify data gaps and next steps for LaMP 2008. LaMP 2006 is presented in a loose-leaf format with general tabbed sections that can be inserted into a three-ringed binder. This format allows for easy updates, additions of new material and removal of outdated information. The following table is a guide to updating your LaMP 2004 with the LaMP 2006 updates.

Lake Superior LaMP 2006 Guide to Changes

File name	Contents	How to update your LaMP 2004 binder
LS Executive Summary	Executive Summary	New. Insert before preface
LS Preface 2006	Preface	Replaces LaMP 2004 preface
LS Chapter 1 2006	Introduction and Purpose of the Lake Superior Lakewide Management Plan	Replaces LaMP 2004 Chapter 1
LS Chapter 2 2006	Public Outreach and Education	Replaces LaMP 2004 Chapter 2
LS Chapter 3 2006	Ecosystem Goals, Objectives, Indicators, Monitoring, and Beneficial Use Impairments	Replaces LaMP 2000 Chapter 3
LS Chapter 4 update 2006	Lake Superior Critical Pollutants Progress Report	Replaces LaMP 2004 update at beginning of Chapter 4
LS Chapter 4 2000	Lake Superior Critical Pollutants	No changes (this chapter is being updated for inclusion in the 2008 report)
LS Chapter 5 update 2006	Human Health Information	Replaces LaMP 2004 update at beginning of Chapter 5
LS Chapter 5 2000	Human Health	No changes
LS Chapter 6 update 2006	Habitat, Terrestrial Wildlife and Aquatic Communities Progress Reports	Replaces LaMP 2004 update at beginning of Chapter 6
LS Chapter 6 2006	Status of Aquatic and Terrestrial Communities and Habitat in the Lake Superior Basin	Replaces LaMP 2000 Chapters 6,7,8 and 10
	Terrestrial Wildlife Communities progress report	Remove LS Chapter 7 update 2004 (replaced by LS Chapter 6 update 2006)
	Terrestrial Wildlife Communities	Remove LS Chapter 7 2000 (replaced by LS Chapter 6 2006)

File name	**Contents**	**How to update your LaMP 2004 binder**
	The Aquatic Community progress report	Remove LS Chapter 8 update 2004 (replaced by LS Chapter 6 update 2006)
	The Aquatic Community Part 1: Fish and Their Habitat	Remove LS Chapter 8 2000 (replaced by LS Chapter 6 2006)
LS Chapter 7 update 2006	Developing Sustainability in the Lake Superior Basin: 2006 Progress Report	New: Insert at beginning of Chapter 7
LS Chapter 7 2004	Developing Sustainability in the Lake Superior Basin	No changes LaMP 2004 Chapter 9 now Chapter 7
LS Chapter 8 2006	Collaborative Efforts	New: Insert after Chapter 7
	Aquatic Nuisance Species	Remove LS LaMP 2000 Chapter 10 (replaced by LS Chapter 6 2006)
LS Appendix A 2006	Lake Superior Areas of Concern/Remedial Action Plan Summary Matrix and Fact Sheets	Replaces LaMP 2004 Appendix A
LS Appendix B 2000	Total Maximum Daily Load (TMDL) Development Strategy for Lake Superior	No change
LS Appendix C 2006	The Lake Superior Zero Discharge Demonstration Program and Relationship to Chemical Contaminants in Lake Superior	Insert after Appendix B
LS Appendix D 2006	Mercury Reduction for Lake Superior: *A Mercury Reduction Assistance Project for Lake Superior Region Facilities*	Insert after Appendix C
LS glossary 2000	Glossary	No change
LS acronyms 2006	Acronyms and Abbreviations	Updated

Acknowledgements
Lake Superior Lakewide Management Plan

The Lake Superior Lakewide Management Plan 2006 was prepared by the Lake Superior Binational Program's Superior Work Group with input from various other agencies and organizations including the Lake Superior Binational Forum. We would like to thank the committees of the Superior Workgroup for their efforts in completing this document.

Member agencies of the Lake Superior Binational Program are:

1854 Authority
Agency for Toxic Substances and Disease Registry
Bad River Band of Lake Superior Chippewa
Chippewa-Ottawa Resource Authority
Environment Canada
Fisheries and Oceans Canada
Fond du Lac Band of Lake Superior Chippewa
Grand Portage Band of Lake Superior Chippewa
Great Lakes Indian Fish and Wildlife Commission
Health Canada
Keweenaw Bay Indian Community
Michigan Department of Environmental Quality
Michigan Department of Natural Resources
Minnesota Department of Natural Resources
Minnesota Department of Health
Minnesota Pollution Control Agency
Ontario Ministry of Natural Resources
Ontario Ministry of the Environment
Parks Canada
Red Cliff Band of Lake Superior Chippewa
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey - Biological Resources Division
U.S. National Park Service
Wisconsin Department of Natural Resources

Contents
Lake Superior Lakewide Management Plan

Chapter 1

Introduction and Purpose of the Lake Superior Lakewide Management Plan

Minnesota North Shore. Photo Credit: Chris Zadak, MPCA.

Lake Superior Lakewide Management Plan
2006

Chapter 1 Contents

Chapter 1
Introduction and Purpose of the Lake Superior Lakewide Management Plan

1.0 INTRODUCTION

The Lake Superior Basin is one of the most pristine and unique ecosystems in North America. Containing the largest surface area of any freshwater lake in the world, Lake Superior has some of the most breathtaking scenery in the Great Lakes and serves as a backdrop to a wide range of recreational and outdoor activities enjoyed by people from all over the world. Sparsely populated even today, Lake Superior has not experienced the same level of development, urbanization, or pollution as the other Great Lakes. Recognizing this unique and invaluable resource, the federal, state, and provincial, and U.S. tribal governments; First Nations; environmental groups; industry; and the public have taken steps to protect this great legacy for generations to come. This shared partnership has served as a model the world over for cooperative binational resource management.

The Great Lakes Water Quality Agreement (GLWQA) between the U.S. and Canada commits the two countries (the Parties) to address the water quality issues of the Great Lakes in a coordinated fashion. Annex 2 of the GLWQA provides a framework for the reduction of critical pollutants as they relate to impaired beneficial uses of open lake waters. In undertaking the Lakewide Management Plans (LaMP), the Parties agree to build upon cooperative efforts with state, tribal, and provincial governments and to ensure that the public is consulted. The Parties, partner agencies, and Tribal/First Nations also recognize the need to conduct lakewide adaptive management using an ecosystem approach which addresses human health, habitat, terrestrial wildlife communities, aquatic communities, and developing sustainability.

1.1 THE LAKE SUPERIOR BINATIONAL PROGRAM

In 1990, the fifth biennial report of the International Joint Commission (IJC) to the U.S. and Canadian governments recommended that Lake Superior be designated as a demonstration area where “no point source discharge of any persistent toxic substance will be permitted.” In response, on September 30, 1991, the federal governments of Canada and the U.S., the Province of Ontario, and the States of Michigan, Minnesota, and Wisconsin announced a **Binational Program to Restore and Protect Lake Superior**. Known as the Lake Superior Binational Program (LSBP), the Program identifies two major areas of activity:

- A Zero Discharge Demonstration Project
- The Broader Program

The LSBP also recognizes that public participation is an important part of the program.

The Zero Discharge Demonstration Program (ZDDP) established Lake Superior as a demonstration project to achieve zero discharge and zero emission of nine toxic, persistent, and bioaccumulative chemicals: mercury, total polychlorinated biphenyls (PCBs), dieldrin/aldrin, chlordane, DDT, toxaphene, 2,3,7,8-TCDD (dioxin), hexachlorobenzene (HCB) and octachlorostyrene (OCS). Voluntary pollution prevention is the preferred approach to achieving reduction goals, but enhanced controls and regulations might be necessary to achieve zero discharge.

The Broader Program recognizes that zero discharge of persistent toxic substances alone will not be sufficient to restore and protect Lake Superior. The Broader Program focuses on the coordination needed among the many resource and environmental agencies.

Public Involvement is critical to the success of the Binational Program. The LSBP highlights the importance of the partnership approach to achieve specified common goals. The Program encourages the commitment of all partners to develop new and innovative approaches to ecosystem management. The citizens of the basin are partners and stakeholders in the Binational Program.

LSBP Organization

Lake Superior Task Force

The Task Force consists of senior Canada and U.S. federal, provincial, tribal, and state representatives who make management decisions related to Lake Superior. The Task Force serves as a steering committee and is responsible for program direction.

Superior Work Group

The Work Group is comprised of Canadian and U.S. technical experts who represent various agencies and organizations that manage Lake Superior water and other resources. The Work Group reports to the Task Force. The Work Group is comprised of a number of committees, currently including: critical pollutants, habitat, aquatic communities, terrestrial wildlife communities, developing sustainability, and public involvement. These committees address pollution prevention and reduction, habitat issues, aquatic and terrestrial community diversity and sustainability, special designations, ecosystem integrity and monitoring, human use and health issues, and public communication and involvement.

Lake Superior Binational Forum

The Forum is a group of 24 Lake Superior citizen volunteers who make recommendations to the governments, consult with the broader public, and carry out joint LaMP implementation projects. Forum members bring perspectives from a variety of community sectors including business, environmental groups, academia, and industry. The vision statement endorsed in 1992 by the Forum is also a philosophical backdrop for the Binational Program.

A VISION FOR LAKE SUPERIOR

As citizens of Lake Superior, we believe ...

that water is life and the quality of water determines the quality of life.

We seek a Lake Superior watershed ...

that is a clean, safe environment where diverse life forms exist in harmony; where the environment can support and sustain economic development and where the citizens are committed to regional cooperation and personal philosophy of stewardship;

that is free of toxic substances that threaten fish, wildlife and human health; where people can drink the water or eat the fish anywhere in the lake without restrictions;

where wild shorelines and islands are maintained and where development is well planned, visually pleasing, biologically sound, and conducted in an environmentally benign manner;

which recognizes that environmental integrity provides the foundation for a healthy economy and that the ingenuity which results from clean, innovative and preventive management and technology can provide for economic transformation of the region;

where citizens accept the personal responsibility and challenge of pollution prevention in their own lives and lifestyles and are committed to moving from a consumer society to a conserver society; and

where there is greater cooperation, leadership and responsibility among citizens of the basin for defining long-term policies and procedures which will protect the quality and supply of water in Lake Superior for future generations.

We believe that by effectively addressing the issues of multiple resource management in Lake Superior, the world's largest lake can serve as a worldwide model for resource management.

Endorsed by the Lake Superior Binational Forum on January 31, 1992
as an expression of the hearts and minds of all of us.

This vision statement expresses the commitment and desire of members of the Lake Superior community to foster a healthy, clean, and safe Lake Superior ecosystem. It reflects the diverse pathways and mechanisms by which humans and nature interact within land and water ecosystems, and challenges the inhabitants of the Lake Superior watershed to accept personal responsibility for protecting the Lake and the landscape that sustains it. The vision statement specifies broad, powerful objectives for the Lake Superior ecosystem, in plain language.

1.1.1 LaMP Documents Produced To Date

Historically, formal LaMP “stages” were to be submitted to the IJC when a key stage of work was completed, in accordance with the framework outlined in Annex 2 of the 1987 amendments to the GLWQA:

- Stage 1: When problem definition is complete and critical pollutants are identified;
- Stage 2: When chemical load reduction schedules are completed;
- Stage 3: When remedial measures have been selected: and
- Stage 4: When monitoring indicates that the contribution of critical pollutants to impaired beneficial uses has been eliminated.

LaMP Stages 1, 2, and 3 have been completed for the chemical portion of the Lake Superior LaMP.

The Lake Superior Stage 1 LaMP, which was submitted to the IJC in September 1995, used environmental data to identify 22 critical pollutants that 1) impaired or were likely to impair beneficial uses in the Lake, 2) were likely to affect human health or wildlife because they exceeded chemical yardsticks, or 3) impaired Lake ecosystem objectives. The Stage 1 LaMP summarizes all known data on critical pollutant loadings from point sources throughout the Lake Superior Basin.

The Stage 2 LaMP, which was submitted to the IJC in July 1999, sets remediation goals or load reduction schedules for the nine virtual elimination pollutants identified in the Stage 1 LaMP. The Lake Superior Binational Forum stakeholders group submitted pollutant reduction recommendations, which were public and agency reviewed, edited, and formed the basis for the final targets set in the Stage 2 LaMP. In Stage 2, the critical pollutants were placed into management categories that reflect pollutant impacts, tendency to bioaccumulate, and occurrence at toxic levels.

The Stage 3 LaMP requirements under the GLWQA, captured in Chapter 4 of LaMP 2000, selects pollutant load reduction strategies and remedial actions with respect to the nine virtual elimination pollutants: mercury, PCBs, dieldrin/aldrin, chlordane, DDT, toxaphene, dioxin, hexachlorobenezene, and octachlorostyrene.

In addition to staged LaMP reporting on the ZDDP, work proceeded in two areas between 1991 and 1998: habitat and non-regulatory special designations. In the program area of habitat, agencies developed ecological criteria for important Lake Superior habitat, set up a database for habitat sites, prepared a comprehensive GIS-based map of important habitat sites and areas, and examined the impact from major dischargers on habitat. In the program area of sustainability, criteria for non-regulatory special designations were developed.

1.1.2 Ecosystem Components

While the initial focus of the LaMP work was on strategies for reducing the critical pollutants and establishing the ZDDP, as well as a broader program that advanced our understanding of habitat and landscapes, work has been carried out in other areas as well. The partner agencies have developed LaMP documents for a number of ecosystem themes, including aquatic communities, terrestrial wildlife communities, habitat, human health, and developing sustainability. The work in these themes was released for the first time for public comment and review in LaMP 2000.

Adopting an ecosystem approach has initiated a shift from a narrow perspective of managing environmental media (water, air, and soil) or a single resource (e.g., fish or trees) to a broader perspective that focuses on managing human uses and abuses of watersheds or bioregions and that comprehensively addresses all environmental media and resources within the context of a living system. The Lake Superior LaMP is guided by a set of ecosystem objectives and indicators to judge progress. Published as a discussion paper in 1995, the document ***Ecosystem Principles and Objectives, Indicators, and Targets for Lake Superior*** describes extensive ecosystem objectives and sub-objectives. These objectives have been refined and updated (see Chapter 3) since the document's original release and are described in abbreviated form below:

1. General Objective - Human activity in the Lake Superior Basin should be consistent with *A Vision for Lake Superior*. Future development of the basin should protect and restore the beneficial uses as described in Annex 2 of the GLWQA.

2. Chemical Contaminants Objective - Levels of persistent, bioaccumulative, and toxic chemicals should not impair beneficial uses of the natural resources of the Lake Superior Basin. Levels of chemical contaminants which are persistent, bioaccumulative, and toxic should ultimately be virtually eliminated in the air, water and sediment in the Lake Superior Basin. A zero discharge demonstration program is the primary means for achieving reductions of in-basin sources of contaminants.

3. Aquatic Communities Objective - Lake Superior should sustain diverse, healthy, reproducing and self-regulating aquatic communities closely representative of historical conditions.

4. Terrestrial Wildlife Objective - The Lake Superior ecosystem should support a diverse, healthy and sustainable wildlife community in the Lake Superior Basin.

5. Habitat Objective - To protect, maintain and restore high-quality habitat sites in the Lake Superior Basin and the ecosystem processes that sustain them. Land and water uses should be designed and located compatible with the protective and productive ecosystem functions provided by these natural landscape features.

6. Human Health Objective - The goal of the Lake Superior LaMP Human Health Chapter is to fulfill the human health requirements of the GLWQA, including: defining the threat to human health and describing the potential adverse human health effects arising from

exposure to critical pollutants and other contaminants (including microbial contaminants) found in the Lake Superior Basin, addressing current and emerging human health issues of relevance to the LaMP, and identifying implementation strategies currently being undertaken to protect human health and suggesting additional implementation strategies that would enhance the protection of human health.

7. Developing Sustainability - Human use of the Lake Superior ecosystem should be consistent with the highest social and scientific standards for sustainable use, and should not degrade it, nor any adjacent ecosystems. Use of the basin's natural resources should be consistent with their capability to sustain the ecosystems' identity and functions, should not risk the socioeconomic and cultural foundations of any citizens, nor deny any generation the benefits of a healthy, natural Lake Superior ecosystem. The obligation of local communities to determine their future should be incorporated in any polices directed at the management of natural and social resources in the basin.

In the ***LaMP 2002 Update***, it was noted that a comprehensive set of ecosystem targets needed to be developed to guide management actions over the long term. In keeping with the public's recommendation to integrate the habitat, terrestrial wildlife, and aquatic committees, the three committees started work on developing a set of ecosystem goals. The ecosystem goals being developed are for (1) uplands, (2) wetlands, (3) tributaries and inland lakes, (4) open lake, and (5) basinwide considerations. The proposed ecosystem goals can be found in Chapter 3.

While LaMP 2002 was a summary progress report, the LaMP 2004 was the first of the biennial updates, with the latest available scientific and technical information incorporated into the existing LaMP document. The primary audience for these biennial reports is the Parties and their partners who are charged with lakewide management. Secondarily, this report will also be used to meet reporting requirements to the IJC.

1.2 LaMP ACCELERATION AND THE LaMP DOCUMENT

1.2.1 What is LaMP 2006?

In May 1999, the Great Lakes States Environmental Directors issued a challenge to the U.S. Environmental Protection Agency (US EPA) that all LaMP documents were to be completed by Earth Day 2000. This challenge was accepted at a meeting of the Binational Executive Committee (BEC), which is composed of senior managers from the US EPA, Environment Canada, the Great Lakes states, the Province of Ontario, and several tribes. A resolution was adopted by the BEC that calls for the completion by April 2000 of a "LaMP 2000" document which would reflect the state of the knowledge and progress of the LaMPs at that time (See Addendum 1-A to this chapter).

LaMPs were published in 2000, and progress reports were released in the spring of 2002 and 2004. Analysis by various LaMP work groups identified a need to refine the LaMP reporting process, particularly with regard to the time, effort, and resources needed to produce the documents. Greater emphasis needed to be placed on implementation and partnerships to protect each Lake basin. To that end, the BEC endorsed an approach to reporting in 2003 that strikes a balance between consistency among LaMPs and individual LaMP needs, while minimizing reporting efforts. LaMP teams endeavor to spend at least 80 percent of their time on LaMP implementation, and a maximum of 20 percent on reporting.

The LaMP document serves several purposes. First, it summarizes the technical research and scientific study of the Lake Superior ecosystem. Second, it represents a framework and road map for guiding and supporting priority actions and/or additional research in the basin. Third, the document presents actual pollution prevention, restoration, and other actions that governments, industries, tribes, and other stakeholders can take to achieve the overall goals and visions of the LaMP. Finally, the document will serve as a strategic plan to help achieve sustainability in the basin ecosystem. Addendum 1-B reflects the current thinking on Lake Superior Binational Program Strategies to achieve LaMP goals.

Specifically, LaMP 2006 has several notable sections that should be highlighted. First, pursuant to public comment, the habitat, aquatics and terrestrial wildlife ecosystem chapters have been combined into one consolidated chapter – Chapter 6. In that chapter, up to date information on the latest invasive species can be found. Since substantial progress has been made on a number of of Lake Superior Areas of Concern (AOCs), including Torch Lake, St. Louis River, Thunder Bay, and Nipigon Bay, we have included narrative AOC progress reports, as well as a summary matrix. An important Great Lakes Basinwide restoration effort, the Great Lakes Regional Collaboration, is detailed and summarized in Chapter 8. The Critical Pollutants section, Chapter 4, is abbreviated this year because a comprehensive report on the status of progress toward the chemical milestones will be issued in Summer 2006. The Developing Sustainability Chapter (Chapter 7) describes on-the-ground sustainability projects in Lake Superior communities.

1.2.2 Action/Projects Matrices

Each of the LaMP chemical and ecosystem components contain specific actions and projects that will be taken to help achieve the goals and objectives of the LaMP. Some of these actions already have commitments and funding by various state, federal, provincial, or other entities. Other actions are categorized as high priority but still need agency commitment or funding. These actions can be found in the respective chapters in the LaMP document.

1.3 RELATIONSHIP OF THE LaMP TO OTHER INITIATIVES AND FFORTS

There are many ongoing collaborative efforts, two of which are highlighted in this chapter. A more comprehensive and detailed description of other collaborative initiatives may be found in Chapter 8.

1.3.1 Remedial Action Plans for Areas of Concern

The GLWQA amendments of 1987 also called for the development of Remedial Action Plans (RAP) for designated Areas of Concern. The primary goal of the RAPs is to restore impaired "beneficial uses," both ecological and cultural, as identified in Annex 2 of the GLWQA amendments, in degraded areas within the basin. The GLWQA amendments directed the two federal governments to cooperate with state and provincial governments to develop and implement RAPs for each AOC. In the Great Lakes Basin, 43 AOCs have been identified by the U.S. and Canadian governments, 26 in U.S. waters, and 17 in Canadian waters (five are shared between the U.S. and Canada on connecting river systems).

Collingwood Harbour and Severn Sound, in Ontario, are the first two of these 43 sites to be de-listed. There are eight AOCs in the Lake Superior Basin, four in Canada, three in the U.S., and one shared between the two countries along the St. Marys River. Narratives and a matrix summarizing the current status of the Lake Superior RAPs may be found in Appendix A of the LaMP. The Michigan Department of Environmental Quality (MDEQ) has developed new statewide delisting guidance. The guidance, as well as proceedings from a February 2006 Michigan AOC Summit can be found on the "Virtual Library of RAP Resources" website at http://www.glc.org/rap/resources/. For more information, see http://www.epa.gov/glnpo/aoc/index.html and http://www.on.ec.gc.ca/water/raps/intro_e.html.

The RAPs and LaMPs are similar in that they both use an ecosystem approach to assessing and remediating environmental degradation, consider the 14 beneficial use impairments outlined in Annex 2, and rely on a structured public involvement process. RAPs, however, encompass a much smaller geographic area, concentrating on an embayment, a single watershed, or stretch of a river. The main focus of a RAP is on environmental degradation in that specific area, and remediating the beneficial use impairments locally. Most of the Lake Superior RAPs have had active local Public Advisory Committees (PACs), with stakeholders in some cases undertaking local remediation projects. In most AOCs, the beneficial use impairment (e.g. habitat loss) can be related or connected to local activities. On the other hand, some fish advisories are attributable to the lakewide concentrations of persistent, bioaccumulative toxic chemicals.

Forging a strong relationship between the LaMPs and the RAPs is important to the success of both efforts. The AOCs can, in many cases, serve as point source discharges to the lake as a whole. Improvements in the AOCs will, therefore, eventually help to improve the entire lake. Much of the expertise about the use impairments and possible remedial efforts reside at the local level; cooperation between the two efforts is essential in order for the LaMPs to remove lakewide impairments.

Due in part to the passage of the U.S. *Great Lakes Legacy Act*, described below, AOCs have taken on added importance and urgency in the U.S. Delisting of the AOCs is a top priority for the U.S. and Canadian governments; increased funding for the Legacy Act will help accelerate the delisting process in the U.S. The main federal funding programs for the RAP program are detailed below.

The *Great Lakes Legacy Act* (U.S.)

Contaminated sediments at the bottom of our rivers and lakes are a significant problem in the Great Lakes Basin. For decades, industrial sources contributed substantial amounts of harmful pollutants to the Great Lakes, including organic molecules like polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) oil and grease, and heavy metals like mercury and cadmium. Recent improvements in controlling these discharges have greatly reduced the amount of contaminants being released into the environment, but high levels of contamination still remain in the sediment as a “legacy” of the historical contamination. These contaminants continue to enter the food chain where they can cause adverse effects to human health and the environment.

To help address the contaminated sediment problem, the *Great Lakes Legacy Act* (GLLA) was enacted in 2002, and funding for the program began in 2004. The Act authorizes $270 million in funding over five years, to assist with the remediation of contaminated sediment in the 31 designated U.S. AOCs. There are three components to the act: remediation, new technology development, and informing the public (see Table 1-1). The goal of the US EPA Great Lakes National Program Office, who is administering GLLA, is to identify all eligible remediation projects within the 31 U.S. AOCs, and begin developing remediation projects for these sites. GLLA remediation projects must lie within a U.S. AOC.

Table 1-1. Three Components of the *Great Lakes Legacy Act*

Remediation Projects (up to $50 million per year)	*Priority is given to:* • Remedial action for contaminated sediment • Projects identified in a Remedial Action Plan • Projects that will use an innovative approach that may provide greater environmental benefits, or equivalent environmental benefits at a reduced cost • Projects that can begin within a year of funding
Research and Development (up to $3 million per year)	• Conduct research on the development and use of innovative approaches, technologies and techniques for the remediation of contaminated sediment at U.S. AOCs • No non-federal match required
Public Information (up to $1 million per year)	• Provide funding for public outreach and public information at U.S. AOCs regarding sediment remediations • No non-federal match required

Remediation of contaminated sediments in the Hog Island Inlet and Newton Creek was recently completed in Superior, Wisconsin. See inset below.

Hog Island Inlet and Newton Creek Sediment Remediation

Recently the Hog Island Inlet and Newton Creek Sediment remediation was completed in Superior, Wisconsin. This project is in the St. Louis River Area of Concern in Superior, Wisconsin (river is part of the MN and WI state boundary). The Wisconsin DNR submitted a proposal in March 2004 for a cost-shared (65 percent Federal, 35 percent non-Federal) sediment remediation project at Hog Island Inlet. The project cost was approximately $6.3 million.

The project involved digging up and disposing of 50,000 tons of petroleum-contaminated sediment and soil from Newton Creek and parts of Hog Island Inlet. After the contaminated sediments were removed, the banks of the creek and inlet were landscaped to prevent erosion. Further planting and re-seeding will occur in spring of 2006. The result is a healthier habitat for fish and other aquatic life, and eventually, reduced levels of contaminants in fish consumed by humans; the inlet is also now safer for recreation. As part of the project completion ceremony, the “No Swimming” sign was removed from Hog Island.

Pollution in the creek was primarily caused by PAHs and metals. Other contaminants include oil and grease, lead, mercury, and chromium, and Volatile Organic Compounds (VOCs). The site is bordered by public and private land. Hog Island (actually a peninsula) is owned by the county. The next step for this site is to develop a full restoration plan, and all parties to continue working together to implement the restoration effort.

Wisconsin Governor Doyle and US EPA Great Lakes National Program Office Director Gary Gulezian symbolically remove the “No Swimming” sign from Newton Creek/Hog Island Inlet following completion of the *Great Lakes Legacy Act* cleanup.

Contaminated sediment excavation at Hog Island, Superior, Wisconsin.

Great Lakes Action Plan (Canada)

The 2005-2010 Great Lakes Action Plan for Areas of Concern provides $40 million from the Government of Canada toward its commitment to restore, protect, and conserve the Great Lakes.

Improving the ecological integrity of the Great Lakes ecosystem has been, and continues to be, a priority for the Government of Canada. This funding, spread over five years, will continue the environmental restoration of key aquatic areas of concern in Ontario.

The Great Lakes Action Plan program is a coordinated effort of the seven federal government departments participating in the federal Great Lakes Program: Environment, Fisheries and Oceans, Health, Public Works and Government Services, Agriculture and Agri-Food, Natural Resources, and Transport.

The $40 million is directed towards remediation activities at the 15 remaining AOCs contained either entirely within Canada (10) or joint Canada-U.S. sites on connecting channels (5). These remediation activities are identified in RAPs that have been prepared for each AOC.

Remediation activities which are the responsibility of the federal government, as identified in RAPs, will include:

- Working in partnership with other agencies on fish and wildlife rehabilitation projects;
- Completing contaminated sediment assessment and remediation strategies for relevant AOCs;
- Undertaking engineering and technical studies to identify cost-effective wastewater treatment technologies and approaches that will assist municipalities in securing infrastructure funding; and
- Leading the development and implementation of multi-agency monitoring plans essential to support the design and evaluation of these activities.

Through the Great Lakes Sustainability Fund (GLSF), partners will be engaged to carry out projects related to habitat restoration, sediment assessment, and municipal wastewater improvements. GLSF provides financial and technical support to projects that aim to significantly accelerate work to restore the environmental quality of Canada's 15 remaining AOCs. GLSF projects reflect diverse and dedicated partnerships with local and provincial governments, community groups, academia, and industry, and focus on an extensive range of restoration activities. These include the development and implementation of innovative strategies for improving municipal wastewater treatment, assessment and remediation of contaminated sediment, restoration of fish and wildlife habitat, non-point source pollution control and watershed stewardship, and public outreach activities to promote various tools and strategies. By completing these federal actions, progress should be made toward the ecological restoration of AOCs.

Federal actions have been completed in Severn Sound and Collingwood Harbour, and ecological restoration has been achieved. These locations have been successfully delisted, or removed from the list of AOCs. Federal actions have been completed in Spanish Harbour, and monitoring of its recovery is underway. Federal actions will be completed in Port Hope under another process.

Added to previous funding, this $40 million budget commitment means more than $300 million of dedicated federal resources have been directed at restoring and protecting the Great Lakes since the first Great Lakes Action Plan was launched in 1989.

ADDENDUM 1-A:

BINATIONAL EXECUTIVE COMMITTEE CONSENSUS POSITION ON THE ROLE OF LaMPS IN THE LAKE RESTORATION PROCESS

Binational Executive Committee Consensus Position on the Role of LAMPS in the Lake Restoration Process

The development and implementation of Lakewide Management Plans (LaMPs) are an essential element of the process to restore and maintain the chemical, physical, and biological integrity of the Great Lakes ecosystem. Through the LaMP process, the Parties, with extensive stakeholder involvement, have been defining the problems, finding solutions, and implementing actions on the Great Lakes for almost a decade. The process has taken much longer and has been more resource-intensive than expected.

In the interest of advancing the rehabilitation of the Great Lakes, the Binational Executive Committee calls on the Parties, States, Provinces, Tribes, First Nations, municipal governments, and the involved public to significantly accelerate the LaMP process. By accelerate, we mean an emphasis on taking action and a streamlined LaMP review and approval process. Each LaMP should include appropriate actions for restoration and protection to bring about actual improvement in the Great Lakes ecosystem. Actions should include commitments by the governments, parties and regulatory programs, as well as suggested and voluntary actions that could be taken by non-governmental partners. BEC endorses the April 2000 date for the publication of "LaMP 2000", with updates every two years.

BEC is committed to ensuring a timely review process and will be vigilant in its oversight.

The BEC respects and supports the role of each Lake Management Committee in determining the actions that can be achieved under each LaMP. BEC expects each Management Committee to reach consensus on those implementation and future actions. Where differences cannot be resolved, BEC is committed to facilitating a decision. BEC recognizes the Four-Party Agreement for Lake Ontario and the uniqueness of the agreed upon binational workplan.

The LaMPs should treat problem identification, selection of remedial and regulatory measures, and implementation as a concurrent, integrated process rather than a sequential one. The LaMPs should embody an ecosystem approach, recognizing the interconnectedness of critical pollutants and the ecosystem. BEC endorses application of the concept of adaptive management to the LaMP process. By that, we adapt an iterative process with periodic refining of the LaMPs which build upon the lessons, successes, information, and public input generated pursuant to previous versions. LaMPs will adjust over time to address the most pertinent issues facing the Lake ecosystems. Each LaMP should be based on the current body of knowledge and should clearly state what we can do based on current data and information. The LaMPs should identify gaps that still exist with respect to research and information and actions to close those gaps.

Adopted by BEC on July 22, 1999.

ADDENDUM 1-B:

LAKE SUPERIOR BINATIONAL PROGRAM STRATEGIES TO ACHIEVE LAMP GOALS

Background

The Lake Superior LaMP 2000 lays out the vision, strategies and actions for achieving binational program goals. The Work Group committee work plans are the short-term (2 year) plans for implementation.

In 2002, the Task Force and Work Group initiated discussion on current issues requiring longer-term activities/strategies to meet the needs of the program. Development of these strategies is not a major new initiative - work group committees are to continue to implement their work plans - but is to be primarily a task of the Task Force and the Work Group leadership. It is anticipated that these strategies be reflected in Work Group committee work plans in the years to come.

It is proposed that these strategies identify attributes of the program by which we can measure management/leadership success. The real purpose of these strategies, however, is to enable the binational program agencies to collectively achieve the vision and goals that are developed for the lake (e.g. load reduction schedules and ecosystem goals) as described in LaMP documents. In that sense, the strategies and building capacity items assist the Work Group committees to implement their work plans.

The following also address a number of requirements in the Task Force's 1997 terms of reference, including to "Focus on long-term goals; articulate strategic program direction and define priorities; Commit resources and work with the Superior Workgroup membership to secure funding and program commitment. Coordinate with other LaMP Management members, as needed, to assure consistency in core program matters and to further progress of the Binational Program".

A summary of the discussions to date, with some additional thoughts from the Work Group and Task Force co-chairs was discussed by the Work Group and Task Force at their April 2003 meetings. There were also discussions and decisions regarding LaMP reporting and outreach during the September 2003 Work Group; and October and December Task Force meetings. Finally, the Task Force agreed to the strategies at its June 9, 2004 Task Force meeting. Tactics and an implementation plan for how the Task Force can help will be the basis of discussions at future Task Force meetings. It is suggested that priorities be established to order these discussions.

The Strategies

1. Research and Monitoring:
    a. Comprehensive Binational Research priorities/agenda and delivery mechanism/network (which harnesses the resources of the academic community).

e.g. acoustical mapping of lower tropic levels and the gap in Herptile information and analysis in the basin

   b. Clear, Coordinated Binational Monitoring Program
      i. Designed and at least partially implemented
      ii. Comprehensive set of agreed to Indicators
      iii. Sources measured and data available on a regular basis
      iv. Emerging issues are identified, such as new chemical toxins and invasive species.

2. Reporting and Evaluation
   a. LaMP progress is regularly reported and evaluated. A long-term planning cycle of LaMP review based on the above Monitoring and Research program goals (adaptive management).
3. Building Capacity
   a. Strong, Diverse Funding Base (people and $) to meet LaMP goals
      i. Need funding for monitoring
      ii. Better connections with national programs and priorities
      iii. Need to look beyond GLNPO and "traditional" funding sources.
      iv. Industrial trust fund to develop: 1) control technologies and 2) alternative energy technology.
      v. Need expanded representation and participation by partners in SWG and TF.
   b. Strong and expanded Partnerships around the Lake (to implement LaMP)
      i. Complete CARD program
      ii. More of a community-level focus on communications, outreach and projects to influence/inform local watershed planning activity and land use planning.
      iii. Additional partners at all levels.
   c. Strong linkages to other programs (BTS, GLRC, SOLEC, RAPs, GLFC, Marine Conservation Area)
      i. Participate in GLFC exercise to develop environmental objectives for the lake
      ii. LSBP to make better connections within its own agencies
      iii. Coordinate existing resources (GLFC, IJC, GLC, AOC Legacy Act and other) to implement LaMP work plans

Chapter 2

Public Outreach and Education

Public education is provided for visitors to Pukaskwa National Park as they enjoy the scenery of Lake Superior.
Photo Credit: John Marsden, Environment Canada.

Lake Superior Lakewide Management Plan
2006

Chapter 2 Contents

Chapter 2
Public Outreach and Education

EXECUTIVE SUMMARY

The Lake Superior Binational Program has a long history of public involvement in the development of the Lake Superior Lakewide Management Plan (LaMP). In particular, the Lake Superior Binational Forum, the primary public group associated with the agencies responsible for carrying out the zero discharge demonstration project, has been key to establishing an effective multi-sector stakeholder process. The Forum has held many workshops over the years for the purpose of acquiring necessary background information to help develop recommendations and proposals for reducing the Lake Superior nine critical pollutants. The Forum has also published many documents on key issues relating to the LaMP.

In addition, a separate Communications/Public Involvement Committee, comprised of staff from government agencies and their partners, was formed to help expand the network of stakeholders and outreach activities. This Committee has produced documents for the purpose of informing the public about all aspects of the LaMP and the Binational Program.

2.0 ABOUT THIS CHAPTER

All the partners involved in the Lake Superior LaMP (i.e., state, provincial, and federal agencies, the Tribes/First Nations, industry, the public and others) have long been committed to an open, fair and significant public involvement process. One of the main goals of the Lake Superior Binational Program is, in fact, to promote meaningful public participation and education so as to ensure that the needs and concerns of the diverse population in the Lake Superior Basin are met. This section of the LaMP will briefly describe the efforts that have been made to date on public outreach and involvement.

2.1 PUBLIC INVOLVEMENT

A major tenet of ecosystem management is the necessity of continuous involvement of the public that is inclusive and respectful of all viewpoints and stakeholders. Public input and support help ensure that the actions recommended in the LaMP are carried out, leading the way to restoring and protecting the Lake ecosystem. The key to public support and the program's success is effective communication between the government agencies and the diverse population of the Lake Superior basin.

LaMP 2006 is presented as a working document, based on existing information. It was the goal of the Binational Executive Committee to provide a *current* foundation for discussion of Lake Superior efforts, not necessarily a *complete historical one.* The LaMP will be modified based on new findings and public input. To that end, public input received on previous documents has been addressed in LaMP 2006. This is a necessary step if we are to institute adaptive management on an ecosystem scale.

A significant project related to public outreach is the Community Awareness Review and Development (CARD) project carried out in 2004-2005. Thirteen communities and some First Nations were surveyed to determine community priorities and awareness of environmental issues. The results of this project will be used to focus future community outreach efforts and engage communities in implementing projects to achieve LaMP goals. See Section 7.1.1 for more information.

2.2 PUBLIC OUTREACH/EDUCATION EFFORTS TO DATE

When the Lake Superior Binational Program first began, public involvement activities were carried out primarily by the Binational Forum (see section 2.2.1 below). As the Program matured, it became apparent that the government agencies and their partners needed their own separate public outreach mechanism. Therefore a separate group was formed entitled the Communications/Public Involvement Committee. Over the years, the two groups have worked together, complementing each other's efforts to involve the Lake Superior population.

2.2.1 Lake Superior Binational Forum

Since 1991, the Lake Superior Binational Forum has served as the principal public body providing input to the governments responsible for carrying out the Binational Program. In 1990, the IJC recommended that Lake Superior be a demonstration area where no point source discharge of any persistent toxic substance would be permitted. The purpose of the Forum is to promote consultation and participation among government, industry, and environmental stakeholders on the restoration and protection of Lake Superior. The Forum is composed of Canadian and American stakeholders representing environmental, Tribal/First Nation, industrial, business, health, and academic interests.

Since 1991, the Forum has held various technical workshops for the purpose of acquiring necessary background information to help develop proposals for phase-out schedules and reduction recommendations. These recommendations on the nine critical pollutants, for example, may be found in the Stage 2 Lakewide Management Plan. The Forum has held workshops on mercury, sustainability indicators, PCBs and pesticides, to name a few. A more complete list and description of recent Forum activities may be found in Addendum 2-A.

In addition to sponsoring workshops, the Lake Superior Forum has published a number of reports and documents, ranging from assessing public attitudes toward pollution prevention, to providing feedback and comment on Lake Superior ecosystem objectives and principles.

The Forum has focused on a series of projects that are conducted jointly with the Superior Workgroup. These have included a newspaper insert, the CARD project, stewardship and awards programs, workshops on mercury and household garbage burning, Lake Superior Day, public input sessions, mercury reduction mentoring, and updates to the monitoring meta-database. Forum activities are reviewed annually during the preparation of the yearly workplan.

2.2.2 Activities of the Communications/Public Involvement Committee

The Communications/Public Involvement Committee of the Work Group is led by staff from Environment Canada and US EPA. The committee implements provisions of a strategy reflecting the Lake Superior Binational Program's long-term commitment to communications, public involvement, outreach, and education.

The Binational Program has produced various documents and brochures for the purpose of informing and educating the public. These documents include a general informational brochure on the Binational Program, as well as a brief introduction of each committee on the Lake Superior Workgroup.

Since the LaMP 2004 Report was finalized, the Communications Committee has produced two highlights brochures. The first, "Lake Superior Lakewide Management Program (LaMP) Highlights 2004", was based on the LaMP 2004 Report and was mailed to Lake Superior stakeholders and distributed at various meetings around the basin. The most recent outreach project that the Communications Committee completed was a "Lake Superior Binational Program Highlights 2005". This colorful brochure highlights the accomplishments of the Lake Superior Binational Program in 2005 by ecosystem theme. It can be found in Addendum 2-B and on the Lake Superior website. It will be distributed to a wide range of Lake Superior stakeholders.

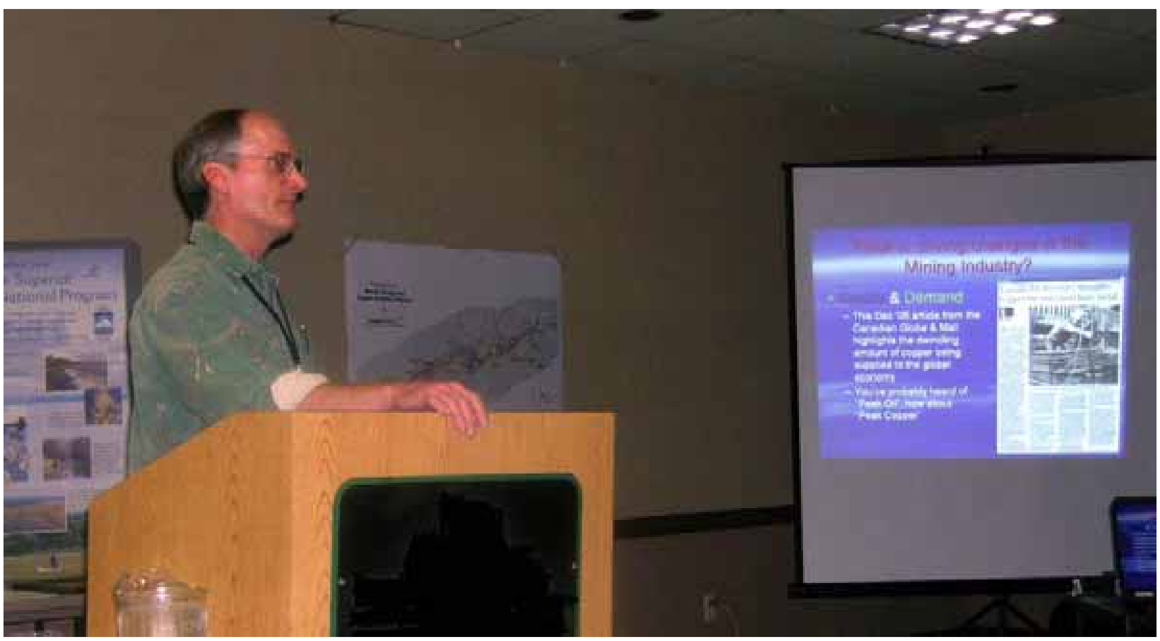


Figure 1. The Lake Superior Binational Forum holds a public input session at each of its quarterly meetings around the basin. At a recent session in Hibbing, MN, guest speaker Mark Severson of the University of Minnesota-Duluth geology department explained the trends in mining around the Lake Superior Basin. Photo Credit: Michelle Lee, Thunder Bay.

In addition, the Communications Committee has coordinated more closely with the US EPA – GLNPO Communications Team so that many Lake Superior highlights are reflected in a quarterly activities report that reaches the highest level of EPA management.

The Binational Program has developed a traveling display as a tool for outreach and education to the general public. This display has been, and will continue to be, used as a means to publicize Lake Superior and the Binational Program at public meetings, seminars and conferences. The display includes a large photograph of the lake, with space for fact sheets, brochures, and other documents. The display booth is staffed by members of the Binational Program. In addition, a table-top display developed by University of Wisconsin - Extension is in use around the basin.

The Committee has been revising the main Lake Superior Binational Program web sites (www.epa.gov/glnpo/lakesuperior/ and www.on.ec.gc.ca/water/greatlakes/lakes/superior/intro-e.html), which consist of a home page and supporting pages. This complements the Forum web site, which can be found at www.superiorforum.info/sitemap.html. In the future, it is anticipated that the main program web site will be moved to a joint Canada-U.S. site (www.binational.net), which is a site devoted to binational programs jointly lead by Environment Canada and US EPA.

The Communications/ Public Involvement Committee is also participating in joint outreach and education projects with the Forum such as a Lake Superior Awards program (see Addendum 2-A) and Lake Superior Day.

A mailing list has been compiled to keep the public informed of new developments in the Lake Superior basin and to provide them with the opportunity to comment. The mailing list includes both U.S. and Canadian government agencies; tribal organizations and First Nations; environmental groups and other public groups.

Assembling material to inform the public on progress toward restoring and protecting Lake Superior is another role the committee fulfills. In that function, the committee is working on success stories for distribution in various newsletters. The Binational Program works in partnership with other organizations toward a common goal of a healthy and safe Lake Superior.

As this Lakewide Management Plan Report 2006 is not intended to be extensively circulated to the public (as are all biennial reports), the agencies produced a separate document (a LaMP Highlights brochure) to inform the public on Binational Program activities.

2.2.3 Lake Superior Pathfinders Program

The Lake Superior Pathfinders program is empowering environmental leadership for its third year!

Pathfinders began in 2002 when educators at the University of Wisconsin-Extension received a grant from the Wisconsin Coastal Management Program (WCMP) to create environmental leadership programs for high school youth and adult audiences. A study group of approximately 12 partner organizations, including Lake Superior Binational Program experts, met for a year to assist with the development of the programs and then conducted pilot versions for both audiences. The youth program was piloted with 38 students in August of 2004, and the adult program was piloted over weekends in September 2004 to 12 participants, of 59 nominated by UW-Extension educators and partners. In 2005 WCMP continued funding for the development of a statewide model for the youth program, drawing 85 participants (59 from Wisconsin) to attend three different week-long sessions. Northland College's Sigurd Olson Environmental Institute also became a partner and supplied funds, educators, and in-kind contributions. During the summer 2006 program, 120 students are expected to attend, including 30 Navigators, or returning Pathfinders who focus mostly on service learning. The adult program is still being pursued, but funding has not become available.

Figure 2. Pathfinders participants paddle past seacaves in kayaks. Photo Credit: Lake Superior Pathfinders Environmental Leadership Program.

The goals of Pathfinders include assisting participants in learning more about their own leadership styles through such tools as low and high ropes challenge courses, climbing walls, and on-the-water experiences kayaks. Educator's help participants learn how to utilize their skills better in their communities and take action concerning critical lake issues. After attending the program, participants understand critical Lake Superior issues, as identified by the Binational Program. They more effectively gather, analyze, and evaluate related information, and have the confidence, knowledge, and desire to take action to respond to these issues in terms of their sustainability. They recognize their own personal leadership skills and develop a personal "action" plan to complete in their community. When addressing an issue, they understand the Lake Superior Basin community and respect different perspectives in seeking a resolution, while networking and forming relationships and partnerships. Participants also gain a sense of place for Lake Superior, as well as insight into the lake's cultural significance and the Anishinabe or Chippewa Tribe's reliance on it as they interact with Tribal elders and educators.

Figure 3. Pathfinders group on the beach. Photo Credit: Lake Superior Pathfinders Environmental Leadership Program.

The Pathfinders program is currently working on a model that can be implemented in Michigan, Minnesota, and Ontario in an effort to expand lakewide, creating leaders in critical environmental issues all around Lake Superior.

For more information on this program, please visit www.northland.edu/pathfinders, or call Elizabeth Post, Lake Superior Pathfinders Program Director, at (715)682-1482. Addendum 2-C presents testimonials from Pathfinders participants and their parents.

2.3 CONCLUSION

The partners involved in the Lake Superior Binational Program have many ongoing outreach, education, and communication activities. The partners believe that these will meet the objectives of informing and educating the public about the program, involving the public in the decision making process and educating and motivating stakeholders into action. These agencies are mindful that involvement by people representing a wide range of interests is essential to the success of the Lake Superior Binational Program. Public input and support will help ensure that actions recommended in the program are carried out, leading the way to restoring and protecting Lake Superior.

ADDENDUM 2-A
LAKE SUPERIOR BINATIONAL FORUM ACCOMPLISHMENTS: 2004-2005

The Lake Superior Binational Forum is a citizen stakeholder group of 24 American and Canadian volunteers working together to provide input and analysis to governments about critical issues. The members also develop strategies to educate the public about how to protect and restore the lake's natural environment.

In 2004-2005 the Forum accomplished the following milestones:

1. Environmental Stewardship Awards Program

In collaboration with the Superior Work Group (SWG), the Forum initiated in 2004 an annual Environmental Stewardship Awards Program to recognize outstanding contributions that help restore or protect the basin's natural environment. Recipients in both the U.S. and Canada were selected from five categories for their innovative or ongoing activities. The first winners of this annual awards program included, in the U.S.:

- Roy Johnson, Cloverland, WI (Individual category)
- Minnesota Power, Duluth, MN (Industry)
- Pinehurst Inn at Pikes Creek, Bayfield, WI (Business)
- City of Superior, WI (Community)

In Canada:

- Josephine Mandamin, Thunder Bay, ON (Individual)
- Canadian Pacific Railway, Thunder Bay, ON (Industry)
- EcoSuperior, Thunder Bay, ON (Organization)

In July 2005, Ben Grumbles, the assistant administrator for the US EPA's Office of Water in Washington DC, presented awards to seven U.S. recipients during a special ceremony in Duluth, Minnesota. A separate ceremony for the Canadian recipient was held during the school year. The winners for 2005 included, in the U.S.:

U.S. award recipients from left to right:
Lynelle Hanson, Executive Director, St. Louis River Citizen Action Committee; Bill Bussey, Safety Director, Lake Country Power; John Twiest, Lineman, Grand Marais Public Utilities; Ben Grumbles, US EPA; Bill Bennett, CEO, LHB Inc; Sarah Cron, Operations Manager, Cooperative Light and Power; Joe Stepun, Duluth, MN. (Not pictured: Western UP Center for Science, Mathematics, and Environmental Education, Houghton, MI). Photo Credit: Michelle Lee, Thunder Bay.

- Western UP Center for Science, Math, and Environmental Education, Houghton, MI (Youth category)
- Joe Stepun, Duluth, MN (Individual)
- A cooperative action with three northeastern Minnesota power utilities: Lake Country Power, Cooperative Light and Power; and Grand Marais Power Utilities (Industry)
- LHB Inc, Duluth, MN (Business)
- St. Louis River Citizen Action Committee, Duluth, MN (Organization)

In Canada:

- Sir Winston Churchill Secondary School: Centre of Excellence for Environmental Studies Program (Youth)

For more information about each of these winners, visit the Forum's web site at www.superiorforum.info.

2. Educational Newspaper Supplement

The Forum also worked with the Superior Work Group to publish and distribute an educational four-page, color newspaper supplement that highlighted 'good news' stories around the basin. The publication, which was inserted in three newspapers in Ontario and Minnesota in the spring of 2005 (circulation 155,000), included stories about the achievements in chemical reduction targets in the Zero Discharge Demonstration Program; wetland restorations at Whittlesley Creek in Ashland, Wisconsin; safe alternatives to open garbage burning; how to reduce the spread of aquatic invasive species while boating or fishing on the lake; how to save energy and reduce mercury emissions at power plants; and other articles. A copy of this insert is presented in Addendum 2-D and is available on the US EPA web site at: http://www.epa.gov/glnpo/lakesuperior/forum_insert.pdf.

3. Lake Superior Day

The Forum wanted to elevate the visibility of Lake Superior by developing and promoting a celebration of the lake's importance, uniqueness, and beauty. Lake Superior Day is now held annually throughout the basin on the third Sunday in July.

Volunteers from the Ashland, WI, area picked up trash along the Lake Superior shore on Lake Superior Day 2005 (held annually on the third Sunday in July) as part of a multi-city community project to celebrate the lake. Photo Credit: Michelle Lee, Thunder Bay.

The purpose of Lake Superior Day is to educate residents about their role as trustees of the lake by making thoughtful behavior choices that eliminate pollution and foster sustainable lifestyles. Lake

Superior Day encourages people to pledge to care for the basin's natural resources and awaken an appreciation for the lake's unique ecosystems.

The main messages were to educate the public about the LaMP and successful implementation of LaMP goals, and to promote activities that reduce impacts on the lake. Target audiences for the first year included local elected officials, libraries, environmental groups, anglers, and churches.

The Forum developed a web site that describes activities and events that target audiences can organize in their communities. The day was promoted through special buttons, post cards, flyers, newspaper ads, and press releases, and was announced at meetings.

Moms and their kids participated in a multi-community beach clean-up event in Ashland, WI, held on Lake Superior Day (July 17, 2005). Almost 50 volunteers from 12 communities picked up trash along the shore on Lake Superior Day. Photo Credit: Michelle Lee, Thunder Bay.

Almost 20 groups organized events for the first basin-wide celebration. For example, several churches in the Chequamegon Bay, WI, area offered ‘blessing of the water’ services, beach clean ups, sermons, and potluck meals. A publisher in Bayfield, WI, launched a new magazine about Lake Superior called Gumee. The Town of Bell, WI, partnered with Wisconsin Indianhead Technical College to sponsor a day-long series of activities including a beach hike, an educational slideshow, displays, and a free community picnic.

For a list of events held in 2005 as well as activity ideas, visit the Forum’s web site at www.superiorforum.info.

4. Public Input Sessions

One of the Forum’s main functions is to serve as a link between the general public and the government agencies that are managing the lake. By holding open meetings and soliciting comments about issues, the Forum can learn what the public wants and needs. The Forum shares this feedback with members of the Lake Superior Binational Program, which considers the feedback to help shape policy regarding lake management strategies.

To enhance this role, in 2004 the Forum initiated a public input session to be held at each of its quarterly meetings. These sessions allow open exchanges between specialists and the public. Time is spent at each session to collect comments from citizens about concerns regarding environmental issues in the Lake Superior Basin. Since public input sessions were initiated in 2004, the following sessions have been held around the lake:

- Successful restoration and protection programs in the U.S. (Duluth, MN)
- The environmental and social impacts of a proposed synfuel facility (Thunder Bay, ON)

- Impacts of aquatic invasive species on the lake and how to reduce their spread (Thunder Bay, ON)
- Stream restoration in the Upper Peninsula (Marquette, MI)
- Impacts of the shipping industry on the lake (Sault Ste. Marie, ON)
- Native American/First Nations protection and restoration programs (Grand Portage, MN)
- Citizen Science: Volunteer water quality monitoring opportunities (Thunder Bay, ON)

5. The Forum continues to provide input and analysis to governments about LaMP implementation.

In addition to holding workshops and public input sessions, the Forum has also written numerous letters to various government representatives about different environmental issues having the potential to negatively impact the Lake Superior ecosystem.

Future Programs

The Forum is currently working on two other joint projects with the SWG: a mercury reduction mentoring program and a monitoring database development project.

1. Mercury Reduction Mentoring Program

The purpose of the mentoring project is to work with the shipping industry, municipal governments, and other target sectors to identify mercury sources and replace mercury-containing devices with non-mercury alternatives.

The Forum plays an important role in this joint project with the SWG. The SWG has begun to identify companies in the basin's shipping sector. The Forum will contact representatives in the shipping and municipal government sectors to invite them to learn how to identify mercury-containing equipment and devices in their facilities, how to dispose of them safely, and how to purchase mercury-free devices. The Forum will serve as the mentor and motivator to new participants and sectors that have not yet conducted this kind of inventory and replacement process.

Using a brochure of information recently published by the SWG, the Forum will motivate new sectors to work with a Canadian contractor to help conduct inventories and replacements. The brochure includes case studies of successful pollution prevention methods already used in basin industries; these case studies serve as models for what other industries can do. The Forum will also work with the participants and sectors that have already completed their replacements to spread the news about their successes in the media. The brochure is presented in Appendix D of the LaMP 2006 report.

2. Monitoring Database Development

To participate jointly in the SWG's focus on monitoring in 2006, the Forum will conduct a search of Michigan, Minnesota, and Wisconsin to find all private, corporate, municipal, tribal, and nonprofit organizations' natural resource monitoring programs at the local, regional, and state levels. The Forum will develop an inventory of who is monitoring which indicators in what region, and produce a map of these programs.

Based on this list and map, the Forum will conduct a gap analysis of what indicators are missing and where monitoring is needed. The Binational Executive Committee (BEC) is currently developing a database of state, federal, and provincial monitoring programs. However, the Forum's focus will be on non-governmental efforts; this joint investigation of who is monitoring what elements in an ecosystem will produce a comprehensive overview of Lake Superior monitoring efforts.

3. Involving Youth in Leadership Activities

The Forum's Outreach Committee is seeking greater youth involvement in Forum activities by organizing a model monitoring assessment program to involve college and university students from basin institutions of higher education, together with their faculty mentors in exploring, evaluating, and expanding the citizen science movement around the basin. Northern Michigan University (NMU) in Marquette has expressed support for this program, and forum members are working with the NMU interdisciplinary Environmental Science Program to develop details and funding sources.

ADDENDUM 2-B
LAKE SUPERIOR BINATIONAL PROGRAM HIGHLIGHTS 2005

HIGHLIGHTS 2005

LAKE SUPERIOR BINATIONAL PROGRAM

INTRODUCTION

Several binational and national initiatives have been developed to protect, restore, and maintain the Great Lakes ecosystem. Foremost among them is the Great Lakes Water Quality Agreement (GLWQA), which has been hailed as an important example of international environmental cooperation. The 1978 GLWQA between the United States and Canada commits the governments to "restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem."

To achieve that goal in Lake Superior, the Canadian and U.S. federal governments, the Province of Ontario, and the States of Michigan, Minnesota, and Wisconsin, in 1991, announced a "Binational Program to Restore and Protect Lake Superior." The Binational Program, through which the Lake Superior Lakewide Management Plan (LaMP) is implemented, identified two major areas of activity: A Zero Discharge Demonstration Program dedicated to the goal of achieving zero discharge or emission of nine persistent bioaccumulative toxic substances (mercury, PCBs, Dioxin, HCB, and five pesticides); and a "Broader Program" focusing on the protection and restoration of the broader Lake Superior basin ecosystem.

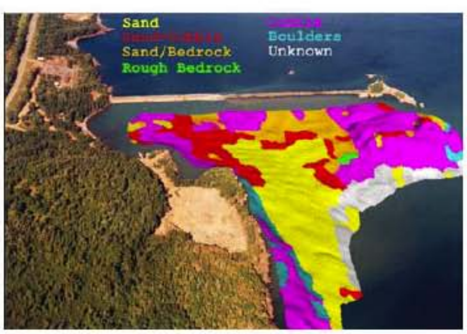
The framework through which participating jurisdictions act to fulfill commitments identified in the 1991 agreement is known as the Lake Superior Binational Program (LSBP). In addition to restoring degraded areas and reporting on progress, the LSBP is conducting ongoing research and monitoring to improve our understanding of the Lake Superior ecosystem and the changes that are occurring as a consequence of human activities in the basin. The ultimate purpose of this work is to secure a healthy ecosystem, which will provide sustained availability of natural resources and associated social, cultural, economic, and health benefits related to wholesome food, clean water, recreation, cultural heritage, and employment. The following sections highlight the progress made in 2005.

AQUATIC COMMUNITIES

An accurate picture of the aquatic food web and estimates of fish food stocks is needed to help agencies manage self-sustaining predator populations such as lake trout. It is necessary to find the relationship between habitat (quantity and quality) and fish production, as fisheries managers seek to put realistic expectations on Lake Superior fish production. Recent activities in the Aquatic Communities area include:

Lower trophic level organism (Mysis)

- *Acoustic Surveys*
  Hydroacoustics is the use of sound waves to measure or monitor underwater processes. Sound waves travel great distances underwater without losing strength, making this an effective tool for studying the open waters of Lake Superior. In 2005, the University of Minnesota-Duluth and U.S. Geological Survey (USGS) continued a hydroacoustic assessment that ranked as the highest priority Aquatic Communities project. The objective is to determine the abundance of prey fish important to lake trout. Sound waves sent from the ship toward the lake bottom bounce off objects (fish, in this case) and return to the ship, where biologists interpret the signals. Mid-water trawls are used to catch fish and verify hydroacoustic data. This year, Michigan waters from Whitefish Bay to the tip of the Keweenaw Peninsula were surveyed. Including work in Ontario and Minnesota waters in prior years, over 2,000 km of transects have now been sampled.



Display of nearshore habitat mapping results

- *Lower Trophic Level Monitoring*
  Understanding lower trophic levels, the base of the aquatic food pyramid upon which prey and predator fish depend, is important for managing Lake Superior's aquatic ecosystem. A binational sampling effort to assess lower trophic levels in Lake Superior began in summer 2005. Benthos (bottom organisms), zooplankton, and Mysis (tiny, swimming crustaceans eaten by fish – see image above) samples were collected in spring, summer, and fall by USGS, Environment Canada, the Ontario Ministry of Natural Resources (OMNR), the U.S. Environmental Protection Agency-Mid-Continent Ecology Division (EPA-MED), and the Wisconsin Department of Natural Resources (DNR). Over 1,500 samples have been collected for processing.

- *Habitat Mapping*
  Using hydroacoustic technology as described above, agencies have been mapping areas of the lake bottom that are important habitat for key fish species, including lake trout, walleye, coaster brook trout, and lake sturgeon. In 2005, substrate mapping was conducted in Nipigon Bay, Ontario, to describe coaster brook trout habitat and at Buffalo Reef, Michigan, to determine the impact of mining waste on a lake trout spawning reef. This work will help agency managers estimate the number of fish that can be produced by the habitat available in Lake Superior.

LAKE SUPERIOR BINATIONAL PROGRAM HIGHLIGHTS 2005

CHEMICAL CONTAMINANTS

The Lake Superior Binational Program's Zero Discharge Demonstration Program (ZDDP) seeks to end the use of nine critical pollutants in industrial processes or products and to prevent their release in the Lake Superior Basin. The LaMP Chemical Committee has been involved in a variety of projects to reduce the nine toxic chemicals targeted in the Lake Superior ZDDP. Recent reduction activities include the following:

PCB transformer phase-out (Grand Marais, MN)

- *Collections*

  Ontario completed its first ever hazardous waste collection in portions of the Lake Superior basin last year. The Upper Peninsula of Michigan also conducted a hazardous waste collection, sponsored by a faith-based coalition known as Earth Keepers, on Earth Day 2005. Programs in Minnesota and Wisconsin received funding to continue collecting hazardous waste.

- *Phase-outs, Exchanges and Equipment*

  The Ontario government and Ontario Dental Association recently agreed to regulations that require dentists' offices to install amalgam collection systems that trap mercury-bearing amalgam before it enters the sewer system. Some dentists on the U.S. side have agreed to use such systems voluntarily. In Minnesota, the Minnesota Dental Association encouraged dentists to install separators, and the Minnesota Pollution Control Agency offered free separators to dentists in the Lake Superior basin. Minnesota also completed a PCB transformer phase-out project and is in the process of analyzing the results. In addition, residents of Duluth and Two Harbors were offered the opportunity to exchange their burn barrels for a rain barrel and a pledge to stop burning trash.

EcoSuperior pesticide collection (Red Rock, ON)

- *Outreach*

  Lake Superior partners have produced and distributed materials on mercury and open burning. In addition, both the U.S. and Canadian jurisdictions have obtained funding for a basin-wide mercury reduction project that will focus on inventory and phase-out activities.

COOPERATIVE MONITORING

In 2001, U.S. and Canadian government agencies identified a need to improve coordination of Great Lakes monitoring activities. Great Lakes managers from Canada and the United States discussed the issue at a series of workshops and developed a set of recommendations for improvement. Based on these recommendations, a Great Lakes Cooperative Monitoring Program was established. U.S. and Canada Cooperative Monitoring is designed to improve monitoring coordination between the two countries, and address key information gaps identified through the LaMP in order to better manage the ecosystem.

The Cooperative Monitoring approach is above and beyond the routine monitoring programs that agencies normally conduct. It is a binational effort that focuses on one lake each year, with the goal of filling key information gaps as identified through the lakewide management programs. The approach complements and builds upon other monitoring and research projects being conducted on the lake in the same year. Recent developments in Cooperative Monitoring include the following:

- *Sampling Activities*

  In 2004, a rotational cycle for Cooperative Monitoring was endorsed, with Lake Superior being the focus for both 2005 and 2006. The Lake Superior LaMP Work Group identified the following key information gaps: atmospheric and open lake concentrations of LaMP pollutants; screening of tributaries to identify sources of LaMP pollutants; status of the lower food web; a better understanding of the comparability of fish tissue contaminant data among agencies; herptile distribution and abundance in the basin; and a method for measuring and reporting on land use changes. In response, during the spring, summer, and fall of 2005, numerous stations in the open lake and nearshore were sampled for LaMP pollutants and the lower food web; additional air and precipitation samplers were installed at Sibley and Eagle Harbor; and Canadian and U.S. tributaries were sampled for LaMP pollutants. The Cooperative Monitoring group is currently awaiting preliminary results from the 2005 sampling efforts. The information collected through the Cooperative Monitoring effort will be shared amongst the principal investigators in order to address LaMP priorities.

- *Future Plans*

  In 2006, additional nearshore sampling will continue; a multi-agency intercomparison study is being launched to assess differences in fish tissue contaminant results; and a pilot project to establish a herptile monitoring protocol will be launched. The projects conducted over these two years involve federal, state, and provincial agencies; First Nations/Tribes; and academia.

LAKE SUPERIOR BINATIONAL PROGRAM HIGHLIGHTS 2005

DEVELOPING SUSTAINABILITY

With a focus on local initiatives, sustainability involves increasing public awareness as to how to balance environmental, economic and social goals. The Developing Sustainability Committee (DSC) reported two major accomplishments in 2005:

▶ *Community Awareness Review and Development Survey*

The first phase of the LSBP's "Community Awareness Review and Development" project (CARD) was completed. The CARD was designed to increase knowledge and awareness of issues relevant to the LSBP and, especially, the Lake Superior LaMP. In order to obtain information that may be used to create educational campaigns targeted at local concerns, the DSC surveyed residents in nine basin communities on the U.S. side of Lake Superior, as well as four in Canada. Economic issues were the most pressing concerns, followed by social then environmental issues. Respondents were asked to rate both their level of knowledge and level of personal concern regarding issues in four general areas – water pollution, air pollution, land use, and health issues. In general, no more than one third reported that they knew a great deal about any given issue. When they did focus on environmental issues, the largest percentage of responses indicated that citizens in the basin were mostly concerned with watershed-related issues and, to a lesser extent, land use practices. Significant numbers of respondents reported little or no knowledge of key sustainability-oriented LaMP issues. The CARD survey also revealed that most respondents cited "inconvenience" and the feeling that one person would not make any difference when describing why people persist in conducting themselves in an environmentally-unsustainable manner. The next phase of the CARD will use the results of the survey to reach out to the targeted communities. At that time, outreach will focus on demonstrating how to be environmentally responsible and how to capitalize on economic opportunities. Given the preferences discovered in the initial survey, outreach activities will rely primarily upon electronic and newspaper venues for delivering information.

▶ *Lake Superior Basin Riparian Buffer Demonstration Project*

The Central Lake Superior Land Conservancy (CLSLC) based in Marquette, Michigan, completed a U.S. EPA-Great Lakes National Program Office (GLNPO)-funded project to restore riparian buffer areas and place conservation easements on five demonstration sites in the Lake Superior basin. At each site, a native plant buffer was installed in the spring and summer of 2005 to serve as demonstration and educational venues for the public. Each site has signage explaining what the project entailed, why native plants were used, and what conservation easements accomplish. The CLSLC conducted assessment and remediation efforts as recommended by the Lake Superior LaMP. The initiative included identifying and prioritizing potential demonstration sites for the remediation, contacting landowners to secure remediation/preservation agreements, determining the scope of interventions, obtaining needed native flora or construction materials, overseeing remediation, and facilitating publicity and outreach at the conclusion of the project. The CLSLC will provide ongoing monitoring of the remediation sites and their conservation easement agreements in the future.

HABITAT

Identification, restoration and protection of critical habitat and the ecological processes that sustain them are essential for a healthy ecosystem. Effective management requires both a recognition of the interconnections between habitat, fish and wildlife and the establishment of ecosystem indicators in order to assess ecosystem health. Trends and changes in aquatic invertebrate populations and community structure in tributaries, for example, can serve as indicators of stresses that may ultimately influence the aquatic community of Lake Superior.

The Habitat Committee is a historic and unique collaborative endeavor by Lake Superior resource managers to protect and restore habitat and the ecological processes that sustain habitat features. Recent habitat accomplishments include:

▶ *Identifying Groundwater Upwelling Areas*

Aerial thermography is being used to survey nearshore areas of Lake Superior, the Nipigon River, and the Lake Nipigon shoreline to locate groundwater upwelling areas, which provide critical habitat for coaster brook trout. Through funding from the Canada-Ontario Agreement (COA), an upwelling survey of the Nipigon River and portions of Lake Nipigon and Nipigon Bay was completed in 2004. A survey from the Pigeon River eastward to Black Bay Peninsula is planned. This information will be used to help protect these critical areas in the future.

Watercourse Stewardship sampling

Stonefly nymph (often found in unpolluted streams)

▶ *LaMP 2000 Chapter Integration*

The Habitat, Terrestrial Wildlife, and Aquatics Committees recently completed a consolidation of four chapters of the LaMP 2000 in order to acknowledge the integrated ecosystems of the region. This chapter describes these interconnected ecosystems in an integrated way and will contribute to sustainability throughout the region.

▶ *Watercourse Stewardship Project*

The goal of this joint project with the Binational Forum is to establish and promote the development of ecosystem indicators to assess the health of the Lake Superior ecosystem. COA funding has been used in part to produce Watercourse Stewardship Action Kits, and a number of workshops and presentations have been conducted to explain the program and to gain public support, interest, and participation.

LAKE SUPERIOR BINATIONAL PROGRAM HIGHLIGHTS 2005

TERRESTRIAL WILDLIFE COMMUNITIES

The ability to detect species declines or increases has a direct bearing on both aquatic and terrestrial habitat management for these species within the basin's forests, grasslands, wetlands, lakes and streams. Recent activities in the Terrestrial Wildlife Communities area include the following:

Gray Treefrog (photo by G.S. Casper)

▶ *Lake Superior Basin Herptile Monitoring Program*

Funding from U.S. EPA-GLNPO will establish and test an intensive monitoring program at several sites within the Lake Superior basin. A data repository will be established, and detection probability statistics will be developed that can be applied to existing programs to advance basin-wide analysis capabilities.

10-month-old lynx kitten in the snow

▶ *U.S. Forest Service Lynx Surveys*

The Superior National Forest is continuing the National Lynx Detection Surveys and initiating snow-track protocols within the Forest. Lynx DNA collection studies implemented in 2002 show that a minimum of 42 individual lynx genotypes exist within the state; this likely represents a small proportion of the actual numbers of lynx in the State of Minnesota. Lynx DNA collection efforts will continue.

The Natural Resources Research Institute at the University of Minnesota-Duluth, in conjunction with the Superior National Forest and the U.S. Fish and Wildlife Service, initiated a radio tracking project for lynx in Minnesota in 2003. Plans exist for the continuation and expansion of this program in the future.

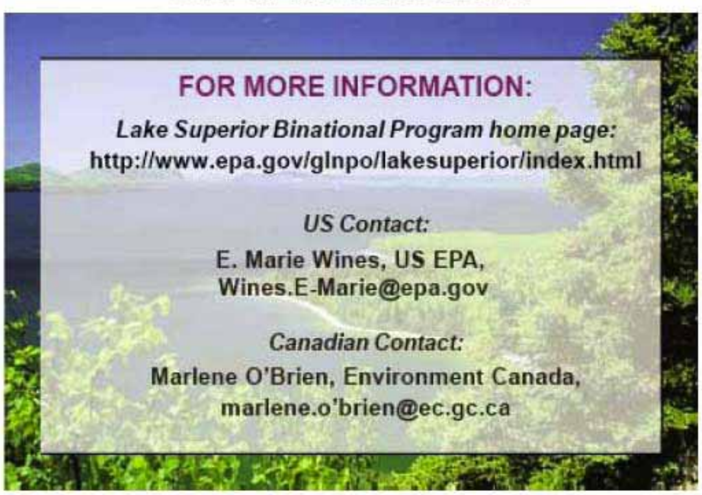
Peregrine falcon (photo by Craig Koppie - USFWS)

▶ *2005 Peregrine Falcon Survey*

The Lake Superior basin is home to the majority of known peregrine falcon nest sites and territories in Ontario. The spring and summer of 2005 marked the survey window for the national peregrine falcon survey conducted every five years in Canada. As part of this effort, Ontario conducted intensive nest and territory searches within the province. The Lake Superior basin effort was coordinated by the Thunder Bay Field Naturalists, in conjunction with the OMNR and many volunteers. Survey results indicate a continued recovery of falcon numbers, with 43 active territories located in the basin (56.6% of the provincial total), up from 31 territories recorded during the 2000 Ontario survey. A minimum of 79 chicks were fledged in the basin during 2005, the highest number recorded to date. Of these, 47 chicks were banded, bringing the total number of chicks banded on the Ontario side of the basin during the past ten years to 319.

LSBP MEMBER AGENCIES:

1854 Authority
Agency for Toxic Substances and Disease Registry
Bad River Band of Lake Superior Chippewa
Chippewa-Ottawa Treaty Fishery Management Authority
Environment Canada
Fisheries and Oceans Canada
Fond du Lac Band of Lake Superior Chippewa
Grand Portage Band of Lake Superior Chippewa
Great Lakes Indian Fish and Wildlife Commission
Health Canada
Keweenaw Bay Indian Community
Michigan Department of Environmental Quality
Michigan Department of Natural Resources



FOR MORE INFORMATION:

Lake Superior Binational Program home page:
http://www.epa.gov/glnpo/lakesuperior/index.html

US Contact:

E. Marie Wines, US EPA,
Wines.E-Marie@epa.gov

Canadian Contact:

Marlene O'Brien, Environment Canada,
marlene.o'brien@ec.gc.ca

Minnesota Department of Natural Resources
Minnesota Department of Health
Minnesota Pollution Control Agency
Ontario Ministry of Natural Resources
Ontario Ministry of the Environment
Parks Canada
Red Cliff Band of Lake Superior Chippewa
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey - Biological Resources Division
U.S. National Park Service
Wisconsin Department of Natural Resources

ADDENDUM 2-C
PATHFINDERS 2005 TESTIMONIALS

"I realized who I am. I could be 100 percent me for the first time. It was amazing!"
- Participant 2005

"I've found accomplishing goals is not as tough as I thought. Also, that there are powerful people here that may just change the world one day." –Participant 2005

I feel more powerful as an individual. I feel more connected and inspired by/to the environment."
– Participant 2005

"First of all, Brian was part of an exceptional group. Kids made everyone feel welcome and they developed a "team" spirit early on. This was fostered by a wonderful group of leaders. With that winning combination and a well planned program, he learned a tremendous amount and grew from the experience. It was the highlight of his summer, for sure." – Parent 2005

"I am more motivated to take a stand on environmental issues and go home and do something about them. I also have more confidence in myself as a leader." –Participant 2005

"I have already recommended this program for its great variety of activities teaching youth about leadership, the environment, and cultural values. The staff was clearly dedicated to its goal! An excellently planned program! Than you counselors and staff for your Exceptional Pathfinders program! You know it's a success when the youth already talk about returning next summer!" – Parent 2005

"I would definitely recommend this program to other parents. I like how you combined the environmental topic with the leadership training. Not only did you make them aware of critical environmental concerns, but you taught them how to take action." –Parent 2005

"The Pathfinders program seeks to empower youth to utilize their unique leadership abilities, and take action on environmental issues in their communities using new skills and strategies. We use Lake Superior and it's critical issues as our living classroom and experientially approach issues, balancing social, economic, and environmental concerns. This program challenges participants to apply critical thinking and engage in service learning, and most of all in helps them become a better world citizen."

ADDENDUM 2-D
SPRING 2005 LAKE SUPERIOR NEWSPAPER INSERT

Making a Great Lake Superior!

NEWS FROM THE LAKE SUPERIOR BINATIONAL PROGRAM Spring 2005

Lake Superior

Terrestrial and aquatic habitat...deep, crystal-clear, frigid waters silently guarding the final resting place of more than 350 shipwrecked vessels...These are some of the images invoked by the "greatest" of the Great Lakes—Lake Superior, or as the Ojibwe people named it, *Gichigami*.

Lake Superior is the cleanest, clearest, and coldest of the Great Lakes. It contains low concentrations of nutrients, suspended sediments, and organic materials, which creates an underwater visibility of about 27 feet (eight metres). Acid precipitation in the form of rain and snow does fall on the lake, but the lake is so large that it hasn't noticeably affected overall quality.

Yet there is a less pleasing side to what appears to be a pristine Lake Superior basin. While toxic pollution is low compared to the other Great Lakes, pollutants such as mercury, dioxin, and PCBs still pose a threat because they do not break down. The lake has a long history of industrial pollution, which has created many contaminated areas near cities and towns. Other human activities that are changing the water quality and surrounding natural ecosystems include:

- Population growth expanding beyond urban areas
- Development of rural and waterfront vacation properties without proper planning and regulation
- Stormwater runoff
- Continuing deposition of pollutants from the air.

These activities can have long-term consequences because water that enters Lake Superior stays in the lake for an average of 173 years before it exits through the St. Marys River in Sault Ste. Marie, Ontario.
All of us have to be vigilant stewards as we try to preserve a lake that contains 10 percent of the world's available surface fresh water.

This special news supplement highlights the people, programs, and partnerships that have successfully restored or protected the lake and its basin. The articles highlight American and Canadian activities that are successfully improving the lake's ecosystem.

What Is the Lake Superior Binational Program?

"Water is life and the quality of water determines the quality of life."

-Lake Superior Binational Program vision statement

In the Great Lakes Water Quality Agreement, Canada and the United States agreed to develop and implement, in consultation with State and Provincial Governments, Lakewide Management Plans (LaMPs) for open lake waters and Remedial Action Plans (RAPs) for Areas of Concern (AOCs). The Lake Superior LaMP is being developed and implemented through a Binational Program.

The *Binational Program to Restore and Protect the Lake Superior Basin* began in 1991 through an agreement between the federal governments of Canada and the United States, tribal governments, the Province of Ontario and the States of Michigan, Minnesota and Wisconsin. The administrative framework through which these jurisdictions jointly act on the commitments identified in the agreement is known as the Lake Superior Binational Program (LSBP). The Program identifies two major areas of activity: A Zero Discharge Demonstration Project and The Broader Program.

Lake Superior's North Shore, Minnesota, Photo courtesy of Minn. Extension Service, Dave Hansen

The Zero Discharge Demonstration Program

Lake Superior is a unique, vast resource of fresh water that has not experienced the same levels of development, urbanization, and pollution as the other Great Lakes. Because of this uniqueness, the International Joint Commission recommended to the US, Canadian, and tribal governments that Lake Superior be designated as a demonstration area where no point source discharge (from a pipe) of any persistent toxic substance will be permitted.

The Zero Discharge Demonstration Program (ZDDP) established Lake Superior as the world's first model to eliminate toxic chemicals and reach zero discharge and emission of the following nine toxic, persistent, and bioaccumulative chemicals from a lake:

1. Mercury
2. Total polychlorinated biphenyls (PCBs)
3. Dieldrin/aldrin
4. Chlordane
5. DDT
6. Toxaphene
7. Hexachlorobenzene (HCB)
8. Octachlorostyrene (OCS)
9. 2,3,7,8-TCDD (Dioxin)

The goal is zero discharge by 2020 to be achieved in a step-wise manner. Voluntary pollution prevention is the preferred way to achieve zero discharge, but regulations might also be necessary.

The **Broader Program** is the other part of binational efforts to protect and restore the lake. Recognizing that the Zero Discharge Program alone will not be enough to restore, maintain, and protect Lake Superior, the *Broader Program* focuses on habitat and wildlife issues. The Broader Program coordinates the basin's many environmental agencies to address issues about forests, wetlands, wildlife, fish, and surface and groundwater. Government and tribal agencies and groups from Michigan, Minnesota, Wisconsin, and Ontario, along with both countries' federal governments, have taken steps that will restore degraded areas and protect this unique lake through wetlands and habitat restoration and rehabilitation projects, invasive-free demonstration zones, fish rehabilitation projects, and stream/inland lake restorations.

You can help!

Involvement of the public is needed to make the Lake Superior Binational Program successful. The citizens of the basin are also partners in the Binational Program. The Zero Discharge Program will succeed only if residents of the Lake Superior basin are aware and willing to make changes in how they use the lake and its resources. Getting to zero means changing from a consumer society to a *conserver* society. By working together, we can help make a Great Lake truly *superior*.

Isle Royale, Lake Superior Keweenaw County, Michigan Michigan Travel Bureau

Zero Discharge Demonstration Program Achievements

Achievements on 2000 targets:

- Reduced mercury emissions from in-basin sources by 60 % from 1990 levels
- Achieved 24% destruction of PCBs in Canada
- Progress on Dioxin/HCB/OCS and pesticides targets.

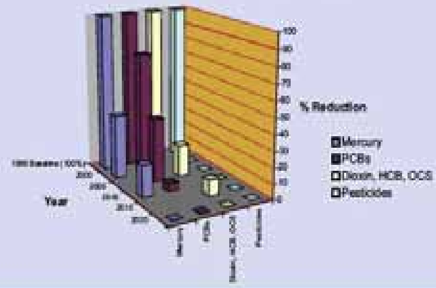
Achievements on 2005 targets will be assessed and reported in 2006.

Lake Superior Binational Program Goals and Activities

Supported by government and industry funding, the following are some examples of activities to reduce pollutants:

- Municipalities are upgrading their storm water and sewage treatment infrastructure
- Dentists are installing amalgam separators to recover mercury
- Programs are in place to recover mercury switches from automobiles, fluorescent lamps, thermostats, thermometers and button batteries
- Schools are learning that going mercury-free is safer for everyone
- Old appliances are being collected to recover mercury switches and PCB ballasts or capacitors
- Municipalities and industry are removing mercury and PCB containing equipment, changing industrial processes, destroying/recycling stockpiles, and researching new pollution control technologies
- Energy conservation and alternative energy sources are being promoted
- People are learning that it's safer to stop burning their garbage so that dioxins are not released (no more burn barrels!)
- Household hazardous waste collection programs are recovering old pesticides, mercury and pharmaceuticals
- Contaminated sediment is being assessed and cleaned up
- Outreach and education programs are being undertaken
- Monitoring of emissions, air, water, sediment and biota are ongoing

Lake Superior LaMP Zero Discharge Demonstration Critical Pollutant Load Reduction Goals



Lake Superior Binational Program Environmental Stewardship Awards Program

In 2004, the Binational Program restarted an annual awards program to honor outstanding environmental achievements of youth, adults, businesses or industry, and community groups or First Nations/Tribes that are protecting or restoring the natural environment of the Lake Superior basin.

The award paid tribute to seven individuals and organizations that have demonstrated a commitment to environmental stewardship through leadership in their respective categories. The Binational Program hopes to encourage all residents in the basin to start actions similar to those awarded wherever they live, work, or play.

Finalists from the US and Canada were selected based on several criteria: importance of the activity to the protection or restoration of the environment; positive impact on the water or land; and whether the activity could be reproduced in other areas.

2004 Award Recipients

Adult Individuals

Roy Johnson, Cloverland, Wisconsin, converted 160 acres of farmland to restored wetlands, including shallow ponds, deep marsh, sedge meadows, and mudflats. Once home to crops and cattle, the wetlands now host a number of sensitive wetland birds and plants.

Josephine Mandamin, Ontario, an Ojibwe woman living in Thunder Bay, organized a 1,300-mile/2,080 kilometre "Water Walk" around the entire coast of Lake Superior to honour Anishinabe womens' responsibility to protect water quality. Mandamin served as the lead Water Walk "grandmother" to help raise awareness about the importance of keeping water clean and free from privatization.

Industry and Business

A tie in the US: Minnesota Power and Pinehurst Inn at Pikes Creek.

Minnesota Power, Duluth, Minnesota, is working on the issue of mercury emissions from coal-fired power plants from both power production and consumption. The company carried out full-scale mercury emissions control technology testing at their Laskin Energy Center (which is within the Lake Superior watershed) as part of an Electrical Power Research Institute study. In an emissions study, Minnesota Power found carbon injection and chemical additives show some promise towards removing mercury from that facility's stack.

To reduce mercury emissions at a consumer level, the company constructed an energy-saving house called the *Millennium Star* in Duluth. The model house showed that building design, materials, and construction techniques can significantly reduce energy consumption and costs.

Pinehurst Inn at Pikes Creek, Bayfield, Wisconsin, is a bed and breakfast that consists of an historic inn and a modern Garden House. The Garden House was built using "green building" techniques, materials, and systems that complemented natural systems. These features minimize the inn's impact on Lake Superior and the surrounding environment by reducing its contribution to air and water pollution, minimizing solid wastes, and enhancing the inn's natural landscaping.

Canadian Pacific Railway, Thunder Bay, Ontario. The company reconstructed at their own expense several railroad water crossings on McKellar Creek (near Terrace Bay, Ontario) to enhance fish spawning opportunities on the creek. Fish surveys in fall 2003 showed that fish were migrating through the new structures, which indicated that the company had successfully restored important fish habitat.

Community/Organization Category

City of Superior, Wisconsin. Staff at the city's wastewater treatment facility has conducted extensive reduction and education programs that prevented mercury from entering the lake through wastewater discharges. By working with state agencies, tribes, schools, and private businesses, the city has kept 300 pounds/136 kilograms of bulk mercury, 400 lab thermometers, 4,000 fever thermometers, and 1,000 vehicle switches that contain mercury out of landfills and waterways.

City staff have incorporated mercury reduction curriculum and activities in public schools, and conducted campaigns for builders, dentists, and the public.

EcoSuperior, Thunder Bay, Ontario. EcoSuperior is a not-for-profit organization that provides Ontario residents with information and motivation for building healthy, sustainable communities. Staff delivers programming in a number of areas including water and energy conservation, waste reduction, green space naturalization, and pollution prevention. The group has delivered effective outreach programs that help change many wasteful or destructive behaviours, including composting Halloween pumpkins and Christmas trees, organizing hazardous waste material collections, and conducting a campaign about the dangers of open garbage burning.

The Binational Program will sponsor the awards program every year. The nomination period runs from February 15 through April 15. For more information, visit the Forum's web site at www.superiorforum.info

Kayak beached on rock, Lake Superior Pukaskwa National Park, Ontario, Robert F. Beltran

Lake Superior Binational Forum

Since 1991, the Lake Superior Binational Forum has served as a partnership of 24 citizen volunteers that provide input and analysis to American and Canadian governments about ways to protect and restore the Lake Superior basin. Through quarterly public input sessions, the Forum also gathers input from citizens and shares this input with binational governments to help shape public policy.

Recently Forum members began to look at how they could also help implement critical priority projects from the Lakewide Management Plan, and have been conducting outreach activities around the basin to raise awareness about:

- Harmful effects of mercury
- Effects of chemical pollutants on human health
- Invasive species
- Dangers of open garbage burning.

Current outreach projects include promoting a basin-wide Lake Superior Day celebration and an environmental stewardship awards program (see articles in this insert).

Forum members agree, as summarized in the group's vision statement, that "water is life and the quality of water determines the quality of life." The Forum recognizes that the Lake Superior region cannot have a sound economy without a healthy environment. This philosophy helps the group make decisions that protect and restore the lake's natural resources.

Who are the members?

Both Canada and the United States select 12 people from a diverse cross-section of community sectors in the Lake Superior basin including businesspeople, environmentalists, industrialists, First Nations/Tribes, municipal officials, and academics. Each member brings his or her own professional experience, sector perspectives, and skills to the Forum's decision-making processes. This diversity strengthens the group. The list of current members is on the Forum's website.

For more information:
In the US, call
(715) 682-1489
In Canada, call 807-343-8811
toll free at (888) 301-LAKE
Or visit the Forum's website at

www.superiorforum.info

Lake Superior Day July 17, 2005

What is Lake Superior Day and why is it being celebrated?

You've heard of *Earth Day*, which focuses on the importance of taking actions that protect the planet. *Lake Superior Day* is a day to celebrate our connection to the world's largest freshwater lake (by surface area) while finding ways to protect and restore basin communities.

Although Lake Superior is the cleanest of the five Great Lakes, it too is being threatened by pollution, contaminated fish, invasive species, loss of habitat, and overdevelopment. The purpose of a special day is to remind people how important the lake and its natural resources are to our health, food supply, recreation opportunities, weather, and lifestyles. Lake Superior Day highlights the many ways we use the lake every day and encourages citizens to take action to restore and protect it.

When is it celebrated?

Lake Superior Day is celebrated every year on the third Sunday in July all around the lake and wherever people around the world want to acknowledge their appreciation for this spectacular lake.

How do I celebrate this day?

People will celebrate this day in many ways—through contemplation, action, art, political means, or recreation. How you celebrate it is up to you.

Where can I get more information?

The Lake Superior Binational Forum will publish an events calendar, a list of celebration ideas, and articles about events on its website at www.superiorforum.info. Please visit the site to register your event or activity or submit media reports so the Forum can help promote your event and you can see what others are doing to celebrate.

A Burning Issue

The average resident of the Lake Superior watershed creates about seven pounds/3.2 kilograms of garbage each day, or 2,555 pounds/1,600 kilograms per year. What happens to all that material? Much of it goes into landfills or is recycled or composted. Some is illegally dumped in backyards, ditches, and the woods, or buried in backyards. The rest is burned.

Many an old-timer remembers that it was the children's job to burn the trash once or twice a week. Sometimes it was burned in a pit, a 55-gallon drum, a woodstove, or a household incinerator. In those days, people burned mostly paper, fabric, rubber, metal cans, and leather.

The old-timers' trash heap was very different from today's trash. Plastics and electronics have joined the heap, and some modern papers and fabrics now contain plastics. And, everyone is now throwing away more and more trash.

Even though the types and amount of trash have changed, people are still using an old-fashioned disposal method - burning trash. They do this for lots of reasons. They may not want to pay for trash service, or they're trying to cut down on how much trash they send to the landfill, or it's a "tradition" to burn garbage.

However, some traditions should be broken, because burning trash creates toxic chemicals. For example, pound for pound, a backyard burn barrel creates 20 times as much dioxin (which causes cancer) as a well-run municipal incinerator. The smoke also can sicken people, especially those who have respiratory illness. Dioxin in the smoke deposits on agricultural fields and can accumulate in the food we eat. In Wisconsin and Minnesota, about 40 percent of wildfires are caused by improper backyard burning. In fact, there are so many problems associated with burning trash that it is illegal in many places.

What can you do instead of burning garbage?

- Sign up for trash pickup service.
- Take your trash to landfills or transfer stations.
- Recycle as much as you can.
- Reuse as many materials as possible. For example, take usable items to a resale store, or repair broken items.
- Compost your organic materials such as food scraps or leaves and grass clippings.
- Try to minimize packaging that will become trash as soon as you get it home.

For more information, visit this binational web site about open burning:

Canadian Centre for Pollution Prevention
http://www.openburning.org
Or EcoSuperior, Thunder Bay
http://www.ecosuperior.com/openburning.html

Coastal Wetlands: Jewels Along the Shore

Many magical coastal wetlands exist along the shores of Lake Superior. Some are drowned river mouths, or secluded wetland refuges behind sand spits, protected from the vicious action of wave and ice. These are places where cold water meets warmer water, where wetland vegetation emerges from silty bottoms and provides underwater refuges for aquatic life, such as young fish and frogs. These places serve as the lake's dinner plate and home for many of its resident and migrating animals such as beaver, birds, and snails.

These wetlands help keep Lake Superior healthy. One very special creek and its wetland in northern Wisconsin was recently designated as a National Wildlife Refuge. The U.S. Fish and Wildlife Service is currently restoring **Whittlesley Creek** near Ashland as a home for fish and wildlife.

Historically, human impacts such as logging and farming changed the creek's natural flow. Floods were more intense because water flowed faster off the land after trees were removed. Farms, homes, and cropland along the floodplain near the creek mouth were often under water during these floods. Ultimately, the water won. Flooding, along with persistently high groundwater, proved too much to take, and most farms and homes near the creek mouth were abandoned.

The goal is to return the creek and its floodplain to its natural residents–sora rails, brook trout, swamp sparrows, yellow warblers, and frogs, to name a few.

The U.S. Fish and Wildlife Service will eventually purchase 540 acres from willing sellers. It's a small piece of land. But, because these coastal wetland areas are so critical to the lake, such action will have a big impact. The Service has already acquired 208 acres and has restored wetland habitats and planted about 10,000 trees on abandoned farmland.

The Service, along with the Wisconsin Department of Natural Resources, has also started to restore the coaster brook trout to Whittlesey Creek. Coasters spend part of their life in Lake Superior and spawn in its creeks or rocky shores. Once common in Lake Superior, populations are only found in a few locations now. Overfishing by early settlers, along with dramatic land use changes, nearly depleted their population.

The Service and its partners hopes to bring this fish back to the Wisconsin waters of Lake Superior. Experimental stocking efforts began in August 2003 when area residents and partners released 80 adult coaster brook trout into the creek. Future stocking will consist of placing various age groups, from eggs to adults, in Whittlesey Creek, through 2009. Results of this experiment will be monitored through 2030.

Though the refuge is still being developed, it is open to limited public use. For more information visit http:/ midwest.fws.gov/ashland/whitt-crk/whit_crk.html.

Stop The Invasion!

They may not be slipping in on flying saucers, but alien creatures are finding their way into the Lake Superior basin. These alien plant and animal species are causing serious problems in the Great Lakes basin.

What is an alien or non-native species?

Non-native species are those that do not naturally exist in an environment, but have been intentionally or unintentionally introduced by human activity or other means. They can be aquatic or land plants, fish, insects, invertebrates, mussels, or crustaceans.

You might also hear them called invasive, non-native, exotic, introduced, non-indigenous, or foreign species.

How did they get here?

Non-native species can sneak into the lake or land in a variety of ways:

- Intentional stockings
- Ballast water carried in international commercial vessels. *Ballast water* is fresh or salt water held in ships' cargo holds to make them heavier and less likely to roll. Upon entering a port, the water is discharged from the ship into the water.
- Building of canal systems
- Gardening and mowing lawns and roadside ditches
- Angling and recreational boating
- Release of unwanted live fish, either from aquariums or ponds, or live fish sold to be consumed
- Through natural methods such as the wind or animal droppings.

Why do they cause problems?

Invasive species negatively affect the *environment* and the *economy*. In the environment, non-natives prey upon native species and compete with them for food or habitat. For example, the ruffe, a small fish that is native to Eurasia, was first observed in Lake Superior in 1986. It was introduced through the ballast water of an ocean-going ship. It now competes with native fish for food and habitat, has no natural predators, and has a very successful reproductive rate, which affects how native fish survive.

Economic impacts have already been experienced in commercial fishing, agriculture, tourism, sport fishing, recreation, and utilities. For example, municipal water intake pipes can become clogged with zebra mussels that cling to hard surfaces.

Where are these species?

In 2000, Minnesota Sea Grant observed 28 non-native species in Lake Superior, including 17 fish, five aquatic invertebrates, and six aquatic plants.

Here are some examples of non-native species already living in the Lake Superior basin:

Fish

Some of the non-natives, such as sea lamprey, are found throughout the lake, while others, such as round nose goby, ruffe, and three-spine stickleback, are found in limited areas of the lake. Ship ballast water continues to be the main source of unintentionally introduced non-native fish species in Lake Superior.

Plants

Non-native aquatic plants of concern include purple loosestrife and Eurasian water milfoil. Both are growing in Lake Superior and are spread when boaters accidentally carry small plant parts in their trailers, live well water, or in personal watercraft treads.

Leafy spurge is a non-native land plant with roots that can extend 35 feet. It can grow through asphalt and flings its seed 15 feet. The deep root system enables it to survive disturbances and sprout even after the foliage is destroyed.

Non-native honeysuckles have been used as ornamentals in gardens for decades, and birds carry their seeds to natural habitats. Once established, honeysuckle can dominate the understory of woodlands.

Other non-native plants causing problems include exotic buckthorns, garlic mustard, and spotted knapweed.

What is being done to stop the spread of these species?

Binational activities are currently dealing with non-native species in Lake Superior and throughout the Great Lakes. For example, governmental agencies, Native American tribes, and nonprofit organizations from the United States and Canada continue fish surveys to document the range expansion of ruffe and detect other non-native species from Thunder Bay, Ontario, to Sault Ste. Marie, Michigan.

In 2003, round goby and white perch were discovered and confirmed in Thunder Bay harbour, Ontario. Fish surveys are continuing in the St. Louis River in Duluth, Minnesota, and four other south shore rivers to monitor ruffe and other non-native populations.

Rusty Crayfish, Lake Superior
Photo courtesy of Minnesota Sea Grant, Jeff Gunderson

Thousands of acres of land are being treated annually to control the spread of non-native plant species by governmental and non-governmental organizations. Educational materials such as pocket guides, signs at boat landings, brochures, and videos are available from Sea Grant, the Lake Superior Binational Program partners, and others. These materials are distributed throughout the Lake Superior basin to prevent the introduction and reduce the spread of non-native species.

What can you do to help stop the invasion?

A few simple actions will help prevent the spread of non-native species to your favorite place:

1. Always inspect your boat and trailer and remove any plants and animals before leaving the water. This is the best way to stop the spread of aquatic plants and fish species to other lakes! Drain water from the motor, live well, bilge, and transom before leaving the water.
2. Never release live baitfish in the water or live earthworms on the land or water.
3. When planting your landscape or garden, use only plants that are native to your region. Consult with professional garden centers and landscape planners on the best native plants for your area.
4. Learn what non-native species look like and additional prevention tips by contacting your local state, provincial, or federal natural resource management agency or university extension service.

For more information about non-native species, visit these web sites:

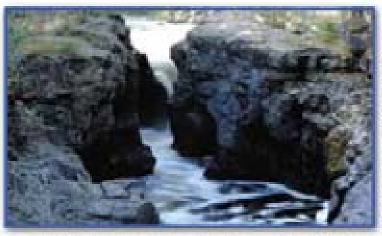
Environment Canada
http://www.on.ec.gc.ca/coa/2001/invaders-e.html

US Environmental Protection Agency
http://www.epa.gov/owow/invasive_species/

Conserving Energy Reduces Mercury Emissions

What Is Mercury?

There is more to mercury than just the silvery liquid in thermometers. Mercury is a naturally occurring element that is present throughout the environment. Scientists believe that more than half the mercury in the environment today is from human-made sources. Human activity, such as some forms of mining and burning fuel, releases mercury into the environment. These releases increase the amount of mercury cycling through the air, soils, plants, and surface and groundwater.



A North Shore stream flows into Lake Superior, Minnesota.
Photograph courtesy of Minnesota Extension Service

Living things easily absorb this mercury.

When atmospheric mercury falls to earth, bacteria or chemical interactions can change it into an organic form known as *methylmercury*. Methylmercury is much more toxic than the original form. It also has the ability to pass through cell walls and build up in living tissue. *Bioaccumulation* occurs when a substance absorbed from the air, water, or food builds up in the tissues of a living organism.

Mercury and the Food Chain

When methylmercury accumulates in natural ecosystems, it gets more and more concentrated in living creatures' bodies. For example, small fish may eat aquatic plants that contain mercury. Bigger fish then eat the smaller fish, and bald eagles eat the big fish. This is called *bioaccumulation*.

Mercury poses risks to wildlife that eat contaminated fish including behavioural problems, reduced reproductive success, impaired growth and development, and even death. Species that are at risk for mercury damage from eating fish include eagles, loons, osprey, mink, otter, and humans.

Mercury cannot be removed from fish before people eat them because methylmercury accumulates in the muscle, not the fat. This is why all US states and the province of Ontario in the Great Lakes region have fish advisories that suggest limits on fish consumption.

Mercury and Human Health

Mercury exposure in human beings can lead to damage of the brain, spinal cord, nervous system, kidneys, and liver. Exposure to mercury while in the womb is now linked to brain development problems in some unborn and growing children. A 2000 National Academy of Sciences report concluded that children of women who consume large amounts of fish are at the highest risk.

A recent public health study based on data from the US Center for Disease Control and Prevention concluded that between 300,000 and 600,000 children born each year in the U.S. have umbilical cord blood levels of mercury associated with loss of IQ. This is equivalent to between 8 and 16% of births in any given year. This startling calculation is a result of exposure to methylmercury while in the womb. It is thought that this loss of IQ is irreversible. The economic costs to the US would be over $8 billion annually.

Mercury and Coal Combustion

Mercury is naturally present in coal. When coal is burned in power plants, mercury is released into the air as a by-product. This means coal-fired power plants are a main source of mercury emissions. Taconite production, which also burns large amounts of coal, is another major source in the Lake Superior basin.

The good news is that we can reduce our energy use at home, work, and school. The more energy we save, the less coal would be burned and less mercury is released. This makes energy conservation an important part of mercury reduction activities.

Practical Steps For Energy Conservation

What's using energy in the average home?

Heating and cooling	38 %
Major Appliances	21 %
Hot Water	19 %
Other Appliances	15 %
Lighting	7 %

Here's how you can reduce energy use where you live:

- Set the furnace thermostat at 68 degrees F/20 degrees C or lower, and the air conditioner thermostat at 78 degrees F/25 degrees C or higher. This can decrease your energy usage by three to five percent per degree.
- In summer, open windows at night to bring in cool night air, and close windows and drapes during sunny days.
- Plant deciduous shade trees on the west and south sides of your house to block the summer sun.
- Close the fireplace damper, except when you're using the fireplace. This prevents warm air from escaping up the flue.
- Reduce heat to unused rooms in the house by closing doors and heat vents.
- Upgrade ceiling insulation to R-38. Higher R-values mean more effective insulation levels and thus more energy savings.
- Insulate exterior heated basement walls to at least R-11. Insulate floors over unheated areas to R-19.
- Install low-flow showerheads to reduce water-heating bills.
- Dry clothes outside on a line whenever possible.
- Run the dishwasher only when you have a full load of dishes.
- Buy energy-efficient room air conditioners and install them only where needed.
- Turn off electric lights when not in use. This is probably the simplest energy-saving thing you can do!
- Install compact fluorescent bulbs in the fixtures that you use most often.

Paper generously donated by
Bowater, Thunder Bay

Fun Facts About the Lake!

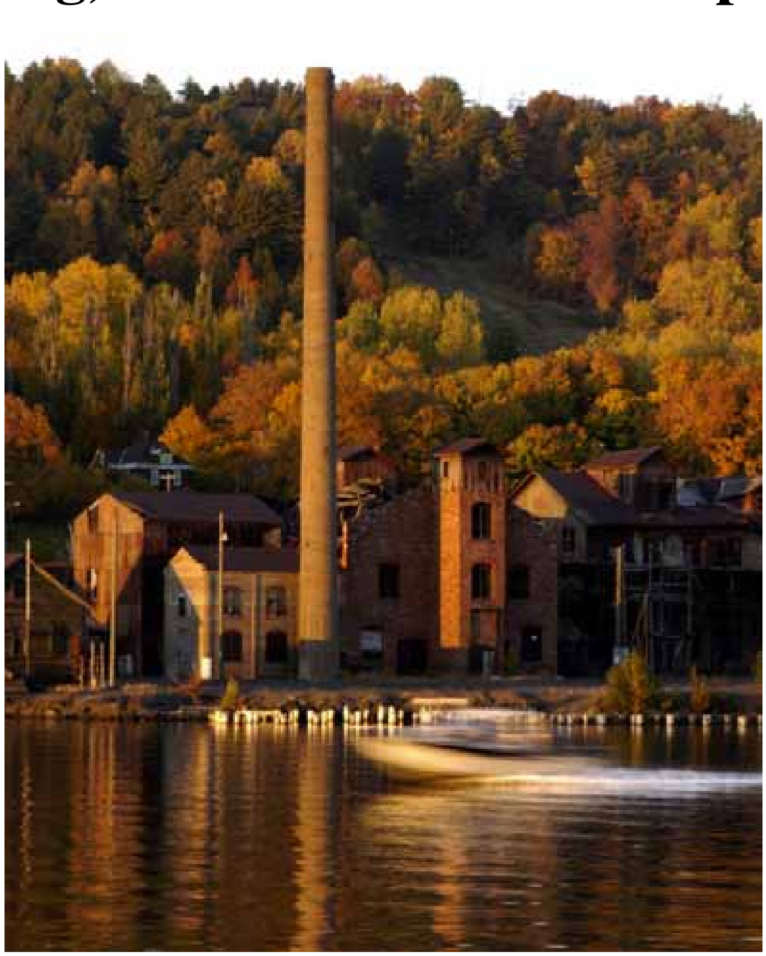
- The biggest, coldest, and cleanest of the Great Lakes, Lake Superior is the largest freshwater lake, by surface area, on Earth. By volume of water, it's the world's second largest lake. Only Lake Baikal in Siberia has more water.
- The lake's surface water is over 31,700 square miles/82,103 square kilometres.
- It's so big it could hold all the water from the other four Great Lakes, PLUS three more lakes the size of Lake Erie!
- The lake contains 10 percent of the world's fresh surface water, enough to submerge all of North and South America under one foot of water.
- If you could travel along the entire Lake Superior shoreline, you'd go 1,826 miles/2,922 km, or the distance from Duluth to Miami, or from Thunder Bay to Halifax.
- Lake Superior's deepest point is 1,332 feet/406 metres.
- French explorers referred to this tremendous body of water as le lac superieur, or "Upper Lake," or the lake above Lake Huron. The Chippewa Indian translation, Gichigami, signifies Great Water.

- Length: 350 miles / 563 km.
- Breadth: 160 miles / 257 km.
- Average Depth: 483 ft. / 147 m.
- Maximum Depth: 1,332 ft. / 406 m.
- Volume: 2,900 cubic miles / 12,100 cubic km.
- Drainage Basin Area: 49,300 sq. miles / 127,700 sq. km.
- Shoreline Length (including islands): 2,726 miles / 4,385 km.
- Average Temperature: 40 degrees F / 4 degrees C
- Elevation: 600 ft. / 183 m.
- Outlet: St. Marys River to Lake Huron
- Retention/Replacement Time: 173 years

Source: Great Lakes Information Network and the University of Wisconsin-Extension's websites.

Chapter 3

Ecosystem Goals, Objectives, Indicators, Monitoring, and Beneficial Use Impairments



Quincy Smelter in the Keweenaw Peninsula.
Photo Credit: Brenda Jones, US EPA.

Lake Superior Lakewide Management Plan
2006

Chapter 3 Contents

Please Note: updated information in this chapter has been taken from published material with the exception of the binational cooperative monitoring update, and the draft habitat and wildlife ecosystem goals (section 3.3). These have not received final approval from the Task Force but are presented here as draft.

Chapter 3

Ecosystem Goals, Objectives, Indicators, Monitoring, and Beneficial Use Impairments

3.0 ABOUT THIS CHAPTER

The Binational Program is committed to the objective of zero discharge and to a broader program to restore beneficial uses and to protect and restore ecosystem integrity in Lake Superior and its watershed. A Vision for Lake Superior (see Chapter 1) expresses this commitment to the Lake Superior ecosystem and its landscapes. It reflects the diverse pathways and mechanisms by which humans and nature interact within land and water ecosystems, and challenges the inhabitants of the Lake Superior watershed to accept personal responsibility for protecting the Lake and the landscape that sustains it. The Binational Program continues to expand the vision into more specific and technically-precise language.

As introduced in Chapter 1 (section 1.1.2), *Ecosystem Principles and Objectives, Indicators and Targets for Lake Superior* (EPO; LSBP 1998), first published in 1995, is the foundation to guide ecosystem management and monitoring in the Lake Superior Basin (see section 3.1). In 1999, so as to best monitor the current status of the ecosystem, the Superior Work Group narrowed the wide range of indicators in the EPO to a suite of "best bet" measures (see section 3.2) to guide its work (LSBP 1999) (http://www.epa.gov/glnpo/lakesuperior/binatmonwkshp.pdf). Ecosystem goals were further defined in 2003 for habitat and terrestrial wildlife (through the Superior Work Group; see section 3.3) and for aquatic communities (through the Great Lakes Fisheries Commission; see section 3.4).

This chapter provides an overview of these efforts to define ecosystem principles, goals, objectives, and indicators for ecosystem management in the Lake Superior Basin. Work Group committees continue to refine existing goals, objectives, principles, and indicators, and to address gaps where they exist (see Chapters 4, 6, and 7 for the most current information).

U.S. and Canada Binational Cooperative Monitoring, as described in section 3.5, was initiated in Lake Superior in 2005-2006. The Cooperative Monitoring approach is above and beyond the routine monitoring programs that agencies normally conduct. Its goal is to address key information gaps as identified through the lakewide management programs. It complements and builds on other monitoring and research projects being conducted on the lake in the same year.

Annex 2 of the Great Lakes Water Quality Agreement requires that each LaMP assess impairments to beneficial water resource uses (see section 3.6) as the first step in identifying restoration and protection actions for each of the Great Lakes. The Lake Superior LaMP identified six beneficial uses as impaired due to critical pollutants, but also recognizes that more than just these beneficial use impairments will need to be addressed before Lake Superior can be fully restored.

3.1 ECOSYSTEM PRINCIPLES AND OBJECTIVES FOR LAKE SUPERIOR

The *Ecosystem Principles and Objectives, Indicators and Targets for Lake Superior (EPO):*

1) Expanded the broad objectives of A Vision for Lake Superior into more specific ecosystem principles, objectives, and categories for key elements of the Lake Superior ecosystem, including aquatic communities, terrestrial wildlife, habitat, human health, and sustainability. This discussion document underwent review among Great Lakes practitioners. Ecosystem objectives developed by consensus do not obviate or override regulations, laws, and guidelines set by governments and resource regulatory agencies. Rather, the *Ecosystem Principles and Objectives* document was prepared to encourage informed discussion of the vision and practice essential for proactive, sustainable, and coordinated management of the Lake Superior ecosystem.

2) Facilitated progress toward a set of informative ecosystem indicators, with quantitative targets, by which the health of the Lake Superior Basin ecosystem, including its physical, biotic, and cultural elements, can be measured.

3) Provided guidance for land and water management in the Lake Superior ecosystem.

Lake Superior ecosystem objectives and sub-objectives were developed by each of the Lake Superior Work Groups committees: chemical, aquatic community, terrestrial wildlife community, habitat, human health and developing sustainability. Table 3.1, Summary of Objectives and Sub-Objectives, presents each committee objectives and elaborates and clarifies them in the sub-objectives column.

A typical indicator identifies a practical measurement such as the abundance or distribution of a plant or animal species or an economic measure that tells us something significant about the health of the Lake Superior ecosystem. Each indicator is accompanied by a target that specifies the desired level of the indicator.

Table 3-1. Summary of Objectives and Sub-Objectives (EPO 1998)

1. General Objective	Human activity in the Lake Superior Basin should be consistent with A Vision For Lake Superior, which prefaces this document. Future development of the basin should protect and restore the beneficial uses described in Annex 2 of the Great Lakes Water Quality Agreement.	
2. Chemical Contaminants Objective	Levels of persistent, bioaccumulative toxic chemicals should not impair beneficial uses of the natural resources of the Lake Superior Basin. Levels of chemical contaminants which are persistent, bioaccumulative and toxic should ultimately be virtually eliminated in the air, water, and sediment in the Lake Superior Basin.	• Per the Binational Program to Restore and Protect the Lake Superior Basin, the management goal for the nine designated persistent, bioaccumulative toxic chemicals is zero discharge and zero emission from sources within the Lake Superior Basin. • Per the Great Lakes Water Quality Agreement, atmospheric deposition of persistent, bioaccumulative toxic chemicals that have an anthropogenic origin should be virtually eliminated. • Open lake concentrations of the chemicals in the zero discharge and zero emission category or the lakewide remediation category should not exceed the most sensitive yardstick of environmental quality (Smith and Smith, 1993). • Concentrations of zero discharge and lakewide remediation chemicals in sediment in nearshore areas (<80 m), and in harbors and bays, should not cause or contribute to impaired uses in the Lake Superior ecosystem. Concentrations of local remediation chemicals in sediment should not impair uses in Areas of Concern in the Lake Superior Basin. • Concentrations of the chemicals in the prevention/monitor category should not increase in air, water, or sediment. • Initially, the presence of chemicals in the prevention/investigate category should be investigated in the ambient environment, in the appropriate media and location(s). In addition, sources of the chemicals in the prevention/investigate category should be identified, and the presence or absence of these sources in the basin should be confirmed. Presence of a source should trigger continued monitoring of the media most likely to concentrate the chemical.
3. Aquatic Communities Objective	Lake Superior should sustain diverse, healthy, reproducing, and self-regulating aquatic communities closely representative of historical conditions.	• Lake trout will continue to be recognized as valuable integrators and indicators of the health of the Lake Superior ecosystem. Other aquatic species may also prove useful as ecosystem health indicators for the Lake Superior Basin. • Native aquatic species associations will be recognized as key elements of a healthy Lake Superior ecosystem. • Aquatic biota living in the Lake Superior ecosystem should be free from contaminants of human origin. • Exotic fish species now present in Lake Superior (including rainbow trout, Pacific salmon, and brown trout) should be managed in a way that is compatible with restoration and management goals established for native fish species by the Lake Superior Committee.

Table 3-1. Summary of Objectives and Sub-Objectives (EPO 1998)

		• New exotic or nuisance species must not be intentionally or unintentionally introduced to waters of the Lake Superior ecosystem; accidental introductions of exotic species should be prevented through effective use of regulatory and technological measures. The use of live bait by anglers must not contribute to the dispersal of exotic species or genetic stocks.
4. Terrestrial Wildlife	The Lake Superior ecosystem should support a diverse, healthy, and sustainable wildlife community in the Lake Superior Basin.	• There is a wildlife community-based program to monitor the health of Lake Superior Basin ecosystems. • Species at risk/concern (federally threatened and endangered) are recovered. • Encourage disturbances that are within natural variation. • Manage land and wildlife populations using practices that mimic natural disturbances. • Understand the relationship between wildlife and disturbance. • Keep wildlife species free of contamination. • Encourage the use of native species in all remedial projects. • Prevent and control the spread of undesirable exotic species. • Educate the public to integrate the values of wildlife in economic development. • Meet the restoration needs of wildlife communities.
5. Habitat	To protect and maintain existing high-quality habitat sites in the Lake Superior Basin and the ecosystem processes that sustain them. Extensive natural environments such as forests, wetlands, lakes, and watercourses are necessary to sustain healthy native animal and plant populations in the Lake Superior ecosystem, and have inherent spiritual, aesthetic, and educational value. Land and water uses should be designed and located in harmony with the protective and productive ecosystem functions provided by these natural landscape features. Degraded features should be rehabilitated or restored where this is beneficial to the Lake Superior ecosystem.	• Ecological health of the Lake determined largely by the health of tributary lakes and rivers; land use planning/regulation should eliminate/avoid destructive water linkages and foster healthy land-water linkages. • Long-term consequences of incremental landscape change, habitat destruction, and fragmentation should be avoided through research and planning. • Importance of nearshore, shoreline, and wetland habitats should be addressed through identification, protection, and restoration of sites for reproduction and rearing of fish, water birds, mammals, other wildlife, and plants.
6. Human Health	The health of humans in the Lake Superior ecosystem should not be at risk from contaminants of human origin. The appearance, taste, and	• Fish and wildlife should be safe to eat and consumption should not be limited by contaminants of human origin. • Water quality should be protected where currently high, and improved where degraded.

Table 3-1. Summary of Objectives and Sub-Objectives (EPO 1998)

	odour of water and food supplied by the Lake Superior ecosystem should not be degraded by human activity.	• Lake Superior should be safe for total body contact activities, including areas adjacent to urban and industrial areas. • Air quality should be protected where currently high, and improved where degraded. • Communities, industries, and regulators outside basin should be informed of consequences of long-range atmospheric transport of contaminants into the basin.
7. Developing Sustainability	Human use of the Lake Superior ecosystem by all people in the watershed should be consistent with the highest social and scientific standards for sustainable use. Land, water, and air use in the Lake Superior ecosystem should not degrade it, or any adjacent ecosystems. Use of the basin's natural resources should not impair the natural capability of the basin ecosystem to sustain its natural identity and ecological functions, nor should such use place at significant risk the socioeconomic and cultural foundations for any group of citizens in the watershed, nor should we deny current and future generations the benefits of a healthy, natural Lake Superior ecosystem. Policies directed at the wise management of natural and social resources in the basin should not usurp the right of local communities to determine their future within the guidelines established by existing statutes and regulations. Technologies and development plans that preserve natural ecosystems and their biodiversity should be encouraged.	• Public and private decisions should be based on understandings, rooted in formal and informal educational settings, which contribute to the integrity and stability of social and biotic communities. • The Lake Superior ecosystem provides resources and services to humans. These include air, water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be valued as environmental capital, in the same way that other capital is assigned value. • Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior ecosystem that is compatible with existing and emergent social conditions. • The basis for guiding sustainable development at the scale of the Lake Superior ecosystem (especially in reference to community land use or comprehensive planning) should be the pattern of land, water, and air use, as these affect ecological, social and economic processes. • These principles and objectives for developing sustainability are based on scientific, ethical, and environmental planning concepts from a number of sources, including: Lee et al. (1992); Architects for Social Responsibility (1991); Ecological Society of America (1991); UNCED (1992); Christensen et al. (1996); and Government of Canada (1990).

The EPO has provided a reference point for discussion and refinement of binational ecosystem management and monitoring in the Lake Superior Basin, and will continue to do so in the future.

3.2 "BEST BET" INDICATORS (1999)

A Lake Superior Binational Monitoring Workshop was held on October 25-27, 1999, to further refine the EPO ideas; a summary of the workshop results can be found below in Table 3-2.

In 1999, sixty people from government, industry, and local environmental groups met to examine existing monitoring activities within the Lake Superior Basin, with a view to developing a coordinated, long-term monitoring program. This coordinated program would incorporate Lake Superior Binational Program's indicators. The workshop represented the first time that monitoring data and indicators were considered at this scale of ecosystem organization for Lake Superior.

The tasks of the workshop were five-fold:

1. To review the list of current "best bet" indicators,
2. To review and update a metadata summary of current monitoring programs,
3. To match monitoring efforts with indicators and identify gaps and overlaps,
4. To identify potential funding sources for future monitoring and coordination,
5. To solicit agency interest and support for future monitoring and coordination efforts.

Participants reached consensus on nine key recommendations for future coordination of monitoring and reporting structure for Lake Superior:

1. Develop a coordinated monitoring strategy for the Lake Superior Basin. All of the Lake Superior Binational Program agencies will participate and seek resources for implementation. The monitoring strategy will be peer reviewed and presented in the LaMP 2002.
2. Prepare a revised list of "better bet" indicators for each theme committee.
3. Build a more complete metadata summary. This involved three steps:
    a. Include additional metadata identified at the workshop in the existing summary table (see Appendix VI of the report);
    b. Approach the International Joint Commission regarding input of a complete Lake Superior metadata list to their website.
    c. Search for additional metadata.
4. Form ad hoc groups to address sampling protocols, sample analysis and data reporting standardization and comparability identified by theme committees.
5. Identify monitoring gaps and make recommendations on those that are most critical
6. Facilitate greater coordination among agencies and theme groups to address common issues (for examples, see section 4.0 of the report). Establish a coordination committee to address these issues.
7. Identify funding necessary to address monitoring gaps and coordination of monitoring activities.
8. Report monitoring results in the LaMP 2002.
9. Adjust the existing Lake Superior Binational Work Group functions to achieve recommendations 1 through 8.

Table 3-2. "Best Bet" Indicators (1999)

A. Chemical Contaminants

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Progress Towards Zero Discharge & Zero Emission	To measure progress towards zero discharge & zero emission of 9 designated persistent, bioaccumulative toxic chemicals[1];	Trends of chemical concentrations in water, fish, sediment & other ecosystem compartments; Measurements & estimates of release of chemicals from basin sources;	Discharge/emissions (measured as kg/yr, mass or other units for surrogate measures) will be compared to 1990 baseline data to indicate whether progress is being achieved;
2. Atmospheric Deposition Trends for Zero Discharge Chemicals[1]	To indicate progress towards virtual elimination of zero discharge chemicals from the environment;	Rates of change in atmospheric loadings of zero discharge chemicals in the wet, dry & gaseous phases;	Magnitude of trend indicates whether virtual elimination is being achieved;
3. Open Lake Concentrations of Zero Discharge & Lakewide Remediation Chemicals[2]	To indicate whether open lake concentrations of chemicals meet water quality yardsticks (most sensitive standard available);	Measurement of zero discharge & lakewide remediation chemicals every 2 yrs. in open lake (>80 m.);	Concentrations will be considered acceptable only if 95-100 percent of data indicate levels below yardstick;
4. Sediment Concentrations of Zero Discharge, Lake Remediation & Local Remediation[3] Chemicals	Zero discharge & lakewide remediation chemicals: To indicate whether sediment concentrations meet sediment yardsticks; Local remediation chemicals: To indicate restoration of impaired uses at Areas of Concern (AOC);	Changes in concentrations of chemicals in sediments at different depths; Upper segments of sediment cores compared to local (AOC) yardstick; Maps of extent of chemical contamination at AOCs;	Sediment Concentrations at depths within sediment core expressed in ug/g; Trends over time indicates change in 3 classes of chemicals; Sediment Concentrations in exceedance of yardsticks, or causing use impairments indicate need for further reductions;
5. Ambient Concentration Trends of Prevention/Monitor Pollutants[4] in Water, Sediment, Air/Precipitation	To indicate whether concentrations of Prevention/Monitor pollutants increase in air, water, or sediment;	Bar graphs showing changes in concentrations over time in air/precipitation & water; Trends in sediment concentrations from dated sediment core profiles;	Concentrations in air, water & sediment not increasing over time will indicate levels are not negatively impacting lake; Chemicals may be added to lakewide or local remediation categories;

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
6. Prevention/ Investigate Chemicals[5]	To determine presence/absence of chemicals in ambient air, water, sediment; To identify potential sources of chemicals;	Decisions to re-categorize these chemicals to be based on information literature search, presence/absence in lake, & sources;	Data from ambient & source monitoring used to determine whether continued monitoring is needed; Chemicals may be added to lakewide remediation, local remediation, or prevention/monitor chemicals;

[1] Zero Discharge Chemicals: chlordane, DDT, dieldrin, dioxin, hexachlorobenzene, mercury, octachlorostyrene, PCBs, toxaphene;
[2] Lakewide Remediation Chemicals: PAHs, alpha-BHC, cadmium, heptachlor, heptachlor epoxide;
[3] Local Remedation Chemicals: aluminum, arsenic, chromium, copper, iron, lead, manganese, nickel, zinc;
[4] Prevention/Monitor Pollutants: 1,4-dichlorobenzene, 1,2,3,4-tetrachlorobenzene, mirex/photo-mirex, pentachlorobenzene, pentachlorophenol, gamma-BHC;
[5] 1,2,3,5-tetrachlorbenzene, 3,3-dichlorobenzidine, 2-chloroaniline, tributyl tin, beta & delta BHC, hexachlorobutadiene;

B. Aquatic Communities

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Off shore Community - Abundance of Key Species - Presence of Exotic Species	To monitor presence & relative abundance of key species (lean & siscowet lake trout, herring) & exotics to evaluate progress toward achieving populations of self-sustaining indigenous species;	Trends in relative abundance of native & non-native fish (benthic, pelagic), plankton & benthic invertebrate species over time; Pie chart to illustrate percent of community made up of exotic species;	Data will allow measure of how stressors (harvesting, exotics, nutrient loadings) affect the offshore community & indicate what regulatory solutions are needed;
2. Nearshore Community: - Abundance of Key Species - Presence of Exotic Species - Habitat Loss or Restoration	To monitor presence & abundance of key species (lean & siscowet lake trout, herring, whitefish, longnose & white suckers, walleye, slimy sculpin, *Diporeia* spp. *Mysis relica*), exotics & habitat changes to evaluate diversity & long-term sustainability of nearshore aquatic community;	Trends in abundance of native & exotic fish, plankton & benthic invertebrate species over time for each jurisdiction; Graphs illustrating trends in abundance of exotic species;	Data will allow measure of how stressors (harvesting, exotics, nutrient loadings, changes to habitat) affect the nearshore community & indicate what regulatory solutions are needed;
3. Harbour-Embayments-Estuaries Community: - Abundance of Key Species	To monitor presence & abundance of key species (walleye, yellow perch, pike, small mouth bass) exotic & benthic	Comparison of trends in abundance of native & exotic fish, species over time at for AOC & non-AOC	Data will allow measure of how stressors (as above & including water diversions, dredging, thermal loading) affect harbours, bays &

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
- Presence of Exotic Species - Habitat Loss or Restoration	invertebrates (chironomids, oligochaetes, burrowing mayfly) to measure the impact of remedial action plans in Areas of Concern;	sites; Comparison of density of benthic invertebrates at AOC & non-AOC sites;	estuaries; Solutions will involve educational, administrative & regulatory actions;
4. Tributary Community: - Abundance of Key Species - Presence of Exotic Species - Habitat Loss or Restoration - Self-sustaining Indigenous Species	To monitor presence & abundance of key species (brook trout, white suckers, walleye, sturgeon, burbot, other salmonines, in selected tributaries to the lake; To monitor growth & abundance or larval sea lamprey in tributaries;	Absolute abundance of juvenile salmonine fish species over time; Number of coho salmon, brown trout, rainbow trout, chinook salmon & brook trout migrating up tributaries over time; Larval lamprey growth & survival in different tributaries;	Data will allow measure of how reductions in stressors (logging, road & pipeline crossings, sedimentation, pollution, exotics, dams, water diversion) tributary communities; Solutions will involve educational, administrative & regulatory actions;
5. Toxic Contaminants in Aquatic Biota	To monitor contaminants (PCB, DDT, chlordane, mercury, dioxin, DDE, dieldrin, toxaphene) in 1 prey & 1 predator species of fish from each of 4 habitat types;	Table documenting levels of the major contaminants found in each species collected from each habitat type on an annual basis;	Changes in levels of contaminants in offshore fish species provides measure of changes in atmospheric loadings to lakes; Changes in levels of contaminants in nearshore fish species provides measure of changes in point-source loadings to lake;

C. Terrestrial Wildlife

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Breeding Birds (50+ species)	To monitor diversity, relative abundance & distribution of birds;	No. of taxa, relative abundance & relative distribution of over 50 breeding bird species;	Indicator provides evidence of effects of habitat change on avian communities;
2. Amphibian Populations	To monitor the diversity & relative abundance of selected amphibian species within the lake basin;	Relative abundance of amphibian species through frog/toad call surveys;	Indicator will track declines which may indicate a problem;
3. Rare & Important Plants (G_1, G_2 of TNC list)	To measure the relative abundance of rare & important plants over time;	Relative abundance of rare & important plants;	Indicator will track declines which may indicate a problem;

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
4. Land Use Change	To measure land use change over time (i.e., forest type, edge density, age structure, landscape characteristics & forest structure);	Land use patterns measured at a level not coarser than 200 x 200 m. resolution at 5-yr. intervals;	Indicator provides evidence of habitat change;
5. Micro & Invertebrate Soil Organisms	To measure changes in the relative density & abundance of soil organisms over time;	Relative density & abundance of soil organisms over time;	Indicator will track declines which may indicate a problem;
6. Tree Swallows	To measure contaminant levels in tree swallows;	Trend in body-burdens of contaminants in tree swallows over time;	Indicator will show changes in levels of contaminant in nearby water;
7. Snapping Turtles	To measure contaminant levels in snapping turtles;	Trends in body-burdens of contaminants in snapping turtles over time;	Indicator will show changes in rates of contaminant bioaccumulation in turtles;
8. Colonial Birds	To measure relative abundance, distribution & contaminant levels in colonial birds;	Trends in relative abundance, distribution maps & contaminant levels in colonial bird populations;	Indicator will show changes in population levels which may indicate a problem, & changes in rates of contaminant concentrations over time;
9. Nocturnal Owls	To measure the relative distribution & abundance of nocturnal owl species;	Trends in relative distribution & abundance of nocturnal owl species;	Indicator will show changes in population levels & distributions which may indicate a problem;
10. Federally Listed Threatened & Endangered (T&E) Species	To measure the relative distribution & abundance of T&E species;	Trends in relative distribution & abundance of T&E species;	Indicator will show changes in distribution & abundance which may indicate a problem;
11. Exotic Plants & Terrestrial Animals (i.e., Gypsy Moth)	To measure the relative distribution & abundance of exotic plants & animals;	Trends in relative distribution & abundance of exotic plants & terrestrial animals;	Indicator will show increases which may indicate a worsening situation;
12. Medium-sized Carnivores	To measure the relative distribution & abundance of carnivores;	Trends in relative distribution & abundance of medium-sized carnivores;	Indicator will show declines which may indicate a problem;
13. White-tailed Deer	To measure the relative abundance of deer;	Trends in relative abundance of deer;	Indicator will show population impacts;
14. Ruffed Grouse	To measure the relative distribution & abundance of grouse;	Trends in relative distribution & abundance of grouse;	Indicator will show declines which may indicate a problem;

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
15. Lichens/ Mosses/Fungi	To measure the relative distribution, abundance and growth of lichens, mosses & fungi;	Trends in relative distribution, abundance and growth of lichens, mosses, fungi;	Indicator will show declines in population/growth which may indicate a problem;
16. Common Loons	To measure productivity & contaminant levels in common loons;	Trends in population productivity & contaminant levels in common loons;	Indicator will show levels of mercury bioaccumulation, & effects of habitat alteration;

D. Habitat

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Stream Flow/Sedimentation	To monitor stream flows & sediment transport to track changes in land use patterns;	Line graphs of mean discharge; stream base flow, peak-to-low ration & sediment loading for streams on annual basis;	Changes in these parameters (e.g., increased frequency of peaking; increased sediment transport) indicate watershed degradation;
2. Benthic Invertebrates	To monitor trends in density & species richness of benthic invertebrate communities in streams, estuaries, inland lakes;	Graphical illustration of benthic community measures (density, taxonomic richness, diversity indices) & physical properties (pH, turbidity, nutrients) for comparison between site and temporal patterns;	Water quality & status of benthic invertebrate communities to detect problem sources and indicate need for mitigation measures;
3. Inland Lake Transparencies	To monitor clarity of inland lakes to determine changes in water quality over time;	Maps of secchi depth readings for lakes to indicate changes in water clarity over time;	Changes in water clarity may provide an indication of the overall ecosystem health of inland lakes;
4. Forest Fragmentation	To monitor patterns of landscape composition & pattern to track forest fragmentation;	Bar or line graphs of metrics including class area, mean patch size, patch size variability, total forest edge, nearest-neighbor distance etc. to indicate changes over time;	Decreases in forested area, mean patch size, increases in nearest-neighbor distance & patch edge indicate increase forest fragmentation, and the potential for forest species declines;

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
5. Accessible Stream Length	To monitor increases in total wetland area & accessible stream length to track habitat rehabilitation and protection efforts.	GIS-based system providing maps & graphs of changes in wetland area and accessible stream length.	Increases in wetland area, accessible stream length will provide indicators in positive change in lake's ability to produce fish & other aquatic life.

E. Human Health

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Fish Contaminants	To monitor levels of contaminants in fish to provide information on human exposure;	Bar graphs showing fluctuation of contaminants over time & space; Contaminants will be summed to provide overall indicator of fish contamination;	Data will be used to monitor changes in contaminant levels for remedial plans, & for the issuing of contaminant advisories to public re: consumption limits;
2. Drinking Water Quality	To monitor quality of raw, treated and distributed water for comparison to water quality objectives & guidelines;	Bar graphs of geometric averages of contaminant concentrations (lead, trihalomethanes, nitrates, benzo[a]pyrene, mercury, etc.) in raw, treated & distributed levels to show trends over time;	Indicator would reveal trends in contaminant levels in water in various locations throughout the lake;
3. Recreational Water Quality	To monitor beach postings and *E. coli* counts spatially & temporally throughout the lake;	Bar graphs showing trends over time for *E. coli*, beach closures & contaminant levels;	Data will show seasonal and local trends in recreational water quality to aid in beach management & prediction of poor water quality episodes;
4. Air Quality	To monitor concentrations of 9 contaminants at 99 sites throughout the lake to provide an index of air quality;	Bar graphs of geometric means showing trends for each pollutant & air quality index over time;	Data will show overall air quality trends & allow regulatory agencies to monitor the effects of remedial plans;
5. Radionuclides	To monitor concentrations of whole milk for radionuclides;	Bar graphs of cesium & strontium concentrations in milk over time; Bar & line graphs showing total radiation as a percent of MAC;	Indicator will provide a measure of the overall exposure to the population to radionuclides from weapons fallout;

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
6. Body Burdens	To monitor concentrations of toxic contaminants in human tissue to determine delivered doses of chemicals;	Methods for illustrating trends in contaminants in human tissue to be determined; May measure contaminant levels in mother's milk;	Body burden information is useful to delineate potential from actually delivered doses of chemicals;
7. Health Effects	To monitor the occurrence or change in rate of adverse health outcomes directly linked to contaminant effects;	Measures such as birth weight, gestational age & malformations of infants will be plotted over time;	Trends in such measures may indicate contaminant effects, or changes in prenatal care;
8. Cohort Indicator of Exposure and Effects	To repeatedly monitor cohort of people within the basin for exposure indicators & expression of health effects;	Epidemiological techniques will be used to illustrate trends in exposure and health effects;	Indicator will help link human health outcomes to levels of contaminant exposure;

F. Developing Sustainability

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Reinvestment in Natural Capital	To monitor balance between what is extracted from social & natural basis for life, & what is returned to the land & society; To promote projects designed to facilitate an equitable balance in future;	Measures include: amount of sustainable forestry, extent of watershed management & restoration programs, native fisheries & wildlife stocking, exotic species control & native plan repatriation, reclamation of mines and industrial sites, replacement of wetlands & biotic diversity;	
2. Quality of Human Life	To measure a range of social indicators to indicate the quality of life in the basin;	Measures include: incidence of crime; migration demographics, demands for social services, transportation infrastructure status, recreational & cultural opportunities, citizen involvement in decision making, public access to lakeshores, population density;	

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
3. Resource Consumption Pattern	To monitor types & quantities of resources consumed in basin, such as energy, water use & waste stream loadings;	Measures include: recycling programs, forest & mining resources remaining in basin, types of electric power generation, quality & volume of aquifers, tourism, depletion of wildlife and fisheries, landfill capacity & incineration volume, urban sprawl, loss of native flora;	
4. Awareness of Capacity for Sustainability	To implement a range of educational programs focusing on sustainability & to assess social conduct;	Measures include: environmental & sustainability education in schools, promotion of resource conservation programs, incorporation of ecological design into building codes, zoning regimes, popular support for environmental regulations, community outreach programs by natural resource agencies, media coverage of sustainability-related issues;	
5. Economic Vitality Measures	To understand the threats & opportunities to economic health of watershed, & implement projects to demonstrate sustainable alliance between environmental & economic sectors.	Measures include: per capita income, cost of living, extent of poverty, local employment trends, regional trade balance, diversity of communities economies, facilitation of transitional economies, value-added industry, regional & local tax bases.	

3.3 ECOSYSTEM GOALS

In order to achieve our vision of Lake Superior and in order to preserve, protect, and enhance healthy, sustainable ecosystems, the following ecosystem goals were established. In many ways, these goals describe the elements we wish to accomplish in the coming years (see Chapter 6 for additional details). We believe that, if we accomplish these elements, we will achieve the overall vision of Lake Superior.

OVERALL GOALS

- Diverse and healthy native plant and animal communities exist in the Lake Superior Basin.
- A program is in place to monitor the abundance, distribution, and health of plant and animal populations and communities in the Lake Superior Basin.
- Species at risk or species of concern are recovered if populations are too low, or controlled if populations are too large.
- A system of representative, high-quality habitats is established, and these areas are protected.
- No further extirpation of native species occurs in the Lake Superior Basin.
- No non-native species will be introduced into the Lake Superior Basin.
- An interagency effort to restore and protect critical habitats will be organized and initiated.
- Partnerships among natural resources management agencies, environmental agencies, and non-agency stakeholders are strengthened and broadened.

In 2003, the Binational Program workgroup ecosystem committees developed more detailed goals. These draft goals can be found below, in Table 3-3. These draft goals will be discussed at upcoming Superior Work Group meetings, and will be presented to the Lake Superior Task Force for their review and approval. These goals will be further refined by these groups, the Forum, and other interested stakeholders.

Table 3-3. Draft Ecosystem Goals for Habitat and Wildlife (Lake Superior Binational Program Work Group 2003)

#	DRAFT GOAL	DRAFT SUB-GOAL
1	Develop ecologically based integrated watershed management plans for all watersheds within the Lake Superior Basin (LSB).	
		Determine which watersheds have existing plans.
		Develop a list of watersheds that need a new or revised plan.
		Prioritize watershed list.
		Develop watershed plans for highest priority watersheds
2	Develop and establish a unified, binational GIS database that includes the most current and functioning basin-wide data and decision support models needed for ecosystem/watershed management. Develop and establish methods for providing data access and distribution - at a scale and in a format that supports Lake Superior Basin planning and watershed management.	
		Develop formal agreements (e.g., MOU/MOA's) for data sharing, participation, and support.
		Establish a mechanism to maintain shareable data once collected.
3	Develop information and educational material for local land use decision makers to implement Binational Program (BNP) goals through land use planning.	
		Have a BNP educator on staff to present material to local governments and decision makers highlighting linkages between land use and ecosystem health.
4	Provide an annual public and technical forum to provide opportunities for researchers and resource managers and public to exchange information. Build Lake Superior track into 2003 Society for Conservation Biology meeting in Duluth, MN.	

#	DRAFT GOAL	DRAFT SUB-GOAL
5	Protect important habitat sites in the Lake Superior Basin.	
		Publicly owned important habitat protected with special designations.
		Educate landowners regarding important habitat.
		Protection of public land important habitat sites.
6	Complete a biological/biophysical inventory for the entire basin.	
		Complete comprehensive, systematic Natural Heritage Inventory/biological surveys in the watershed to identify remaining high-quality natural communities and locations of rare plants and animals.
		Inventory extent of exotic, invasive, and terrestrial wildlife species.
		Inventory degraded habitats and communities on which terrestrial wildlife depend.
7	Inform and educate decision makers on how their actions move the basin toward a healthy Lake Superior vision.	
		Develop communications plan for # 7 above.
8	No new invasive exotics.	
9	Establish and implement Best Management Practices for a range of forestry, recreation, and intra-lake shipping procedures to prevent the introduction and spread of exotics.	
10	Complete inventory and control plan for priority existing exotic species at the scale of the Lake Superior Basin.	
		All agencies will institute treatment programs for priority species.
11	Institute a long-term Lake Superior Basin wide program to monitor ecosystem health utilizing standardized methodology.	
		Explore the development of an inventory, monitoring, assessment and reporting (IMAR) system for the basin and how it might be implemented.
		Develop, test, and implement standardized monitoring protocols, sampling procedures, and data handling for ecological indicators to enable BNP agencies to report on the status of the basin's ecosystem health (# of implemented indicators).
		Neotropical Migratory Birds
		Reptiles and Amphibians
		Soil Invertebrates
		Medium-Sized Carnivores
		Land Use Change
		Exotic and Invasive Species
		Rare Resources
		Culturally Important Resources
		Over Abundant Species
		Indicators of Contaminants in the Environment
12	Identify and restore ecologically-important areas which are degraded.	
13	Assess impacts to habitat at a basinwide scale from current and historic sources of degradation.	
14	Incorporate existing information about important habitat into the existing database.	
15	Restore 25 percent of degraded wetland acres in the Lake Superior Basin.	
16	Develop and distribute a GIS map of coastal wetland acres, types, and condition and areas where restoration can occur.	
17	Have in place a policy that results in zero loss of wetland acres and function.	
18	Restore or protect (e.g., via conservation easement) 25 percent of riparian conifer forest acres.	

#	DRAFT GOAL	DRAFT SUB-GOAL
19	Develop a guidance document for agencies' vegetation restoration for projects in the Lake Superior Basin.	
20	Encourage the appropriate use of native species for all projects requiring vegetation restoration.	
		Develop sources of native plants and seeds in an ecologically appropriate manner throughout the Lake Superior Basin for use in vegetation restoration.
		Establish standards of native species propagation and use as well as definitions of seed zones.
		Develop a list of critical native species that are regionally / habitat specific and ecologically appropriate.
		Educate citizens in the Lake Superior Basin about the importance and appropriate use of local native plants in restoration and landscaping projects.
21	Complete a Lake Superior IMAX film.	
22	Obtain the web site www.lakesuperior.info for our use.	
23	Eliminate biological impacts of contaminants in terrestrial wildlife.	
24	Determine which species are most impacted by contaminants.	

3.4 FISH COMMUNITY OBJECTIVES (2003)

The development of fish-community objectives for each lake is mandated by *"A Joint Strategic Plan for Management of Great Lakes Fisheries"* (Great Lakes Fishery Commission 1997). This multi-agency agreement also reflects a commitment to habitat protection and restoration through the following statement:

> *The Parties must exercise their full authority and influence in every available arena to meet the ecological, chemical, and physical needs of desired fish communities.*

Accordingly, these fish-community objectives highlight habitat issues. Table 3-4 presents fish community objectives by indicator or species (Horns et al. 2003).

Table 3-4. Fish Community Objectives (2003)

Indicator/Species	Objective
Overall Objective	Achieve no net loss of the productive capacity of habitat supporting Lake Superior fishes. Where feasible, restore habitats that have been degraded and have lost their capacity for fish production. Reduce contaminants so that all fish are safe to eat. Develop comprehensive and detailed inventories of habitats.
Prey Species	A self-sustaining assemblage of prey dominated by indigenous species at population levels capable of supporting desired populations of predators and a managed commercial fishery.
Lake Trout	Achieve and maintain genetically diverse self-sustaining populations of lake trout that are similar to those found in the lake prior to 1940, with lean lake trout being the dominant form in nearshore waters, siscowet lake trout the

Indicator/Species	Objective
	dominant form in offshore waters, and humper lake trout a common form in eastern waters and around Isle Royale.
Lake Whitefish	Maintain self-sustaining populations of lake whitefish within the range of abundance observed during 1990-99.
Walleye	Maintain, enhance, and rehabilitate self-sustaining populations of walleye and their habitat over their historical range.
Lake Sturgeon	Rehabilitate and maintain spawning populations of lake sturgeon that are self-sustaining throughout their native range
Brook Trout	Maintain widely distributed, self-sustaining populations in as many of the historical habitats as is practical.
Pacific Salmon, Rainbow Trout, and Brown Trout	Manage populations of Pacific salmon, rainbow trout, and brown trout that are predominantly self-sustaining but that may be supplemented by stocking that is compatible with restoration and management goals established for indigenous fish species.
Sea Lamprey	Suppress sea lampreys to population levels that cause only insignificant mortality on adult lake trout.
Nuisance Species	Objective 1: Prevent the introduction of any non-indigenous aquatic species that is not currently established in Lake Superior. Objective 2: Prevent or delay the spread of non-indigenous nuisance species, where feasible. Objective 3: Eliminate or reduce populations of non-indigenous nuisance species, where feasible.
Species Diversity	Protect and sustain the diverse community of indigenous fish species not specifically mentioned earlier (burbot, minnows, yellow perch, northern pike, and suckers). These species add to the richness of the fish community and should be recognized for their ecological importance and cultural, social, and economic value.

The fish-community objectives were developed in conformity with twelve guiding principles that summarize the values and practical realities that constrain or guide fisheries management on Lake Superior. Additional objectives pertain to prey species, lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), walleye (*Stizostedion vitreum vitreum*), lake sturgeon (*Acipenser fulvescens*), brook trout (*Salvelinus fontinalis*), pacific salmon (*Oncorhynchus spp*.), and trout (*Salmonidae spp*.), sea lamprey (*Petromyzon marinus*), nuisance species, and species diversity. Habitat issues impeding achievement of any objective are described. The most-pressing habitat concerns are in streams and embayments, and accordingly affect:

- Tributary-spawning species, including brook trout, walleye, and lake sturgeon
- Warm- or cool-water species, including yellow perch (*Perca flavescens*), northern pike (*Esox lucius*), and smallmouth bass (*Micropterus dolomieu*)

Although numerous non-native species have invaded Lake Superior, with the effective control of sea lamprey, the offshore fish community has returned to a condition broadly similar to that which existed prior to the modern era. The agencies envision an offshore fish community dominated by lake trout as the top predator and requiring the continued control or eradication of sea lamprey.

The Binational Program adopted the following overall objective for the aquatic community of Lake Superior:

> Lake Superior should sustain diverse, healthy, reproducing and self-regulating aquatic communities closely representative of historical conditions.

Consistent with those goals, the Lake Superior fishery-management agencies adopt the following fish-community goal:

> To rehabilitate and maintain a diverse, healthy, and self-regulating fish community, dominated by indigenous species and supporting sustainable fisheries.

Along with agreement on the overall goals, complex fishery management requires agreement on specific principles to guide the development of policies and programs. A combination of fisheries science, management experience, and public participation has led to the development of a number of widely accepted management concepts that are essential for establishing a consistent, cooperative management approach for Lake Superior.

3.5 COOPERATIVE MONITORING OF LAKE SUPERIOR INITIATED IN 2005

In 2001, U.S. and Canadian government agencies identified a need to improve coordination of Great Lakes monitoring activities. Great Lakes managers from Canada and the United States discussed the issues at a series of workshops and developed a set of recommendations for improvement. Based on these recommendations, a Great Lakes Cooperative Monitoring program was established.

The Cooperative Monitoring approach is above and beyond the routine monitoring programs that agencies normally conduct. It is a binational effort that focuses on one lake each year, with the goal of filling key information gaps as identified through the lakewide management programs. It complements and builds on other monitoring and research projects being conducted on the lake in the same year.

In 2004, a rotational cycle for Cooperative Monitoring was endorsed, with Lake Superior being the focus for both 2005 and 2006. The Lake Superior LaMP Work Group identified the following key information gaps: atmospheric and open lake concentrations of LaMP pollutants; screening of tributaries to identify sources of LaMP pollutants; status of the lower food web; a better understanding of the comparability of fish tissue contaminant data among agencies; herptile distribution and abundance in the Basin; and a method for measuring and reporting on land use change. In response, during the spring, summer and fall of 2005, numerous stations in the open lake and nearshore were sampled for LaMP pollutants and the lower foodweb;

additional air and precipitation samplers were installed at Sibley and Eagle Harbor; Canadian and U.S. tributaries have been sampled for LaMP pollutants. In 2006, a multi-agency intercomparison study is being launched to assess differences in fish tissue contaminant results as well as a pilot project to establish a herptile monitoring protocol. The projects conducted over these two years involve federal, state and provincial agencies, First Nations/Tribes and academia.

Sampling efforts conducted in 2005 have been completed and we are currently awaiting preliminary results. The information collected through the Cooperative Monitoring effort will be shared amongst the principal investigators in order to address LaMP priorities.

The Great Lakes Monitoring inventory of current monitoring and research programs on the Great Lakes was established and will allow a one-window access point to facilitate better cooperation and coordination.

3.5.1 Lake Superior Cooperative Monitoring Programs

In 2005 and 2006, Lake Superior is the focus of Cooperative Monitoring, addressing key information needs identified by the Lake Superior Binational Program Working Group. Numerous scientists from both the U.S. and Canada are participating, both in terms of providing input to the design of the programs, as well as conducting sampling, laboratory analysis, and data interpretation. There are many projects being undertaken, and although each one is independent, they each contribute to the bigger picture: a better understanding of Lake Superior. Below is a brief description of the activities to be undertaken in the Lake Superior Basin.

1. **<u>Chemical Concentrations in the Lake Superior Basin</u>**

Various media were sampled and analyzed for LaMP pollutants, including new and emerging compounds. This will provide updated information on current concentrations, as well as atmospheric loading estimates to the lake.

Water/Air: Three open lake cruises were conducted in Lake Superior in which water concentrations were measured for LaMP pollutants with an expanded list that included emerging compounds. Air samples were also collected to determine concentrations for selected compounds and air/water exchange for selected compounds was studied.

Air**:** Samples were taken during each of the three open lake cruises. An additional air sampler was co-located at Eagle Harbor that will sample for new and emerging compounds. This sampler has been refitted to remove all Teflon parts. This work will complement the existing IADN sampler at Eagle Harbor.

Precipitation: an additional precipitation sampler has been co-located at Sibley to sample for new and emerging compounds. This sampler has been refitted to remove all Teflon parts. This work will complement the existing IADN sampler at Sibley. The duration of this program will be one year.

Sediment: During the spring open lake cruise, bottom surficial sediments were sampled at every station for organic contaminants, including some new and emerging chemicals. Superior has been sampled for bottom sediments in the past and this will provide a spatial and temporal "snapshot" of the chemicals in 2005. Also, samples were taken for methyl mercury analysis. At some nearshore stations, core samples have been collected.

Fish: Currently, DFO has fish archives from 2004, and more fish were caught in 2005. These fish will be analyzed for the LaMP chemicals, including new and emerging compounds.

Lower Food Web: Net hauls were conducted on each of the three open lake cruises for zooplankton and mysids. Also, large volumes of water were filtered to capture bacteria. The resultant catch will be analyzed for the same list of compounds as fish.

Lake Siskiwet, Isle Royale: Bottom sediment, cores, water, fish and net hauls for lower food web were sampled for most LaMP and emerging chemicals. Samples from this site will be used as a reference samples as the area is impacted only by atmospheric inputs.

2. Fish Contaminants Intercomparison Study

The Chemical Committee also identified a need to better understand the differences in fish tissue contaminant data. In response to this, a phased-in multi-agency intercomparison program is being initiated. Phase 1 will collect information from all participating agencies on their field and analytical methodologies, as well as current concentration data; this will be reviewed for differences. The next two phases will compare laboratory variability. Phase 2 requires that each participating agency analyze an injection-ready reference standard (DFO is supplying the reference standard), while Phase 3 requires that each lab analyze a composite sample. At each Phase, discussions will be held to review the results.

3. Tributary Sampling for Source Trackdown

Since the Lake Superior Binational Program includes a commitment to Zero Discharge, the Chemical Committee identified a need to confirm the absence of inputs from tributaries. Sediment in the depositional zone of every accessible tributary (US and Canadian) that drains into Lake Superior was sampled for the LaMP chemicals, as well as metals and emerging contaminants.

4. Status of the Lower Food Web

The Aquatics Committee, in cooperation with the Lake Superior Technical Committee, identified a need for information on the status of the lower food web. In response to this, workshops were held with experts from both sides of the border to identify specific questions to be addressed, and to develop a comprehensive lakewide lower food web program as part of this cooperative monitoring initiative.

Open Lake Sampling: During the three open lake cruises scheduled for 2005, sampling was conducted at approximately 11 stations to determine biomass estimates of the lower food web. Net hauls were conducted to sample zooplankton, mysids and diporeia; ponars were used to sample benthic invertebrates; and water samples were collected for microbial food web. Additional boxcores were taken for amphipods, worms, and other invertebrates for stable isotopes and lipids. Also, nutrient samples (TP, TFP, Silica and chlorophyll a) were taken during all three cruises to supplement the lower food web information.

Nearshore Sampling by USGS and US EPA: Sampling for the lower food web was conducted during the regular fish trawls by USGS. Hydroacoustic surveys conducted by US EPA in summer 2005 proved useful as a new technology for lower food web sampling.

Nearshore Sampling (Impacted vs Unimpacted): Sampling was conducted by OMNR during the spring, summer and fall of 2005 at four sites. The sites chosen (Duluth, Thunder Bay, Apostle Islands, and Nipigon Bay) represent two sites from each country, with one site being impacted and the other site unimpacted. Net hauls were supplemented by sampling for nutrients.

5. Land-use Change

Several Lake Superior Committees (Sustainability, Habitat, Terrestrial Wildlife) identified a need for a protocol to measure and report on land-use change in the Basin, including monitoring recommendations. A breakout session at the 2004 SOLEC conference brought together experts in the field to initiate this discussion, however, further discussion at the Work Group level is required to define the questions to be addressed.

6. Herptile Monitoring - Pilot Program

The Terrestrial Wildlife Committee requested that herptile indicator monitoring be initiated in the Basin. A pilot scale monitoring program funded by GLNPO has begun and will continue through 2007.

7. Value-added Science

In addition to key information needs identified by the Lake Superior LaMP, additional science initiatives are being supported that will complement existing programs insofar as they can be accommodated. For example, meteorological buoys, radiation and temperature moorings will be deployed during the open lake cruises in support of a Climate Change project that will model the impact of climate on lake-atmosphere heat exchange, and the lake thermal and hydrodynamic response.

3.6 IMPAIRED BENEFICIAL USES (DUE TO CHEMICAL POLLUTANTS)

Annex 2 of the Great Lakes Water Quality Agreement requires that each LaMP assess impairment to14 beneficial water resource uses as the first step in identifying restoration and protection actions for each of the Great Lakes. The Lake Superior LaMP also recognizes that more than just these 14 beneficial use impairments will need to be addressed before Lake Superior can be fully restored. These other issues, or stressors, are discussed in other sections of the LaMP document.

For example, the 1991 Lake Superior Binational Program sets a goal of zero discharge for designated PBT substances. The Stage I LaMP identified six beneficial uses as impaired due to critical pollutants (Table 3-5 below). Impairments were noted for open-lake and nearshore areas. Data from Areas of Concern (AOC), their Remedial Action Plans (RAPs) and other nearshore areas were used together with data for open-lake areas. When an impaired beneficial use is identified, it means that impairment is occurring somewhere in that basin, not necessarily throughout the entire basin. The removal of use impairments is proposed as an environmental goal for all critical pollutants.

However, nine of the 23 critical pollutants were targeted for zero discharge. The Stage 2 LaMP (1999) sets load reduction targets for the nine zero discharge chemicals up to 2020. The other chemicals require remediation so that they are no longer critical (i.e., restoring beneficial uses through the RAP process or meeting lake ecosystem objectives). The critical pollutant focus of the LaMP therefore shifted to the nine zero discharge chemicals. While these nine contribute to beneficial use impairments, remediation would in most cases be insufficient to meet zero discharge goals. The emphasis in the LaMP therefore is on source reductions of chemicals including emissions and discharges in manufacture or as by-products, and proper disposal of products containing any of these nine substances.

As the ecosystem of Lake Superior changes over time, periodic assessments of each beneficial use will be needed. The LaMP hopes to have all beneficial use impairments assessed in future.

Table 3-5. Beneficial Use Impairments Associated with Critical Pollutants (Lake Superior Binational Program Work Group 1995)

Beneficial Use Impairments[a]	Status[b,c]	Indicators of Impairment
1. Restrictions on fish and wildlife consumption	Impaired due to PCBs, Hg, chlordane, toxaphene, dieldrin, DDE, and dioxin and furans.	Contaminants at levels at which agency or jurisdiction issues advisories to limit consumption
4. Fish tumors or other deformities	Impaired, associated with general contamination in Thunder Bay and Jackfish Bay, possibility of impairments in St. Louis River RAP Area of Concern.	Tumor frequency elevated
5. Bird or animal deformities or reproduction problems	Impaired reproduction (terns, bald eagles), associated with PCBs, Hg, DDE, dieldrin, and toxaphene. Also, habitat factors are likely important for lowered reproduction rates.	Reproduction below inland levels
6. Degradation of benthos	Impaired in most U.S. and Canadian RAP areas and other nearshore areas due to heavy metals (Cu, Pb, Cr, Zn, As, Ni, and Hg), PCBs, PAHs, dioxins, furans. Also, habitat factors are likely important.	Population structure “degraded”
7. Impacts on dredging; materials require special handling	Restrictions in St. Louis River, St. Mary’s River, Chequamegon, Thunder Bay, Nipigon Bay, and Peninsula Harbor. Elevated concentrations of PCBs, PAHs, Hg, Cd, Cu, Pb, Zn, Cr, Ni, As, Fe, Mn, or HCB.	Contaminants in sediment prompt special handling requirements for dredged materials
8. Eutrophication	Impaired in Nipigon Bay, and excessive phosphorus loading to St. Louis River.	Phosphorus or other indicators of eutrophication[d]

[a] Numbering corresponds to the order used in the Great Lakes Water Quality Agreement. A missing number indicates that the beneficial use is not impaired.
[b] The determinations are based on Remedial Action Plan (RAP) and other work summarized in the Stage 1 LaMP.
[c] This column includes the compounds causing the impairments. PCBs: polychlorinated biphenyl; PAHs: polyaromatic hydrocarbons; DDE: dichlorodiphenylethane; Hg: mercury; Cd: cadmium; Cu: copper; Pb: lead; Zn: zinc; Cr: chromium; Ni: nickel; As: arsenic; Fe: iron; Mn: manganese; and HCB: hexachlorobenzene.
[d] Phosphorus loading and eutrophication are problems in particular RAP areas. These issues are being addressed through the appropriate RAPs rather than through the LaMP.

3.7 REFERENCES

Lake Superior Binational Program (LSBP). 1998. *Ecosystem Principles and Objectives, Indicators and Targets for Lake Superior*. Lake Superior Work Group of the Lake Superior Binational Program, Thunder Bay, Ontario. 110 p.

Lake Superior Binational Program Monitoring Workshop Proceedings: Directions for Measuring Progress October 25-27, 1999. Holiday Inn Waterfront, Sault Ste. Marie, Ontario.

Horns, W.H., C.R. Bronte, T.R. Busiahn, M.P. Ebener, R.L. Eshenroder, T. Gorenflo, N. Kmiecik, W. Mattes, J.W. Peck, M. Petzold, D.R. Schreiner. 2003. Fish-community objectives for Lake Superior. Great Lakes Fish. Comm. Spec. Pub. 03-01. 78 p. March 2003.

Great Lakes Fishery Commission, 1997: *"A Joint Strategic Plan for Management of Great Lakes Fisheries"*.

Chapter 4

Lake Superior
Critical Pollutants Progress Report

Ontario power generation facility, Thunder Bay, Ontario.
Photo Credit: John Marsden, Environment Canada.

Lake Superior Lakewide Management Plan
2006

Chapter 4 Contents

Chapter 4
Lake Superior Critical Pollutants Progress Report

This report provides an update of activities related to critical pollutants in the Lake Superior Basin. It is organized to introduce the contents of two technical documents to be released later in 2006 and report on agency activities related to critical pollutants between 2004 and 2006. Those upcoming technical documents include:

- An assessment of the 2005 milestones from the Stage 2 LaMP and strategies for making progress toward the 2010 milestones; and
- A report on chemical integrity in Lake Superior that will be presented at the 2006 State of the Lakes Ecosystem Conference (SOLEC).

The technical milestones report will include a discussion of emerging contaminants and how they relate to Lake Superior. The chemical integrity report will include more detailed information on the concentrations of chemicals in the Lake Superior ecosystem and management recommendations.

4.0 THE ZERO DISCHARGE DEMONSTRATION PROGRAM

Reducing toxics loadings to Lake Superior is a key component in the effort to achieve a sustainable basin. The LaMP Stage 2 document sets a goal of eliminating discharges and emissions of the nine critical pollutants in the Lake Superior Basin by 2020, with interim targets in 2000, 2005, 2010 and 2015 (Table 4-1). The baseline for the reduction targets is 1990. The Lake Superior Binational Program's Zero Discharge Demonstration Program (ZDDP) is a unique experimental program intended to end the use of these nine critical pollutants in industrial processes or products, and to prevent their release in the Lake Superior Basin.

Table 4-1. Lake Superior load reduction schedule for the nine critical pollutants (percentage reductions).

Chemical	2000	2005	2010	2015	2020
Mercury	60	--	80	--	100
PCBs	33	60	95	--	100
Dioxin, HCB, OCS	--	80	--	90	100
Pesticides: Aldrin/Dieldrin Chlordane DDT/DDE Toxaphene	100	--	--	--	--

Why Zero Discharge for Lake Superior?

Among the Great Lakes, Lake Superior provides the best opportunity to achieve zero discharge and zero emission. The governments around Lake Superior announced *A Binational Program to Restore and Protect the Lake Superior Basin* in 1991, with an agreement to work together on the ZDDP and on broader ecosystem issues. The 1991 agreement stresses voluntary pollution prevention but acknowledges that enhanced mandatory controls may be necessary.

4.1 POLLUTANT CONCENTRATIONS IN THE ENVIRONMENT

Enforcement of environmental regulations, changes in industrial development patterns, implementation of pollution prevention, and the efforts of individual citizens have significantly reduced releases to Lake Superior. However, the goal of zero discharge and zero emission is a challenging one, and a significant amount of work remains to be done.

The ZDDP, and other programs, are aimed at reducing toxic chemicals at their sources, resulting in the eventual reduction in the ecosystem. Concentrations of a suite of toxic organic contaminants in water, including the Lake Superior critical and lakewide remediation pollutants, declined more than 50 percent between 1986-87 and 1996-97. Chemical contaminant data collected as part of the coordinated monitoring effort in 2005 will provide a current snapshot of concentrations in various components of the Lake Superior ecosystem

Table 4-2a identifies "yardsticks" for water quality in Lake Superior. These are standards from the four Lake Superior jurisdictions, current as of April 2006. These yardsticks will be used in determining the status of Lake Superior critical chemicals in the upcoming technical report. The most protective of these standards will be used for comparison purposes in this report. Table 4-2b shows concentrations of some persistent bioaccumulative toxic chemicals in Lake Superior water. As part of the technical reporting, the latest 2005 coordinated monitoring data will be added to Table 4-2b and compared to the yardsticks in Table 4-2a.

Table 4-2a. Jurisdictional Lake Superior water quality yardsticks for some LaMP critical pollutants (ng/L).

Pollutant	Water Quality Yardsticks (ng/L)			
	MN[1]	MI[1]	WI[1]	ON
PCBs	0.0045	0.026	0.003	1.0
HCB	0.074	0.45	0.22	6.5
Dieldrin	0.0012	0.0065	0.0027	1.0 (+Aldrin)
Chlordane	0.04	0.25	0.12	60
DDT	0.011	0.011	0.011	3.0 (∑DDE, DDD, DDT)
Mercury	1.3	1.3	1.3	200
Toxaphene	0.011	0.068	0.034	8.0
g-BHC (lindane)	80	25	18	10

[1] Water quality based standards for the Lake Superior states are based on the Great Lakes Water Quality Initiative methodology.

Table 4-2b. Concentrations (ng/L) of some critical pollutants in Lake Superior open lake water.

Pollutant	Open Lake Concentration
PCBs	0.0705[1]
HCB	0.014[2]
Dieldrin	0.126[2]
Chlordane	<0.03[3], 0.0099[4]
DDT	0.005[2] (p,p'DDE)
Mercury	0.71[5]
Toxaphene	0.7[6]
g-BHC (lindane)	0.357[3]

[1] Warren, G. (1996 data)
[2] Williams et al., 2004 (2001 data)
[3] Williams and Kuntz, 1999 (1997 data)
[4] Jantunen et al., in press (1996-1998 data)
[5] Dove, A. (2003 data)
[6] Muir et al. 2004 (1998 data)

A presentation summarizing current chemical contaminant concentrations and trends in the Lake Superior ecosystem was given at the Lake Superior Task Force meeting in November 2005 (Appendix C). Below is a summary of some key points discussed related to contaminant concentrations in the Lake Superior ecosystem:

- Lake Superior's physical, thermal, and biological properties make it unique and particularly sensitive to retaining PBT chemicals;
- Atmospheric deposition is main source of PBTs to the lake – some source regions have been identified;
- In general, concentrations of many legacy PBT contaminants have declined over time (i.e., government intervention has been effective);
- In most cases, concentrations in various media are decreasing at much slower rates or have leveled off over time;
- New chemicals of concern such as PBDEs are increasing in fish and sediments in Lake Superior; and
- Fish consumption advice is continually changing due to new monitoring data and new information on toxicological interactions of individual contaminants and contaminant mixtures.

4.2 LaMP ACCOMPLISHMENTS 2004 TO 2006

Actions undertaken or completed since the release of the LaMP 2004 report are summarized below. Earlier actions not reported in the 2004 update are also presented.

4.2.1 LaMP Chemical Reduction Activities

The following are the chemical reduction projects (directly related to the Lake Superior LaMP) that have been implemented since the LaMP 2004 update.

Figure 1. PCB transformer phase-out (Grand Marais, MN).

PCB Phase-out

- The Minnesota Pollution Control Agency (MPCA) used state and federal funding to work with three utilities to identify, test, and change-out 452 transformers suspected of containing PCBs.

Collections

- With Environment Canada and other partner funding, the six townships around the Thunder Bay area are conducting a hazardous waste collection event during 2006. The goal is to maximize the recycling of toxic compounds (e.g., mercury) and to minimize the disposal of hazardous waste through incineration.
- EcoSuperior, with support from Environment Canada and through a partnership with local small businesses, conducted an incentive program to divert electronic waste from a landfill. Participants were given a subsidy when they brought in computers and other electronic waste for recycling and proper disposal. Electronic waste contains many toxic substances, including mercury, and recycling is environmentally preferable to landfilling.
- EcoSuperior organized "Household Hazardous Waste Collections" in the Ontario North Shore towns of Nipigon, Red Rock, Schreiber, and Wawa. This initiative was supported by the Ontario Ministry of the Environment, Environment Canada, and participating municipalities. Events were well-publicized with high rates of participation.
- Under the Earth Keeper Initiative, the Central Lake Superior Watershed Partnership coordinated a Clean Sweep (hazardous waste collection) event in Michigan's Upper Peninsula. The "Clean Sweep" was sponsored by nine faith communities, two environmental groups, the Keweenaw Bay Indian Community, and Michigan Governor Jennifer Granholm's office of Faith-Based Initiatives. The Clean Sweep was an unprecedented success. A total of 45.7 tons of toxic materials were collected in the event, which was held on Earth Day, April 23rd. Wastes that were collected included: pesticides, herbicides, mercury (including over 40 pounds of raw mercury), oil-based paints and thinners, car batteries, anti-freeze, and harsh cleaners. The hazardous wastes

were distributed to the Delta County and Marquette County hazardous waste processing facilities. The Delta County facility received more hazardous waste in the Earth Keeper event (25.5 tons) than in the previous seven years, and the Marquette facility received (20.2 tons) more than it normally does in an entire year!

- The Grand Portage Band conducted a "white-goods/appliances" removal for proper disposal in the fall of 2004 (130 units), and fall of 2005 (48 units). The Band plans to continue these collections at least annually.

Figure 2. Mercury recovered in Ontario collections. Photo Credit: Jim Bailey, EcoSuperior.

- The Grand Portage Band conducted its first Business Hazardous waste removal during the summer of 2005. They collected and recycled 46 fluorescent lights. The Band anticipates that the amount of waste will increase as they continue to conduct these removals.

Open Burning Outreach

- Western Lake Superior Sanitary District (WLSSD) held a workshop called *Open Garbage Burning: Preventable Pollution* for local officials and produced a guide entitled *Clearing the Air: Tools for Reducing Residential Garbage Burning*.
  The workshop materials are available at:
  http://www.wlssd.com/Open_Burning/OB_Workshop.htm, and the guide is at:
  http://www.wlssd.com/Open_Burning/Clearing_the_Air_downloadvs.pdf.
- The Northwest Wisconsin Regional Planning Commission produced a video for open burning outreach with an emphasis on protecting Lake Superior.
- EcoSuperior conducted outreach to residents of rural communities around Thunder Bay, as well as to residents of the Canadian North Shore of Lake Superior. Activities included a workshop and multi-media campaign targeted at townships, parks, and First Nations communities.
- EcoSuperior set up displays discouraging open burning at pow-wows in the communities of Pays Plat, Pic River, and Rocky Bay.
- Guidance is being provided to seven rural townships in the vicinity of Thunder Bay to promote and increase recycling, and to reduce the practices of burning household garbage and garbage burning at landfills. Activities have included: a presentation to municipal officials on the hazards associated with garbage burning; qualitative audits of the individual landfills; and a follow-up training presentation for landfill staff in the late winter of 2006.
- A campaign to promote awareness of the hazards related to open burning was conducted with First Nations along the north shore of Lake Superior. Display booths, promotional materials, and presentations were available at a series of aboriginal conferences during 2004-2005. It was determined that the best method for transferring information is

through community events such as pow-wows, annual gatherings, and community feasts, and by publishing articles in local/First Nation publications. It was also determined that, in order for First Nations to move towards eliminating the practice of burning domestic garbage, additional and continued support is essential to establish a permanent recycling infrastructure. Presently, there are a limited number of First Nations that have available infrastructure to recycle or even for overall waste management. Support is needed in the form of long term financial commitments, capacity building, and education. The communities which committed to implementing a recycling project are Pic River First Nation, Pays Plat First Nation, Lake Helen (Red Rock) First Nation, and Biinjitiwaabik Zaaging Anishinaabek (Rocky Bay) First Nation. Ontario First Nations Technical Services Corporation prepared a proposal to establish a pilot recycling project for First Nations within the Lake Superior Watershed. The program is dealing with jurisdictional and policy issues prior to funding decisions and initiation of a recycling program.

- The Bad River Air Quality Department conducted a "Burn Barrel Buy Back Program" in the fall of 2005. Based upon windshield surveys of burn barrels located on the Reservation, and surveys conducted with tribal members who burn, this collection contributed to the reduction of approximately 2.5 tons/yr of pollution generated from backyard burning and a 25 percent reduction in the total number of burn barrels on the Reservation. To further the reduction of burn barrels and pollutants on the Reservation, another collection is scheduled for the spring of 2006.
- The MPCA used state and federal funding to work with four local governments to implement open burning abatement projects. The ongoing project has included a variety of activities including billboards, county fair displays, a compost bin outreach project, a video for firefighters, and a mini-drama presented to secondary schools by CLIMB Theatre.
- A second project for the MPCA was a barrel-for-a-barrel swap in which the agency purchased 100 rain barrels and exchanged them for burn barrels in the Duluth and Two Harbors, MN, area.

Figure 3. Burn barrels collected during MPCA's barrel-for-a-barrel swap. Photo Credit: Gina Temple-Rhodes, Western Lake Superior Sanitary District.

Mercury Products

- EcoSuperior, in conjunction with North Shore municipalities, has set up fluorescent light recycling programs for homeowners in Thunder Bay, Red Rock, and Wawa. The programs operate with the support of Environment Canada, Ontario Ministry of the Environment, and Ontario Power Generation. Many industries in North Shore towns also recycle fluorescent lights. MGM Electric Inc. in Thunder Bay operates a "pay-as-you-go" depot for commercial generators of fluorescent lights. This depot receives and recycles between 20 and 30 thousand spent lights per year.
- EcoSuperior, in cooperation with small business and industry, continues to operate effective programs to recycle standard, wall-mounted thermostats and fluorescent lights in Thunder Bay and North Shore communities. The thermostat program operates with support from Environment Canada, Ontario Ministry of the Environment, and Honeywell Inc.
- At the end of 2004, the City of Superior, Wisconsin, completed a three-year Wisconsin Great Lakes Protection Fund project for community-based mercury reduction. Over 400 pounds of elemental mercury, 10,000 fluorescent bulbs, and thousands of mercury devices were collected and recycled. Because of the city’s outreach, all dentists in the city have installed mercury amalgam separators. In September 2004, the City of Superior received the National Pollution Prevention Roundtable’s Most Valuable P2 Award for its outstanding educational outreach programs http://www.ci.superior.wi.us/publicwks/wastewater/p2index.htm.
- Murphy Oil USA and the City of Superior, Wisconsin, worked in partnership with funding from US EPA GLNPO to develop a mercury and PCB inventory at the refinery and develop a pollution prevention guidebook: “Prescription for Mercury and PCB Elimination, Mercury and PCB Reduction Guidance for Oil Refineries.” http://www.ci.superior.wi.us/publicwks/wastewater/p2index.htm
- Ontario continues to support the *Switch Out* program for mercury switches in automobiles. There are currently 204 recyclers in Ontario registered in the *Switch Out* program, 28 of which were new participants as of 2005. In 2005, 11,550 mercury switches were collected in Ontario. Most auto recyclers on the Canadian side of the Lake Superior Basin participate in the *Switch Out* program.
- Wisconsin kicked off a mercury switch recycling service that is free to auto salvage operators. An auto recycling trade association is assuming responsibility for continuing the program as government funding expires.
- The Ontario Ministry of the Environment is working with partners to develop: fluorescent lamp recycling pilots aimed at municipalities and schools; a pilot program for recycling mercury thermostats; and a mercury clean sweep event for schools.

Figure 4. Mercury compounds collected at Ontario schools. Photo Credit: Jim Bailey, EcoSuperior.

- EcoSuperior has visited high schools in Thunder Bay, Red Rock, Geraldton, Manitouwadge, Marathon, and Wawa, Ontario, to encourage mercury removal. Significant quantities of mercury have been removed for recycling, including: elemental mercury, mercuric oxide, mercuric iodide, mercuric nitrate, scientific thermometers, and assorted equipment containing mercury.
- Keweenaw Bay Indian Community has received funding to provide a mercury thermometer exchange for Tribal members.
- In September 2004, the Lake Superior Binational Forum held a government and industry summit entitled “Getting to Zero: Mercury Reductions and the Zero Discharge Demonstration Program.” Recommendations from the summit were used by a group of participants to develop a basin-wide mercury reduction project during the fall of 2004.
- In 2005, Wisconsin and Minnesota scoping projects determined opportunities for mercury reduction in Lake Superior Basin industries, particularly in the shipping industry. Forum industry members agreed to serve as peer mentors for a basin-wide mercury reduction project. WDNR and the City of Superior, Wisconsin, with input from the chemical committee and forum, developed a 12-page brochure to market the basin-wide mercury reduction and mentoring program for basin industries.
- The City of Superior, Wisconsin, received US EPA funding for 2005-6 to carry out the U.S.-side technical assistance for the basin-wide mercury reduction project. The grant will focus on the shipping industry with peer-to-peer mentoring available.
- A joint Work Group-Forum-Industry mentoring program is being conducted on the Canadian side of the Lake Superior Basin in order to audit and inventory elemental mercury at industrial facilities during 2005/2006. The mentor will also assist in assuring best purchasing and management practices, and will provide guidance for the responsible recycling of mercury, where required. Several site visits and workshops have already been conducted, and priority locations will involve any future paper mill and mine site closures and decommissioning exercises.

- Starting in May 2004, the MPCA swapped more than 255 mercury-free digital thermostats for mercury-containing thermostats in Grand Marais, Two Harbors, and Duluth, Minnesota.
- Red Cliff Band's mercury elimination coordinator carried out projects which included testing tribal buildings for mercury vapor with a Lumex, exchanging mercury thermometers and thermostats with digital models, and providing information to the community about mercury at health fairs and on a local radio program.

Ontario Landfill Workshop

- EcoSuperior, with the support of Environment Canada and Ontario Ministry of the Environment, conducted a workshop for townships, First Nations, and government officials involved in landfill operation. This workshop encouraged recycling, hazardous waste collection, and other waste minimization alternatives as well as discouraged open burning at landfills. EcoSuperior, with support from Environment Canada, is conducting a workshop for landfill attendants in March 2006.

Wastewater Infrastructure

- In January 2005, the Bayfield, Wisconsin, area broke ground for a new regional wastewater treatment plant. The plant is described as a "zero discharge" facility because it is designed to perform at a level that significantly exceeds state and federal standards. Local funding was supplemented by state and federal grants to pursue the "zero discharge facility" goal. In addition to conventional treatment, the plant will use an innovative filtering technology as well as energy saving and other green design elements on-site.

Sediment Remediation

- One of the first two U.S. *Great Lakes Legacy Act* projects was completed in November 2005 at Newton Creek and the Hog Island Inlet in Superior, Wisconsin (St. Louis River AOC). The $6.3 million project removed just over 60,000 tons of sediments contaminated predominantly with PAHs and lead. The Legacy Act project was the final step in the cleanup of 3-mile-long Newton Creek and Hog Island Inlet. Murphy Oil Co. in Superior cleaned up the upper reaches of Newton Creek in the mid-1990s, and Wisconsin Department of Natural Resources cleaned up the middle stretches in 2003. The project's connection to LaMP and RAP goals was instrumental in acquiring state and federal funding.
- Keweenaw Bay Indian Community's Sand Point stamp sand brownfields site soil cap/clean up project is scheduled to start in the spring of 2006. Capping and revegetating the site will reduce heavy metal sediment load entering Keweenaw Bay.

Superfund Activities

- The construction completion date for the Torch Lake Superfund Sites was September 23, 2005. The remedial action recommended under the Torch Lake Superfund Record of Decision for the Superfund Sites was for the uplands, capping with 6 inches of sandy loam with vegetative cover, and natural attenuation for Torch Lake proper. About half of the Superfund Sites were located within the Torch Lake AOC. The completed remedial actions help prevent additional copper and other heavy metal loadings to the lake by wind or water erosion from stamp sands and other mining by-products piled into and along the lake from historical mining and milling processes.

Inventory of Selected Toxic Chemicals for the Milestones Report, 2005

- In collaboration with U.S. efforts, the goal of this project is to complete the most recent Canadian inventory of sources and trends of selected toxic chemicals in the Lake Superior Basin. The information is being gathered from readily available sources, including government databases, private sector data, published documents, and other literature. Estimates of inputs from products, landfills, other sources and emissions from industrial, government, and energy-related sources will be compiled using accepted estimation methods. The inventory project will also review and update the 1990 LaMP Canadian baseline inventory with any new information as it becomes available.
- A similar inventory, funded by US EPA, is being developed on the U.S. side of the basin.
- Lake Superior Research Institute at University of Wisconsin, Superior, completed a US EPA funded project to evaluate priority sources and quality assurance information for dioxin emissions on the U.S. side of the basin.

Lake Superior Binational Forum Activities

- In February 2004, the Forum sent letters to local and regional schools, colleges and universities regarding mercury reduction and asking for input on how these institutions handle mercury usage and disposal and what challenges they face with respect to mercury use and disposal.
- A subcommittee of the Forum Chemical Committee was formed to work with a contractor on the mercury reduction project for the Lake Superior Basin to assist with peer-to-peer mentoring, industry visits, and moving the project forward.
- The committee helped to develop a workshop on mining trends and issues which was held in Hibbing, MN, in March of 2006.
- Additional Lake Superior Binational Forum activities are provided in Addendum 4A.

4.2.2 Other Projects Aligned with LaMP Goals

These are recent projects that were not a direct result of the LaMP but are in alignment with the LaMP goals:

Open Burning Survey

- The Minnesota Office of Environmental Assistance carried out a statewide survey of rural open burning practices. Residents of Northeastern Minnesota turned out to be better informed of the problems associated with open burning and had a lower rate of trash burning (36 percent) than the state as a whole (45 percent). Further information is available at http://www.moea.state.mn.us/lc/byburn/MOEABurnBarrelReport.pdf.

Air Defenders

- Air Defenders is an interdisciplinary, multi-media educational program and publicly available website (www.airdefenders.org) for students 10 years of age and older. It was developed by the State of Wisconsin in response to concerns related to household trash burning. Air Defenders is designed to help health officials and other community educators, as well as teachers, create hands-on classroom lessons for students about the dangers of burning trash. The Air Defenders kit has received national attention from US EPA for its focus on open burning. In 2004, the Wisconsin Department of Natural Resources received a Great Lakes National Program Office (GLNPO) grant to generalize the kit contents and produce and distribute 5,000 additional kits in the Great Lakes area. These kits were provided to the various state and provincial environmental agencies in late 2005.

Ongoing Collections

- The Northwest Wisconsin Regional Planning Commission conducts two annual clean sweep events in each Lake Superior County. In 2004, they completed a special project funded by the Wisconsin Great Lakes Protection Fund to conduct “milk run” collections. This cost-effective hazardous waste collection project was utilized by rural schools districts, government facilities, tribes, and small businesses.
- Grand Portage, Fond du Lac, Bad River, and Red Cliff either hold annual household hazardous waste collection events or offer sites where these materials can be brought for proper disposal.
- Grand Portage continues to implement a Pesticide Use Policy on the Reservation to help avoid unnecessary and unscrupulous spraying.
- In Minnesota, other hazardous waste collection programs are found in the Lake Superior Basin at WLSSD (both business and household), St. Louis County, Lake County, and Carlton County. Cook County contracts with WLSSD to conduct collections.
- In Michigan, other ongoing hazardous waste collection programs are found in Chippewa and Houghton Counties. In addition, there is a Clean Sweep program for mercury and pesticides in Marquette County. Information on both programs can be accessed at http://www.michigan.gov/deq/.

Wood Stoves

- A partnership of Environment Canada and the Hearth, Patio and Barbeque Association (HPBA) will be conducting a project to measure emissions from conventional woodstoves and verify historical emission factors.

Energy Conservation

- EcoSuperior delivers the "Energuide For Houses" program in Thunder Bay for Natural Resources Canada. This program advises homeowners on how to economically improve home energy efficiency and reduce emissions as part of Canada's climate change solution. Several hundred homes in Thunder Bay have been evaluated through this program. Retrofits that reduce energy consumption have been completed on many of these homes.
- EcoSuperior, in partnership with Thunder Bay Hydro, provided rebates for the purchase of Energy Star rated appliances, as well as education to homeowners about energy conservation. This program was extremely well subscribed.
- EcoSuperior, in partnership with Environment Canada, conducted programming and outreach as part of the Canadian “One-Tonne Challenge.” This program asks individual Canadians to take energy conservation measures sufficient to reduce greenhouse gas emissions by 1 tonne.
- LHB (a Duluth engineering/architectural firm) won a Lake Superior Binational Stewardship award for designing energy efficient buildings in and near the Lake Superior Basin, including Whole Foods Co-op, Minnesota Department of Natural Resource Consolidated Tower Headquarters, Members Cooperative Credit Union - Spirit Valley Branch, Northwoods Credit Union, and the McLean Environmental Living and Learning Center at Northland College.

Alternative Energy and Energy Issues

- Bad River passed a resolution (August 2005) approving a Renewable Energy and Energy Efficiency Tribal Task Force. As a result, they are currently collecting wind speed data for the possibility of wind energy development.
- Fond du Lac has received funding to pursue a biomass gasification unit which will be used at the Fond du Lac Ojibway School to reduce energy needs and costs. This unit will use wood left over from fire reduction work. Air monitoring of this unit will be conducted by the Fond du Lac air program. They are also looking into solar voltaic panels for the school.
- Fond du Lac has two anemometers installed and is getting good response from them. Data will be collected for a year, when decisions will be made as to the possibilities of wind energy on the reservation.
- Grand Portage is pursuing grants to set up a large wind turbine, as results from their anemometer studies were favorable for the possibility of wind energy development.
- WDNR is working with the state Public Service Commission to evaluate clean coal technologies that would have environmental benefits over traditional coal plants.

- The Federation of Municipalities announced a $50,000 Green Municipal Fund grant awarded to the town of Marathon to explore the feasibility of developing, constructing, and commissioning a mid-sized (20 to 50 MW) wind energy farm on the shores of Lake Superior. The field study involves the Town of Marathon and Marathon Pulp. Commissioning of the facility could provide a reduction of up to 56,000 tonnes of CO_2, 224 tonnes of NO_3, and 64 tonnes of SO_2, annually.
- Wind power proposals: Algoma – see 10 percent Renewable Energy Goal, below.

St. Louis River Mercury Total Maximum Daily Load (TMDL) Partnership

- A partnership of businesses, WLSSD, and environmentalists reviewed existing mercury reduction efforts in the lower St. Louis River region and developed a plan for filling gaps in these reduction activities. Further information is available at http://www.barr.com/PDFs/Papers/SLRP/SLRP%20mercury.pdf.

Sediment Remediation

- Using federal funding, the MPCA worked with a variety of partners in the St. Louis River AOC on a project to lay the groundwork for a Comprehensive Sediment Quality Management Plan. Partners continue to work together on the strategy. Further information is available at http://www.pca.state.mn.us/water/sediments/slr-qmp.html.
- Contaminated sediment characterization work has continued in Thunder Bay, Peninsula Harbour, and the St. Marys River AOCs.
- The Wisconsin Coastal Management Program is funding phase IV of the contaminated sediment GIS database for the St. Louis River AOC. The project represents a partnership between states and the St. Louis River Citizens Action Committee, and will allow mapping of contaminant concentrations throughout the AOC.
- Bad River and Red Cliff have been involved in the Ashland/NSP Coal Tar Site (Superfund) Remedial Investigation, as well the natural resources damage assessment. WDNR supports US EPA in its lead role on this Superfund site, which includes 10 acres of PAH-contaminated sediments in Chequamegon Bay.

Solid Waste Management

- In 2005, the Marquette County Solid Waste Management Authority removed over 75,000 pounds of toxic/hazardous material from the waste stream. These materials included household hazardous waste such as mercury, volatile organic compounds, and poisons.
- In 2005, the Marquette County Solid Waste Management Authority updated the landfill to run as a bioreactor, allowing the system to facilitate the treatment of waste. Part of this update was a cost reduction of leachate treatment from $0.06 to $0.003 per gallon discharged. This savings allows the Authority to invest in new technology and better controls.
    - Improvements include treatment of liquid wastes on-site and the break down and treatment of resilient toxic materials. Paint waste and metals are biologically treated and stabilized. The total control of batch treatment facilitates effective remediation of toxic/reactive materials found in the solid waste stream. Because

the system relies on treatment instead of dilution, the materials don't end up in the Lake.
  - The upgrade to the landfill also reduced the volume and increased the life of the facility. The organic portion of Marquette County's solid waste was reduced in volume by approximately 50 percent.

- As a result of legislative proposals and discussions, automobile manufacturers negotiated, through their trade association, the Alliance of Automobile Manufacturers (AAM), a 2004 agreement with Minnesota Waste Wise (MWW). Through the agreement, the MWW, a non-profit technical assistance arm of the Minnesota Chamber of Commerce, will operate a two year switch outreach, collection, transportation, and recycling program. About 350 salvage yards were found to be eligible. The collection program has begun with MWW conducting on-site visits. The Minnesota Office of Environmental Assistance will release a progress report in 2006.

- The Michigan Mercury Switch/Sweep (M2S2) Program began in August 2004 with a memorandum of understanding (MOU) between the Michigan Department of Environmental Quality (DEQ) and the Alliance of Automobile Manufacturers. The program's goal is to remove mercury switches from at least 80 percent of all end-of-life vehicles processed in Michigan annually. 8,000 switches were collected in the first year.

Stormwater

- Bad River conducted an annual flyover using hyperspectral, thermal, and straight photography for a non-point source pollution assessment with special focus on failed septics.
- Grand Portage will receive an EQIP grant (U.S. Dept. of Agriculture, Natural Resource Conservation Service, Environmental Quality Incentive Program) to create five rain gardens and conduct stream channel restoration near the lodge and casino. This is the beginning of numerous activities to reduce non-point source pollution in this area.
- Grand Portage has been complying with the NPDES Stormwater rules at construction sites.
- Education on the importance of stormwater controls to protect the western Lake Superior Basin is carried out cooperatively between the University of Wisconsin Extension, WDNR, Superior, Wisconsin, Duluth, Minnesota, South St. Louis County Soil Conservation District, and Minnesota Sea Grant. This includes the "View from the Lake" program conducted aboard the UW-Superior education vessel, the *L.L. Smith*, throughout the summer.

Wastewater Infrastructure

- The City of Thunder Bay, Ontario, completed construction of its new secondary sewage treatment facility. In addition to secondary sewage treatment, the new facility includes nitrification to eliminate ammonia from the wastewater. Plans for next year include construction of a cogeneration plant and a change in the disinfection process from chlorine treatment to ultraviolet radiation.

- Bad River completed the first phase of a long-term five-phase project, with the ultimate goal of bringing all failing systems up to code. Inspection and diagnosis of 146 septic systems and 69 septic tank systems within the boundaries of the Bad River Reservation were completed.
- Grand Portage completed a project extending sewer lines to connect 30 additional homes along the Lake Superior shoreline in the spring of 2004. They are planning to hook up more homes and businesses in the future.
- In the spring of 2006, Keweenaw Bay Indian Community will begin construction of sewer and water line extensions to serve lake front properties along the east shore of Keweenaw Bay.
- The City of Washburn, Wisconsin, completed an upgrade to its sanitary and storm sewers in 2005. A significant benefit of the project is the projected elimination (except for extreme “100 year” storms) of sewage bypasses to Lake Superior that have typically occurred during large storm events.

<u>Monitoring</u>

- The Great Lakes Indian Fish and Wildlife Commission (GLIFWC) completed studies of 37 PBT contaminants (including 7 of the 9 zero discharge pollutants) in Lake Superior lean lake trout and lake whitefish.
- GLIFWC also compiled contaminant monitoring data in the Lake Superior ecosystem and presented the results in a presentation entitled, *Chemical Contaminants in Lake Superior: Current Status and Trends*, to the Lake Superior Task Force in November 2005. See Appendix C of the LaMP 2006 report.
- Red Cliff continued a Surface Water Quality Monitoring Program that tests 21 different locations on the reservation for 22 different parameters including mercury, dioxin 2,3,7,8-TCDD, PCBs, toxaphene, and chlordane. Keweenaw Bay, Grand Portage, Fond du Lac, and Bad River currently have in place or are developing similar surface water quality monitoring programs.
- Bad River collected one year’s worth of total and methyl mercury in wet precipitation to: begin to characterize the extent of the mercury problem on the Reservation, supplement data from tribal fish assessments for methylation rates, and assess deposition changes over a short period of time.
- Bad River closed out one old Underground Storage Tank (UST) in October 2005. Another is still being monitored and they anticipate close out in June 2006.
- In 2005, MOE conducted a recovery study in the Kaministiquia River (which flows into the Thunder Bay Harbour). Sediment and water samples were collected and analyzed for contaminants such as metals, PAHs, PCBs, pesticides, and nutrients. Benthos samples were also collected for identification and enumeration.
- To address the “degradation of phytoplankton and zooplankton” beneficial use impairment in the Thunder Bay AOC, MOE conducted a total phosphorus and chlorophyll study in 2005.
- MOE collected sediment, water, and benthos in Lake George and Little Lake George in 2005. These two lakes are located within the St. Marys River AOC. Sediment and water were analyzed for contaminants such as metals, PAHs, TPHs, oils and greases, and

nutrients. Toxicity tests, using benthic invertebrates, were conducted using the collected sediment.
- MOE, with the assistance of Environment Canada, deployed suspended sediment traps upstream of the Bellevue Marine Park in the St. Marys River AOC in 2005. The purpose of this study was to determine the quality of the sediments depositing over the contaminated area, and to input this information into a sediment management plan.

Mercury at Taconite Processing Facilities

- Preliminary investigations by the Minnesota Department of Natural Resources indicate that the percent of ionic mercury can be increased by adjusting the taconite pelletizing process and that the ionic mercury can then be captured by wet scrubbers and may be diverted from emissions.
- Bench scale tests by industry show potential for mercury removal from effluent by taconite tailings. Levels in the final effluent were less than the Great Lakes Water Quality Initiative standard of 1.3 ng/L.

4.2.3 New Regulations and Policies Aligned with LaMP Goals

In addition to the activities described above, some government regulations and policies have taken place since the LaMP 2004 update that target releases of the nine chemicals slated for zero discharge. Those that are most closely aligned with contaminant sources in the Lake Superior Basin include the following:

Wisconsin Special Designation

- Lake Superior would be better protected from wastewater pollution under the 2005 proposed rule changes. These changes would expand the current state designation of Lake Superior tributaries currently classified as Outstanding Resource Waters, a designation triggering additional levels of protection. In addition, waters within one-quarter mile of the islands of the Apostle Islands National Lakeshore would also be classified as Outstanding Resource Waters. New or increased discharges in the Lake Superior Basin containing zero discharge pollutants would also be required to use best technology.

Figure 5. Boat at Silver Islet Harbor. Photo Credit: Carri Lohse-Hanson, MPCA.

Mercury Permitting Strategy

- In February 2000, the Michigan Department of Environmental Quality (MDEQ) implemented a mercury permitting strategy, including a multiple discharger variance. The strategy addresses implementation of US EPA's analytical Method 1631 in National Pollutant Discharge Elimination System (NPDES) permits issued during Fiscal Years (FYs) 2000 to 2004. The MDEQ has updated its strategy and multiple discharger variance for NPDES permits issued during FYs 2005-2009. The updates to the mercury permitting strategy include lowering the Level Currently Achievable (LCA) from 30 nanograms per liter (ng/L) to 10 ng/L and adding the option for reduced monitoring for facilities that average less than 5 ng/L of mercury in their discharge over a 12-month period. The revised strategy will further the goal of attaining the mercury water quality standard of 1.3 ng/L through the reduced LCA and continued implementation of pollutant minimization plans. In the Michigan portion of the Lake Superior Basin, all facilities are or will shortly be required to meet strict limits using US EPA approved sampling protocols and methods. Currently, one of the wastewater treatment plants and a landfill are required to meet the new LCA of 10 ng/L of mercury. In additional, a MDEQ Mercury Strategy Workgroup was formed in January 2006; this workgroup is developing a DEQ Mercury Strategy for Michigan.
- In Wisconsin, the WDNR initiated a requirement for municipalities that request a variance to the Great Lakes Water Quality Agreement water quality standard of 1.3 ng/L of mercury and discharge more than 1 million gallons per day. As part of the requirement, municipalities must submit a plan for a mercury minimization program. The plan must include implementation of best-management-practices for mercury by medical, dental, and school dischargers to the sanitary sewer system within two years, including the installation of amalgam separators at dental offices.

Amalgam Separation

- Ontario Regulation 196/03 requires dentists that place, repair, or remove mercury amalgams to install mercury separators that capture at least 95 percent of mercury particles and prevent discharge to sewers. It is estimated that the compliance rate for Ontario dentists is 99 percent, and the Royal College of Dental Surgeons of Ontario is following up on the 1 percent of remaining cases.
- The Superior District Dental Society (Marquette, Michigan), working with the Central Lake Superior Watershed Partnership and the Marquette Wastewater Treatment Plant, passed a resolution to voluntarily install mercury amalgam separators. The Dental Society represents 58 dental offices in Marquette and Alger County.
- According to the Minnesota Dental Association, there are currently 1,042 dental offices statewide that have already installed amalgam separators as part of the association's separator initiative. Another 300 offices have pledged to install separators. The participation rate is over 90 percent of all eligible offices.

Pesticides

- In 2005, an agreement was signed between the Ontario Ministry of the Environment and Health Canada Pest Management Regulatory Agency to coordinate surveillance, outreach, and enforcement activities relating to pesticides. MOE Pesticide Specialists design and deliver programs annually. In 2004, pesticide vendors were visited by MOE staff to determine compliance issues and information needs of the vendors. This continued in 2005, resulting in reminder letters outlining the errors vendors were making in storage and display, as well as sources of information that could be supplied to their clients.

Ontario Hazardous Waste

- In Ontario, the *Land Disposal Restrictions (LDR) Regulation* (Ontario Regulation 461/05) prohibits the land disposal of untreated hazardous wastes, as well as requires that wastes meet specific treatment standards. These treatment standards will significantly reduce the harmful components in the waste, or minimize the ability of the hazardous components to enter the environment once they have been disposed. The new rules will also apply to approximately 85,000 tonnes of hazardous wastes imported from the U.S. and other provinces for land disposal in Ontario.

New Ontario Air Standards

- A new provincial air pollution regulation, Ontario Regulation 419/05: Air Pollution – Local Air Quality, came into effect on November 30, 2005. The regulation includes: setting new and updated air standards for 40 harmful pollutants; updating air dispersion models; and implementing a new approach to set and implement air standards more quickly.

Ontario Source Water Protection

- The *Clean Water Act* was introduced in legislature in December 2005 to address the recommendations from the Walkerton Inquiry which pertain to the protection of drinking water sources. Justice O'Connor's report recommends that "Drinking water sources should be protected by developing watershed-based source protection plans. Source protection plans should be required for all watersheds in Ontario" (D.R. O'Connor 2002). The report also recommends that "The Ministry of the Environment should ensure that draft source protection plans are prepared through an inclusive process of local consultation. Where appropriate, this process should be managed by conservation authorities" (D.R. O'Connor 2002). This is being implemented on Lake Superior by the Lakehead Region Conservation Authority and the Sault Ste Marie Region Conservation Authority.

Canada-Wide Standards

- Ontario will eliminate mercury emissions from its coal-fired electric power generation plants by 2010 as part of a proposed Canada-Wide Standard (CWS) agreement. The CWS will achieve a 52 percent reduction in mercury emissions from this sector by 2010 through the installation of control technology, plant closures, and fuel switching. The CWS sets provincial caps for mercury for existing plants and new plant standards for new

coal-fired plants. The CWS also sets emission limits for new plants, using the best available control technology economically achievable.
- Ontario continues to implement the Canada-wide Standards for mercury and dioxins/furans from municipal waste, sewage sludge, hazardous waste, and medical waste incinerators. In the past year, the ministry included these limits in the Certificates of Approval for sewage sludge incinerators, whose limits came into effect on December 31, 2005.
- The Ontario Ministry of the Environment is in the process of amending the Certificates of Approval for electric arc furnaces to include the dioxin/furan CWS limits which will come into effect on December 31, 2006 (phase 1) and December 31, 2010 (phase 2).

Proposed Revisions to the Canadian *Chlorobiphenyls Regulations* and the *Storage of PCB Material Regulations* under CEPA.

- Proposed changes will include specific deadlines for ending the use of PCBs and destroying PCBs in storage. The proposed revisions will also introduce new labeling requirements and provisions for reporting the destruction of PCBs in storage and reporting the destruction of the remaining PCBs in use. The earliest proposal for action involves the end of use of all PCB equipment containing levels in excess of 500 mg/kg by December 31, 2009.

Canadian-Ontario PCB Storage Phase-Out Initiatives

- Various commitments have been made in the Canada-Ontario Agreement regarding the destruction of PCB material currently in storage. Ontario has set a goal to destroy all PCBs in storage by 2008.
- Canadian Municipalities initiated the Green Municipal Fund to increase environmental quality.
- The Government of Canada has endowed $550 million to the Federation of Canadian Municipalities to establish and manage the Green Municipal Fund. The fund supports funding partnerships of municipalities with the public and private sector to undertake projects which increase air, water, and soil quality and climate protection. Funding by the town of Marathon is being used to study the feasibility of a wind farm to augment energy requirements of the surrounding community (see further details under the Alternative Energy and Energy Issues section above).

Improving the Great Lakes PCB Inventory

- As part of the Binational Toxics Strategy, the US EPA is currently compiling PCB disposal information for 2004 and updating the PCB transformer registrations. Upon completion of the update, the US EPA will re-evaluate data gaps within the inventory. Environment Canada, Ontario Region is currently working to update its inventory by canvassing facilities throughout Ontario, with the ultimate goal of being able to more accurately state the percentage reductions to be achieved by 2006. The GLBTS PCB Workgroup should further examine the overall PCB equipment inventory program and spearhead improvements in the database. This should be completed in order to ensure that adequate PCB capacitor and transformer inventories exist, and that they can be easily accessed on a lake-by-lake basis. This improved Great Lakes inventory will allow for a better assessment of reductions to meet challenge goals in the Lake Superior Basin.

Ontario Targets 10 percent Renewable Energy by 2010

- The government of Ontario made a commitment to implement a Renewable Energy Policy with the goal to have 5 percent (1,350 megawatts) of all generating capacity to come from renewable energy sources by 2007 and 10 percent (2,700 megawatts) renewable energy by 2010. Renewable Energy projects planned for the Lake Superior Basin include a partnership of private investors and Pic River First Nation of White River to build the 23 megawatt Umbata Falls Hydroelectric project and the 99 megawatt Prince Wind Farm to be located in Prince Township, near Sault Ste Marie, Ontario. Further information is available at http://www.energy.gov.on.ca/index.cfm?fuseaction=english.renewable.

Ontario Targets Renewable Energy and Reductions to Greenhouse Gases

- Ontario Regulation 232/98 (*Landfilling Sites*) under CEPA requires the collection of landfill gas for new or expanding landfill sites larger than three million cubic metres or 2.5 million tonnes. The Thunder Bay landfill is licensed eight million cubic metres, and the facility is currently burning off methane gas and obtaining credits. The facility is also moving toward power production.

Minnesota Statewide Mercury Total Maximum Daily Load (TMDL)

- The MPCA is in the process of developing a statewide mercury TMDL. The TMDL focuses on deposition as the major source of mercury to Minnesota waters. The TMDL uses the more sensitive waters in northeastern Minnesota to drive emission reductions from sources in the state.

US EPA Regulations to Reduce Mercury Emissions from Coal-Fired Power Plant Emissions

- In 2005, US EPA issued the first-ever federal rule to permanently cap and reduce mercury emissions from coal-fired power plants. This rule makes the U.S. the first country in the world to regulate mercury emissions from coal-fired power plants. The Clean Air Mercury Rule will build on US EPA's Clean Air Interstate Rule to significantly reduce emissions from coal-fired power plants—the largest remaining sources of mercury emissions in the country. When fully implemented, these rules will reduce utility emissions of mercury from 48 tons a year to 15 tons, a reduction of nearly 70 percent.
- Although Wisconsin passed state regulations in 2004 to reduce mercury emissions from utilities by 75 percent by 2015, these regulations were superseded by the 2005 federal rule.

Tribal Activities

Figure 6. Grand Portage, Minnesota. Photo Credit: John Marsden, Environment Canada.

- Bad River has submitted a "final" draft to US EPA Region 5, requesting treatment in a manner as a state (TAS), under the *Clean Water Act*.
- Grand Portage completed the process of writing an Nonpoint Source Assessment Report (August 2004) and a Nonpoint Source Management Program (December 2004), and obtaining Treatment as a State (TAS) status from US EPA (January 2005).
- Grand Portage water quality standards were approved by US EPA on November 30, 2005. These standards are the same as or more restrictive than the State of Minnesota's standards.
- Bad River obtained Treatment as a State (TAS) designation under the Clean Air Act in February 2005 allowing the Tribe to comment on air pollution permits issued within 50 miles of the Reservation.

Great Lakes Regional Collaboration

- The Great Lakes Regional Collaboration effort resulted in a strategy adopted in December 2005. The strategy includes a series of recommendations, including the following related to toxic substances: 1) reduce and virtually eliminate sources of current priority pollutants, 2) prevent new chemical threats from entering the basin, 3) develop a sufficient knowledge base to address toxic chemicals in the Great Lakes environment, 4) protect public health and engage the public to do its part in reducing persistent toxic substance sources, and 5) address international sources.

4.3 CHALLENGES

4.3.1 Overall Challenges

More specific information on challenges will be contained in the milestones report that is currently under development. Generally the challenges can be summarized as follows:

- Inventories must be up-to-date and as accurate as possible. The PCB inventory has been a challenge as there is no comprehensive and up-to-date inventory.

- Outreach and coordination internally and externally are essential and must be strengthened.
- More easily achieved reductions have been accomplished, and the remaining sources will be more difficult to reduce.
- Out-of-basin sources continue to be a major source of deposition to the Lake Superior watershed.
- The topic of emerging chemicals must be addressed. As stated in the Emerging Contaminants section of this report: "Research that leads to development of criteria values for various relevant toxicological endpoints is sorely needed to judge the importance and potential impacts of the contaminant levels detected in the Lake Superior ecosystem."

4.3.2 Emerging Contaminants

The continuing discovery of chemicals used in industrial, agricultural, and personal applications in air, water, sediment, and biota has brought forth a formidable challenge for environmental scientists, managers, and policy makers. The universe of new chemicals being discovered in the environment is often lumped into a collective group referred to as "emerging contaminants". While it has been known for over 20 years that compounds such as pharmaceuticals enter the environment, improvements in instrumentation and analytical methodology for detecting chemical substances in environmental media have brought increased awareness and concern over the presence and potential risk that these chemicals may pose to the health of humans and other organisms in the environment (Daughton 2001).

What are emerging contaminants?

There are approximately 75,000 chemicals currently registered under the *Toxic Substances Control Act* (TSCA) inventory in the U.S. (US EPA 2005). Very few have regulations governing their release to the environment, and very few are the focus of contaminant monitoring programs (Daughton 2001). The term "emerging contaminants" has come to define an emerging awareness of the presence in the environment of many chemicals used in commerce, along with concern over the risk that these chemicals may pose to human and wildlife health.

Emerging contaminants are often grouped according to their typical anthropogenic uses. Examples of these groups include: flame retardants, fluorinated surfactants, personal care products, pharmaceuticals, detergents, plasticizers, antimicrobial agents, current-use pesticides, and others. Many of these compounds are released to the environment from municipal, industrial, and agricultural sources and source pathways (Daughton 2001). Table 4-3 provides an example list of some emerging contaminant groups, some of the chemicals that fall into those groups, and their general uses. These groups contain chemicals that may differ greatly in their chemical properties and level of understanding with regard to environmental fate and toxicology. Much research is being devoted to developing analytical methods for emerging contaminants, understanding their fate and transport properties in the environment, and determining what ecological and human health effects they may be causing.

Table 4-3. Examples of some common classes of emerging contaminants, some specific chemicals of interest in those groups, and some of their common uses.

Chemical Group	Examples of Chemical Uses
Flame Retardants • Polybrominated diphenyl ethers (PBDEs) • Polybrominated biphenyls (PBBs) • Tetrabromobisphenol A (TBBPA)	Retard flammability of plastics, foams, polymers, wiring insulation
Fluorinated Surfactants • Perfluorooctane sulfonate (PFOS) • Perfluorooctanoic acid (PFOA)	Fire fighting foams, water, oil, soil and grease repellents on surfaces such as carpets, fabrics, and upholstery
Personal Care Products • Triclosan • Benzalkonium chloride (BAC) • Synthetic musk fragrances	Anti-microbial soaps, perfumes, disinfectants, shampoos, etc.
Pharmaceuticals • Steroids • Hormones – estrogens and androgens • Caffeine • Cotinine	Over the counter, prescription, veterinary drugs
Detergents • Alkylphenol ethoxylates (APEs)	Industrial and institutional cleaning, metal finishing, textiles
Plasticizers • Phthalates	Added to plastic formulations to change rigidity
Current-use Pesticides • N,N-diethyltoluamide (DEET) • Dachtal • Chlorothalonil • Pyrethroid pesticides	Insect repellants, fungicides, insecticides, herbicides
Short Chain Chlorinated Paraffins (SCCP)	Mainly used in extreme pressure lubricants in the metal processing industry

What do we know?

Sources

Emerging contaminants are often found to be present in the environment in areas close to municipal sewage treatment facilities. Compounds such as pharmaceuticals and personal care products are rinsed down the drain, carried in runoff, or excreted as waste and end up at sewage treatment facilities. These compounds vary widely in their chemical properties, which affects how readily they are removed or broken down by current sewage treatment techniques. Depending on the chemical, current treatment can remove close to 100 percent of some of these chemicals, while others may only be reduced by less than 10 percent (Mills et al. 2005, Daughton 2001). Removal efficiency will also vary depending on the variety of compounds present and their concentrations in the input wastewater. Regardless of these removals as a co-benefit of current municipal sewage treatment, these facilities are not designed to specifically remove these compounds, and many are released to the environment. Concentrations in natural surface waters (including oceans) generally range from ppb (μg/L) to ppt (ng/L) (Daughton 2001).

Once into the environment, the fate of these chemicals released from municipal sewage treatment varies widely depending on the chemical structure of the compounds. Thus, the relative ability of a compound to elicit a biological response or cause environmental stress will be related to how biologically active it is, its concentration, its persistence, and how it behaves in a mixture of other similar compounds. For instance, compounds that have an estrogenic mode of action are often expressed in estrogen equivalent concentrations that relate the relative estrogenicity of each compound to the most potent estrogen, 17β-estradiol (Legler 2001). Whole effluent toxicity (WET) and toxicity identification and evaluation (TIE) are two methods that have been developed for evaluating chemical mixtures present in various effluents for their potential toxicity (US EPA 1991a, b and c, US EPA 2000). WET approaches are commonly used to identify the total toxicity of an effluent while TIE approaches are aimed at identifying the individual chemical component/s that cause toxicity within an effluent (St J. Warne, 2003).

While municipal sewage treatment facilities are a major source for many types of emerging contaminants, many other sources exist. For instance, many compounds used as flame retardants and coatings to repel water, oil, and grease are used ubiquitously. While small releases can occur from industrial manufacturing facilities, most releases occur as volatilization from products the compounds are used in. Other sources of emerging contaminants include veterinary use of antibiotics and hormones in pets, runoff from agricultural activities such as pesticide application, and hormones and antibiotics used in cattle and other animal production.

Chemicals such as polybrominated diphenyl ethers (PBDEs) and perfluorooctane sulfonate (PFOS) were manufactured to resist breakdown, which makes them effective for their designed uses, but also means that they will resist breakdown in the environment. These properties have led to their global distribution through many of the same pathways that have led to global distribution of PCBs and many organochlorine pesticides. PBDEs and PFOS have been shown to bioaccumulate and are toxic to some organisms in laboratory studies (Haglund et al. 1997, McDonald 2002, Boudreau et al. 2003), but their true significance as environmental pollutants is still unclear.

Research

To date, much of the work on emerging contaminants has focused on monitoring for their presence in the environment and developing methods to evaluate their potential toxicity to various organisms. The universe of chemicals used by society includes thousands of compounds that have not been analyzed for, much less have any information on environmental fate and transport, toxicity, and persistence. Many questions remain about whether emerging contaminants are truly an environmental concern and how they should be managed.

The properties of many emerging contaminants and the uses they are designed for in society are the same properties that have led to concern when they are found in the environment. Many of these compounds are designed to be biologically active, and the compounds themselves, their breakdown products, or the presence of the compounds in a mixture may cause unintended responses by organisms living in the environment. The theory of endocrine disruption describes how certain chemicals can behave in a similar manner to natural biological hormones, and when those chemicals are present at high enough concentrations in the environment, they can trigger unintended responses by the endocrine system. Examples of these types of responses that have been observed in organisms, particularly below municipal sewage treatment outflows, include reduced reproductive ability, abnormally elevated levels of certain proteins in male fish that are normally found only in females (i.e., vitellogenin), and intersex gonads, such as where female ovary tissue can be found distributed throughout the male testes (Giulio et al. 2004, US EPA 1997, Jobling et al. 2003).

Improving techniques in molecular biology allow researchers to measure responses to chemicals at the sub-cellular level. These techniques provide the possibility of being able to detect environmental stress at extremely low levels of biological organization. One of the big questions that remains unanswered is whether effects that are measured at the sub-cellular level have any relevance at higher levels of biological organization, such as at the population level. This missing link is critical to determining whether many of these compounds, that may cause observable effects to organisms near a point source, are actually causing harm on a greater scale.

Another concern is that these chemicals are not present individually in the environment. Chemicals in a mixture can interact in an additive, synergistic, or antagonistic manner. These types of effects are difficult to measure. While approaches such as WET and TIE offer some answers, prioritization of which anthropogenic chemicals currently in use are of the greatest concern is a growing challenge. These chemicals should be monitored and/or regulated to determine if their presence is a risk to the health of humans and other organisms in the environment. A further discussion on the questions and research gaps surrounding some emerging contaminants can be found on the US EPA's website at http://www.epa.gov/nerlesd1/chemistry/pharma/needs.htm.

Emerging contaminants in Lake Superior

Emerging contaminants have been detected in the Lake Superior ecosystem. Most studies to date have focused on brominated flame retardants (PBDEs and polybrominated biphenyls [PBBs]) as well as perfluorinated chemicals (PFOS and perfluorooctanoic acid [PFOA]). The following is an overview of some of these studies.

PBDEs have been detected in air at the Lake Superior Integrated Atmospheric Deposition Network (IADN) station at Eagle Harbor, MI (Strandberg et al. 2001). Concentrations of PBDEs were similar in air above all the Great Lakes and showed a strong urban signal from Chicago. Similar spatial results have also been found for PCBs.

Two classes of brominated flame retardants (total PBDEs and total PBBs) were measured in composites of six-year-old lake trout captured in 1997 from all the Great Lakes except Lake Michigan (Lake Michigan samples were not measured) (Luross et al. 2002). Lake Superior lake trout had the second highest PBDE concentrations (mean of 56 ppb) and the lowest PBB concentrations (mean of 0.25 ppb).

Archived lake trout tissue collected between 1980 and 2000 was analyzed for PBDEs and one PBB (#153) (Zhu and Hites 2004). Concentrations of PBB-153, a component of a flame retardant banned in the 1970s, did not show a significant decreasing trend as many other banned chemicals (i.e., PCBs, DDT) have. PBDEs increased exponentially with a doubling time of every 3-4 years. Similar results were also found in lake trout and/or walleye from the other Great Lakes.

Total PBDEs were detected at a mean concentration of 7.9 ppb in bald eagle nestling blood plasma samples collected from the Wisconsin shores of Lake Superior in 2000-2001 (Dykstra et al. 2005). This compared to a mean total PCB concentration of 51.5 ppb and a mean DDE concentration of 13.4 ppb also in samples from 2000-2001 (Dykstra et al. 2005).

Sediment cores from six off-shore locations in Lake Superior were analyzed for ten PBDE congeners (Song et al. 2004). In general, and in contrast to concentrations of PCBs in the same samples, PBDE concentrations were increasing significantly in recent years. The authors estimated an annual PBDE loading rate for Lake Superior at 80-160 kg/year.

Perfluorinated chemicals have been reported for surface waters and in lake trout from Lake Superior (Furdui et al., 2006a; Furdui et al., 2006b). Mean PFOS and PFOA concentrations of less than 1 ng/L were lowest in Lake Superior compared to Lakes Ontario, Erie, and Huron (Furdui et al., 2006a). In lake trout, the mean PFOS concentration was 5 ng/g and again was lowest for lake trout from the five Great Lakes. Similarly, total perfluoroalkyl contaminants (sum of perfluorosulfonates and perfluorocarboxylic acids) were lowest in Lake Superior lake trout (mean 13 ng/g) (Furdui et al., 2006b).

Emerging contaminants and yardsticks of environmental quality and LaMP pollutant management categories

Although emerging contaminants have been detected in Lake Superior, it is difficult to assess their ecological impacts without criteria to indicate levels that cause harm. Research that leads to the development of criteria values for various relevant toxicological endpoints is sorely needed to judge the importance and potential impacts of contaminant levels detected in the Lake Superior ecosystem.

The Lake Superior LaMP has used the term "yardsticks" to summarize the concept of a standard, criteria, or guidance value with respect to water quality, sediment quality, or biota tissue concentrations. The LaMP "Lake Superior yardstick" for a contaminant is the most stringent standard, criteria, or guidance value for a medium from any of the jurisdictions around Lake Superior. The presence of pollutants at levels exceeding the Lake Superior yardstick was a factor used to identify critical chemicals for the LaMP.

The LaMP has two major management categories for pollutants: critical and prevention (Table 2-1 Lake Superior LaMP Stage 2, 1999). Lake Superior critical pollutants include those targeted in the Lake Superior Zero Discharge Demonstration Program as well as lakewide and local remediation pollutants. In general, the list of prevention pollutants for the Lake Superior LaMP was derived from lists of bioaccumulative toxic pollutants addressed through U.S. and Canadian environmental initiatives in the mid 1990s (the US EPA Great Lakes Water Quality Guidance, 1995, and the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem, 1994). Pollutants in the prevention category 1) do not exceed Lake Superior yardstick values in the environment or 2) appear on the above-mentioned lists as bioaccumulative contaminants of concern, but have not been monitored in the Lake Superior environment.

The Lake Superior LaMP Stage 2 (1999) Appendix B describes the chemical pollutant management goal flow chart. Emerging contaminants do not fit easily into an established management category for Lake Superior because of the lack of yardstick values to judge potential impacts. In addition, there is no universe of accepted emerging concern contaminants as a starting point (such as provided by the GLI-COA lists for bioaccumulative pollutants in the 1990s). However, emerging contaminants fit into the overall management approach for Lake Superior prevention pollutants, which is to prevent the pollutants from becoming problems in Lake Superior in the future.

Emerging contaminants and the Lake Superior Binational Program

The Lake Superior Binational Program has recognized the importance of emerging contaminants to the future of management decisions in Lake Superior and to the overall health of the Lake Superior ecosystem. The milestones report that will be released later this year will include a list of strategies that lay a foundation for addressing issues related to emerging contaminants. Generally, the strategies will address the need for prevention, education, opportunities for pollution prevention, monitoring, and development of environmental quality yardsticks.

Monitoring efforts by the US EPA, Environment Canada, and Ontario Ministry of the Environment on Lake Superior in 2005 and 2006 will provide information on some emerging contaminants in air, precipitation, water, sediment, fish, and zooplankton.

4.4 NEXT STEPS

The LaMP Chemical Committee is preparing a milestones report for public comment. As noted previously, this report will assess progress towards the 2005 milestones from LaMP Stage 2 and the strategies for making progress towards the 2010 milestones. The draft should be available in Summer 2006 for public comment.

In addition, the Chemical Committee is preparing a chemical integrity report that will be presented at SOLEC 2006 in November 2006. This report will include more detailed information on the concentrations of chemicals in the Lake Superior ecosystem and management recommendations.

4.5 REFERENCES

Boudreau, T.M., P.K. Sibley, S.A. Mabury, D.C.G. Muir, K.R. Solomon. 2003. Toxicity of perfluorinated organic acids to selected freshwater organisms under laboratory and field conditions. MS thesis. University of Guelph, Guelph, ON, Canada.

Daughton, C.G. "Pharmaceuticals in the Environment: Overarching Issues and Overview," in Pharmaceuticals and Personal Care Products in the Environment: Scientific and Regulatory Issues, Daughton, C.G. and Jones-Lepp, T. (eds.), *Symposium Series 791*; American Chemical Society: Washington, D.C., 2001, pp. 2-38.

Dove, A., Environment Canada Surveillance Program. 2006. Personal communication, data from Lake Superior 2003 spring surveillance cruise, Ecosystem Health Division, Environment Canada, Burlington, Ontario.

Dykstra C.R., M.W. Meyer, P.W. Rasmussen, and D.K. Warnke. 2005. Contaminant Concentrations and Reproductive Rate of Lake Superior Bald Eagles, 1989–2001. *Journal of Great Lakes Research*. 31:227-235.

Furdui, V.I., Crozier, P.W., Reiner, E.J., Mabury, S.A. 2006a. Optimized trace level analysis of perfluorinated acids in the Great Lakes watershed. *Environ. Sci. Technol*., submitted.

Furdui, V.I., Stock, N., Whittle, D.M., Crozier, P.W., Reiner, E.J., Muir, D.C.G., Mabury, S.A. 2006b. Perfluoroalkyl contaminants in lake trout from the Great Lakes. Presented at the 41st Central Canadian Symposium on Water Quality Research, February 13 &14, 2006, in Burlington, Ontario, Canada.

Haglund P., Zook D.R., Buser H.R., Hu J. 1997. Identification and Quantification of Polybrominated Diphenyl Ethers and Methoxy-Polybrominated Diphenyl Ethers in Baltic Biota. *Environmental Science and Technology*. 31:3281-3287.

Jantunen, L.M., Helm, P.A., Ridal, J.J., Bidleman, T.F., *In Press*. Air-water gas exchange of organochlorine pesticides in the Great Lakes, including some chiral compounds. *Environmental Pollution*

Jobling, S., D. Casey, T. Rodgers-Gray, J. Oehlmann, U. Schulte-Oehlmann, S. Pawlowski, T. Baunbeck, A.P. Turner, C.R. Tyler. 2003. Comparative responses of mollusks and fish to environmental estrogens and an estrogenic effluent. *Aquatic Toxicology*. 65:205-220.

Legler, J. 2001. Development and application of in vitro and in vivo reporter gene assays for the assessment of (xeno-)estrogenic compounds in the aquatic environment. PhD thesis. Wageningen University, Utrecht, The Netherlands.

Luross, J.M., M. Alaee, D.B. Sergeant, C.M. Cannon, D.M. Whittle, K.R. Solomon, and D.C.G. Muir. 2002. Spatial distribution of polybrominated diphenyl ethers and polybrominated biphenyls in lake trout from the Laurentian Great Lakes. *Chemosphere*. 46:665-672.

McDonald, T.A. 2002. A perspective on the potential health risks of PBDEs. *Chemosphere*. 46(5):745-755.

Mills, M.A., G.D. Sayles, P. McCauley, R, Brenner, E.J. Kleiner. 2005. Wastewater treatment and its management of endocrine disrupting chemicals. Poster given at: United States Environmental Protection Agency Science Forum. Washington, D.C., May 16-18.

Muir, D.C.G., D.M. Whittle, D.S. De Vault, C.R. Bronte, H. Karlsson, S. Backus, and C. Teixeira. 2004. Bioaccumulation of Toxaphene Congeners in the Lake Superior Food Web. J. Great Lakes Res. 30:316-340.

Song, W., J.C. Ford, A. Li, W.J. Mills, D. Buckley, and K.J. Rockne. 2004. Polybrominated Diphenyl Ethers in the Sediments of the Great Lakes. 1. Lake Superior. *Environmental Science and Technology*. 38:3286-3293.

St J. Warne, M. 2003. A Review of the ecotoxicity of mixtures, approaches to, and recommendations for, their management. In *Proceedings of the Fifth National Workshop on the Assessment of Site Contamination*. National Environment Protection Council Service Corporation. Langley A, Gilbey M and Kennedy B (Eds). pp. 253-276.

US EPA (United States Environment Protection Agency). 1991a. *Technical support document for water quality-based toxics control.* Office of Water Enforcements and Permits, Washington, DC. EPA/505/2-90-001.

US EPA (United States Environment Protection Agency). 1991b. *Methods for toxicity identification evaluations.* TJ Norberg-King, DA Mount, EJ Durham, GT Ankley, LP Burkhard, JR Amaato, JT Lukasewycz, MK Schubauer-Berigan, L Anderson-Carnahan (Eds), EPA-600/6-91/003.

US EPA (United States Environment Protection Agency). 1991c. *Toxicity identification evaluation: Characterisation of chronically toxic effluents. Phase I.* EPA-600/6-91/005.

US EPA (United States Environment Protection Agency). 1997. Special report on environmental endocrine disruption: An effects assessment and analysis. EPA/630/R-96/012. Risk Assessment Forum, Washington D.C.

US EPA (United States Environment Protection Agency). 2000. Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testing (40 CFR Part 136). EPA/821/B-00/004.

US EPA (United States Environment Protection Agency). 2005. http://www.epa.gov/region5/defs/html/tsca.htm

Warren, G., US EPA, Great Lakes National Program Office, personal communication. 1996 data.

Williams, D.J., K.W. Kuntz and V. Richardson. 2004. Lake Superior Surveillance Program: Spatial Distributions and Temporal Trends of Selected Parameters, with emphasis on 2001 Data. Environment Canada Report #EHD/ECB-OR/04-02/I. 50pp.

Williams, D.J. and K.W. Kuntz. 1999. Lake Superior Surveillance Program: Spatial Distributions and Temporal Trends of Selected Parameters, with emphasis on 1996-1997 Data. Environment Canada Report #EHD/ECB-OR/99-01/I. 44pp.

Zhu, L.Y. and R.A. Hites. 2004. Temporal Trends and Spatial Distributions of Brominated Flame Retardants in Archived Fishes from the Great Lakes. *Environmental Science and Technology*. 38:2779-2784.

ADDENDUM 4-A: LAKE SUPERIOR BINATIONAL FORUM CHEMICAL COMMITTEE ACTIVITIES REPORT FOR 2004-2006

In February 2004, the Lake Superior Binational Forum sent letters to local and regional schools, colleges, and universities regarding mercury reduction. The Forum requested input on how these institutions handle mercury usage and disposal and what challenges they face with respect to mercury use and disposal.

Committee members worked with Lake Superior Work Group (SWG) members to help with a proposal to ban mercury thermometers in small communities, e.g. Manitouwadge, Ontario.

The Committee provided input to the SWG on their inventory of critical pollutant emission sources – including identifying additional significant source categories, ways to measure these sources, and identifying any missing sources of significance.

The Committee provided input to the SWG on their chemical strategies list including reviewing each strategy as to validity and currency, identifying gaps and identifying which activities were relevant to meeting the next milestones.

Committee members helped organize and plan a joint industry/Forum/SWG/Task Force meeting in September 2004 in Duluth to discuss issues and challenges faced by these groups toward achieving the goal of zero discharge.

The Committee sent comments to the Ontario Ministry of the Environment regarding the White Paper on Watershed-based Source Protection Planning and the Draft Ontario Source Protection Act.

A subcommittee of the Forum Chemical Committee was formed to work with a contractor on the mercury reduction project for the Lake Superior Basin to assist with peer-to-peer mentoring, industry visits, and moving the project forward.

The Committee is currently looking at developing a process for adding emerging chemicals of concern to the current list of critical pollutants.

Chapter 5

Human Health Information

Children at the beach.
Photo Credit: Liz LaPlante, US EPA.

Lake Superior Lakewide Management Plan
2006

Chapter 5 Contents

Chapter 5
Human Health Information

5.0 INTRODUCTION

The Lake Superior LaMP seeks to restore and protect the beneficial uses of the Great Lakes, such as safe beaches, clean drinking water, and healthy fish and wildlife populations. Awareness of the underlying causes of these beneficial use restrictions from chemical and microbial contaminants and the associated health consequences will allow public health agencies to develop societal responses protective of public health.

These beneficial uses include “Swimmability”, “Fishability”, and “Drinkability”. Swimmability means that all beaches are open and available for public swimming. Fishability means that all fish are safe for human consumption. Drinkability means that treated drinking water is safe for human consumption.

Chemical and microbial pollutants enter the human body through three major routes: ingestion (water, food, soil), inhalation (airborne), and dermal contact (skin exposure). Within the scope of the LaMP update, exposure to pollutants through water contact will be highlighted. The major areas of health concern in the Great Lakes Basin are pollutant exposure from ingestion of contaminated fish, incidental ingestion of water while swimming along beaches, and ingestion of contaminated water.

5.1 LaMP 2004-2006 ACCOMPLISHMENTS

5.1.1 Formation of the Great Lakes Human Health Network

In 2002, the Binational Executive Committee (BEC) approved the formation of a binational human health network. The Great Lakes Human Health Network has created a forum to discuss human health issues directly related to Great Lakes water quality. The network addresses health issues related to the ecosystem of the Great Lakes Basin, including drinking and recreational water quality and fish consumption.

In order to best serve Great Lake stakeholders, the U.S. and Canada took direction from the BEC and each formed domestic networks. The U.S. network took shape in 2003 and the Canadian network took shape in 2004. In the interim, there has been communication between Health Canada and US EPA as the domestic networks were formed. The U.S. and Canadian governments plan to join networks in 2006.

The U.S. network has held regular conference calls to exchange information. The members transmit the shared information to their organizations and the communities that they serve. The network also supports the LaMP and RAP processes. Current information on the U.S. network and its work may be found at www.epa.gov/glnpo/health.html.

Current Status of the (Canada - Ontario) Great Lakes Public Health Network

Background. In an effort to reduce human health risk from contaminants in the Great Lakes Basin, federal-provincial responsibilities are laid out under the Great Lakes Water Quality Agreement (GLWQA) and formalized by the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA). To support COA, one of Health Canada's commitments is to establish and facilitate the work for a Public Health Network in the Canadian portion of the Basin.

The purpose of the Great Lakes Public Health Network (GLPHN) is to facilitate information sharing on environmental health issues amongst all levels of government and their agencies that are mandated to protect public health in the Great Lakes Basin in Ontario. This Network is expected to assist members in the delivery of their environmental health programs. It is expected that this Canadian Network will join the American equivalent, Great Lakes Human Health Network (GLHHN), in 2006, to form a binational Network whereby there is a regular exchange of environmental health information across the border.

The Medical Officers of Health (MOH), who head the 37 Ontario Public Health Units, were identified as key partners in the establishment of the domestic GLPHN. Accordingly, Health Canada's Ontario & Nunavut Region has been working closely with the Ontario Ministry of Health and Long-Term Care (MOHLTC) to expedite cooperation with the MOHs. MOHLTC involvement has been substantial, including the organization of conference calls, a letter to the MOHs from the Chief Medical Officer of Health, and the assignment of a senior official in the Public Health Division to work with Health Canada.

Following the appointment of Dr. Sheela Basrur as the new Chief Medical Officer of Health in early 2004, Health Canada's Regional Executive met with her and reconfirmed the Ministry's commitment and support to the establishment of the Network. Health Canada has also dedicated resources to moving this initiative forward.

Status. During a consultation session with Ontario Public Health Units and Medical Officers of Health in December 2003, it was agreed that a working group be struck under the leadership of Health Canada and MOHLTC to design a structure for the environmental health network and write the terms of reference for a steering committee.

To this end, Health Canada and the MOHLTC in consultation with Environment Canada, the Ontario Ministry of Environment, Windsor-Essex Health Unit, Leeds Grenville Lanark District Health Unit, and Toronto Public Health have drafted a Terms of Reference for the Steering Committee and a draft Charter for the GLPHN. In the fall of 2004, a GLPHN Steering Committee made up of representatives from Ontario Public Health Units, Health Canada, MOHLTC, Environment Canada (EC), and the Ontario Ministry of the Environment (MOE) was formed.

The Network was launched in the fall of 2005 with plans for regular conference calls on relevant topics. The first two calls addressed consumption of Great Lakes fish (including blood mercury levels among Ontario anglers and sport fish eaters) and revisions to the Air Quality Health Index.

On the first call, over 50 individuals met by teleconference including Medical Officers of Health and staff from 26 Public Health Units and representatives from the Ministry of Health and Long-Term Care, the Ministry of the Environment, Environment Canada, the Canadian Food Inspection Agency, and the U.S. Environmental Protection Agency.

Future topics that are being considered for upcoming teleconferences include Pharmaceuticals and Personal Care Products (PPCPs), Pesticides, PBDEs and flame retardants, children's health and environment, health based air quality index, environmental and occupational causes of cancer, health risks of pesticides and best practices to reduce exposure, bluegreen algae and microtoxins.

It is expected that this Canadian Network will join its American counterpart later in 2006 to form a binational Great Lakes Human Health Network, thereby facilitating the regular exchange of environmental health information across the border.

NOAA Center of Excellence for Great Lakes and Human Health

The National Oceanic and Atmospheric Administration (NOAA), along with its scientific and academic partners, announced the creation of three research centers in Washington, South Carolina, and Michigan. These centers study how humans impact the oceans and Great Lakes and how, in turn, those bodies of water can impact human health.

Each center focuses on issues such as beach safety, seafood quality, coastal pollution, and marine toxins and pathogens. The centers work with each other as well as the four new research centers established by the National Science Foundation and the National Institute of Environmental Health Sciences.

The Great Lakes Environmental Research Laboratory (GLERL) in Ann Arbor, Michigan, uses multidisciplinary research to develop technology for predicting the formation of toxic algal blooms, beach closings, and water quality in the Great Lakes Basin. The goal of the center is to use GLERL's broad scientific expertise to significantly reduce threats to human health through ecological forecasting, which uses scientific understanding and models of climate, weather, circulation patterns, hydrology, land use, and biology to predict the location and severity of toxins in the water, beach closures, and water quality conditions. Key partners include: Michigan State University, University of Michigan, Florida Institute of Oceanography, US EPA, the U.S. Geologic Survey, and the NOAA Beaufort Laboratory. Dr. Stephen Brandt, director of GLERL, is the center's director.

For more information go to http://www.glerl.noaa.gov/res/Centers/HumanHealth/.

Children's Health Activities/Accomplishments

Children are different from adults and may be more vulnerable to environmental exposures. Consider that:

- Children's neurological, immunological, digestive, and other bodily systems are still developing and are more easily harmed;
- Children eat more food, drink more fluids, and breathe more air than adults in proportion to their body mass—their food, fluids, and air, therefore, must be safe;
- Children's behavior patterns—such as crawling and placing objects in their mouths—often result in greater exposure to environmental contaminants.

US EPA has forged partnerships and taken increasingly more steps to protect children's health from the variety of contaminants and pollutants that may affect them in the air they breathe, the water they drink, and the food they eat. We direct our efforts toward ensuring that their homes and schools are healthy and safe places where children can live and learn. Our goal is to insure that state, local and tribal governments, communities, school districts, and caregivers in the Great Lakes regions will understand the relationship between the environment and the health of children and will take action to improve the health of children by reducing risks and exposures to environmental hazards where they live and learn.

More information on children's environmental health can be found at www.epa.gov/children**.**

More information on school environmental health, including US EPA's new integrated assessment tool for school districts, Healthy School Environments Assessment Tool, can be found at www.epa.gov/schools.

Toxicity and Exposure Assessment for Children's Health (TEACH), www.epa.gov/teach, contains information pertaining to scientific literature in the field of children's environmental health for 18 chemicals or chemical groups of concern to children, which may potentially impact children's health. The goal of the TEACH project is to complement existing children's health information resources by providing a listing and summary of scientific literature applicable to children's health risks due to chemical exposure.

5.1.2 Accomplishments/Activities Related to Beaches Safe to Swim

Background. The Great Lakes Water Quality Agreement (IJC, 1994) calls for recreational waters to be substantially free from bacteria, fungi, and viruses. These microbial organisms of fecal origin have the potential to cause relatively mild illnesses (e.g., gastroenteritis) to more serious illnesses (e.g., hepatitis, typhoid fever) from a single exposure.

Lake Superior's myriad recreational activities do present opportunities for contamination to occur (i.e., swimming, water-skiing, sail-boarding, and wading). Apart from the risks of accidental injuries, the major human health concern for Lake Superior recreational waters is microbial contamination by bacteria, viruses, and protozoa (Health Canada, 1998; WHO, 1998).

To improve water quality testing at the beach and to help beach managers better inform the public when there are water quality problems, Congress passed the *Beaches Environmental Assessment and Coastal Health (BEACH) Act* in October, 2000. One of the provisions of the *BEACH Act* authorizes US EPA to award grants to eligible states, tribes, and territories to develop and implement beach monitoring and public notification programs at coastal and Great Lakes beaches.

Progress on Developing and Implementing Beach Monitoring and Notification Plans. Since passage of the *BEACH Act*, approximately $7.8 million in BEACH grants have been issued to Great Lakes states to implement beach programs, which has resulted in a significant increase in the number of monitoring and notification programs at Great Lakes beaches. All of the Lake Superior states have beach monitoring and public notification programs in place at most of their coastal beaches and at all of their high priority coastal beaches.

Following are beach program summaries for Michigan, Minnesota, Wisconsin, and Ontario.

A. Michigan's Beach Program. The Michigan Department of Environmental Quality (MDEQ) has received a total of $1,084,966 in *BEACH Act* funding since 2002 to support monitoring programs for 327 public beaches in 41 counties along the state's 3,200 miles of Great Lakes shoreline. Along Lake Superior:

- There are 40 total public Michigan beaches in nine counties.
- An estimated $32,275 (est. 12 percent of BEACH Act Fund for 2005) was distributed to monitor 21 beaches in seven counties on Lake Superior in 2005.
- Two closure events occurred at two beaches in Chippewa County totaling four days.

The monitoring of beaches in Michigan is voluntary and is conducted by the local health departments, which are required to notify various entities of the test results within 36 hours, and which may petition the Circuit Court for an injunction ordering the owners of a beach to close the beach. The MDEQ provides Clean Michigan Initiative-Clean Water Fund (CMI-CWF) and *BEACH Act* grants to the local health departments to aid in the implementation or enhancement of their beach monitoring programs. The CMI-CWF and *BEACH Act* grants are designed to fund proposals that determine and report levels of *E. coli* in the swimming areas of public beaches. The objectives of MDEQ's beach program are to:

- Assist local health departments to implement and strengthen beach monitoring programs.
- Determine whether waters of the state are safe for total body contact recreation.
- Create and maintain a statewide database.
- Compile data to determine overall water quality.
- Evaluate the effectiveness of MDEQ programs in attaining water quality standards for pathogen indicators.

Local health departments request an average of $380,000 of *BEACH Act* funds per year from the MDEQ for local beach monitoring programs for approximately 200 high-priority beaches. The *BEACH Act* allocation for Michigan provides funding to support monitoring once per week at 80 beaches for part of the summer and 100 beaches for most of the summer. In 1998, only 20 counties monitored their beaches. Since the MDEQ has been providing grants for beach monitoring, the number of counties with a beach monitoring program has risen steadily. Twenty-four counties monitored at least one of their beaches in 2000, 36 counties monitored in 2001, and 38 counties monitored in 2003 and 2004. Although no grant funding was available in 2002, monitoring was conducted in 26 counties.

All beach monitoring data are reported to and evaluated by the MDEQ. The MDEQ incorporates beach monitoring data into other water pollution prevention programs to encourage strategic improvements in water quality. Michigan's Beach Monitoring web site (http://www.deq.state.mi.us/beach/public/default.aspx) immediately provides current and historical test results for *E. coli* and beach closings/advisories as they are reported from health departments for all public beaches in Michigan. All public beaches are required to post a sign indicating whether the beach is monitored and where the results can be found.

B. Minnesota's Beach Program. The Minnesota Pollution Control Agency (MPCA) administers Minnesota's Beach Monitoring Program. The purpose of the program is to implement a consistent coastal beach water monitoring program to reduce the risk of exposure of beach users to disease-causing microorganisms in water. Approximately 58 miles of public beach and a total of 79 coastal beaches were identified along Lake Superior. Thirty-nine (39) selected beaches along Lake Superior are monitored in accordance with *BEACH Act* requirements with prompt notification to the public whenever bacteria levels exceed US EPA's established standards.

The state has received $816,870 in *BEACH Act* grants since 2001 to develop and implement beach monitoring and notification programs. A Beach Team comprised of state and local-level environmental and public health officials, and other interested parties, was formed to design MPCA's Beach Program. A standard sampling protocol was developed and standard advisory signs were designed based on feedback from Beach Team members and public meetings held in coastal communities. The 2005 beach season was the third full season that a consistently implemented beach-monitoring program was conducted in the coastal area of Minnesota. In 2005:

- There were 1044 monitoring visits.
- 39 sites were monitored once a week, May through October, for both *E. coli* and fecal coliform.
- 12 of the monitoring sites had one or more advisories posted during the monitoring season.
- Four of the monitored beaches were under advisory for most of July, August, September, and into October.
- 90 percent of Minnesota's Lake Superior beaches met bacteria standards more than 95 percent of the time.

MPCA has improved many aspects of its public notification process. The state has developed an exceptional interactive and informative web site (www.MNBeaches.org) which summarizes key information about beach advisories and closings. This site also provides information on beach logistics, amenities, and local weather. E-mail notices are automatically sent to interested parties. A local phone message is continually updated with the latest advisories (218-725-7724).

<u>*Minnesota Success Stories and Current Research Projects*</u>. At all 39 Lake Superior beaches, potential sources of pollution either on the beach or nearby have been identified. These sources include storm water discharges or streams with storm water discharges into them. The city of Duluth and the Western Lake Superior Sanitary District have conducted dye testing in the sewer lines and storm water pipe tanks to eliminate them as potential sources of bacteria at the New Duluth Boat Club site on Park Point. They have also conducted a limited amount of spatial testing to determine if there is one specific point of discharge. The University of Minnesota, Duluth, has received a grant from Sea Grant to research DNA fingerprinting at two of the more polluted beaches, including the New Duluth Boat Club beach. The sources of bacteria are as yet unknown, but further investigation will take place during the 2006 monitoring season.

The principal success of MPCA's Beach Monitoring Program is the continued public awareness the advisories bring to on-going water pollution issues. Since the MPCA started monitoring 35 beaches in 2002 (39 since 2005), the level of awareness of bacterial pollution of recreational waters in the region, as well as in the state, has risen dramatically. The understanding that wastewater overflows and by-passes can have an effect on beach water quality, even a short-lived one, has led to the demand for solutions to the inflow and infiltration problems in the region. Residents and tourists are starting to realize that bacteria problems can occur in any part of the Lake Superior Basin, but that they occur with more frequency in the most urban areas and during storm events. Residents and visitors are picking up after their dogs on a more regular basis. They continue to be vocal about sewage overflows and demand that they be corrected. The coastal cities are installing large holding tanks, back-up generators, and home sump pumps to slow and/or stop storm-related sewage overflows.

C. Wisconsin's Beach Program. The Wisconsin Department of Natural Resources (WDNR) operates Wisconsin's Beach Program. Since 2001, WDNR has received $907,196 in *BEACH Act* grants to develop and implement monitoring and notification programs at beaches along Lake Michigan and Lake Superior. Passage of the *BEACH Act* has enabled WDNR to substantially increase the number of beaches it monitors, from six to 127 coastal beaches. Along Lake Superior, Ashland, Bayfield, Douglas, and Iron Counties have 200 miles of Lake Superior shoreline. Among these counties, 35 beaches are monitored.

To design its beach monitoring and notification program, WDNR formed a workgroup composed of state-level environmental and public health officials and other interested parties. Using GPS technologies, 190 beaches were identified along Lake Michigan and Lake Superior. Additional GPS data layers were added to include the location of all wastewater treatment plant outfalls along with their proximity to the beaches. Additional information was collected for each beach which evaluates the potential for impacts from storm water runoff, bather and waterfowl loads, and the location of outfalls and farms. This information was used to rank and classify beaches as high, medium, or low priority. These rankings indicate how often the beaches should be monitored to ensure that water quality conditions are safe for swimming.

WDNR's public notification and risk communication measures were developed in collaboration with the workgroup and other stakeholders, including the public. These efforts included development of signs at beaches to give notice to the public that the coastal recreational waters are not meeting, or are not expected to meet, water quality standards. These signs, which are also in Spanish and Hmong, were designed based on feedback from a beach user survey and public meetings held around the state.

Other products that were developed include: an automatic e-mail service to which the public can subscribe to receive daily updates on beach conditions; a statewide informational brochure, approximately 100,000 copies of which were distributed at local beaches, parks, and health departments; a statewide Beach Health web page (www.wibeaches.us) for collecting monitoring and advisory data and reporting up-to-date conditions at all coastal beaches; and an internal web site for local health departments to report their daily advisory and monitoring data in the format required for US EPA reporting at the end of the beach season. The Wisconsin Beach Health web site is accessible to the public and stores up-to-date monitoring data and advisory information (www.wibeaches.us).

Current Research Projects. The *BEACH Act* funding was inadequate for a comprehensive monitoring program, so other funding was sought. Several groups have been brought together to create a comprehensive monitoring and source-tracking program. These groups include: the local health departments, Northland College, University of WI-Oshkosh, and the Lake Superior Alliance. The following objectives have been pursued by this collaboration:

- Investigate any high levels of *E. coli* with additional spatial sampling to assist in identifying the source of contamination. This includes investigation of tributaries, outfalls, and other inputs to Lake Superior in proximity to the beaches. This included vertical and horizontal sampling at several beach locations.
- Recovery of *E. coli* isolates from a variety of sources so that a database could be constructed to help determine the source of *E. coli* recovered from beach water samples. Over 2,000 *E. coli* isolates have been recovered from sources such as dogs, cattle, sheep, deer, gulls, geese, human sources, and from the beaches (beach water) under study.
- Investigate the implications of sampling at different water depths: 12, 24, 36, and 48 inches.
- Utilize genetic fingerprinting techniques, antibiotic resistance patterns, and spatial sampling to determine the source of beach water *E. coli* isolates.
- Conduct watershed investigations at select locations to determine impacts on beach water quality.
- Work with local health officials to mitigate any source of *E. coli* and beach contamination so that beaches can remain open and the public health is protected. Currently there are several proposals under consideration to mitigate *E. coli* at some of the locations with elevated levels.

Successes

- Testing Lake Superior's public beaches has spurred counties to test their local inland beaches as well. Vilas and Oneida Counties in northern Wisconsin modeled their inland

beach programs after the Wisconsin Coastal Beach Program and sampled 16 beaches in the summer of 2005.
- Twenty-seven Lake Superior beaches now have baseline *E. coli* data, and beach management decisions can be based on good scientific data.
- The use of genetic testing, antibiotic resistance patterns, and spatial sampling has identified several likely sources of *E. coli*.
- Identifying potential sources of contamination has allowed the process of source mitigation to begin.
- There have been several public meetings at several locations in the Lake Superior region to bring all interested parties together to discuss water quality and beach "health" issues.

D. Ontario's Beach Program. Ontario Public Health Units, who are responsible for the monitoring of Ontario public beaches, collect, document, and house detailed data on the beaches they monitor, including: a beach pollution survey or similar report, either historical, or done at the beginning of the bathing season, to include information on potential sources of contamination impacting the bathing beach area; *E. coli* data; beach postings data; and additional information on beach conditions on the day of monitoring (rain, winds, temperature, visibility, etc.). Ontario beaches are posted with warnings of possible health risks when elevated *Escherichia coli (E.coli)* densities are present. The recreational water quality guideline of 100 *E. coli* per 100 mL of water is set jointly by the provincial ministries of Environment and Health. *E. coli* are bacteria present in the droppings of virtually all warm-blooded animals and are the indicator bacteria for fecal contamination of surface waters. Generally, it is up to the Medical Officer of Health (MOH) for the local Health Unit to decide when a beach should be posted. Once a beach has been posted for elevated *E coli* levels, more frequent water samples are taken by the Health Unit. Beach Postings are removed after *E. coli* levels decrease to acceptable levels. The Ontario Ministry of the Environment has a historic database that identifies total annual beach postings for public beaches in Ontario from 1988 onward. Although a comprehensive database is not available, there are estimated to be more than 16 beaches on the Canadian side of Lake Superior. During 2005, at least three were closed for more than 10 percent of the time (see Addendum 5-A).

SOLEC staff are working with the Ontario Public Health Units and MOH to develop a central clearinghouse for beach postings/sampling data called SWMRS (seasonal water monitoring and reporting system) for use by Environment Canada and partners.

5.1.3 Accomplishments/Activities Related to Drinking Water

Background. Access to clean drinking water is essential to good health. The waters of the Great Lakes and surrounding areas are a primary source of drinking water for people who live in the Great Lakes basin. The average adult drinks about 1.5 liters of water a day.

Communities across the Great Lakes use basin water for drinking, bathing, and other household uses. This water is obtained from a variety of suppliers, both public and private. Public suppliers provide water, which is drawn from either surface water sources (including Great Lakes and/or surrounding waters), groundwater sources, or from a combination of these sources. For private suppliers, a large portion of permanent and seasonal residents use private water supply systems, water is drawn from wells or surface water sources (Health Canada 1998b). Therefore, health effects could be serious if high levels of some contaminants are present (Health Canada, 1993, 1997).

A variety of contaminants can adversely impact drinking water, including micro-organisms (e.g. bacteria, viruses, and protozoa such as Cryptosporidium), chemical contaminants (including naturally occurring chemicals and anthropogenic [synthetic] chemicals), and radiological contaminants – including naturally occurring inorganic and radioactive materials (IJC, 1996, Health Canada, 1997, Lake Erie, LaMP 1999, OME 2000). Some contaminants of raw water supplies, such as aluminum, arsenic, copper, and lead, can be both naturally occurring and/or result from human activities. Other contaminants, such as household chemicals, personal care products, pharmaceuticals, industrial products, urban storm water runoff, fertilizers, human and animal waste, nitrate (from fertilizers and sewage), and pesticides may also end up in raw water supplies (US EPA, 1999b, Health Canada, 1998b, Kolpin et al, 2002).

Sampling for Chemical and Biological Contaminants

Under the authority of the Safe Drinking Water Act (SDWA), US EPA sets standards for approximately 90 contaminants in drinking water. The categories of contaminants include:

- Microbial contaminants, such as bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife.
- Inorganic contaminants, such as salts and metals, which can occur naturally or result from urban storm water runoff, industrial or domestic wastewater discharges, oil and gas production, mining, or farming.
- Pesticides and herbicides, which may come from a variety of sources such as agriculture, storm water runoff, and residential uses.
- Organic chemical contaminants, including synthetic and volatile organic chemicals, which are by-products of industrial processes and petroleum production, and can also come from gas stations, urban storm water runoff, and septic systems.
- Radioactive contaminants, which can be naturally occurring or be the result of oil and gas production and mining activities.

For each of these contaminants, US EPA sets standards, which may take the form of a legal limit, called a maximum contaminant level, or a treatment technique, which requires a certain treatment. Water that meets these standards is safe to drink, although people with severely compromised immune systems and children may still be affected due to their increased sensitivity.

Under the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) water systems using a surface water source serving 10,000 or more people are required to monitor their source water for *E. coli*, *Cyptosporidium*, and turbidity for two years beginning in October of 2006. Water systems using a surface water source serving fewer than 10,000 people are required to monitor their source water for *E. coli* for one year beginning in October of 2008, and also monitor *Cyptosporidium* for two years if they exceed the *E. coli* trigger level. Depending on the level of *Cyptosporidium* in source water, systems are assigned bin categories that dictate the number of additional logs of *Cyptosporidium* protection they must provide beyond 2 log removal already required by the Interim Enhanced Surface Water Treatment Rule, and Long Term 1 Enhanced Surface Water Treatment Rule. Systems can use any combination of listed source, pre-filtration, treatment performance, additional filtration, and inactivation tools to provide the additional logs of *Cyptosporidium* protection.

For a more detailed description, or for more information about how standards are set, or for additional information about US EPA's Office of Ground Water and Drinking Water, go to http://www.epa.gov/safewater/. For the list of contaminants which are evaluated by the local water suppliers, go to http://www.epa.gov/safewater/mcl.html#mcls.

Route of Exposure and Associated Adverse Health Effects from Exposure to Contaminated Drinking Water

In Canada and the U.S., community water suppliers deliver high quality drinking water to millions of people every day, and a network of government agencies are in place to ensure the safety of public drinking water supplies (OGWDW 1999a). Although our drinking water is safer today than ever, problems can, and do, occur, although they are relatively rare. Localized outbreaks of water-borne disease have been linked to contamination by bacteria or viruses, probably from human or animal waste (US EPA, 1999b).

Some individuals or groups, particularly children and the elderly, may be more sensitive to contaminants in drinking water than the average person (Health Canada, 1993). Although drinking water quality guidelines are for the general population, they are based on health effects observed in the most sensitive subgroup of the population (e.g. lead and children).

Microbial contamination of drinking water can pose a potential public health risk in terms of acute outbreaks of disease. The illnesses associated with contaminated drinking water are mainly of a gastro-intestinal nature, although some pathogens are capable of causing severe and life-threatening illness (Health Canada 1995a). In most communities, drinking water is treated to remove contaminants before being piped to consumers. Municipal water supplies contaminated with microbial agents have been largely eliminated by adding chlorine or other disinfectants. By treating drinking water, we have virtually eliminated diseases such as typhoid and cholera. Although other disinfectants are available, chlorine still tends to be the treatment of choice. When used with multiple barrier systems (i.e. coagulation, flocculation, sedimentation, filtration), chlorine is effective against virtually all-infective agents. (US EPA and Government of Canada, 1995; Health Canada, 1993, 1997, and 1998b).

Government Actions to Protect Public Health

Ontario Source Water Protection. The *Clean Water Act* was introduced in the Ontario legislature in December 2005 (and is currently under review) to address the recommendations from the Walkerton Inquiry which pertain to the protection of drinking water sources. Justice O'Connor's Inquiry report recommends that "Drinking water sources should be protected by developing watershed-based source protection plans. Source protection plans should be required for all watersheds in Ontario" (D.R. O'Connor 2002). The report also recommends that "The Ministry of the Environment should ensure that draft source protection plans are prepared through an inclusive process of local consultation. Where appropriate, this process should be managed by conservation authorities" (D.R. O'Connor 2002, see also http://www.ene.gov.on.ca/water.htm). This is being implemented on Lake Superior by the Lakehead Region Conservation Authority and the Sault Ste Marie Region Conservation Authority. Additional information on the Ontario *Clean Water Act* can be found at http://www.ene.gov.on.ca/envision/water/cwa.htm.

Source Water Assessment and Protection Program Status. The *Safe Drinking Water Act Amendments of 1996* established the Source Water Assessment and Protection Program (SWAP) to help States locate and identify existing and potential threats to the quality of public drinking water for the purpose of fostering local efforts to benefit and protect the resource. States are responsible for assessing the condition of source water for all public water systems within their borders. Each assessment must include a delineation of the source water area for each public water system, an inventory of potential contaminant sources, a determination of the system's susceptibility to contamination from those sources, and must be made available to the public. Assessments are intended to be a useful tool in helping water system develop plans and implement measures to protect their water source.

Minnesota, Wisconsin, Illinois, and Michigan have completed all assessments. The focus of this program has now shifted to using the assessments to encourage States and local water utilities to develop source water protection plans and implement protection measures. US EPA and the States will be working to establish partnerships with volunteer and nonprofit organizations, and integrate source water protection with other regulatory programs in order to achieve results.

Long Term Objectives: By 2011, 80 percent of the community water systems will be substantially implementing source water protection plans.

More information on this program is available at the following Internet address http://www.epa.gov/OGWDW/protect/protect.html.

Water Quality Tracking. A key action was set in the *2002 Great Lakes Strategy* that, "Beginning in 2002, the US Environmental Protection Agency (US EPA), in cooperation with local utilities, will track water quality at the intake points of selected drinking water treatment plans around the Lakes. Findings will be reported to the public through the biennial State of the Lakes Ecosystem Conference (SOLEC) State of the Lakes report." See http://www.epa.gov/glnpo/gls/gls04.html.

For 1999-2001, the US EPA has examined data provided by 41 public water systems in the Great Lakes Basin and by the U.S. Safe Drinking Water Information System. Specifically, US EPA has evaluated various contaminants, including the following:

- Atrazine, an agricultural pesticide;
- Nitrate and nitrite, which are naturally occurring nutrients found at high levels in fertilizers; and
- Total coliforms, *E. coli*, *Giardia*, and *Cryptosporidium*, which are microorganisms that may contaminate water supplies after sewage spills.

US EPA has also examined the turbidity, taste, odor, and organic carbon content of drinking water supplies to assess any other potential health issues. Of the public water systems evaluated between 1999 and 2001, none exceeded drinking water standards for atrazine, and only one exceeded drinking water standards for nitrate and nitrite after treatment. However, atrazine, nitrate, and nitrite are detected at elevated levels in the Great Lakes, which indicates that advanced treatment technologies prevent the entry of significant concentrations of these contaminants from entering drinking water systems. For total coliform and *E. coli*, only one violation of drinking water standards occurred between 1999 and 2001 in the Great Lakes Basin. Finally, public water systems rarely have problems with turbidity, taste, odor, or organic carbon content.

For 2002-2003, the US EPA has examined data in annual Consumer Confidence Report/Water Quality Reports (CC/WQRs) for 57 public water systems' in the Great Lakes Basin for operational year 2002 (2003 when available) and in the U.S. Safe Drinking Water Information System. U.S Water Treatment Plants (WTPs) are required to provide an annual CC/WQR to their customers which includes information on source water type, the water treatment process, contaminants detected in finished water, any violations, and other relevant information. Specifically, US EPA has evaluated the same contaminants and other parameters to assess any other potential health issues described above. The U.S. Safe Drinking Water Information System was used as a means to verify violation information presented in the CC/WQRs and to provide other relevant information, where CC/WQRs were not available.

Of the public water systems evaluated between 2002 and 2003, none exceeded drinking water standards. Organic carbon was detected in finished water from WTPs using all source types (Great Lake, rivers, small lakes/reservoirs, and groundwater) except those using Lake Huron and Lake Superior source water.

The Ontario Drinking Water Surveillance Program (DWSP) is a voluntary program operated by the Ministry of the Environment (MOE) in cooperation with municipalities to gather scientific data on drinking water quality in Ontario. From 2000 to the end of 2002, 179 municipal drinking-water systems were collecting samples for the program. Laboratory analyses are provided by the MOE and the Ministry of Labour.

Summaries and detailed reports for the 179 municipal drinking-water systems that were monitored from 2000 to 2002 are provided on a web site (http://www.ene.gov.on.ca/envision/water/dwsp/0002/index.htm) as part of the Ontario government's commitment to make information about drinking water readily available to the public. Results showed that 99.8 percent of the tests performed for chemical, physical, and radiological parameters in treated drinking water and water in the distribution systems indicated non-adverse water quality conditions. Tests for microbiological organisms, such as *Escherichia coli (E. coli*), are performed routinely by each drinking-water system and were not monitored by the DWSP.

Over 555,300 inorganic, organic, and radiological tests were performed on raw water, treated drinking water, and water in the distribution systems. Of the over 121,700 tests for chemical, physical, and radiological parameters in treated drinking water and water in the distribution systems, over 121,500 test results met the health-related Ontario Drinking Water Objectives / Standards. One hundred and ninety test results exceeded a health-related objective / standard. The health-related objective / standard for atrazine plus N-dealkylated metabolites, chloramines, fluoride, lead, N–nitrosodimethylamine (NDMA), nitrates, selenium, total trihalomethanes, and turbidity were exceeded on at least one occasion at 35 municipal drinking-water systems for the 2000 to 2002 monitoring period. In addition, of the 3,950 tests reported for free and combined chlorine residuals, over 3,930 test results were above the minimum criteria for disinfectant residuals. Sixteen test results, at nine municipal drinking-water systems, were below the minimum criteria for disinfectant residuals resulting in adverse water quality.

The MOE has developed new rules to ensure that information about drinking water testing is disclosed to the public on a regular basis. These new rules came into effect on August 26, 2000, with the implementation of the *Drinking Water Protection Regulation for Larger Waterworks* (Ontario Reg. 459/00). As of June 1, 2003, under the *Safe Drinking Water Act*, the Drinking-Water Systems Regulation (Ontario Reg. 170/03) came into effect, superceding Ontario Reg. 459/00.

Prior to Ontario Reg. 459/00, standard DWSP practice was to inform the operating authority and the MOE district manager with a DWSP “Alert Notification” when a health-related objective was exceeded. It was the responsibility of the operating authority to address the issue and to notify the local Medical Officer of Health. DWSP analytical results were also sent to the operating authority when the analyses were completed.

The Drinking-Water Systems Regulation stipulates that the owner of a water treatment or distribution system is required to ensure that notice is given to the local Medical Officer of Health and to the MOE if a parameter does not meet the Maximum Acceptable Concentration (MAC) or Interim Maximum Acceptable Concentration (IMAC) of the Ontario Drinking Water Quality Standards (ODWQS) (Ontario Reg. 169/03), or if a test result indicates adverse water quality. The Medical Officer of Health, through the *Health Protection and Promotion Act* (Chapter 10, Part 3, Sections 10, 11, 12, and 13) has the authority to judge if drinking water is safe for human consumption.

ODWQS are the provincial standards of drinking water quality, most of which have been adopted from the Canadian drinking water quality guidelines established by the Federal-Provincial-Territorial Committee on Drinking Water. The guidelines are derived from risk assessment based exposure limits as modified by a risk management process incorporating review of the geographic scope and prevalence of the contaminant, available technology to remove it and associated costs. Several provinces, including Ontario, also set unique limits for parameters specific to their provincial drinking water quality.

Comprehensive compliance inspections are performed annually by the MOE at all municipal drinking-water systems. Where necessary, MOE staff issue Provincial Officer Orders that direct owners and operators of municipal drinking-water systems as to what must be done to bring their supplies into compliance. Ministry staff follow up to ensure compliance with all Orders.

For further information on drinking water testing done by individual municipalities as required by the Drinking Water Systems Regulation, including drinking water annual reports, readers are urged to contact the municipality.

Parasites. Parasites such as *Giardia* and *Cryptosporidium* (the most common source of which is animal feces), which are resistant to common disinfection practices, may pass through water treatment filtration and disinfection processes in sufficient numbers to cause health problems (Health Canada 1998a).

For example, in 1993, Milwaukee, Wisconsin, experienced a widespread outbreak of Cryptosporidiosis that affected over 400,000 residents, causing severe diarrhea, nausea, stomach cramps, and other symptoms. While most people recovered without treatment, the outbreak contributed to the deaths of at least 100 people already ill with AIDS-related illnesses, cancer, or other maladies. The outbreak was caused by *Cryptosporidium* oocysts that passed through the filtration system of one of the city's two water-treatment plants (WI DNR 1994, WI DNR 1998, Health Canada 1997).

Boiling water is the best method for killing *Cryptosporidium* and other harmful microorganisms in emergency situations (Health Canada 1997), and "Boil Water" orders are generally the standard public health protection method when drinking water is found to be contaminated. Since the Milwaukee outbreak, US EPA has strengthened treatment requirements and standards for public water supplies using surface water. Health Canada, in collaboration with the provinces, is currently developing a drinking water guideline for *Giardia* and *Cryptosporidium*, is reviewing its turbidity guideline, and recently published a document titled "Guidance for Issuing and Rescinding Boil Water Advisories" (November 1998, revised March 1999), as a tool for health and environment authorities who must make the decisions concerning boil water advisories.

Drinking Water Academy. Established by the US EPA Office of Ground Water and Drinking Water, the Drinking Water Academy (DWA) is a long-term training initiative whose primary goal is to expand US EPA, State, and Tribal capabilities to implement the 1996 *Amendments to the Safe Drinking Water Act* (SDWA). In addition to providing classroom and web-based training, the DWA is a resource for training materials pertaining to SDWA implementation. The DWA website is at http://www.epa.gov/safewater/dwa.html.

Drinking Water Security Education Materials. The US EPA has recently developed a collection of useful education and resource materials on drinking water security. The information includes resources on emergency preparedness, drinking water security, and law enforcement information. All materials can be found at http://www.epa.gov/safewater/security/flyers/index.html.

Emerging Issues

Water Infrastructure Security. Under both the *Safe Drinking Water Act* (SDWA) and the *Clean Water Act* (CWA), US EPA works closely with partner organizations — other government agencies, and water utilities and associations (both drinking water and wastewater) to ensure clean and safe water. Industry and government are also working cooperatively to improve drinking water and wastewater security. Building on and supporting long-established relationships with our partners, US EPA helps the water sector to: (1) understand and utilize the best scientific information and technologies for water security; (2) support assessment of utilities (i.e., vulnerabilities to possible attack); (3) take action to improve security; and (4) respond effectively and efficiently in the event that an incident occurs.

This commitment is outlined in US EPA's Strategic Plan for Homeland Security.

A number of actions are underway to:

- Support development of tools, training, and technical assistance for small and medium drinking water, and wastewater utilities; and
- Promote information sharing, and research on water security.

Public Health Security and Bioterrorism Preparedness and Response Act of 2002. Drinking water utilities today find themselves facing new responsibilities. While their mission has always been to deliver a dependable and safe supply of water to their customers, the challenges inherent in achieving that mission have expanded to include security and counter-terrorism. In the *Public Health Security and Bioterrorism Preparedness and Response Act of 2002*, Congress recognizes the need for drinking water systems to undertake a more comprehensive view of water safety and security. The Act amends the *Safe Drinking Water Act* and specifies actions community water systems and the U.S. Environmental Protection Agency must take to improve the security of the nation's drinking water infrastructure.

5.1.4 Accomplishments Related to Communication to the Public

Because it has been shown that people who engage in recreational water sports have a higher incidence of symptomatic illnesses, it has become increasingly more important to make the public aware of the potential health hazards that are associated with recreational waters. Recent progress has been made on the national and local levels to provide the public with useful tools that can provide needed information regarding the use of recreational waters. At the national level, the following public communication tools are available:

- BEACH Watch. This web site (www.epa.gov/OST/beaches) contains information about US EPA's BEACH Program, including grants, US EPA's reference and technical documents including US EPA's *Before You Go to the Beach* brochure, upcoming meetings and events, conference proceedings, and links to local beach programs. The web site also provides access to BEACON (Beach Advisory and Closing On-line Notification), US EPA's national beach water quality database.

- Annual Great Lakes Beach Association (GLBA) Conference. The GLBA is comprised of members from U.S. states, Environment Canada, local environmental and public health agencies, and several universities and NGOs. The GLBA's mission is the pursuit of healthy beach water conditions in the Great Lakes area. Since 2001, the GLBA has held beach conferences annually to bring together beach managers, scientists, and agency officials to exchange information on improving recreational water quality. The next conference is planned for October 2006, in New York. For more information, see www.great-lakes.net/glba/.

- BEACHNET. BEACHNET is an email discussion list that seeks to facilitate communication among people interested in the improvement of recreational beach water quality in the Great Lakes Basin. The listserv is sponsored by the GLBA and is hosted by the Great Lakes Information Network (GLIN). Both the GLBA and the listserv are open to anyone interested in improving beach water quality, understanding bacterial contamination, developing better ways to detect and monitor pollution, or monitoring and assuring beach visitors' health. There are currently several hundred subscribers to BEACHNET (http://www.great-lakes.net/glba/beachnet.html).

- BeachCast**.** This web site (http://www.glc.org/announce/03/07beachcast.html) provides Great Lakes beach goers with access to information on Great Lakes beach conditions, including health advisories, water temperature, wave heights, monitoring data, and more. BeachCast is a service of the Great Lakes Commission and its GLIN.

Adoption of Bacteria Criteria that Meet National Standards. One of the provisions of the *BEACH Act* required coastal and Great Lakes states to adopt for their coastal recreation waters, by April 10, 2004, water quality criteria for pathogens or pathogen indicators as protective as US EPA's 1986 water quality criteria for bacteria. The *BEACH Act* further directed US EPA to propose and promulgate such standards for states that did not do so.

US EPA worked collaboratively with all the states and territories that contain coastal recreation waters to identify their existing water quality standards, review them for consistency with the *BEACH Act* requirements, and determine what steps were needed to meet the *BEACH Act* requirements. On November 16, 2004, US EPA published in the Federal Register a final rule that promulgated water quality standards for states and territories that had not yet adopted water quality criteria for bacteria that were as protective of human health as US EPA's 1986 bacteria criteria. Information about the promulgation can be found online at www.epa.gov/waterscience/beaches/bacteria-rule.htm.

5.1.5 Accomplishments/Activities Related to Fish Consumption Advisories and Contaminants in Fish

United States. The *Council of Great Lakes Governors' Toxics Agreement of 1986* established the goal of common fish consumption advisories on the Great Lakes. The Council's Fish Consumption Advisory Task Force, with representation from each of the eight Great Lakes states, was assigned the task of developing a single method for assessing risks and issuing fish consumption advisories. The Task Force developed the "*Protocol for a Uniform Great Lakes*

Sport Fish Consumption Advisory," which addressed polychlorinated biphenyl (PCB)-based fish advisories for the Great Lakes. In September 1993, the Protocol was submitted to the Council of Great Lakes Governors. Although the Task Force disbanded, the health departments of the Great Lakes states formed a consortium, which over the past decade collaborated on research projects and maintained the relationships begun by the Task Force.

Mercury is a ubiquitous contaminant in fish. All the Great Lakes states issue fish consumption advice based on mercury levels in fish. The issuing of the FDA/US EPA national mercury fish consumption advisory underscored the need for a consistent approach for issuing advisories. The Protocol has been instrumental in providing a common fish advisory methodology and communication structure for Great Lakes states. The states periodically coordinate communication strategies, joint outreach campaigns, and advisory awareness evaluation projects. These efforts have only addressed PCB and other halogenated organic fish contaminants. There has been no mechanism to advance a coordinated mercury communication strategy in the Great Lakes states. The Consortium sought and received a small grant from the US EPA to develop a mercury addendum to the 1993 Protocol. Consumption advisory program staff from state health and environmental agencies in the Great Lakes Basin developed a draft mercury addendum in 2005.

Canada. The *2005-2006 Guide to Eating Ontario Sport Fish* is substantially different from previous editions. It now contains important information on consumption of sport fish from Ontario waters for both the general population and the sensitive populations of women of child-bearing age and children under age 15. This is the result of long-term epidemiological studies on mercury intake which have found developmental effects in young children at levels lower than previously thought. Since there is no evidence of any adverse effects on adults at similarly low levels, Health Canada provides two health protection guidelines, which have been incorporated into the Guide. Health Canada has also revised health protection guidelines for PCBs and dioxins (including dioxins, furans, and dioxin-like PCBs). These revised guidelines have increased the proportion of fish under advisory in Lake Superior and changed the relative importance of the contaminants causing restrictions. Whereas toxaphene previously had caused the majority of consumption restrictions (71 percent), dioxins (65 percent) and PCBs (25 percent) are now responsible for the majority of the restrictions.

For more information on the *2005-2006 Guide to Eating Ontario Sport Fish*, go to http://www.ene.gov.on.ca/envision/guide/.

Emerging Contaminants. Although there are advisories in the United States for a total of 39 chemical contaminants, most advisories in Lake Superior have involved five primary contaminants: mercury, PCBs, chlordane, dioxins, and toxaphene. Emerging contaminants, summarized in the Chemical Chapter, Chapter 4, in fish will likely result in advisories also. To better understand the presence of some emerging contaminants in fish, the Great Lakes National Program Office's Great Lakes Fish Monitoring Program (GLFMP) recently added polybrominated diphenyl ethers (PBDEs) to its annual basin-wide monitoring program. In addition, the GLFMP has instituted a program to identify and monitor for a specified list of emerging contaminants in fish, such as polychlorinated naphthalenes (PCNs) and perfluorooctane sulfonate (PFOS), over one sampling year. The GLFMP steering committee will rely upon the Great Lakes Binational Toxic Strategy and LaMP teams to create a list of additional emerging contaminants to be included in this additional year of monitoring. Examples of additional analytes are perfluorinated compounds, musk fragrances, alkylphenol ethoxylates (APEs), pharmaceuticals and other personal care products (pseudopersistence), other flame retardants, etc.

5.2 CHALLENGES AND NEXT STEPS FOR 2006 TO 2008

- Implement actions outlined in the Great Lakes Regional Collaboration's Coastal Health Strategy.
- Reduce pathogen levels in all recreational waters.
- Improve beach monitoring and public notification.

Addendum 5-A presents information on Lake Superior Basin beach closings.

5.3 INFORMATION

The web links listed below provide reference material for information cited in this chapter.

Government Action to Protect the Public Health

Monitoring

Contaminants evaluated by local water suppliers
http://www.epa.gov/safewater/mcl.html#mcls

Source Water Assessment Program
http://www.epa.gov/safewater/protect/assessment.html#Anchor-Source-11481

Water Quality Tracking
http://www.epa.gov/glnpo/gls/gls04.html

Research

Office of Research & Development's Water Supply and Water Resources Division
http://www.epa.gov/ORD/NRMRL/wswrd/research.htm

Communication Outreach

Drinking Water Academy
http://www.epa.gov/safewater/dwa.html

Drinking Water Security Education Materials
http://www.epa.gov/safewater/security/flyers/index.html

Remedial Action

Drinking Water State Revolving Fund
http://www.epa.gov/safewater/dwsrf.html

Emerging Issues

Water Infrastructure Security
http://www.epa.gov/safewater/security/index.html

Pharmaceuticals, Hormones, and Other Organic Wastewater Contaminants
http://toxics.usgs.gov/regional/emc.html

Lake Superior States' Beach Web Pages

MI: www.michigan.gov/deq/1,1607,7-135-3313_3686_3730---C1,00.html
MN: www.pca.state.mn.us/water/beaches/
WI: www.dnr.state.wi.us/org/water/wm/wqs/beaches/

Great Lakes Sea Grant

Great Lakes Sea Grant Network, http://www.greatlakesseagrant.org/
Michigan Sea Grant, http://www.miseagrant.umich.edu/
Minnesota Sea Grant, http://www.seagrant.umn.edu/
Wisconsin Sea Grant, http://www.seagrant.wisc.edu/

US EPA

US EPA's BEACH Watch home page including links to the *BEACH Act*, the *National Beach Guidance and Required Performance Criteria for Grants*, US EPA's national beach water quality database, and technical and reference documents.
http://www.epa.gov/waterscience/beaches/

US EPA Great Lakes National Program Office
http://www.epa.gov/glnpo/

US EPA's *Report to Congress: Impacts and Control of CSOs and SSOs* (delivered August 26, 2004)
http://cfpub.epa.gov/npdes/cso/cpolicy_report2004.cfm

Great Lakes Monitoring – The Swimmability Index
http://www.epa.gov/glnpo/glindicators/water/beachb.html

Great Lakes Strategy 2002 – A Plan for the New Millennium
http://www.epa.gov/grtlakes/gls/gls04.html

BEACON – Beach Advisory and Closing On-line Notification
http://oaspub.epa.gov/beacon/beacon_national_page.main

Other Web Sites

Great Lakes Water Institute – Bacterial Genetics Research Lab
http://www.uwm.edu/Dept/GLWI/ecoli/

Great Lakes Beach Association
http://www.great-lakes.net/glba/

Great Lakes Information Network (GLIN)
http://www.great-lakes.net/

Great Lakes Beach Association Annual Proceedings 2005
http://www.great-lakes.net/glba/2005conference.html

Beaches in the Great Lakes Region
http://www.great-lakes.net/tourism/rec/beach.html#new

Center for Disease Control - Healthy Swimming
http://www.cdc.gov/healthyswimming/

Great Lakes BeachCast – Great Lakes Beach Information (many links from this site)
http://www.great-lakes.net/beachcast/nr_moreinfo.html

Great Lakes Research Consortium
http://www.esf.edu/glrc/

NOAA Great Lakes Environmental Research Laboratory (GLERL)
Center of Excellence for Great Lakes and Human Health
http://www.glerl.noaa.gov/res/Centers/HumanHealth/

USGS Great Lakes Science Center
http://www.glsc.usgs.gov/

Great Lakes Commission
http://www.glc.org/

International Joint Commission
http://www.ijc.org/

Council of Great Lakes Research Managers – Great Lakes-St. Lawrence Research Inventory
http://ri.ijc.org

Great Lakes Protection Fund
http://www.glpf.org/

International Association for Great Lakes Research
http://www.iaglr.org/

Lake Superior Duluth Streams
www.DuluthStreams.org

5.4 ADDITIONAL INFORMATION

A collection of additional useful resources (journal articles, publications, published abstracts, and technical reports) has been compiled below for future use.

Alm, E., J. Burke, and A. Spain. 2003. Fecal indicator bacteria are abundant in wet sand at freshwater beaches. Water Research 37(16), 3978-3982.

Bolton, F.J., S. B. Surman, K. Martin, D.R.A. Wareing, and T.J. Humphrey. 1999. Presence of campylobacter and salmonella in sand from bathing beaches. Epidemiol. Infect. 122, 7-13.

Bonde, G.J., 1966. Bacteriological methods for estimation of water pollution. Health Lab. Sci. 3, 124-128.

Brenner, K.P., C.C Rankin, Y.R. Roybal, G.R. Stelma, P.V. Scarpino, and A.P. Dufour. 1993. New medium for simultaneous detection of total coliforms and *Escherichia coli* in water. Appl. Environ. Microbiol. 59, 3534-3544.

Brown, A., J. Felt, G. Kleinheinz, and C. McDermot. 2004. Detection of *E.coli* contamination at Door County, WI beaches: Association with environmental factors. ASM North Central Branch Annual Meeting, Nov. 12-13, 2004, Madison, WI.

Byappanahalli,M., D. Shively, M. Nevers, M. Sadowsky and R. Whitman. 2003. Growth and survival of *Escherichia coli* and *enterococci* populations in the macro-algae *Cladophora* (Chlorophyta). FEMS Microbiol. Ecology 1575(2003): 1 – 9.

Calderon, R.L., E.W. Mood, and A.P. Dufour. 1991. Health effects of swimmers and nonpoint sources of contaminated water. Int. J. Environ. Health Res. 1, 21-31.

Dombek, P., L. Johnson, S. Zimmerley and M. Sadowsky. 2000. Use of repetitive DNA sequences and the PCR to differentiate *Escherichia coli* isolates from human and animal sources. Appl. Environ. Microbiol. 66: 2572-2577.

Dorfman, M. 2004. Testing the Waters 2004-A Guide to Water Quality at Vacation Beaches. Natural Resources Defense Council (NRDC).

Dufour, Alfred P. et al. National Epidemiological and Environmental Assessment of Recreational Water Study. Great Lakes Beach Association Annual Meeting, October 22, 2003. www.great-lakes.net/glba/2003conference.html

Dufour, A.P., G. Anderson, and R.L. Whitman. 2002. New approaches to rapid testing of indicators of fecal contamination. Great Lakes Beach Conference, 2002 October 30. Chicago, Illinois. www.great-lakes.net/glba/2002conference.html

DuFour, A. P. 1992. Water Quality Health Effects Criteria for Marine and Fresh Recreational Waters: A Review of Studies Carried Out in the United States of America, in Annex 1 of Health Risks from Bathing and Marine Waters, a report on a joint WHO/UNEP meeting. WHO regional office for Europe.

Dufour, A. 1984. Bacterial Indicators of Recreational Water Quality. Canadian Journal of Public Health. 75(1):49-56.

Felt, J., C. Otte, A. Brown, G.T. Kleinheinz and C. McDermott. 2004. Source-tracking of microbial contamination at Door County, WI. ASM North Central Branch Annual Meeting, Nov. 12-13, 2004, Madison, WI.

Fogarty, L., S.K. Haack, M.J. Wolcott and R. Whitman. 2003. Abundance and characteristics of the recreational water quality indicator bacteria *Escherichia coli* and *enterococci* in gull faeces. J. Appl. Micrbiol. 94(5): 865 – 878.

Garza EL, and R.L. Whitman. 2004. The nearshore benthic invertebrate community of southern Lake Michigan and its response to beach nourishment J. Great Lakes Research 30 (1): 114-122.

Geldreich, E.E. 1978. Bacterial populations and indicator concepts in feces, sewage, stormwater and solid wastes. In: G. Berg (Ed.), Indicators of viruses in water and food, pp. 51-97. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.

Guan, S., R. Xu, S. Chen, J. Odumeru and C. Gyles. 2002. Development of a procedure for discriminating among *Escherichia coli* isolates from animal and human sources. Appl. Environ. Microbiol. 68: 2690 – 2698.

Hatch, J.J., 1996. Threats to public health from gulls (*Laridae*). Int. J. Environ. Health Res. 6, 5-16.

Health Canada. 1998. Summary: State of Knowledge Report on Environmental Contaminants and Human Health in the Great Lakes Basin. Great Lakes Health Effects Program, Ottawa, Canada.

Health Canada, 1998a. *Health Canada Drinking Water Guidelines. It's Your Health. Fact Sheet Series*, May 27, 1997.

Health Canada. 1998b. *Health-Related Indicators for the Great Lakes basin Population: Numbers 1-20*. Great Lakes Health Effects Program, Ottawa, Canada.

Health Canada. 1997. *State of Knowledge Report on Environmental Contaminants and Human Health in the Great Lakes Basin*. Great Lakes Health Effects Program, Ottawa, Canada.

Health Canada, 1995a. *Great Lakes Water and Your Health: A summary of A Great Lakes Basin Cancer Risk Assessment: A Case-control Study of Cancers of the Bladder, Colon and Rectum*. Great Lakes Health Effects Program, Ottawa, Canada.

Health Canada. 1993. *The Undiluted Truth about Drinking Water.*

Health Canada. 1992. Guidelines for Canadian Recreational Water Quality.

Heath Kelsey, R., I. Geoffrey Scott, E. Dwayne Porter, B. Thompson and L. Webster. 2003. Using multiple antibiotic resistance and land use characteristics to determine sources of fecal coliform bacterial pollution. Environ. Monitoring Assess. 81(1-3): 337 – 348.

Hughes, S. S. Hartrich, T. Sandrin, W. Gorman, C. McDermott, and G. Kleinheinz. 2004. *E.coli* and Lake Superior Recreational Beaches. ASM North Central Branch Annual Meeting, Nov. 12-13, 2004, Madison, WI.

IJC (International Joint Commission), Indicators Evaluation Task Force. 1996. Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement.

IJC (International Joint Commission). 1994. Revised Great Lakes Water Quality Agreement of 1978 as Amended by Protocol Signed November 18, 1987. Reprint February 1994.

IJC (International Joint Commission). 1989. Proposed Listing/Delisting Criteria for Great Lakes Areas of Concern. Focus on International Joint Commission Activities. Vol.14:1 (insert).

IJC (International Joint Commission). 1987 (reprinted 1994). Revised Great Lakes Water Quality Agreement of 1978, As Amended by Protocol, Signed November 18, 1987.

Irvine, K.N. and G.W. Pettibone. 1993. Dynamics of indicator bacteria populations in sediment and river water near a combined sewer outfall. Environ. Technol. 14, 531-542.

Jeter, S., G. Kleinheinz, and C. McDermott. 2004. *E.coli* and *Stapylococcus aureus* as indicators of contamination of recreational water. ASM North Central Branch Annual Meeting, Madison, WI, Nov. 12-13, 2004.

Kinzelman, J., A. Dufour, L. Wymer, G. Rees, and R. Bagley. 2004. Composite Sampling as an Alternative Technique for the Determination of Bacterial Indicators in Recreational Waters - US EPA National Beaches Conference, San Diego, CA, October, 2004.

Kinzelman, J. 2004. The Effectiveness of Spatial Distribution Studies in the Development of Successful, Cost-Effective, Targeted Remediation Efforts - US EPA National Beaches Conference, San Diego, CA, October, 2004.

Kinzelman, J., A. Dufour, L. Wymer, G. Rees, and R. Bagley. 2004. Comparison of Multiple Point and Composite Sampling for the Purpose of Monitoring Bathing Water Quality - American Society for Microbiology, New Orleans, LA, May, 2004.

Kinzelman, J. 2004. Integrating Research and Beach Management Strategies for the Improvement of Public and Environmental Health - Sustainable Beaches Summit, Sandestin, FL, March, 2004.

Kinzelman J, SL McLellan, RC Bagley, S Pedley, K Pond, and G. Rees. 2004. Integrating Research and Beach Management Strategies for the Improvement of Public and Environmental Health. Annual Report to the SC Johnson Fund.

Kinzelman, J., S. L. McLellan, A. D. Daniels, S. Cashin, A. Singh, S. Gradus, and R. C. Bagley. 2004. Non-point Source Pollution: Determination of Replication versus Persistence of Escherichia coli in Surface Water and Sediments with Correlation of Levels to Readily Measurable Environmental Parameters, J. Wat. Health 2(2): 103-114.

Kleinheinz, G. and E. Englebert. 2005. *Cladophora* and the beach: Implications for Public Health. In-press: Technical Report, UW-Milwaukee WATER Institute.

Kleinheinz, G. and E. Englebert. 2004. *Cladophora* and the beach: Implications for Public Health. Presentation at *Cladophora* research and management in the Great Lakes meeting held at the UW-Milwaukee WATER Institute, December 8, 2004.

Kinzelman, J. 2003. Assessing Current Beach Management Practices to Reduce Bacterial Contamination of Surface Water - Public Beach Closings Conference, Milwaukee, WI, May, 2003.

Kleinheinz, G.T., McDermott, C.M., and R.W. Sampson. 2003. Recreational Water: Microbial Contamination and Human Health. In: C. Meine (Ed.), Wisconsin's waters: A confluence of 16 Perspectives. Transactions of the Wisconsin Academy of Sciences, 90:75-86.

Kolpin, D.W, Furlong, E.T., Meyer, M.T., Thurman, E.M., Zaugg, S.D., Barber, L.B., and Buxton, H.T., 2002, Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000--A national reconnaissance: Environmental Science and Technology, v. 36, no. 6, p. 1202-1211.

Lake Erie LaMP. 1999. Lake Erie LaMP Status Report 1999. Lake Erie Lakewide Management Program.

Lauber, C., L. Glatzer and R. Sinsabaugh. 2003. Prevalence of pathogenic Escherichia coli in recreational waters. J. Great Lakes Res. 29(2): 301 – 306.

Levesque, B., P. Brousseau, F. Bernier, E. Dewailly, and J. Joly. 2000. Study of the bacterial content of ring-billed gull droppings in relation to recreational water quality. Wat. Res. 34, 1089-1096.

Levesque, B., P. Brousseau, P. Simard, E. Dewailly, M. Meisels, D. Ramsay, D., and Joly, J., 1993. Impact of the ring-billed gull (*Larus delawarensis*) on the microbiological quality of recreational water. Appl. Environ. Microbiol. 59, 1228-1230.

Levitt, J.T., van der Kraak, G., and Sorensen P.W., 2002. Ten-Week Exposure to Treated Sewage Discharge has Relatively Minor, Variable Effects on Reproductive Behavior, and Sperm Production in Goldfish. Environ. Toxicol. Chemistry 21(10): 2185-2190.

McCauley, D. J. 2001. Stormwater Source Identification, Sampling and Analysis at Select Storm Drains and Tributaries to Grand Traverse Bay (Lake Michigan). A Report to the Watershed Center Grand Traverse Bay. Great Lakes Environmental Center
Traverse City, MI.

McDonald, A., Kay, D., A. Jenkins, 1982. Generation of fecal and total coliform surges by stream flow manipulation in the absence of normal hydrometeorological stimuli. Appl. Environ. Microbiol. 44, 292-300.

McLellan, S.L. 2004. Genetic diversity of Escherichia coli isolated from urban rivers and beach water. Appl. Environ. Microbiol. 70:4858-65.

McLellan, S.L., E.T. Jensen, and C.O. Scopel. 2004. Comparison of bacterial source tracking methods in an urban coastal system, the Great Lakes. Environmental Pollution Source Tracking Workshop of Bathing Waters. Robens Centre for Environmental and Public Health, University of Surrey, Guildford, UK, January 11-13, 2004.

McLellan, S., A. Daniels and A. Salmore. 2003. Genetic characterization of *Escherichia coli* populations from host sources of fecal pollution by using DNA fingerprinting. Appl. Environ. Microbiol. 69(5): 2587-2594.

McLellan SL, AD Daniels, AK Salmore. 2002. Elevated indicator bacteria levels at South Shore Beach: *Escherichia coli* source detection using repetitive element anchored PCR. Great Lakes WATER Institute Technical Report contribution #432.

Mendes, B., M.J. Nascimento, and J.S. Oliveira. 1993. Preliminary characterization and proposal of microbiological quality standard of sand beaches. Water Sci. Technol. 27, 453-456.

Milwaukee Metropolitan Sewerage District. 2003. Deep Tunnel Fact Sheet. http://www.mmsd.com/tunnelfactsheet.html

Murray, C., B. Sohngen, and L. Pendleton. 2001. Valuing Water Quality Advisories and Beach Amenities in the Great Lakes. Water Resources Research. 37(10) 2583 - 2590.

Ontario Ministry of the Environment, 2000. Drinking Water in Ontario: A Summary Report 1993-1997. Website at: http://www.ene.gov.on.ca/programs/3295.pdf.

Osinga, V., R. Sampson, S. Swiatnicki, G.T. Kleinheinz, and C.M. McDermott. 2004. Survival of a Beach-Recovered *E. coli* Isolate in a Lake Water Microcosm. ASM North Central Branch Annual Meeting, Madison, WI, Nov. 12-13, 2004.

Otte, C., D. Horn, J. Okon, T. Sandrin, G. Kleinheinz, and C. McDermot. 2004. Monitoring and Molecular Source-tracking of *Escherichia coli* on Door County, WI beaches. ASM North Central Branch Annual Meeting, Nov. 12-13, 2004, Madison, WI.

Papadakis, J.A., A. Mavridou, S.C. Richardson, M. Lampiri, and U. Marcelou. 1997. Bather-related microbial and yeast populations in sand and seawater. Wat. Res. 31, 799-804.

Sabat, G., P. Rose, W. Hickey and J. Harkin. 2000. Selective and sensitive method for PCR amplification of *Escherichia coli* 16S rRNA genes in soil. Appl. Environ. Microbiol. 66(2): 844 – 849.

Sampson, R., S. Swiatnicki, C. McDermott and G. Kleinheinz. 2005. *E.coli* at Lake Superior Recreational Beaches. Journal of Great Lakes Research. (In-press)

Sampson, R., S. Swiatnicki, V. Osinga, J. Supita, C. McDermott, and G. Kleinheinz. 2004. Effect of temperature and sand on *E. coli* survival in a lake water microcosm. Submitted: Journal of Water and Health.

Sampson, R., S. Swiatnicki, C. McDermot and G. Kleinheinz. 2004. The effects of rainfall on *E. coli* and total coliform levels at 15 Lake Superior Beaches. Submitted: Water Resource Management.

Sampson, R, S. Swiatnicki, C. McDermott, and Kleinheinz, G.T. 2003. Source Tracking and Assessment of *E. coli* at Lake Superior Beaches, Proceedings of the North Central Regional Meeting of the American Society for Microbiology, Oshkosh, WI.

Sampson, R, S. Swiatnicki, and G.T. Kleinheinz. 2003. Lake Superior beach monitoring and microbial source tracking, MI Branch "Twig" Meeting of the American Society for Microbiology. Marquette, MI.

Scott, T. M., T.M. Jenkins, J. Lukasik and J.B. Rose. 2005. Potential Use of a Host Associated Molecular Marker in *Enterococcus faecium* as an Index of Human Fecal Pollution; Environ. Sci. & Tech. 39: (1) 283 – 287

Scott, R.M., J.B. Rose, T.M. Jenkins, S.R. Farrah and J. Lukasik. 2002. Microbial Source Tracking: Current Methodology and Future Directions. Appl. Environ. Microbiol. 68 (12):5796-5803.

Selvakumar, A., M. Borst, M. Boner, and P. Mallon. 2002. Effects of Sample Holding Time on Concentrations of Microorganisms in Water Samples. Water Environ. Research 76 (1): 64 – 72.

Seyfried, P., Tobin, R., Brown, N., Ness, P., 1985a. A prospective study of swimming related illness. I. Swimming-associated health risk. American Journal of Public Health. 75(9):1068-70.

Seyfried, P., Tobin, R., Brown, N., Ness, P., 1985b. A prospective study of swimming related illness. II. Morbidity and the microbiological quality of water. American Journal of Public Health. 75(9):1071-1075.

Slifko, T.R., D.E. Huffman, D. Bertrand, J.H. Owens, W. Jakubowski, C.N. Haas, and J.B. Rose. 2002. Comparison of Animal Infectivity and Cell Culture Systems for Evaluation of *Cryptosporidium parvum* oocycts. Exp. Parasit. 101:97-106.

United States Geologic Survey. 1998. How do we determine when the beaches are safe for swimming? USGS Fact Sheet FS-112-98.

US EPA, 1999a. Office of Drinking Water and Ground Water Home Page, Website at http://www.epa.gov/safewater/about.html, Revised December 2, 1999.

US EPA, 1999b. How Safe is my Drinking Water? Office of Ground water and Drinking Water. Website at: http://www.epa.gov/OGWDW/wot/howsafe.html, Revised March 19, 1999.

US EPA. 2001. EPA Report to Congress on Implementation and Enforcement of the CSO Control Policy. http://cfpub.epa.gov/npdes/cso/cpolicy_report.cfm?program_id=5.

US EPA 2002. National Beach Guidance and Required Performance Criteria for Grants. http://www.epa.gov/waterscience/beaches/grants/guidance/index.html

US EPA. 2003. Great Lakes Strategy 2002. http://www.epa.gov/grtlakes/gls/gls04.html

US EPA. 2003. The National Epidemiological and Environmental Assessment of Recreational (NEEAR) Water Study: Water Quality. http://www.epa.gov/nheerl/neear/index.html

US EPA. 2003. National Pollution Discharge Elimination System (NPDES). http://cfpub1.epa.gov/npdes/home.cfm?program_id=5

US EPA. 2004. Assessing and Monitoring Floatable Debris. http://www.epa.gov/owow/oceans/debris/floatingdebris/

US EPA and Government of Canada, 1995. The Great Lakes: An Environmental Atlas and Resource Book.

Whitman, R., Gochee, A., Dustman, W., and K. Kennedy. 1995. Use of coliform bacteria in assessing human sewage contamination. Natural Areas Journal. 15:227-233.

Wisconsin Department of Natural Resources, 1998. "*Cryptosporidium: A Risk to our Drinking Water*" Fact Sheet. Website at http://www.dnr.state.wi.us/org/water/dwg/Crypto.htm#what_steps, Revised June 1, 1998.

Wisconsin Department of Natural Resources, 1994. Wisconsin Water Quality Assessment Report to Congress. Madison, WI. Publ - WR254-94-REV.

World Health Organization. 1998. Guidelines for safe recreational water environments: Coastal and fresh-water.

ADDENDUM 5-A:
LAKE SUPERIOR BASIN BEACH CLOSINGS

Beach managers across the basin assess beach quality as part of their daily activities. The State of the Lakes Ecosystem Conference (SOLEC) assesses the beach manager's data to evaluate the amount of beach closings, swim advisories, and posting days.

Ecosystem Objective

Waters used for recreational activities involving body contact should be substantially free from pathogens, including bacteria, parasites, and viruses, that may harm human health. As the surrogate indicator, *E. coli* levels should not exceed national, state, and/or provincial standards set for recreational waters.

Seven beaches in the U.S. and three in Canada in Lake Superior have been closed more than 10 percent of the swimming season (June, July, and August). Table 5-1 presents information on the seven U.S. beaches, and Table 5-2 presents information on the three Canadian beaches. For more information, see the *Draft State of the Great Lakes Report 2005* at http://www.solecregistration.ca/en/reports/greatlakesreport.asp.

Table 5-1. U.S. Lake Superior Beaches That are Closed More than 10 percent of the Swimming Season

County	Waterbody	Beach ID	Beach Name	Number of Days Posted	State Priority Ranking Tiers	Times Monitored Per Week	Causes Reported for Postings
St. Louis	Great Lakes	MN524952	LS St. Louis Bay, Pk Pt Boat Club/14th St., Duluth	35	T1	Twice	Unknown
St. Louis	Great Lakes	MN591851	LS Pk Pt, Southworth Marsh, Duluth	58	T1	Twice	Unknown/ Storm
St. Louis	Great Lakes	MN801949	LS St. Louis Bay, Pk Pt/20th Hearding Is., Duluth	65	T1	Twice	Unknown
Douglas	Great Lakes	WI545475	Amnicon River Beach	13	T3	Once	Unknown
Douglas	Great Lakes	WI573145	Wisconsin Point Beach #3	11	T3	Once	Unknown
Douglas	Great Lakes	WI750300	Brule River State Forest Beach #2	15	T3	Once	Unknown
Douglas	Great Lakes	WI888427	Wisconsin Point Beach #1	32	T2	Twice	Unknown

Table 5-2. Canadian Lake Superior Beaches Closed More than 10 percent of the Swimming Season during 2005*

Municipality	Waterbody	Beach Name	Number of Days Posted**	Times Monitored Per Week	Causes Suspected for Postings
Thunder Bay	Current River	Boulevard Lake - Sunnyside	10	Twice	Bird droppings suspected
Sault Ste. Marie	St. Marys River	Kinsmen (Hiawatha) Park	10	Twice	Unknown
Sault Ste. Marie	St. Marys River	Centennial Park (Pumpkin Point)	12	Twice	Unknown

* Swimming season calculated as 92 days from June 1 through August 31.
** Based on public postings from the local Health Unit.

Chapter 6

Habitat, Terrestrial Wildlife and Aquatic Communities Progress Reports

Lake Superior Lakewide Management Plan
2006

Chapter 6 Contents

Chapter 6
Habitat, Terrestrial Wildlife and Aquatic Communities Progress Reports

6.0 ABOUT THE CHAPTER

The Habitat, Aquatic, and Terrestrial Wildlife Committees of the Binational Program have cooperated to compile this progress report. This chapter highlights the actions taken to restore and protect fish, wildlife, and their habitats in the Lake Superior Basin since the release of the LaMP 2004 Progress Report. The LaMP 2004 contained separate descriptions of the work in each of these areas, but the committees have combined efforts in recognition of the interconnected nature of the ecosystems in Lake Superior and its basin. These committees are part of an historic and unique collaborative endeavor by Lake Superior resource managers to protect, maintain, and restore aquatic and terrestrial wildlife, and high-quality habitat sites in the Lake Superior Basin and the ecological processes that sustain them. The committees are comprised of technical personnel from federal, state, provincial, and tribal natural resource agencies. A list of the members of each committee can be found at the end of this chapter.

Another product of the three committees working jointly is a single chapter that consolidates and replaces four chapters of the LaMP 2000. As suggested in comments from the public and as directed by the Lake Superior Task Force and Work Group, the Habitat, Aquatic, Terrestrial Wildlife, and Invasive Species chapters of the LaMP 2000 were consolidated into one chapter. The resulting document presents information on the characteristics, status, and trends of living natural resources in the Lake Superior Basin in a coordinated fashion. In accordance with the "three ring binder" approach to the LaMP, users should replace Chapters 6, 7, 8, and 10 of the LaMP 2000 with this consolidated chapter (new Chapter 6). Readers can find the consolidated chapter on the new Habitat/Terrestrial Wildlife committees' website, http://www.fs.fed.us/twcc/. For a CD copy of the consolidated chapter, please contact the co-chairs of the Habitat Committee, whose contact information can be found at the above web address.

6.1 ACCOMPLISHMENTS/PROGRESS

The following chapter recognizes many accomplishments over the past two years; however, readers should note that these are not all of the actions that have been taken to restore and protect the basin. The committees are tracking projects completed in furtherance of the LaMP; these represent a sample of projects completed in the past two years. The format of this chapter contains sections discussing broad, watershed scale projects, updates on native and non-native species efforts, and outreach and education initiatives (see Chapter 2 for additional outreach efforts).

6.1.1 Watershed Initiatives/Protection/Restoration

This section presents updates on initiatives to protect or restore the ecological health of the Lake Superior watershed.

Important Habitat in the Lake Superior Basin. Developing and maintaining an inventory of important habitat sites in the basin has been a key charge of the Lake Superior Binational Program since its inception. The map "Important Habitat Conditions in the Lake Superior Basin" was included in the LaMP 2000 as a revision to the original Important Habitat Map published in 1996. The Habitat Committee has recently undertaken a second revision to the map and its accompanying habitat site information databases. This effort will include reviewing the map and attempting to gather additional information about the sites already listed, and contacting state, federal, and tribal agencies to identify additional sites that are not currently on the map. In addition, the information gathered will be incorporated into the Site Explorer kiosks that are located at six sites around the basin.

Watercourse Stewardship Project. The ecological health of Lake Superior is determined in large part by the health of its tributary streams. These watercourses support resident and anadromous fish species, sustain healthy native animal and plant populations, provide wildlife corridors, and at the same time, contribute nutrient and sediment loads to Lake Superior. One way to determine the health of Lake Superior using these water systems is to adopt environmental indicators. Benthic invertebrates, one such indicator, respond to ecosystem changes faster than other members of the aquatic community. Trends and changes in aquatic invertebrate populations and community structure can serve as indicators of short-term, action-required stresses that may ultimately influence the aquatic community of Lake Superior.

The Watercourse Stewardship project is a joint endeavor between the Superior Workgroup and the Forum. To date, the project has established Regional Reference Values for benthic macro-invertebrate communities in 15 local, "healthy" Lake Superior tributary streams that can be used to determine the biological health of selected sites in areas that are believed to be impaired. Ten additional reference sites have been selected between Nipigon and Sault Ste. Marie in order to expand this project to other AOCs along the north shore of Lake Superior.

The stewardship component involves public education and the creation of a user-friendly stream monitoring program (i.e., Citizen's Guide to Monitoring Water Quality) that will enable the general public to sample stream communities to determine local water quality conditions. Community-based monitoring programs provide an essential early-warning system that identifies critical problem areas. To that end, the over-arching goal of this project is to facilitate citizen-driven protection and stewardship of streams and rivers along the north shore of Lake Superior with a long-term objective of improving water quality and fish habitat.

Lake Superior National Marine Conservation Area. In October 2002, the Government of Canada announced an action plan to create ten new national parks and five new national marine conservation areas over five years. The national marine conservation area of Canada (NMCA) in Lake Superior will be the first marine conservation area to be created under this plan.

National marine conservation areas are part of the Parks Canada family of protected areas. They consist of highly protected zones surrounded by cooperatively managed multiple-use areas where activities such as commercial fishing, shipping, and traditional uses continue. The guiding management principle is ecologically sustainable use. Dumping, mining, oil and gas exploration and extraction are prohibited throughout an NMCA.

More than 70 species of fish inhabit the near-pristine waters, including lake herring, walleye, yellow perch, lake whitefish, lake trout, and brook trout. Ring-billed and herring gulls, cormorants, great blue heron, and white pelican feed in these waters. All but the latter use island habitats for breeding during the late spring and early summer.

The signature of an agreement in principle confirms the intent of the governments of Canada and Ontario to work toward the establishment of an NMCA in Lake Superior. Negotiation of a comprehensive final agreement will now proceed, guided by the understandings set out in the agreement in principle.

At the same time, consultations with First Nations in the region will continue to reach a shared understanding regarding their future role in the management and operation of the NMCA, the economic opportunities it will create for Aboriginal communities, and the protection of cultural resources. Local people and First Nations will be actively engaged as stewards of the NMCA.

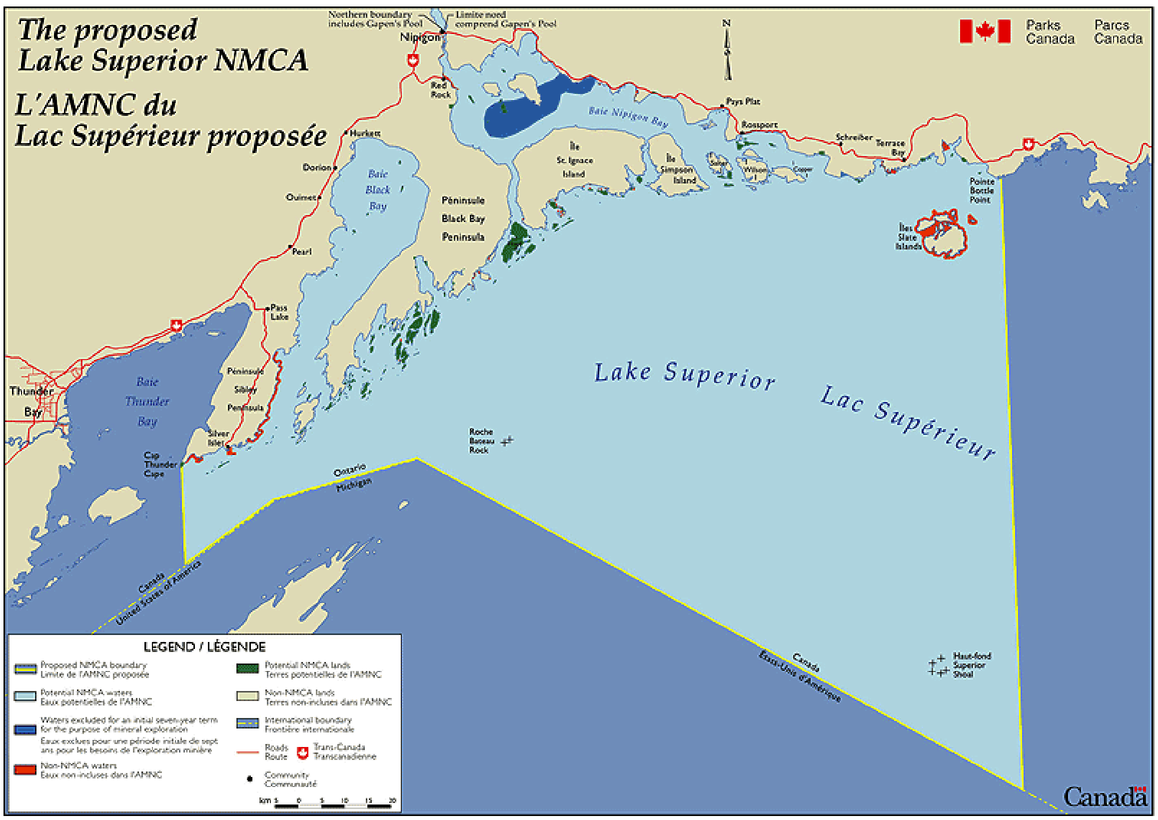


Figure 1. Proposed Lake Superior National Marine Conservation Area. Photo Credit: Parks Canada.

The proposed NMCA would extend from Thunder Cape at the tip of Sleeping Giant Provincial Park in the west, to Bottle Point just east of Terrace Bay, and out to the Canada-U.S. border. It would include the waters of Black Bay and Nipigon Bay, and encompass just over 10,000 square kilometres of lakebed as well as the overlying waters, along with a number of islands, shoals, and some of the mainland. When it is ultimately created, the NMCA in Lake Superior will become Canada's largest national marine conservation area, and the first to be established under the *Canada National Marine Conservation Areas Act*, which became law in June 2002.

Lake Superior Coastal Wetland Initiative. The North American Wetland Conservation Act Partner Team is a unique partnership supported by many local agencies and organizations and the North American Wetland Conservation Act Program. The six-year project is nearing completion. The project brings together the U.S. Fish and Wildlife Service; U.S. Natural Resources Conservation Service; WDNR; Ashland, Bayfield, Douglas, and Iron County Land Conservation Departments; The Nature Conservancy; Sigurd Olson Environmental Institute; Ducks Unlimited; and the Red Cliff and Bad River Bands of Lake Superior Chippewa Indian Tribes to protect and restore coastal and inland wetland communities in Wisconsin's Lake Superior Basin. The overall goal is to protect coastal wetlands in the area by working with willing partners to acquire land, purchase easements, and restore habitat on private lands. Over 5,000 acres of habitat have been positively affected through the project.

Watershed Habitat Rehabilitation. Progress is being made basinwide in the effort to construct and restore road-stream crossings to benefit passage of aquatic organisms, protect stream and riparian habitat, and ensure roadway integrity. COA has supported tributary habitat restoration for native fish species on Clearwater Creek and the Montreal River in Ontario and investigations into habitat supply and fish population status on the White, Michipicoten, and Montreal Rivers. Minnesota DNR surveyed road crossings in portions of streams accessible to migratory fish to determine if and what type of maintenance might be required to allow for fish passage during both spring and fall spawning runs.

Training workshops for installation of fish friendly culverts and other road-stream crossing structures were held in the Lake Superior Basin in Ashland and Grandview, Wisconsin. These workshops involved 96 individuals representing seven town governments and more than a dozen natural resource agencies.

The Bad River Watershed Association recently inventoried all road-stream crossings in the watershed and is working with local, state, and federal government agencies to obtain grants to help repair crossings impeding fish passage or contributing sediment to streams (http://www.badriverwatershed.org). Recently developed educational and training videos, CD's, and web sites are available for local government and road department officials as well as the general public. For more information visit http://www.fws.gov/midwest/Fisheries/streamcrossings/index.htm.

Wetlands Consortium Update. The Consortium's purpose is to design an implementable, long-term program to monitor Great Lakes coastal wetlands. This is being accomplished through the development of indicators to assess the condition of Great Lakes coastal wetlands. The indicators were selected through the State of the Lakes Ecosystem Conference (SOLEC) process. The Consortium will provide scientific support for this monitoring program; create a database that is publicly accessible; recruit the leadership required to implement the long-term monitoring program; and develop a network of funders and agencies who will support the Great Lakes coastal wetlands monitoring program.

This project is premised on the recognized need to assess the health of Great Lakes coastal wetlands, which are an integral part of the Great Lakes basin ecosystem. Coastal wetlands have critically important ecological values and functions, yet there are currently few basinwide data available for assessing their ecological health.

As described above, the Great Lakes Coastal Wetlands Consortium is developing a long-term Great Lakes coastal wetlands monitoring program. In a complementary effort, the Great Lakes Environmental Indicators (GLEI) research project (described below) is an effort to develop indicators for Great Lakes coastal habitats which assess habitat condition and point to causes of impairment.

Great Lakes Environmental Indicators Project Update. The US EPA funded a five-year major competitive research grant (2001-2006) to the University of Minnesota, Duluth to develop a new generation of environmental indicators for coastal regions of the U.S. Great Lakes. The project focused on the coastal and nearshore zone for the entire U.S. portion of the Great Lakes, from Lake Ontario to Lake Superior. The project included over 27 scientists in a consortium of 10 universities and was a cooperative agreement with US EPA's Mid-Continent Ecology (MED) Division in Duluth.

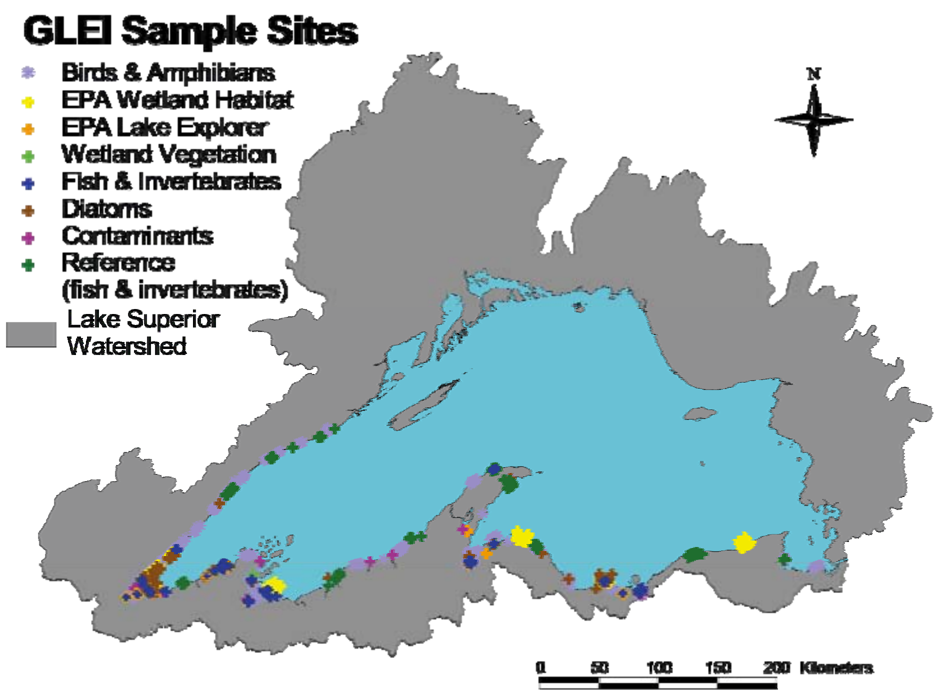


Figure 2. GLEI Sample Sites. Source: Natural Resource Research Institute, Duluth, MN.

The project has just concluded, and a final report will be completed in April 2006. This summary focuses on the results for the Lake Superior relative to the other U.S. Great Lakes coastal regions. The goal of the project was to develop indicators that both estimated ecological condition and suggested plausible causes of ecosystem degradation. The project consisted of measuring eight major responses, each with different sampling methodologies and sample size requirements. These indicators included populations of amphibians, birds, diatoms, fish, macroinvertebrates, and wetland plant communities. In addition, contamination due to polycyclic aromatic hydrocarbons (PAHs) and land cover in the U.S. Lake Superior Basin were characterized.

Field sampling was completed with a random stratified design which incorporated over 200 stressor variables among six major categories: agriculture, atmospheric deposition, land cover-land use, human population densities, point source pollution, and shoreline modification. The entire U.S. coastal region was subdivided into two major ecological provinces and further subdivided into 762 "segment sheds." Segment sheds represented a combination of the coastline and the watershed. Field sampling was completed primarily in 2002 and 2003, while the landscape characterization was completed for 1992 and compared with 2001 to determine land use change. More than 100 sites in Lake Superior were sampled, especially wetland ecosystems and high energy shorelines. The number of sites sampled in the Lake Superior coastal region for the various components were the following: 110 sites for birds, 12 sites for PAH contamination, 40 sites for diatoms, 32 sites for fish and macroinvertebrates, and 25 sites for wetland vegetation. In addition, US EPA-MED sampled more than 15 sites as well as extensive regions of the near-shore zone in the western portion of Lake Superior.

The preliminary results indicate that agriculture and population density had major influences on the indicator responses for all of the components studied. Strong signals in birds, diatoms, fish, and macroinvertebrates were observed in areas where either agriculture was predominant in the landscape or where human population densities were greatest. Considerable variation in the responses was exemplified at different spatial scales and many at surprisingly large scales. PAH contamination was found in several of the major areas of industrial activity such as in the St. Louis River of MN and near Ashland, WI. Land use change in the Lake Superior Basin was not as extensive as was found in the southern and eastern portions of the U.S. Great Lakes Basin; however, there was some conversion of forested areas to urbanized, residential areas within the basin.

In general, the Lake Superior Basin and near shore areas, as indicated from the biological responses measured, were in relatively good condition compared with many portions of the southern and eastern U.S. Great Lakes coast. However, many wetland and high energy shores had conditions that were approaching the highly degraded regions of the southern and eastern U.S. Great Lakes areas. A hierarchical framework will be developed to link responses with specific stressors in the coastal region. These data provide some of the most extensive and comprehensive sampling ever completed for a substantial portion of the U.S. Lake Superior coastal region. These data also provide a solid baseline that will allow comparisons to be made with future changes in coastal resources and potentially provide a mechanism to track further degradation or improvements in the health of the coastal region of Lake Superior. Further information on GLEI is available and more will be forthcoming (see http://glei.nrri.umn.edu).

The Nature Conservancy Issues Binational Conservation Blueprint for the Great Lakes. The Nature Conservancy and the Nature Conservancy of Canada have jointly developed a Binational Conservation Blueprint for Coordinated Action. The blueprint includes a map of the Great Lakes Basin identifying more than 500 sites as priorities for conservation. These include forests, coastlines, islands, wetlands, rivers, and inland lakes. Sites identified in the Lake Superior Basin include the Manitou River in Minnesota, the Chequamegon Bay watershed in Wisconsin, the Keweenaw south shore and bluffs in Michigan, the Black Bay peninsula, and Goulais Bay in Ontario. The Conservation Blueprint and the map can be found on the web at http://nature.org/wherewework/northamerica/greatlakes/resources/art11461.html.

Upper Peninsula Land Protected. A large tract of Upper Peninsula land, most of which is in the Lake Superior drainage basin, will be protected under a plan with federal, state, and private backing. The Northern Great Lakes Forest Project will protect more than 271,000 acres in the Upper Peninsula through a working forest easement on 248,000 acres with the State of Michigan and The Forestland Group, and through an acquisition by The Nature Conservancy of 23,338 acres in the Two Hearted River watershed (see Figure 3). The total cost of the project is nearly $58 million.

Highlights of the project include:

- More than 300 natural lakes, including 74 lakes larger than 10 acres;
- 192 miles of Class I trout streams, including the Two Hearted River (a state-designated Michigan Natural River) and the Presque Isle River (a federally designated National Wild and Scenic River), as well as over 324 miles of additional riparian habitat along major rivers and tributaries (roughly 516 miles total);
- More than 31 miles of land bordering Pictured Rocks National Lakeshore, including 20,000 acres of adjacent buffer;
- Roughly 10,000 acres of buffer and inholdings to Tahquamenon Falls State Park;
- Roughly 10,000 acres of buffer and inholdings to Porcupine Mountains Wilderness State Park;
- More than 52,000 acres of wetlands;
- Habitat for state and federal endangered species, including bald eagle, common loon, osprey, gray wolf, and a host of state-listed plant species and communities;
- Approximately 50,000 acres of watershed protection and buffer lands adjacent to Seney National Wildlife Refuge;
- 23,338 acres of adjacent land and inholdings to The Nature Conservancy's existing nature preserve in the Big Two Hearted River watershed.
- Important natural features like unique old-growth hemlock gorges, and high-elevation peatland-forest ecosystems;
- 30,000 acres of adjacent buffer and inholdings to Hiawatha National Forest;
- 27,000 acres of adjacent buffer and inholdings to Ottawa National Forest; and
- Approximately 100,000 acres of adjacent buffer and inholdings to various state forests.

For more information see http://nature.org/wherewework/northamerica/states/michigan/slideshows/sld196.html.

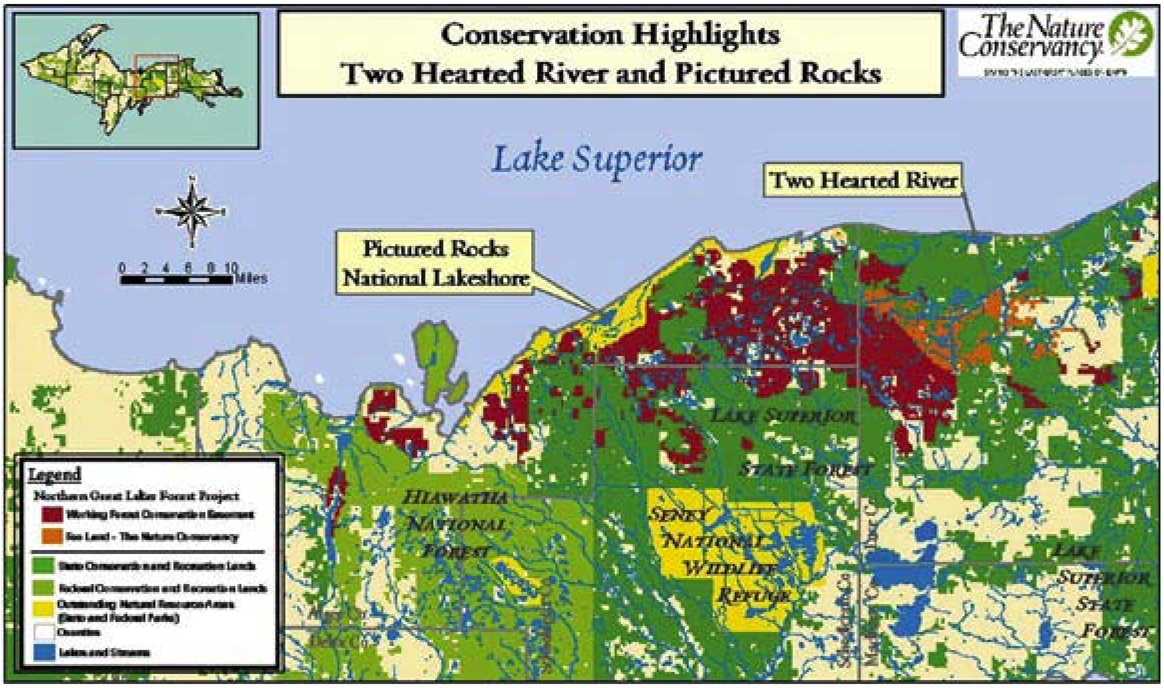


Figure 3. This map shows the lands included in the Northern Great Lakes Forest Project, which involves protecting more than 271,000 acres in the Upper Peninsula. The $57.9 million agreement, spearheaded by The Nature Conservancy, received some financial backing in President Bush's proposed 2007 budget (AP Photo/The Nature Conservancy).

The Wisconsin Lake Superior Basin Partner Team was originally formed in 1998 by the WDNR to help implement the Lake Superior Binational Program in Wisconsin. The Partner Team is a unique consortium of stakeholders who created a watershed health initiative to address erosion and sedimentation, which is the leading cause of water quality and habitat impairments in the Wisconsin portion of the basin. In 2005 the Partner Team received a grant from the Great Lakes Commission to conduct a pilot project for watershed planning and management in the basin. The Marengo River watershed, which is part of the Bad River watershed, was selected by the Team as the pilot location because of the variety of land uses, issues, and governmental bodies. In addition to a strategy for the Marengo River watershed, the project will result in a model watershed planning guidance document that can be used by other organizations in Wisconsin for watershed planning in the Lake Superior Basin.

Wisconsin Lake Superior Watershed Health Initiatives. Watersheds in Wisconsin's Lake Superior Basin are unusual, with "flashy" streams cut deep into layers of clay and sand that form ravines and high slumping banks. Over the last 150 years, logging, forest fires, agriculture, drainage, and road construction have changed the watersheds. These changes, combined with the tight clay soils, make water run off the land rapidly. The increased flow carves at streambanks and bluffs, which accelerates erosion and degrades fish habitat.

To help address watershed issues and stream flow dynamics, the WDNR funded several projects with USGS to collect information on the North Fish Creek, Bark River, Sioux River, Whittlesey

Creek, and the Cranberry River. The USGS verified that the power of flood events is presently twice that of the pre-settlement era. These flood events changed the character of some stream sections and even destroyed middle and lower river historical spawning reaches. This greatly affected brook trout reproduction and reduced their potential future success in Bayfield peninsula streams. The other larger salmonids, although still limited, are better able to utilize this damaged habitat. Study results suggest that we need to develop strategies to "slow the flow" or reduce the speed that snowmelt and rainfall events drain off the land. Results also suggested the need to concentrate on watershed areas upstream of critical spawning and rearing reaches.

For more than 50 years, there have been many attempts to reduce erosion and sedimentation problems associated with the red clay-like till soils of Wisconsin's Lake Superior Basin. The primary focus in the past has been on mechanical stabilization. Recently, the agencies' focus has changed to watershed processes that contribute to excess runoff and peak stream flow.

Comparative Analysis of Sub-watersheds in the Wisconsin Portion of the Lake Superior Basin. This project was completed in 2005 through efforts of the WDNR, Wisconsin Coastal Management Program, and the Ashland Bayfield Douglas and Iron County Land Conservation Department. Research by USDA-Forest Service Research Hydrologist Sandy Verry has shown that sub-watersheds that have more than 60 percent of their area in either open field or forest clearcuts which are less than 15 years old deliver accelerated surface runoff to the streams and thus greatly increase the velocity and volume of episodic stream flows.

This project identified the location of sub-watersheds which are above the threshold of open land and young clearcuts in order to coordinate forest and land management activities. The project mapped open land and clearcuts over the last 16 years using satellite imagery and GIS technology. Results were presented to over 70 resource managers attending the *Clean Water and Healthy Watersheds: Wisconsin Lake Superior Basin Watershed Mapping Workshops* held in Ashland, Wisconsin, in March 2005.

Lake Superior Basin Plan. As part of our effort to strategically target key watersheds, the Minnesota Pollution Control Agency (MPCA) completed a watershed assessment for all 435 minor watersheds in its portion of the Lake Superior Basin. This assessment, which is based on an adapted version of the U.S. Forest Service's East-wide Watershed Assessment Protocol, is used to generate a cumulative score for each watershed based on 19 condition and vulnerability parameters. These parameters, which are outlined in the plan, include land use, population and road density, recreational pressure and percent of the riparian corridor in forest or wetland. The assessment has a significant habitat component, including a focus on watersheds that serve as entry points for exotic plant and animal species that arrive from Lake Superior or through overland routes. The Watershed Assessment has also been used to select a pilot watershed for the development of a pro-active strategy for watershed protection.

Sucker River Pilot Project. The Sucker River Watershed was selected as a pilot project for the development and employment of a watershed protection approach. The MPCA and the US EPA provided support for the project as part of a slate of innovative pollution prevention initiatives. Approximately $35,000 was provided to the South St. Louis County Soil and Water Conservation Service District to provide staff support to the project. The project was unique in that it was one of the few attempts by any agency to intervene prior to the identification of a serious water quality issue. It also utilizes a new approach to watershed projects, focusing very heavily on community-based social marketing techniques and quantifiable outcomes.

City of Sault Ste. Marie, Ontario, Plans to Protect Upland Aquifers. The City of Sault Ste. Marie, Ontario, has approved new zoning rules designed to protect aquifer recharge zones in the foothills of the Canadian Shield above the city. Studies of the aquifers beneath the city indicated that the gravelly soils of the recharge zone are very vulnerable to leaching of pollution which could possibly contaminate the city's drinking water supply. The new zoning laws are also designed to protect remaining habitat on the city's edge. The new zoning ordinances include restrictions on the storage of fuels and chemicals, restrictions on severing current land parcels, and new rules regarding the discharge of storm water. The stormwater on site must be collected, stored, and treated or properly disposed of in order to remove contaminants before the stormwater is allowed to enter into the ground or exit the property. See http://www.city.sault-ste-marie.on.ca/eng/plan/ZoningByLaw/plan_zmain.htm.

Figure 4. Stream feeding into the St. Marys River. Photo Credit: Mike Ripley, CORA.

Sault Michigan Planning for Cleaner Urban Creeks. Sault Ste. Marie, Michigan, citizens and agencies, with the help of the Chippewa/East Mackinac Conservation District, are taking part in a planning process to protect and restore water quality in urban creeks that flow through the city. The St. Marys River is actually a connecting channel between Lake Superior and Lake Huron and is one of 43 areas of concern (AOCs) in the Great Lakes. In the past 15 years, great progress has been made to reduce point source pollution in the St. Marys River, and now there will be efforts to control non-point source pollution.

The Sault Ste. Marie Area Watershed Project is a non-point source pollution planning project that attempts to address water quality issues, identify pollution sources, and construct a plan to reduce those sources within Sault city limits. The Sault Project will encompass several small "sub-watersheds" of the St. Marys River that course through the city, including Ashmun Creek, Mission Creek, Seymour Creek, and the rest of the city limits area east to Frechette Creek. The rationale for the project is to create awareness about non-point source pollution, the effect that pollution has on aquatic resources, and land management that can benefit water quality. When complete, these efforts should lead to improvements to beneficial uses such as fish and wildlife habitat, water quality, and aesthetics.

Lake Superior Tributary Fish Habitat Rehabilitation. Seventeen Lake Superior tributaries covering 11.7 river miles have been improved through 2005 as part of a WDNR fish crew's

Figure 5. Stakeholders take a tour of the urban creeks in Sault Ste. Marie, Michigan. The group will be helping to develop a plan to protect and restore watersheds which flow into the St. Marys River. Photo Credit: Chippewa/East Mackinac Conservation District.

effort to maintain and improve habitat to sustain naturally reproducing populations of trout and salmon, including native brook trout. The effort involved removing sand, tag alder trees, beaver dams, and woody debris from trout and salmon spawning grounds to expose the rocks, large logs, and gravel that had been buried for more than a century.

Inland Aquatic Resources Update. Fish population surveys were conducted annually on 10-15 lakes and 2-3 streams within Minnesota's Lake Superior Basin. The Forest Service conducted restoration projects on 2,300 acres of inland lake and 53 miles of inland stream habitat, some of which is located in the Lake Superior watershed. In addition, eight watershed assessments were performed.

Wildlife Habitat Enhancements. Between 2004 and 2006, the U.S. Forest Service restored or enhanced 2600 acres of wildlife habitat in forests wholly or partly within the Lake Superior Basin. In these same forests, 750 acres of endangered or threatened species habitat were restored or enhanced, 200 acres of land were treated for noxious weeds, and soil/water resource improvements were made on another 125 acres.

St. Louis River Habitat Assessment. The Minnesota DNR, 1854 Authority, and Fond du Lac have cooperated in a St. Louis River assessment. The purpose of the assessment was to collect physical, chemical, and biological information necessary to implement management plans and/or special designations by the Minnesota DNR. This was a two-phase assessment. Phase I included identifying and mapping the physical characteristics of the river. Information gathered included GPS locations of stream features, channel width, river depth, and water temperature. Phase II consisted of establishing stations and collecting water quality information, invertebrates, and fish.

Lake Superior State University Takes Snapshot of Ecosystem Health. Nine faculty and staff and 25 students from Lake Superior State University's School of Biological Science and Department of Chemistry and Environmental Science are involved in a three-year $715,000 project to determine the health of the St. Marys River. The study, entitled "Biotic Integrity and Habitat Assessment within the St. Marys River Area of Concern," is designed to determine the health of the ecosystem in this river that connects Lake Superior to Lake Huron. The study looks at coastal marshes to determine the status of habitat and the wildlife that use it. The researchers have been collecting biological samples and performing chemical analysis of samples taken from the water and bottomlands.

6.1.2 Native Species Rehabilitation/Protection

The following section describes progress in efforts to rehabilitate or protect native species in the Lake Superior Basin.

Herptile Monitoring Work in Progress. Reptiles and amphibians have been identified as a critical group of species to be monitored by the State of the Lake Ecosystem Conference and the LaMP 2000. Herptiles are sensitive to anthropogenic perturbations and chemical contaminants, and many species are in decline worldwide. Lake Superior is at the northern edge of the natural range of many herptile species, and thus changes in their abundance in the basin may be indicative of pending environmental changes elsewhere. They may also be particularly useful for monitoring in Areas of Concern to document progress in remediation and restoration.

In 2002, the Terrestrial Wildlife Committee commissioned a report by Gary Casper, Herpetologist for the Milwaukee Public Museum, to describe the status of herptiles in the Lake Superior Basin. In 2003, a herptile workshop was held in conjunction with the Society for Conservation Biology meeting in Duluth. To continue the development of a basin monitoring program, a joint United States/Canadian herptile monitoring project was funded in 2005.

Figure 6. Wood Turtle. Photo Credit: http://www.glfc.cfs.nrcan.gc.ca/landscape/herp_e.html.

Steve Hecnar, from Lakehead University in Ontario, and Gary Casper will lead the project which will develop and field test a basinwide amphibian and reptile monitoring program and data repository process. This will be done by selecting representative sampling sites in the Canadian and U.S. portions of the Lake Superior Basin. Components of the project include sampling site selection, intensive surveys, database development, and statistical analyses. The statistical analyses will utilize a proportion of area occupied model capable of incorporating data from existing monitoring programs in order to achieve basinwide analysis.

Results will be applicable throughout the Lake Superior Basin for use in amphibian and reptile habitat protection and restoration. The project will allow researchers to monitor 21 herptile species and determine trends in species occupancy. The ability to detect species declines or increases will have direct bearing on both aquatic and terrestrial habitat management for these species within the basin's forests, grasslands, wetlands, lakes, and streams.

Lake Superior Prey Fish Monitoring. Researchers at the University of Minnesota Duluth, U.S. Geological Survey (USGS), and partner Lake Superior fishery agencies completed year three of a four year project to develop methodology for a pelagic prey fish monitoring program for Lake Superior. Objectives of the project were to estimate the density and biomass of prey fish in Lake Superior, to determine the level of effort and budget needed, and to identify and calibrate acoustic target strength for different prey species. Accurate estimates of forage fish biomass are critical to help agencies manage self-sustaining predator populations, primarily lake trout, and to better understand and predict ecosystem dynamics. Researchers have found that using a combination of trawl surveys and acoustics provides the best estimate of prey biomass and better coverage of the complex and spatially variable nature over the vast expanse of Lake Superior. In addition, through annual sampling in one area of the lake, they are also increasing their knowledge of annual variability in prey density. The same hydroacoustic technology was employed to assess the status of lake herring in Thunder Bay and Black Bay, Ontario, and the Apostle Islands, Wisconsin, during the 2005 fall spawning season.

Lake Superior's Lower Food Web. Last year, natural resource agencies conducted the most extensive biological sampling effort on Lake Superior in history. Six agencies from the U.S. and Canada coordinated efforts and shared resources to collect samples of organisms from microscopic plankton to fish in an effort to gain a thorough understanding of Lake Superior's lower food web. The six agencies with large research vessel and/or lower food web sampling equipment included Environment Canada, Department of Fisheries and Oceans, Ontario Ministry of Natural Resources, US EPA, WDNR, and USGS.

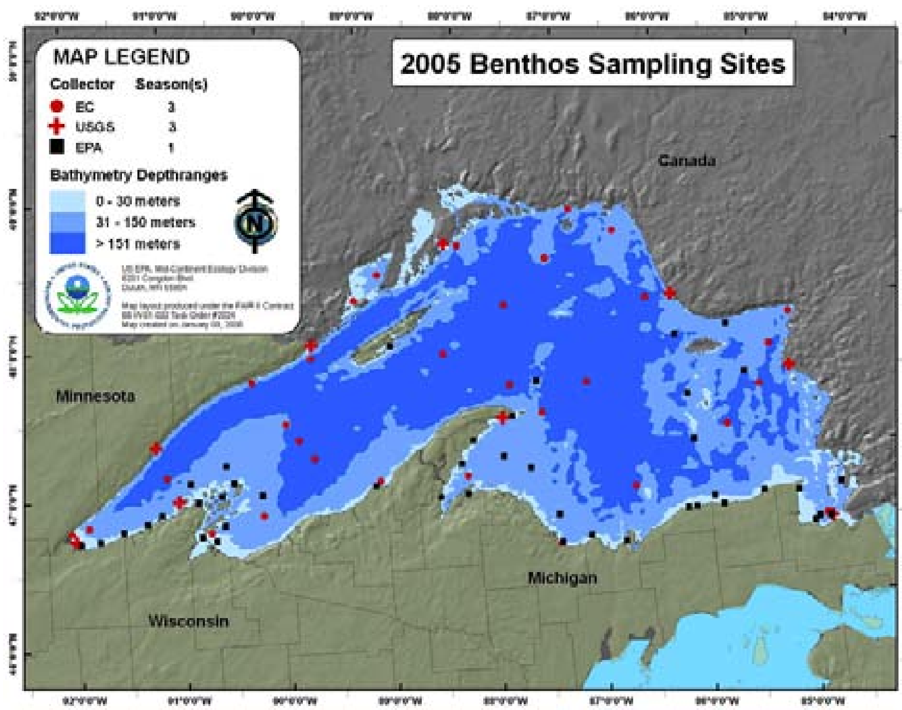


Figure 7. Locations and Depths of Zooplankton Samples Collected in 2005. Source: US EPA.

The survey components took place during spring, summer, and fall cruises. Objectives of the sampling were to describe seasonal biomass and abundance densities of phytoplankton, zooplankton, *Mysis* (tiny free swimming crustaceans), and *Diporeia* (tiny bottom dwelling crustaceans) across the lake, and to determine the production of these trophic levels if possible. Nearly 1,500 samples were collected which included 776 for zooplankton (animal plankton), 298 for *Mysis*, and 411 bottom samples. The range of locations and depths for zooplankton samples is shown in Figure 7. In addition, automated optical phytoplankton and zooplankton counters were towed by vessels and recorded data along transects totalling 1,000 km.

This collaborative and extensive sampling effort has resulted in significant progress toward understanding Lake Superior's food web. Many samples are being processed by various agencies; however, most zooplankton samples have yet to be processed. To complete the picture of the Lake Superior lower food level in a timely manner, additional funding is required to process these remaining samples.

There is a desire among agencies to establish a regular monitoring schedule for the lower food chain work. At one time, a rotating five-year cycle was mentioned whereby a focused effort would occur annually on each Great Lake. At this time, it is unclear whether agencies can commit to this type of long-term arrangement.

Lake Superior's Offshore Zooplankton Community 1998 to 2005

The US EPA's Great Lakes National Program Office has been monitoring the zooplankton populations of Lake Superior since 1992. Data collected from the past eight years during their spring and summer assessments of 19 deepwater stations (130 to 284 m) indicate that the offshore crustacean zooplankton community of Lake Superior is dominated numerically by the calanoid copepods *Diaptomus sicilis* and *Limnocalanus macrurus* and the cyclopoid *Diacyclops thomasi*. During the summer months, the cladocerans *Daphnia galeata mendotae* and *Holopedium gibberum* also appear in low numbers. Spring density of copepod adults and copepodites averages 1,100 organisms per m^3. Densities are higher in the summer (3,500 per m^3), primarily due to reproduction of diaptomid copepods. Crustacean zooplankton biomass increases from an average of 6.1 mg/m^3 in the spring to 12.5 mg/m^3 in late summer. During the past eight years, there has been relatively little change in the composition of the offshore zooplankton community of Lake Superior.

Fish production is closely linked to the availability of appropriately sized prey. The larvae of many planktivorous species are limited by the size of prey item they can swallow, which restricts them to feeding on small zooplankton during their first few months of life. As the fish grow, they switch to larger prey items. While the density of zooplankton in Lake Superior is low compared to that of the other Great Lakes, the size distribution pattern of the major species is appropriate to support the growth of planktivorous fish. The density of small (0.4 to 1.0 mm) cyclopoid copepods increases during the spring and summer months and is supplemented by the production of young diaptomids. While the density of the larger adult *Diaptomus sicilis* (1.5 mm) and *Limnocalanus macrurus* (2.5 mm) is lower, the larger individual sizes of these zooplanktons result in an increased biomass of prey for adult planktivores.

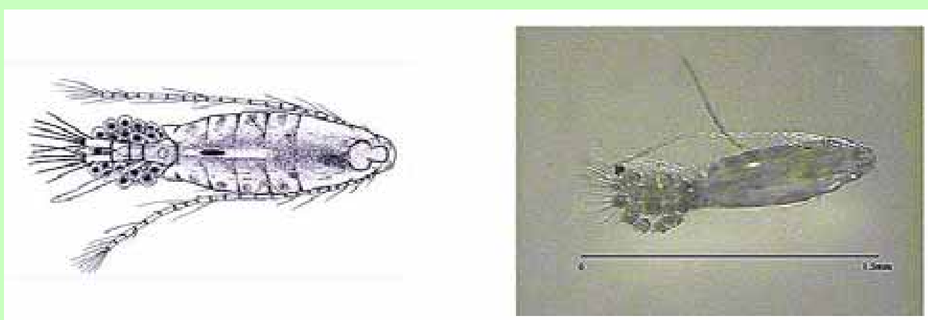


Figure 8. Adult *Diaptomus sicilis* (1.5 mm). Photo Credit: US EPA.

Status of Diporeia in Lake Superior

Over the past few decades, one of the most dramatic and enigmatic changes in the biotic community of the Great Lakes has been the decline of the deep-water amphipod *Diporeia spp*. This organism was once the dominant benthic taxa in offshore waters (> 30 m) of all the lakes. Recently, however, population declines have been documented in Lakes Michigan, Huron, Erie, and Ontario, and large areas in each of these lakes are now completely devoid of this organism (Dermott and Kerec 1997; Nalepa et al. 1998; Dermott 2001; Lozano et al. 2001; Nalepa et al. 2003).

Diporeia has long been considered a keystone species in the food web of offshore waters. It resides in the upper sediments and feeds on fresh organic material settled from the water column and, in turn, is fed upon by many fish species. Thus, it plays an important role in cycling energy from lower to upper trophic levels. Diporeia is high in lipids and therefore rich in calories, making it a valued food resource for fish. Recent changes in the condition, distribution, and abundances of several fish species have been attributed to the loss of this organism (Madenjian et al. 2003, Mohr and Nalepa 2005, Hondorp et al. 2005). One of the theories of the Diporeia decline relates to the appearance and spread of *Dreissena polymorpha* (zebra mussel) and *Dreissena bugensis* (quagga mussel). The observed declines in the lower lakes raise the question of whether similar declines may occur in Lake Superior.

Diporeia Trends in Lake Superior Unclear

A Great Lakes Diporeia workshop (Nalepa, et al. 2006) in the fall of 2005 brought together the multi-year survey findings of the following different surveyor groups: US EPA's Great Lakes National Program Office; US EPA's ORD-Duluth Mid-Continent Ecology Division; NOAA Great Lakes Environmental Research Laboratory; Dr. Mary Balcer, UW-Superior; and researchers at Michigan Technological University.

Evidence and discussion presented at the workshop suggest that zebra and quagga mussels may have a role in Diporeia decline in the other Great Lakes via food competition, toxic excretions, or mussel-caused environmental changes that increase susceptibility to disease, predation, pathogens, or oxygen levels in sediments. However, the absence of zebra mussels in deep offshore waters in western Superior suggests that the decline noted in this area may not be related to zebra mussels.

While the workshop concluded that a broad Diporeia decline in Lake Superior is not evident yet (not every study observed declines, see figure below), it recommended that agencies: 1) continue to monitor Diporeia, 2) combine datasets for analysis, and 3) examine the age structure in declining offshore populations to determine if Lake Superior is in the early stages of a decline similar to those reported in the other Great Lakes.

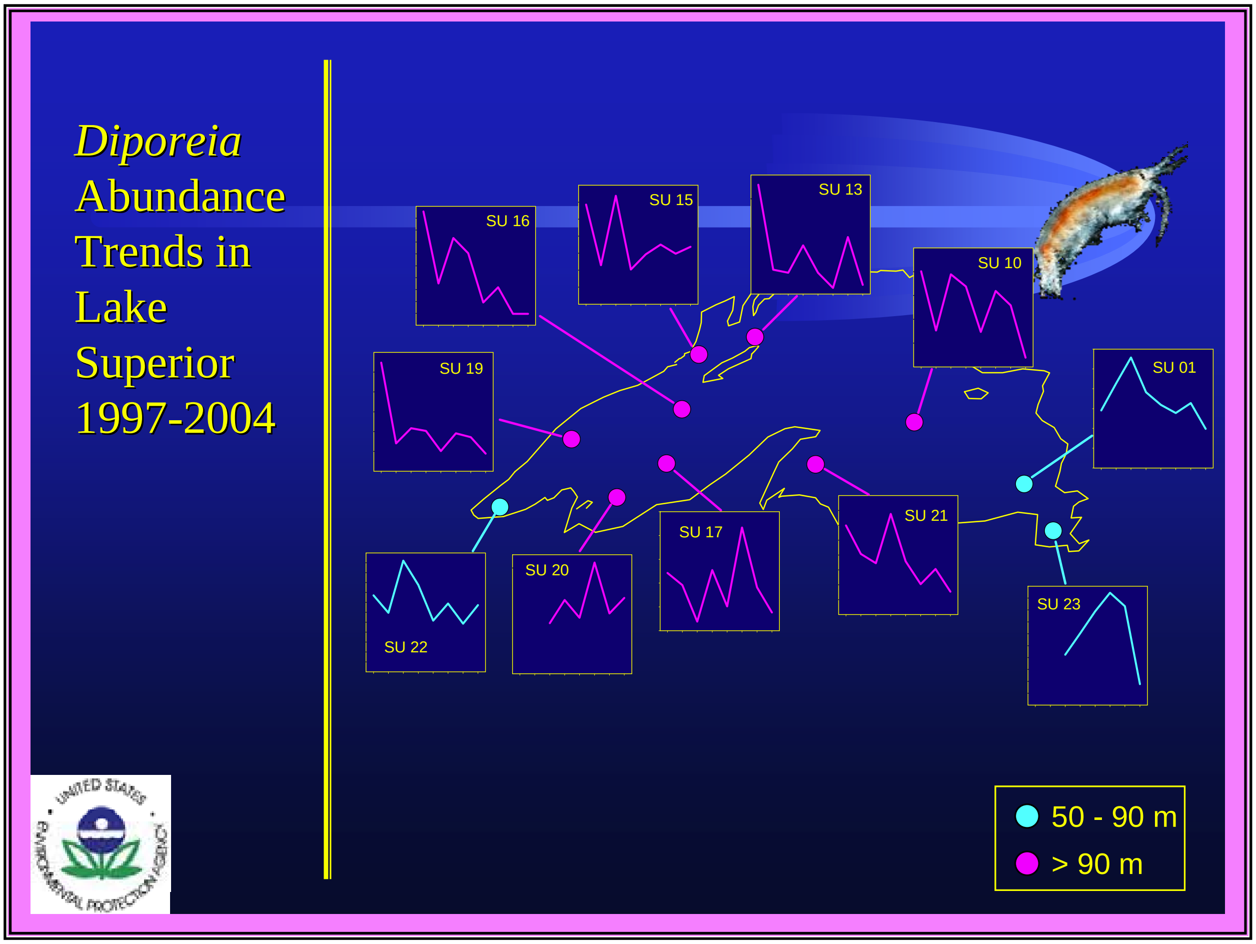


Figure 9. Diporeia Abundance Trends in Lake Superior 1997-2004. Source: David Rockwell, MS, US EPA; Mary Balcer, Ph.D., UW-Superior; Richard Barbiero, Ph.D., Grace Analytical Labs.

Mapping of Important Fish Habitat. Finding the relationship between habitat quantity and quality and fish production is an important quest as fisheries managers seek to put realistic expectations around how many fish Lake Superior can be expected to produce. By bouncing sound waves off the lake bottom and recording the strength of the return signal, the composition of the substrate can be determined. As sound waves are sent and received, location and water depth are simultaneously recorded, which allows scientists to create a geo-referenced map of the substrate. The final products of this acoustic mapping procedure are descriptions of current habitat conditions which will support decision making processes that seek to rehabilitate and sustain near shore fisheries. Our knowledge of what substrates (sand, clay, gravel, cobble) are present, in what surficial quantity, at what depth, and exactly where they are relative to other substrates or bottom features is slowly increasing.

The National Water Research Institute of Environment Canada and the USGS-Lake Superior Biological Station and others have applied their expertise in acoustic mapping surveys. Since 2002, 12 projects to map the distribution of substrates in specific areas of Lake Superior have been completed. Recent projects have addressed lake sturgeon, brook trout, walleye, and lake trout habitat in near shore and tributary sites around the lake. Sea Lamprey Control is also mapping tributary and lentic habitat (11 sites) of sea lamprey larvae to improve control efforts. The mapped details will contribute to a large-scale Lake Superior GIS mapping exercise supported by the Great Lakes Fishery Commission that is underway to synthesize all available habitat information into a user-friendly product for resource managers working in the Lake Superior Basin.

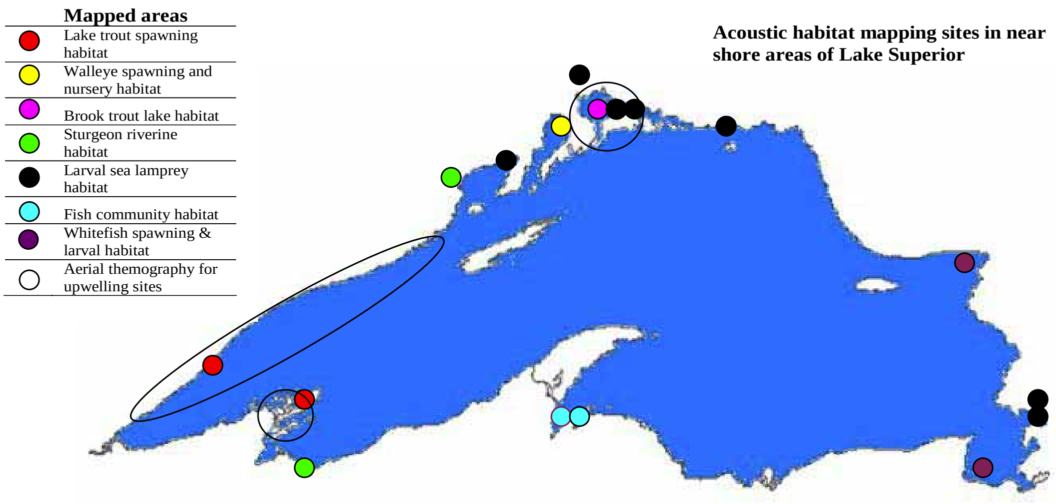


Figure 10. Acoustic Habitat Mapping Sites in Near Shore Areas of Lake Superior. Source: Aquatic Committee Co-chairs.

Individual Species Activities

Peregrine Falcon Update. The recovery of the peregrine falcon in North America has been called one of the most successful wildlife conservation projects in history. In a collaborative binational effort, non-profit organizations teamed with agencies and volunteers to recover populations of this dynamic bird of prey. In level flight, the normal speed for peregrine falcons is about 40 to 55 miles per hour. In a dive they can attain speeds in excess of 200 miles per hour as they attack their prey. The peregrine falcon was nearly extirpated in most of North America after World War II. The cause of the bird's decline was accumulation of organochlorine pesticides such as DDT in birds' tissues, which resulted in eggshell thinning and breakage during incubation. The pesticide DDT was banned in Canada in 1970 and in the United States in 1972. As a result of the ban, eggshell thinning subsided and the population recovered to the point that the species was delisted from the *Endangered Species Act* in the United States. The peregrine falcon remains designated as "Threatened" under the *Species At Risk Act* in Canada.

The Lake Superior Basin is home to the majority of known peregrine falcon nest sites and territories in Ontario. In 2005, Ontario conducted intensive nest and territory searches as part of a five-year national peregrine falcon survey in Canada. The Lake Superior Basin effort was coordinated by the Thunder Bay Field Naturalists in conjunction with the Ontario Ministry of Natural Resources (OMNR) and many volunteers. Survey results indicate a continued recovery of falcon numbers, with 43 active territories being located in the basin (56.6 percent of the provincial total). This is up from 31 territories recorded during the 2000 Ontario survey. A minimum of 79 chicks were fledged in the basin during 2005, the highest number recorded to date. Of these, 47 chicks were banded, bringing the total number of chicks banded on the Ontario side of the basin over 10 years to 319.

Figure 11. Peregrine in Flight. Photo Credit: USFWS.

Within the U.S. portion of the Lake Superior Basin, 15 pairs of peregrine falcons nested in 2005. Twelve pairs nested in Minnesota, 3 pairs in Michigan, and none in Wisconsin. A minimum of 26 chicks were fledged in the U.S. basin during 2005, and of these a total of 6 were banded.

Lynx Update. The Superior National Forest is continuing to perform National Lynx Detection Surveys and is initiating snow-track protocols. Lynx DNA collection studies implemented in 2002 show that a minimum of 42 individual lynx genotypes exist within the state, and this is likely a small proportion of the actual numbers of lynx in the State of Minnesota this year. Lynx DNA collection efforts will continue.

Figure 12. Lynx Kitten. Photo Credit: http://www.nrri.umn.edu/lynx/index.html.

The Natural Resources Research Institute, University of Minnesota, Duluth, in conjunction with the Superior National Forest and U.S. Fish and Wildlife Service, initiated a radio tracking project for lynx in Minnesota in 2003. Twenty-five different adult and yearling lynx have been radio-collared as of 2005. The radioed animals consist of 11 males and 14 females. Box traps are used to capture the lynx.

Researchers have located multiple dens and kittens. In 2004 and 2005 there were 23 lynx kittens individually identified at den sites. Observers have documented that at least 14 of the kittens born during the two year period survived the most precarious first few months of life and were doing well going into their first winter. If all goes well, these young lynx could have litters of their own in the spring of 2006.

Figure 13. 10-Month-old Lynx Kitten in the Snow. Photo Credit: http://www.nrri.umn.edu/lynx/index.html.

Native Species Rehabilitation. Since the publication by the Great Lakes Fishery Commission of lakewide rehabilitation plans for lake trout, brook trout, lake sturgeon, and walleye (http://www.glfc.org), fisheries management agencies around the lake have continued efforts to protect and re-establish these four species in habitats where they were once common.

Lake Trout. One of the greatest success stories for the Great Lakes is the rehabilitation of lake trout populations in Lake Superior that resulted from stocking, sea lamprey control, and fishery harvest regulations. Currently, self-sustaining lake trout populations are present in most areas of Lake Superior. To ensure the long-term sustainability of lake trout stocks in the face of continued recreational and commercial fishing, fishery managers must accurately estimate the maximum level of mortality that populations can withstand without overexploitation/depletion.

Researchers at the University of Wisconsin–Stevens Point are working with WDNR to develop a model that will estimate the maximum sustainable total annual mortality rate for lake trout and minimize the risk of overexploitation. They have developed a model of an age-structured population of lake trout to mimic the real population. Previously developed statistical catch-at-age and stock-recruitment models to estimate abundance, recruitment, natural mortality, fishing mortality, gear selectivity, and catchability of lake trout in Wisconsin waters of Lake Superior were updated with the most recent WDNR data. Natural mortality was modeled as a combination of a fixed base rate and a density-dependent sea lamprey induced mortality rate. Recruitment was simulated as a density-dependent function of adult lake trout abundance. Lastly, various commercial and recreational harvest allocations were modeled to account for different patterns of selectivity between large-mesh gill nets, the predominant commercial fishing method, and angling, the predominant recreational fishing method. The model will help predict effects of different levels of commercial and recreational fishing mortality on the population. The results of the simulations will be analyzed to estimate the extinction risk, the time to extinction, and the maximum sustainable harvest rate for the fishing mortality rates.

The model is currently designed for the eastern Wisconsin waters of Lake Superior, and is expected to be used by WDNR to predict how lake trout populations will react to various allocations of commercial and recreational fishing mortality and to estimate the maximum sustainable level of lake trout mortality. The model may ultimately be used by fishery managers throughout Lake Superior.

Brook Trout. *Supporting Management Actions* – Ontario, Wisconsin, and Michigan set new regulations for coaster brook trout in Lake Superior since 2003. Coaster brook trout regulations in the lake are now similar for all jurisdictions on Lake Superior. Ontario's regulations included tributaries to Lake Superior. These regulation changes are intended to protect brook trout through maturity and multiple spawning seasons in hopes of increasing reproductive success and fish abundance in the lake and its tributaries. Coasters at Isle Royale, Michigan, are fully protected through catch and release only regulations.

WDNR Bark River Brook Trout Experiment

This experiment attempts to increase brook trout abundance so that some fish will again enter Lake Superior and become coasters. It includes seeking ways to improve watershed health that restores in-stream conditions, habitat improvement at critical spawning sites, beaver control, restrictive angling regulations and monitoring population changes.

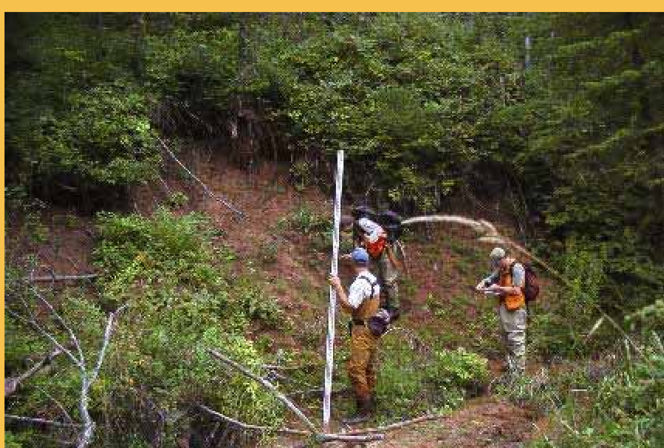


Figure 14. A crew surveys eroding stream banks. Photo Credit: WDNR.

WDNR and U.S. Fish and Wildlife Service completed the Wisconsin Lake Superior Brook Trout Plan in summer 2005. The plan's goal is "to protect and improve the self-sustaining brook trout populations and their habitat in Wisconsin's Lake Superior Basin, and attempt to rehabilitate or establish several populations that exhibit life history diversity (both stream resident and migratory "coaster" life history types). The plan can be read at http://www.fws.gov/midwest/ashland/pdf/Restorecoasterbrooktrout.pdf. The success of this plan will depend on a long-term commitment to manage watersheds to protect and restore tributary habitat. See the Watershed Initiatives section for more information on implementation activities.

Rehabilitation Activities – Rehabilitation for brook trout has followed several pathways: 1) engagement of researchers and local communities in the dissemination of information; 2) establishment of conservative fishing regulations lakewide, as described above; 3) continuance of monitoring, assessment, and research of brook trout in the lake and tributary habitats; and 4) habitat restoration.

In Ontario, Canada Ontario Agreement (COA) funding supported five coaster brook trout monitoring, assessment, and research initiatives. Projects include: identifying the range of coasters in 15 streams that had historic populations, collecting information on the timing and frequency of out-migration from tributaries, linking riverine habitats with production of coaster brook trout in the Nipigon Bay watershed, and aerial infrared photography surveys to identify areas of groundwater upwelling or springs which are potential coaster spawning sites in the Nipigon Bay area.

Figure 15. Coaster Brook Trout. Photo Credit: Ontario Ministry of Natural Resources.

The U.S. Fish and Wildlife Service and the Minnesota DNR have contracted to utilize aerial infrared photography to identify significant ground water contributions to tributaries and along the Lake Superior shoreline of Wisconsin and Minnesota. Survey work continues to determine the presence, relative abundance, and biological characteristics of coasters in many areas of Lake Superior, including numerous rivers in Michigan, Wisconsin, and Minnesota, and in streams and nearshore waters of the Keweenaw Bay Indian Community and Red Cliff Indian Reservation and Isle Royale. Stocking and evaluation of stocked fish are underway on the Grand Portage Band, Red Cliff Band, and Keweenaw Bay Indian Community Reservations, as well as in several streams in Michigan and one in Wisconsin.

Figure 16. Impaired Habitat at a Stream Crossing. Photo Credit: Ontario Ministry of Natural Resources.

Minnesota DNR has surveyed road crossings in portions of tributaries to Lake Superior that are accessible to coasters to determine if and what type of maintenance might be required to allow for fish passage during both spring and fall spawning runs. Projects targeted at restoring fish passage and limiting impairments to habitat are underway in all States. Trout Unlimited has coordinated a multi-partner project on five streams tributary to Lake Superior in the Bayfield Peninsula of Wisconsin to improve fish passage at road crossings or culverts, restore stream bank and bluff stability, reduce peak flow during heavy snowmelt and rainfall events, and stabilize in-stream habitat for potadromous species.

Walleye. OMNR's efforts to rehabilitate the largest walleye stock in Lake Superior (Black Bay stock) continue with the development of a Black Bay Walleye Stocking and Assessment Plan. Supporting work has included creation of a genetic profile of remnant and historical walleye stocks, hydro-acoustic mapping to examine historical Black Bay walleye habitat, and stocking of 100,000 fingerlings in 2004 and 200,000 in 2005. Discussion with Sea Lamprey Control and others is underway to determine the fate of the timber dam on the Black Sturgeon River, which has blocked spawning migration up the river for decades.

Walleye assessments to determine spawning populations' size and characteristics are conducted by WDNR and Minnesota DNR in the St. Louis River, Minnesota-Wisconsin, in the Kakagon River, Wisconsin, by the Bad River Band, and by Michigan DNR in numerous Lake Superior tributaries. In Michigan, abundance data is being related to the amount and quality of habitat.

To help address the Lake Superior Walleye Rehabilitation Plan (http://www.glfc.org/lakecom/lsc/lschome.php#pub) objective for the Bad River, Wisconsin, walleye population, the Bad River Band has stocked 500,000 fingerlings and 4 million fry since 2004.

The Great Lakes Indian Fish and Wildlife Commission has completed studies of contaminants in walleye and lake sturgeon in Lake Superior.

Figure 17. Sturgeon Population Assessment. Photo Credit: Ontario Ministry of Natural Resources.

Lake Sturgeon. Investigation into the status of lake sturgeon in Lake Superior has covered 15 of the 22 known historic spawning rivers. This work has occurred or is in progress in the Kaministiquia, Black Sturgeon, Nipigon, Pic system, White (Ontario), Batchawana, Chippewa, and Goulais Rivers in Ontario, the Bad and White (Wisconsin) Rivers, and Chequamegon Bay in Wisconsin, the St. Louis River, Minnesota/Wisconsin, the Pigeon River, Minnesota-Ontario, and the Sturgeon and Ontonagon Rivers, and Portage Lake in Michigan. Lake sturgeon status (spawning activity, recruitment, movement) in seven of the rivers has been completed, and genetic profiles for each population have identified the relatedness and tributary fidelity of these populations.

Figure 18. Fluctuating Water Levels May Strand Spawning Sturgeon. Photo Credit: Ontario Ministry of Natural Resources.

Habitat related work includes assessing the impacts of hydro power generation strategies on habitat and reproductive success through examination of river habitats and sturgeon behaviour associated with current and proposed hydro power generation on the Kaministiquia River, in Ontario. A multi-year agreement with Ontario Power Generation has been implemented to study these impacts (water levels and flow rates) on sturgeon habitat and reproductive success and behaviour.

Mapping and description of lake sturgeon habitat in the lower Bad River, Wisconsin, and Kaministiquia River were completed and will support studies of habitat preferences of juvenile sturgeon. Habitat preference of stocked sturgeon is being studied in the Ontonagon River, Michigan.

In 2004, the second of three planned Great Lakes Lake Sturgeon Coordination Meetings was held. Sturgeon researchers and managers from around the Great Lakes Basin continue to assess sturgeon status and communicate rehabilitation progress and to plan and coordinate next steps through this venue.

Juvenile Lake Sturgeon Habitat Research Project. The Grand Portage Band received funding and is working with the 1854 Authority, U.S. Fish and Wildlife Service, Fond du Lac Band, Minnesota DNR, and the U.S. Geological Survey to investigate habitat use of young lake sturgeon in the St. Louis River and presence of lake sturgeon in the Pigeon River. Lake sturgeon have been captured and tagged with a combination radio/acoustic transmitter and will be tracked for one year. This information will allow managers to identify, protect, and/or rehabilitate critical habitats utilized by juvenile lake sturgeon.

6.1.3 Nuisance Species Developments/Efforts

Many Great Lakes researchers and managers consider invasive exotic species the single most important and immediate threat to Great Lakes ecosystems and their food webs. The following section describes accomplishments related to prevention and control of invasive species.

Developing a Landscape-Scale Invasive Free Zone. The goal of this long-term project, initiated in 2005, is to create an invasive-free zone by eliminating non-native invasive terrestrial and emergent aquatic plants on the Whittlesey Creek National Wildlife Refuge, associated

Viruses; bacteria; parasites; red, green, & brown algae; phytoplankton; zooplankton; amphipods; oligochaetes; snails; flatworm; mussels; fish

Source: Great Lakes Aquatic Nonindigenous Species List, NOAA

Ballast Water Regulation in Michigan

To prevent any new aquatic invasive species entering the Great Lakes through Michigan's ports via ballast water discharge from ships (the primary pathway historically), Michigan enacted legislation in 2005 requiring all oceangoing vessels engaging in port operations in the state to obtain a permit from the Department of Environmental Quality (MDEQ). In addition, the legislation required the MDEQ to facilitate formation of a Great Lakes Aquatic Nuisance Species coalition and to seek agreements with other states in the Great Lakes to implement on a basinwide basis water pollution laws that prohibit the discharge of aquatic nuisance species from oceangoing vessels. The MDEQ is finalizing the permit and facilitating the Coalition in 2006, toward a January 1, 2007 implementation date.

Michigan Public Act 33 of 2005 reads: "Beginning January 1, 2007, all oceangoing vessels engaging in port operations in this state shall obtain a permit from the department. The department shall issue a permit for an oceangoing vessel only if the applicant can demonstrate that the oceangoing vessel will not discharge aquatic nuisance species or if the oceangoing vessel discharges ballast water or other waste or waste effluent, that the operator of the vessel will utilize environmentally sound technology and methods, as determined by the department, that can be used to prevent the discharge of aquatic nuisance species. "

A general permit for port operations in Michigan by ocean-going vessels is under development by the MDEQ-Water Bureau in 2006. Extensive public consultation and consultation with other states is occurring on the permit. The permit will apply to all ocean-going vessels that a) engage in port operations in Michigan and do not discharge aquatic nuisance species into the waters of the state; b) discharge ballast water treated by one or more of the ballast water treatment methods determined by the MDEQ to be adequate treatment; and c) have not been determined by the MDEQ to need an individual permit. Treated ballast water will be authorized to be discharged from ocean-going vessels specified in individual certificates of coverage under the general permit. Ocean-going vessels will need a permit for port operations in Michigan starting January 1, 2007, to protect Michigan from new aquatic invasive species.

private lands, and adjacent U.S. Forest Service property at the Northern Great Lakes Visitor Center (720 acres in total). Native plant communities will also be restored. Monitoring via chronological GPS mapping and GIS analysis, photo-point imagery, and plant species density ratings will document treatment and restoration success.

Thus far, twenty-one species have been identified and mapped on approximately 600 acres. Mapping will be completed in 2006, and treatment and restoration plans will be developed. In addition, control has been initiated on nine species, and the University of Wisconsin-Extension is working on interpretive planning. Invasive species control and habitat restoration will continue and be expanded as funding allows.

Project partners include numerous private landowners, National Park Service Great Lakes Network Office-Exotic Plants Management Team, U.S. Forest Service, Great Lakes Indian Fish and Wildlife Commission, Northland College and Sigurd Olson Environmental Institute, WDNR, and the University of Wisconsin-Extension.

Aquatic Invasive Species. Most invasive organisms that have entered Lake Superior have originated from marine and estuarine environments in Europe and Asia. They have arrived here by various human transport systems, primarily ship ballast water. The exchange of ship ballast water in Great Lakes waters remains a serious concern. This includes ships entering the Great Lakes with no ballast water on board (NOBOB), as the sludge in their ballast tanks can hold organisms which may be discharged with ballast water that they may take on and exchange in the Great Lakes system. The Superior Work Group continues to encourage adherence to best management practices to reduce the risk of exotic species introduction.

All Lake Superior ports are at risk of receiving aquatic nuisance species (ANS) if vessels discharge the contents of ballast tanks while in or near the port. In Ontario, the imminent re-establishment of interlake ship traffic between Michipicoten Bay and the lower lakes puts the bay's aquatic ecosystem under threat. Presently Superior Aggregates Ltd., a company owned by Carlo Companies, a U.S. road-building contractor, is seeking permits to continue developing an aggregate extraction operation on the backshore area adjacent to Michipicoten Harbour. The company has stated its intent to ship the aggregate by lake carrier to lower lakes ports. The Superior Work Group has communicated its concerns to the company and offered suggestions to eliminate the potential transfer of non-native organisms between lakes.

Recently an addition was made to the list of known aquatic invasive species in the Lake Superior Basin. In December 2005, an adult Chinese mitten crab was found on a Thunder Bay hydro plant water intake screen. These crabs have successfully established themselves in marine coastal areas in North America and Europe and use both salt and fresh water habitats to complete their life cycles. They have not adapted to a wholly fresh water environment in other areas and are not expected

Figure 19. Adult Chinese mitten crab found on a Thunder Bay hydro plant water intake screen. Photo credit: Ontario Ministry of Natural Resources.

to do so in the Great Lakes. This discovery re-emphasizes the risks associated with ballast water exchange within the Great Lakes.

Nuisance species that continue to expand their range in Lake Superior include the fish Eurasian ruffe and round goby, and the spiny water flea (*Bythotrephes longimanus*). Ruffe have spread from the point of first discovery in Duluth, Minnesota, along the south shore of the lake and into local tributaries as far east as Marquette Harbour, Michigan. An isolated population is also being monitored in Thunder Bay, Ontario. The round goby is known to be established in Duluth-Superior Harbour, Minnesota/Wisconsin, and Thunder Bay Harbour, Ontario; recently it was found in the Amnicon River, Wisconsin. Michigan has detected round goby in the live bait purchase of at least one angler in the Upper Peninsula. Zebra mussels remain locally associated with multiple harbours and nearby embayments.

Figure 20. Confirmed Ruffe Sightings in the Great Lakes. Photo Credit: USFWS and USGS.

To monitor fish community structure, fish community surveys were continued in Thunder Bay Harbour and four U.S. tributaries colonized by ruffe and other ANS. In April 2005, the University of Wisconsin-Extension sponsored an ANS awareness conference for lake associations and resort owners in northwest Wisconsin. Over 60 participants attended the conference near Cable, Wisconsin. In October 2005, the Great Lakes Indian Fish and Wildlife Commission hosted a conference to improve regional (MN, WI, MI) cooperation and collaboration among all organizations actively engaged in managing ANS in the upper Great

Lakes Basin. Educational materials (pocket guides, signage at boat landings, brochures, videos, etc.) continue to be produced by Sea Grant, Federation of Ontario Anglers and Hunters, and others. These materials are distributed throughout the Lake Superior Basin to help prevent the introduction and to control the spread of ANS.

Emerald Ash Borer Confirmed in Lake Superior Basin. The emerald ash borer (EAB) is a non-native beetle from Asia that invades and readily kills ash trees. In the Great Lakes region, that includes three common and important species: white, black, and green ash. EAB was first reported in the U.S. in 2002 in the Detroit and Windsor areas. However, surveys and research since that time indicate that the beetle has been present in Michigan for a much longer time, perhaps since the early 1990's. EAB has proven to be a tremendously effective tree killer, with estimates of 15 million dead trees at this time. Spread is a major concern, and numerous outlying populations have been located throughout the Lower Peninsula of Michigan, northwest Ohio, and in northeastern Indiana.

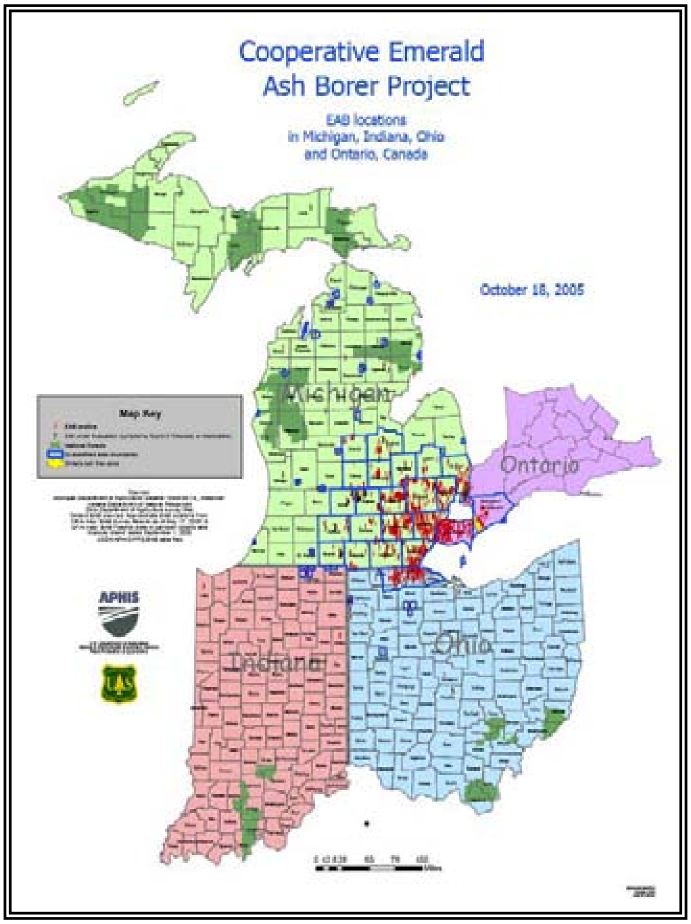


Figure 21. Emerald Ash Borer Locations. Photo Credit: USDA.

In September 2005, an introduction was also confirmed in Michigan's eastern Upper Peninsula within the Lake Superior Basin. Almost all of the outlying infestations have been traced back to firewood introductions from the original core area of southeast Michigan. Further surveys are underway, although a viable trap or attractant has not yet been discovered. This makes finding new introductions difficult. At this time, the overall program goal is to contain the infestation and eliminate the long distance spread of infested firewood. A number of agencies are evaluating tools that might be used to limit the movement of firewood. Managers hope that this will provide researchers time to develop viable management strategies.

Sea Lamprey Program. Sea lamprey management and control activities include laboratory experimentation of new control and management techniques. The program is committed to a number of different control techniques that support the integrated management (lampricide treatment, sterile male release, trapping, research into pheromone attractants) of sea lampreys in the Great Lakes. Adult lampreys are trapped annually in about 20 Lake Superior tributaries as a source for the Sterile Male Release program as well as to monitor success in suppressing sea lampreys in the lake. The Sea Lamprey Control program has added additional treatment efforts since 2001 to reduce sea lamprey abundance in the basin, and 23 streams and 3 lentic areas are targeted during 2006 for lampricide treatment in Lake Superior. The program is making significant progress towards determining what stream and lake habitats are important nursery areas for larval sea lamprey and therefore may make the biggest contributions to the adult parasitic stock in the lake. Acoustic habitat mapping to inventory key areas offshore of major sea lamprey producing tributaries has resulted in the treatment of several lentic areas since 2004, and this work continues. This work has saved additional thousands of pounds of lake trout, which significantly contributes to lake trout recovery in Lake Superior. Additionally, work is being directed at determining which streams contribute lampreys as survivors of stream lampricide treatments to target more treatment effort at likely sources where increased fish wounding has been reported.

6.1.4 Education/Outreach Initiatives

The following section discusses a few initiatives related to outreach and education efforts.

Wisconsin State, County, and Private Forest Certifications. In June 2005, Wisconsin received certification of sustainable management for privately owned, non-industrial forestland enrolled in the state Managed Forest Law (MFL). Forests owned by Wisconsin counties received certification in March 2005, and state-owned forests were certified in summer 2004. Nearly 5 million acres of forest are certified as sustainably managed in Wisconsin statewide. Forest certification is a process in which forest landowners undergo an audit of their practices by an independent third party organization.

The Great Wisconsin Birding and Nature Trail. This initiative will develop a mapped auto trail that will be statewide when complete. It is a project of the Wisconsin Bird Conservation Initiative, with leadership from the WDNR's Endangered Resources Program. The Wisconsin Department of Tourism produced a viewing guide for the Lake Superior and Northwoods region in 2004. For more information, visit www.wisconsinbirds.org/trail/overview.htm.

Bird's Eye View of Marquette County Shoreline on Central Lake Superior Watershed Partnership's Website. A Lake Superior "Aerial Shoreline Viewer" has been developed by the Central Lake Superior Watershed Partnership as part of a state funded coastal management effort. You can use the viewer to see the Lake Superior shoreline of Marquette County from an altitude of 500 feet or 1,000 feet. The Central Lake Superior Watershed Partnership worked with Benchmark GIS and the Bayfield County Land Records Department in the creation of this unique application, which is located at http://www.superiorwatersheds.org/shorelineviewer.asp.

6.2 CHALLENGES AND NEXT STEPS

The Habitat, Terrestrial Wildlife, and Aquatic committees have identified a number of challenges as we move forward in the implementation of the LaMP for Lake Superior. In general, all committees will continue to encourage projects by partner agencies and governments which further the objectives of the LaMP. All the agency partners are acting within their areas of jurisdiction with the good of the Lake Superior Basin in mind. Many of the committees' and partners' accomplishments are highlighted in this report. The committees will remain focused on forwarding the message, "complete all projects with the big lake in mind."

In the new LaMP Chapter 6, representing the consolidation of four chapters of the LaMP 2000, the committees identify five broad action areas: Information Gathering, Monitoring, Communication, Planning, and Stewardship. Taking effective actions in these areas can be said to represent the overall challenges to achieving a sustainable Lake Superior ecosystem that is a global model for resource management.

More specifically, active and continuous *information gathering* is required to help us understand and piece together the intricacies of the complex relationship between living organisms and their physical environment. *Monitoring* may take many forms and is ultimately designed to direct management activities and policy development. Monitoring of population trends (change, stability), or research-oriented monitoring to gain an understanding of the cause and effect of specific actions on species or habitats, or why a project was a success or failure, will provide sign posts to improve future management within the lake basin. Together these actions will provide insight and knowledge that can be communicated to governments, policy makers, planners, managers, and citizens of the basin. This will enable informed and effective *communication* about the links between land and resource use and ecosystem health with industry, business, landowners, and the public. Moving toward actively *planning* at a basinwide scale will assist in addressing the gaps in, and impediments to, sustainable resource management of land and water resources, help speak to the needs of today, and prepare us for future challenges. Finally, addressing *stewardship* needs will help foster the development of a healthy basin ecosystem that is resilient to perturbations from human activities and provides a broad range of sustainable benefits to its citizens. This category of active stewardship actions includes those "on-the-ground" activities that most directly impact the ecosystems that make up the basin.

The challenge of protecting and preserving Lake Superior and its basin require a long term approach by governments, industry, non-governmental organizations, and individuals. In 2004 the committees noted a number of significant needs that, if successfully addressed, would make important contributions to the LaMP goals related to the Lake Superior ecosystem and ultimately human health. While these needs remain, progress has been made on many of them.

Over the next two years, the committees and partner agencies have identified a number of steps that will help us begin to meet the needs and challenges described above. Future accomplishments continue to be dependent upon commitments by governments and other organizations, including individuals, to support the science, resource management, and legislative activities that will protect and restore the basin. During the 2006-2008 reporting period, the committees will continue to support, resource, and seek funds and partners for presently occurring projects and issues, new projects, and emerging issues.

6.2.1 Information Gathering

- *Challenge: Map and quantify critical habitat for species of interest to management agencies.*

Next Step: Agencies will continue to conduct projects to describe, quantify, and map habitat (substrate and water depth) in areas of important fish habitat, as resources become available. Thus far, funding for these efforts has been piecemeal both in terms of location and species focus and is dependent upon individual agency interest and needs. A comprehensive lakewide effort would be of great benefit to generate information that will help agencies develop fish abundance goals based on the quantity of critical habitat throughout Lake Superior.

- *Challenge: Fund continued monitoring efforts for invasive species and fish community changes and status*.

Next Steps: 1) Support the continuance of research to examine the feasibility of using sea lamprey pheromones as an additional tool for control and management of sea lamprey; 2) Recommend that agencies attempt to develop protocols and obtain resources needed to monitor all areas of the lake that are at high risk (upper St. Marys River, all ports of call by lake carriers, baitfish harvesters) to aquatic nuisance species establishment; 3) Support proactive efforts to assess and describe fish community composition that will facilitate agencies ability to predict or evaluate changes due to introduced species.

- *Challenge: Prevent invasion and transport of non-native species within the Lake Superior Basin.*

Next Steps: 1) Continue educational and voluntary efforts to prevent introduction of aquatic nuisance species; 2) Identify and implement practices that reduce the potential for introduction of aquatic nuisance species, such as ballast water treatment or regulatory measures that prevent transport of species to or from Lake Superior.

- *Challenge: Provide ongoing support and maintenance of the geographic database and projects associated with the Lake Superior Decision Support System (LSDSS).*

Next Steps: This information is essential to the effective implementation of the LaMP, as it provides natural resource information to decision makers. One of the databases associated with the LSDSS contains information on important habitat conditions in the Lake Superior Basin and has been used to produce a map of important habitat in the basin. The Habitat Committee has recently undertaken a revision to the map and its accompanying habitat site information databases. This effort will include reviewing the map and attempting to gather additional information about the sites already listed as well as contacting state, federal, and tribal agencies to identify additional sites that are not currently on the map. In addition, the information gathered will be incorporated into the Site Explorer kiosks that are located at six sites around the basin. This work will assist the committee in meeting another of the challenges identified in the LaMP 2004, to fill information gaps on the status and trends of habitat conditions in the Lake Superior Basin and develop management recommendations to protect and restore important habitat sites.

- *Challenge: Expand knowledge of inland and aquatic systems and the human induced perturbations that may have changed or limited their productivity*.

Next Step: 1) Identify contacts and consolidate information on inland aquatic resources to be reported for LaMP 2008; 2) Coordinate and develop partnerships among governmental agencies at all levels, and among local and regional road commissions, and secure resources needed to correct road crossings that are improperly functioning and limit the productivity of aquatic resources.

- *Challenge: Describe baseline aquatic conditions and restore aquatic habitat related to mine exploration, present sites and future development*. Mining exploration and interest in development in the basin is increasing. Resource management agencies lack baseline information on aquatic communities needed to adequately address environmental issues related to mine development or to evaluate changes that may occur if mines are constructed.

Next Steps: Encourage agencies to seek funding for information gathering activities that will provide baseline environmental conditions to address environmental issues related to mine development or to evaluate changes that may occur if mines are constructed.

6.2.2 Monitoring

- *Challenge: Establish agency support for and maintenance of long-term biota and habitat monitoring programs*.

Next Steps: Support the 2006 lower trophic level monitoring effort for Lake Superior and advocate for establishment of a long- term, partnership-based lower trophic level monitoring program. Two important monitoring program efforts (acoustic surveys for prey fish and lower trophic level surveys) have been designed and successfully tested. Agencies are now challenged in their ability to institutionalize these efforts as monitoring programs capable of establishing long term data sets. Diporeia monitoring by agencies should continue with combined analysis of all data sets to determine Diporeia status in near and off shore habitats in Lake Superior compared to the other Great Lakes.

Next Steps: Support the development and implementation of a partnership to develop a basinwide monitoring program for herptiles (see description of accomplishment related to herptiles in the Native Species Rehabilitation/Protection section, above).

Next Steps: The Terrestrial Wildlife Committee will focus on medium-sized carnivores (see "Medium-Sized Carnivore Monitoring" sidebar) and breeding bird monitoring.

Next Steps: Monitoring land use change is receiving growing attention in the Lake Superior Basin and nationwide. Land use change is the paramount issue affecting all natural resources, and decisions made today will effect fish and wildlife populations far into the future. As more habitat is lost to development, wildlife populations will most likely decline. The TWC and Habitat Committees propose the development of a method by which land use change can be monitored over time in order to track this issue as we work toward LaMP implementation.

Next Steps: The Great Lakes Environmental Indicators (GLEI) project has provided baseline information for a variety of wetland ecosystems and high energy shorelines in the U.S. Lake Superior coastal region. These efforts focused on many important biological communities, PAH contamination in sediments, and landscape characterization in the basin. Some efforts are moving forward to provide information for the Canadian portion of the coastal region as well. In order to make best use of the data that has been gathered, infrastructure needs to be developed to periodically monitor a suite of the parameters gathered as part of the GLEI effort. These data would provide the information necessary to inform managers as well as the public about whether coastal conditions are improving or declining. Moreover, an

Medium-Sized Carnivore Monitoring

Monitoring medium-sized carnivores is one of the monitoring goals of the Lake Superior LaMP. Yet this diverse group of mammals is comprised of secretive and often solitary species which are difficult to count. Thus, techniques to monitor medium-sized carnivores are usually labor intensive and expensive.

The integration of non-invasive survey techniques and molecular ecology may be able to solve some of these monitoring dilemmas. Pioneering work by Bronwyn Williams, graduate student at Michigan State University, developed a technique to monitor fishers and martens on the Ottawa National Forest within the Lake Superior Basin. This technique involves the use of a hair snare in which animals are enticed into a wooden structure on a tree with glue pads and bait inside. As the animal reaches for the bait it brushes against the glue pads and a few hairs are pulled out. These hairs can then be either field identified or sent to a genetics lab for positive identification.

This technique is now being applied as one of the first large-scale monitoring efforts in Wisconsin for American marten. This collaborative effort between USFS, GLIFWC and WDNR is designed to obtain distributional data on martens for northern Wisconsin, an area almost entirely in either the Lake Michigan or Lake Superior Basins. Jonathan Gilbert, GLIFWC wildlife biologist and the U.S. Co-Chair of the Wildlife Committee of Lake Superior, is leading the effort on behalf of the GLIFWC. He is hopeful that, if this technique works for martens in Wisconsin, it can be adapted for use in the Lake Superior Basin.

Figure 22. American Marten with Radio Collar. Photo Credit: John Wright, U.S. Forest Service.

appropriate infrastructure and monitoring design framework can help diagnose the causes of major ecosystem degradation in the Lake Superior coastal region. This would then allow appropriate management decisions to be made to curtail degradation and maintain or improve ecosystem health.

6.2.3 Communication

- *Challenge:* Educate the public on important habitat and ecological resources in the Lake Superior Basin by expanding the use of interactive information kiosks.

Next Steps: The Habitat Committee will maintain the current kiosk network and update information in the databases that support the kiosks. The update to the important habitat map will assist in this regard (see description of accomplishment in the Watershed Initiatives section, above).

- *Challenge:* Develop communication tools to present information, issues, and solutions related to the Lake Superior Basin ecosystem.

Next Steps: The Habitat and Terrestrial Wildlife Committees will maintain and update their joint web site. In addition, the Committees will work with the Communications Committee as appropriate to develop communication tools.

6.2.4 Planning

- *Challenge: Ensuring the maintenance of healthy aquatic communities on rivers with, and those identified for, hydro power development.*

Next steps: First steps have begun in Ontario with the participation of Ontario Power Generation in a five year study of the impacts of water flow and level on sturgeon in the Kaministiquia River. Other rivers under hydro power proposals or development need clarification of water use. The term "run of the river" does not yet have a shared definition by involved parties in Ontario. Planning by a multi-agency team continues for restoration of natural resource damages caused by the 2003 failure of two dams on the Dead River, Michigan. The Power Company decided to rebuild the dam at the Silver Lake reservoir; however, a decision has not yet been made for the Tourist Park dam

- *Challenge: Maintaining continued support for LaMP projects in order to accomplish LaMP goals will require continued effort by the LaMP to ensure governments keep the LaMP in the top priority of their funding targets.*

Next Steps: 1) Communicate the importance of the Canada-Ontario Agreement as a funding mechanism to achieve LaMP objectives to senior level managers in the Canadian federal and Ontario provincial government; 2) List the important U.S. funding sources and means to keep LaMP priorities at the top of granting lists.

6.2.5 Active Stewardship

- *Challenge: Preventing invasion and transport of non-native species within the Lake Superior Basin.*

The little to no progress that has been made on this most difficult challenge has managers and others exceedingly concerned. Ruffe have been transported to Marquette Harbour, round goby has made it into angler bait buckets in Michigan, a Chinese mitten crab was found in Thunder Bay Harbour, and the emerald ash borer has been confirmed in the Eastern Upper Peninsula of Michigan. Public, angler, and industry education is either not having an impact, is being actively ignored, or the response is perceived to be too costly to implement. The Sustainability Committee's community awareness survey noted that inconvenience was a significant reason for basin residents not making a greater effort to change negative environmental behaviour.

Next Steps: 1) Continue to monitor the expansion of existing invasive species and occurrence of new ones, and communicate findings to public, stakeholders, agencies, and industry, emphasising their roles for prevention and containment; 2) Establish contact with shipping and other industries whose activities are or may be contrary to the goals and objectives of the LaMP. Seek their voluntary compliance and use of mitigating actions to ensure no invasive species are introduced to presently uninfected areas.

- *Challenge: Continue to implement Rehabilitation Plans for lake sturgeon, walleye, lake trout, and brook trout and manage the prey base to support self-sustaining lake trout populations.*

Next Steps: 1) Continue to work with local communities and stakeholders to rehabilitate coaster brook trout, walleye, and sturgeon populations and manage the lake trout fishery to ensure stocks are self-sustaining; 2) Complete a report on the status of lake herring since the recovery of its top predator, lake trout.

- *Challenge: Protecting critical lake and tributary habitats*.

Next Steps in Ontario: 1) Ontario will continue to work with Parks Canada to ensure the details in the new Lake Superior National Marine Conservation Area management plan support LaMP goals and objectives; 2) Seek a means to protected lands, under development threat, which maintain critical ground water flows for coaster brook trout spawning in the area known as Gapen's Pool in the Nipigon River.

Next Steps in Wisconsin: A new Lake Superior Conservation Reserve Enhancement Program (CREP) in the Wisconsin Lake Superior Basin is a federal, state, and county partnership that will provide substantial financial incentives to land owners to establish forested riparian buffers along streams to reduce runoff. Previously, few Lake Superior Basin landowners qualified for this program because the land did not meet cropping history requirements. The new program expands eligibility to pasturing and hay production, which are more prevalent agricultural uses in the basin. The goal is to apply the CREP program to agricultural lands along 80 miles of streams in the Lake Superior Basin.

Hog Island Inlet Next Steps: In November 2005, the cleanup of Hog Island Inlet in the St. Louis River AOC was completed, the second contaminated sediment project under the U.S. *Great Lakes Legacy Act*. Because of its location, the 17-acre embayment off Superior Bay has excellent shallow water habitat potential now that contaminants have been removed. It is a quiet embayment surrounded by wetland near the high energy environment of Superior Bay and the entry to Lake Superior, which makes it an excellent stopping point for fish and birds and excellent nursery habitat for fish. Many agencies and local organizations are interested in a future habitat restoration project for the area. Restoration of this shallow bay habitat helps meet goals of the St. Louis River Habitat Plan (2002).

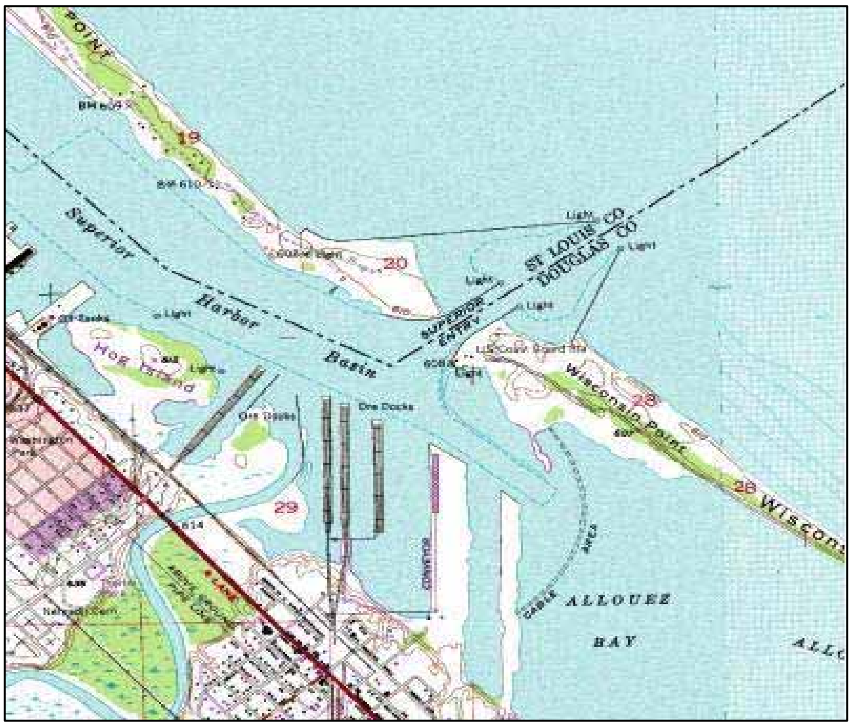


Figure 23. Map of Hog Island Inlet. Source: WDNR.

6.3 REFERENCES

Balcer, M., Schmude, K., Rockwell, D. C., and Barberio, R. "Diporeia are declining throughout the Great Lakes: does this include Lake Superior?" Workshop Presentation, October 20-21, 2005.

Dermott, R. 2001. Sudden disappearance of the amphipod *Diporeia* from eastern Lake Ontario, 1993-1995. J. Great Lakes Res. 27: 423-433.

Dermott, R. and Kerec, D. 1997. Changes to the deepwater benthos of eastern Lake Erie since the invasion of *Dreissen*a: 1979-1993. Can. J. Fish. Aquat. Sci. 54: 922-930.

Hondorp, D. W., Pothoven, S. A., and Brandt, S. B. 2005. Influence of *Diporeia* density on the diet composition, relative abundance, and energy density of planktivorous fishes in southeast Lake Michigan. Trans. Amer. Fish. Soc. 134: 588-601.

Lozano, S.J., Scharold, J.V. and Nalepa, T.F. 2001. Recent declines in benthic macroinvertebrate densities in Lake Ontario. Can. J. Fish. Aquat. Sci. 58: 518-529.

Madenjian, C. P., Holuszko, J. D. and DeSorcie, T. J. 2003. Growth and condition of alewives in Lake Michigan, 1984-2001. Trans. Amer. Fish. Soc. 132: 1104-1116.

Mohr, L. C. and Nalepa T. F. 2005. Proceedings of a workshop on the dynamics of lake whitefish (*Coregonus clupeaformis*) and the amphipod *Diporeia spp*. in the Great Lakes. Great Lakes Fish. Comm. Tech. Rep. 66.

Nalepa, T. F., Rockwell D. C. and Schloesser D. W. 2006. Disappearance of the Amphipod Diporeia in the Great Lakes: Workshop Summary, Discussions and Recommendations. 22 p.

Nalepa, T. F., Fanslow, D. L., Lansing, M. B. and Lang, G. A. 2003. Trends in the benthic macroinvertebrate community of Saginaw Bay, Lake Huron, 1987 to 1996: responses to phosphorus abatement and the zebra mussel, *Dreissena polymorpha*. J. Great Lakes Res. 29: 14-33.

Nalepa, T. F., Hartson, D. J., Fanslow, D. L., Lang, G. A. and Lozano, S. J. 1998. Declines in benthic macroinvertebrate populations in southern Lake Michigan, 1980-1993. Can. J. Fish. Aquat. Sci. 55: 2402-2413.

Scharold, J. "Recent trends in abundance of Diporeia in Lake Superior." Workshop Presentation, October 20-21, 2005.

Scharold, J. V., S. J. Lozano, and T. D. Corry. 2004. Status of the amphipod Diporeia spp. in Lake Superior, 1994-2000. J. Great lakes Research 30 (Supplement 1): 360-368.

Urban, N. E., Auer, M. T., Auer, N.A., and Verhamme, E. "Diporeia distribution and carbon fluxes in Lake Superior." Workshop Presentation, October 20-21, 2005.

Members of the Committees that cooperated to produce this chapter are:

Terrestrial Wildlife Committee

Co-Chairs:	Jonathan Gilbert, Great Lakes Indian Fish and Wildlife Commission Neil Dawson, Ontario Ministry of Natural Resources
Members:	Julie Van Stappen, Apostle Island National Lakeshore Paul Sandstrom, Natural Resources Conservation Service Dr. Azim Mallik, Lakehead University Pam Dryer, U.S. Fish and Wildlife Service Ed Lindquist, Superior National Forest, USFS Maya Hamady, Minnesota DNR Bob Doepker, Michigan DNR JoAnn Hanowski, CWE/NRRI Cheri Ford, Ottawa National Forest, USFS Ted Koehler, U.S. Fish and Wildlife Service Lisa Venier - Canadian Forest Service Scott Jones, Ontario Ministry of Natural Resources Ted Gostomski, Wisconsin DNR Steve Schlobohm, U.S. Forest Service

Habitat Committee

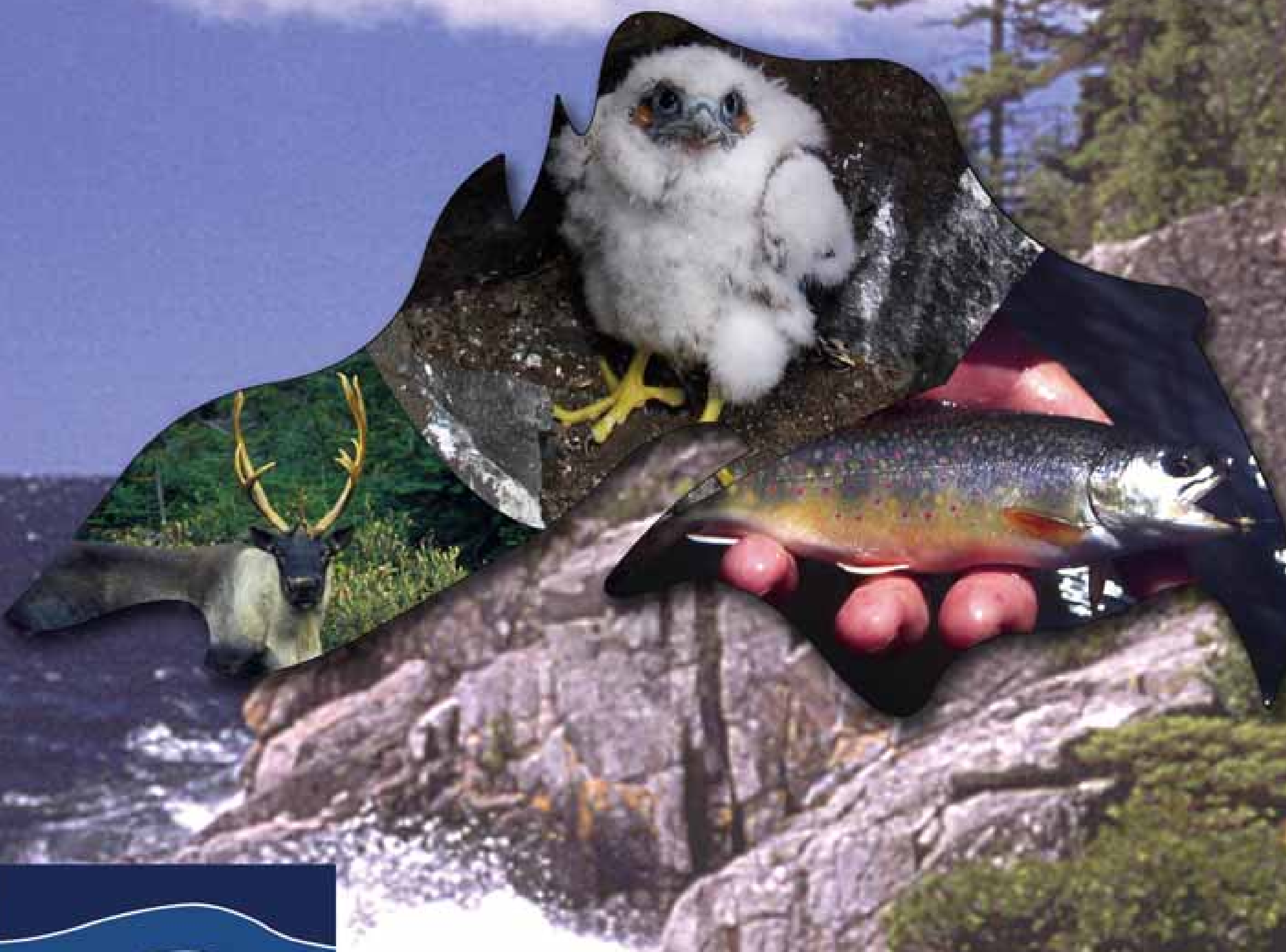
Co-chairs:	Marilee Chase, Ontario Ministry of Natural Resources Ann McCammon-Soltis, Great Lakes Indian Fish and Wildlife Commission
Members:	Mike Ripley, Chippewa Ottawa Resource Authority Joan Elias, National Park Service Carlye Olson, 1854 Authority Brigitte Collins, Canadian Wildlife Service Leah Anne Gibala, Bad River Band of Lake Superior Chippewa Roger Eberhardt, Michigan Department of Environmental Quality Norman Grannemann, U.S. Geological Survey Steve Schlobohm, U.S. Forest Service

Aquatic Communities Committee

Co-Chairs:	Sue Greenwood, Ontario Ministry of Natural Resources Henry Quinlan, U.S. Fish and Wildlife Service
Members:	Mark Ebener, Chippewa-Ottawa Resource Authority Don Schreiner, Minnesota Department of Natural Resources Steve Schram, Wisconsin Department of Natural Resources Jason Stockwell, U.S. Geological Survey Bill Mattes, Great Lakes Indian Fish and Wildlife Commission

Shawn Sitar, Michigan Department of Natural Resources
Mike Fodale, U.S. Fish and Wildlife Service, Sea Lamprey Management
Doug Cuddy, Department of Fisheries and Oceans, Sea Lamprey Management
Tom Pratt, Department of Fisheries and Oceans
Al Rowlinson, Department of Fisheries and Oceans, Fish Habitat Management
Marty Auer, Michigan Technological University
Stephen Chong, Ontario Ministry of Natural Resources
Kirsten Cahow, Bad River Band of Lake Superior Chippewa
Janet Keough, U.S.EPA National Health and Environmental Effects Research Laboratory
Ken Gebhardt, U.S. Forest Service
Seth Moore, Grand Portage Band

Chapter 6
Status of Aquatic and Terrestrial Communities and Habitat in the Lake Superior Basin



Lake Superior Lakewide Management Plan
2006

Table of Contents

LIST OF FIGURES

LIST OF TABLES

I. MISSION, PRINCIPLES AND GOALS

This chapter represents the integration of four chapters from the 2000 Lakewide Management Plan for Lake Superior (LaMP 2000). Those chapters were the Habitat Chapter (formerly Chapter 6), Terrestrial Wildlife Chapter (formerly Chapter 7), Aquatics Chapter (formerly Chapter 8), and Exotic Species Chapter (formerly Chapter 10). These four chapters were integrated to produce this current version, because discussing Lake Superior's resources and basin in four separate places did not acknowledge the integrated ecosystems of the region. This chapter describes these interconnected ecosystems in an integrated way and will contribute to sustainability throughout the region.

When producing a management plan, it is important to start with a vision of the future. Statements regarding the direction of management must be articulated and used to guide the plan. This is particularly true when dealing with ecosystem resources. The Lake Superior vision statement can be found in Chapter 1 of this document, and it articulates a future direction in a very broad based manner. Another statement of future direction from a more resource-oriented perspective can be found in the Ecosystems Mission statement:

MISSION

A mission of the Lake Superior Binational Program is to support intact, diverse, healthy, and sustainable ecosystems and the native plant and animal communities that depend upon them.
When reading this statement, the sense of a "healthy ecosystem" stands out. In fact, in Chapter 1 of the LaMP 2000, a series of objectives is put forth by the various committees of the Lake Superior Work Group. Both the Wildlife and the Aquatics committees reference "healthy ecosystems" in these statements of objectives. This raises the question: what is meant by "healthy ecosystems?"

Healthy Ecosystems

Ecosystems are comprised of biotic and abiotic components, which interact to support diverse and sustainable communities of plants and animals. Healthy ecosystems are recognized as containing a full complement of species living within them and supporting all the processes that connect the living and non-living portions of the system. It is also important to recognize the role of humans in healthy ecosystems. Humans can have a positive role in the functioning of ecosystems, and they can have a detrimental role. Healthy ecosystems must include benefits that humans can bring to an ecosystem while minimizing detriments.

Natural Processes Found in a Healthy Ecosystem

For an ecosystem to be considered healthy, the following natural processes must be present and function well:

- Energy flow to all trophic levels historically found in the habitat.
- Nutrients cycle throughout the ecosystem using appropriate pathways.
- Natural disturbances (e.g., fire, wind throw, and floods) take place at appropriate frequencies and over appropriate areas.
- Plant and animal communities are comprised of diverse, native species.
- All indigenous species are present, or, if not present, the habitat exists to rehabilitate or restore extirpated species.
- Native fish, wildlife, and wild plants produce young to result in sustainable populations and remain genetically viable.

- Predator and prey interactions are intact and in balance over the long-term.
- Populations of plants and animals fluctuate in natural cycles relative to one another.
- No populations are so abundant that they impact other populations in a negative, long-term manner.

Human-Induced Processes

Human-caused stresses must be managed to recreate a healthy terrestrial wildlife community. Just as some processes must be present in healthy ecosystems, some processes must be eliminated or minimized to ensure that ecosystems remain healthy or can be restored to a healthy state.

- Contaminant levels in plants and animals are sufficiently low so they do not negatively affect the life cycles of species, nor do they negatively affect human health.
- Exotic species of plants and animals, especially those that are harmful or invasive, are either eliminated or are reduced to the point that biodiversity of the native community is not impaired.
- Species of concern, especially threatened or endangered species, are recovered and are no longer in jeopardy.
- Human uses of our natural resources, including timber harvest, agriculture, recreation, mineral extraction, fish and wildlife harvest, energy generation and use, and construction of new dwellings and transportation systems, are done in an ecologically sustainable manner.
- Management practices mimic natural disturbance or are not outside of the range of natural variation of disturbance regimes.

The integrated ecosystem chapter was written from this perspective of healthy ecosystems. The authors used the following principles to guide our writing. As we described the characteristics of the Lake Superior basin and the status and trends of the resources living there, we considered the following principles. The reader will see that many of the notions of healthy ecosystems, both from a natural and anthropogenic perspective, are restated in these principles.

PRINCIPLES

- Healthy ecosystems support self-regulating communities comprised of naturally reproducing indigenous species, habitat upon which these species depend, and provide sustainable benefits to society.
- A holistic, ecosystem-based approach is critical to the protection and management of the Lake Superior basin.
- The aquatic environment is interconnected with the wetland, riparian, and terrestrial environments of the Lake Superior basin.
- Native species maintained by natural reproduction provide the greatest potential for sustainability.
- Chemical contamination of fish and wildlife impairs natural reproduction and benefits to society.
- Prevention of additional species introductions and control of existing non-indigenous species will facilitate restoration of a healthy ecosystem.
- An intact ecosystem is resilient and does not require management intervention.

In order to achieve our vision of Lake Superior and in order to preserve, protect, and enhance healthy, sustainable ecosystems, the following goals were established. In many ways, these goals describe the elements we wish to accomplish in the coming years. We believe that if we accomplish these elements, we will achieve the overall vision of Lake Superior.

GOALS

- Diverse and healthy native plant and animal communities exist in the Lake Superior basin.
- A program is in place to monitor the abundance, distribution, and health of plant and animal populations and communities in the Lake Superior basin.
- Species at risk or species of concern are recovered if populations are too low, or controlled if populations are too large.
- A system of representative, high-quality habitats is established and these areas are protected.
- No further extirpation of native species occurs in the Lake Superior basin.
- No non-native species will be introduced into the Lake Superior basin.
- An interagency effort to restore and protect critical habitats will be organized and initiated.
- Partnerships among natural resources management agencies, environmental agencies, and non-agency stakeholders are strengthened and broadened.

II. CHARACTERISTICS OF THE LAKE SUPERIOR BASIN

1. PHYSICAL ENVIRONMENT

1.1 Geology and Glacial History

Geology

Most of the Lake Superior basin is underlain by the Precambrian Canadian Shield (Figure 1), consisting of ancient sedimentary, igneous, and metamorphic rocks. Volcanic rocks, ranging in age from ca. 2.9 to 2.7 billion years ago, along with related sedimentary rocks, form "greenstone" belts.

The Midcontinent Rift extends from southwest of Lake Superior, under the lake, and south through Michigan. During a period of approximately 20 million years (ca. 1,110 to 1,090 million years ago), an estimated 2 million cubic kilometers (km^3) of volcanic rocks, predominantly flood basalts, were erupted. Coarse, sedimentary rocks were deposited during hiatuses in eruption activity. Associated, intrusive igneous rocks predominate in northeastern Minnesota, as well as around Lake Nipigon, and extend north of Lake Superior. Rocks of the Midcontinental Rift are only exposed around Lake Superior. Elsewhere, they are overlain by younger sedimentary rocks.

Sedimentary rocks of the Cambrian (570 to 500 million years ago) and Ordovician (500 to 440 million years ago) periods are restricted to the southeastern portion of the Lake Superior basin, near Sault Ste. Marie. They are situated in an area of subsidence in which sandstones, limestones, and other sedimentary rocks accumulated during Paleozoic time (Figure 1).

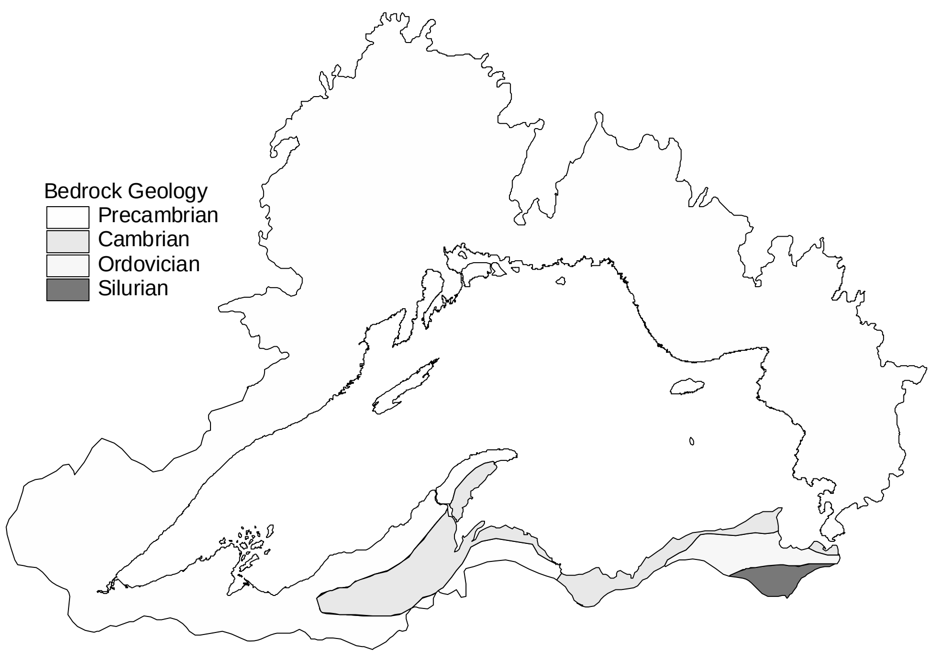


Figure 1. Generalized geology of the Lake Superior area (Government of Canada and U.S. EPA 1995).

Glacial History
Twenty thousand years ago, the Lake Superior basin was covered by the Laurentide ice sheet. The most recent stage of glaciation, the Wisconsin, began approximately 115 thousand years ago and ended 10 thousand years ago.

Erosion caused by advancing ice produced widespread till deposits of varying thickness, whose composition reflects the eroded source:
- Sandy tills, derived from the erosion of crystalline Precambrian rocks;
- Silty tills, derived from the erosion of Paleozoic carbonate rocks; and
- Clayey tills, derived from the incorporation of proglacial, glaciolacustrine sediments.

Till is less than one meter (m) thick over much of the rocky uplands bordering Lake Superior. However, in bedrock valleys or in areas south of Lake Superior, glacial drift thickness may average 30 to 60 m and may exceed 200 m.

Although the front of the Laurentide ice sheet began its final recession 15 thousand years ago, ice remained in the Lake Superior basin until about 9.5 thousand years ago (Table 1). The ice margin was very lobate in the Great Lakes region in response to topographic controls and ponded water near the ice front. The retreat of ice about 11 thousand years ago was accompanied by the development of proglacial, ice-contact lakes. Lake Duluth and Lake Ontonogan developed on the southwestern and southern flanks of the Superior lobe, respectively. Water from Lake Duluth drained southward via the Brule-St. Croix valley into the Mississippi River valley. Glaciolacustrine sediments (gravel, sand, silt, and clay) were deposited in these fluctuating lake basins as the ice sheet retreated northward. Flowing meltwater produced outwash deposits of stratified sand and gravel.

The Marquette Readvance of the Superior ice lobe 10 thousand years ago filled the Lake Superior basin with ice and extended down to the Grand Marais moraines in northern Michigan. Following the retreat of Marquette ice, glacial Lake Minong developed and eastern outlets for glacial Lake Agassiz developed through Lake Nipigon. The resultant flooding may have triggered the erosion of the drift barrier at the eastern end of the Superior basin, leading to rapid lowering of water levels, culminating in the lowest, Houghton phase ca. 7.5 thousand years ago. Following the rebound of the North Bay outlet, water from the Nipissing Great Lakes flooded into the Superior basin, giving rise to the Nipissing maximum level. Many of the resultant, raised shorelines now preserved around Lake Superior are related to a main, beach-forming event approximately 4.6 thousand years ago. Lake levels subsequently fell to lower levels, such as the Algoma, Sault, and Sub-Sault. The basin was isolated when uplift of the St. Mary's River sill ca. 2.2 thousand years ago isolated the Superior basin, resulting in the Sault and later, Sub-Sault levels that are only represented in the Superior basin. Modern-day levels of Lake Superior, ca.183 m above sea level, were substantially achieved approximately 2 thousand years ago.

Isostatic rebound of ice-depressed land around the basin during progressive deglaciation has led to submergence and emergence on the southern and northern shores of Lake Superior, respectively. Rates of submergence at Duluth, Minnesota have been estimated at 0.21 m per century while emergence rates of approximately 0.27 m per century have been estimated in the Michipicoten area of Ontario.

Table 1. Post-glacial lake phase names for the Lake Superior basin, with approximate ages (from Geddes and others 1987).

YEARS BEFORE PRESENT	LAKE PHASE	ELEVATION (At Marathon, Ontario; In Meters Above Sea Level)
0	(present Lake Superior level)	183
1,000	Sub-Sault	190
2,000	Sault	197
3,000	Algoma	205
5,000	Nipissing	220
6,000		
7,000	Houghton	246
8,000	Post-Minong IV (Dorion) III II I	260 270 280 292
9,000 9,500	Minong III II I	308 315 325

1.2 Soils

Present soil conditions reflect the glacial history (Figure 2). Shallow, well-drained tills cover most of the Ontario basin and northern Minnesota, with local clay and organic deposits. Soils are relatively nutrient-poor, acidic, and rocky.

On the south shore, the Lake Superior Lake Plain extends for approximately 322 kilometers (km) along the lakeshore from Duluth/Superior to the Keweenaw Peninsula. Soils are lacustrine clays and clayey till. Most of the Keweenaw Peninsula is bedrock knob and sandy till.

The eastern part of the U.S. basin is dominated by well-drained ground moraine and lacustrine sand deposits with poorly drained clay in lower areas. Organic soils overly the clay in depressions (McNab and Avers 1994).

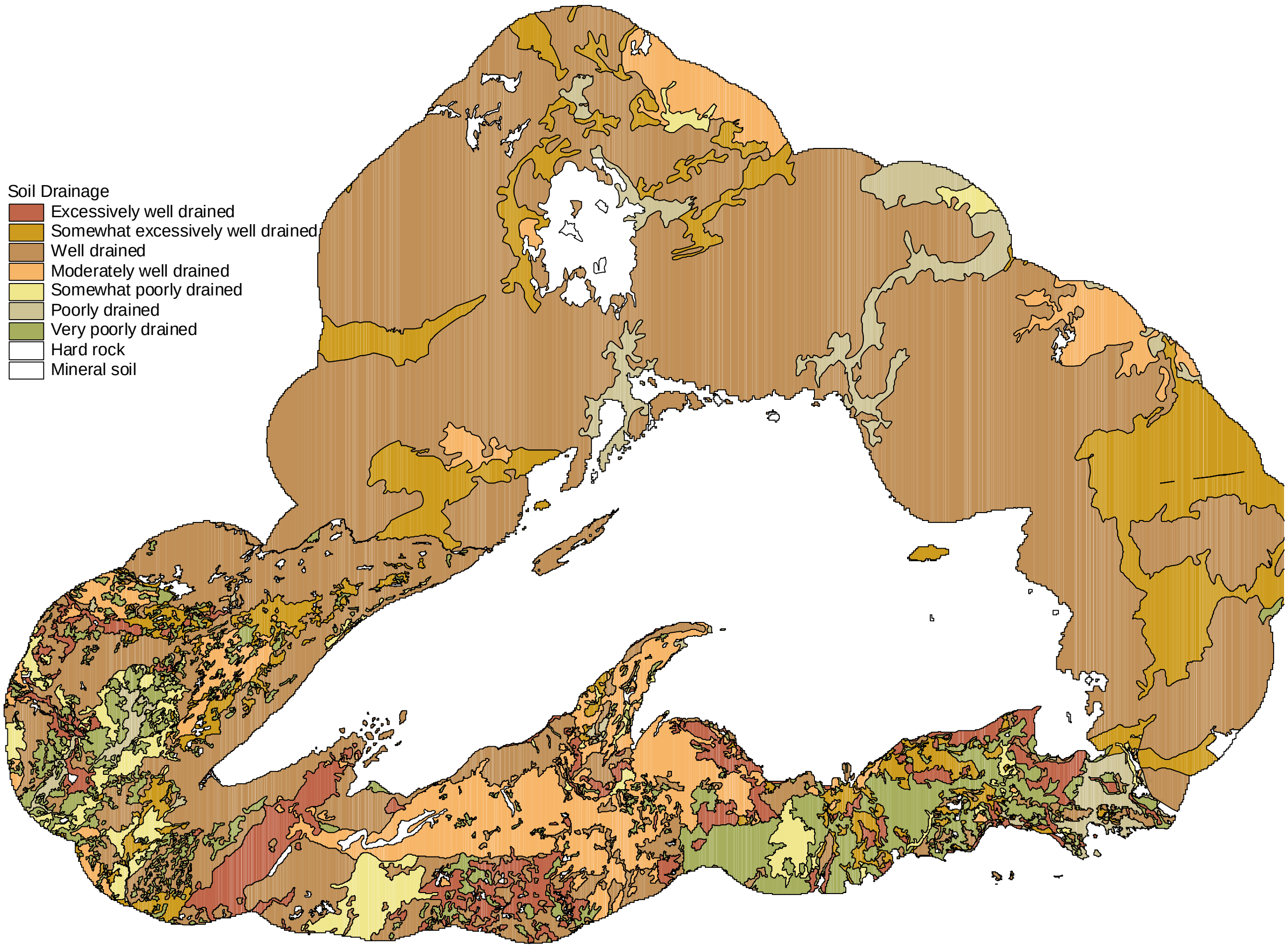


Figure 2. Soil drainage (Lake Superior Decision Support Systems data).

1.3 Climate

Lake Superior has a strong effect on the climate of Wisconsin, Michigan, and eastern Ontario, but less on Minnesota and the northern part of the basin (Albert 1995). While mean annual temperatures increase steadily from north to south (Figure 3), the lake has a strong effect on climate within a few kilometers of the shore. Shorelines experience cooler summers and milder winters than sites a few kilometers inland. Winter storms tend to be more intense near the lake, but the lake increases stability of the air masses and reduces the intensity of spring and summer storms (Albert 1995).

The wettest areas are immediately east of the lake, north of Sault Ste. Marie, Ontario, and parts of Wisconsin and Michigan where there is a strong lake influence (Figure 4). These areas also have the greatest snow accumulation. Portions of the Michigan Upper Peninsula average 875 centimeters (cm) of snow while Duluth, outside the greatest lake influence, receives only 138 cm (Minnesota Pollution Control Agency (MPCA) 1997).

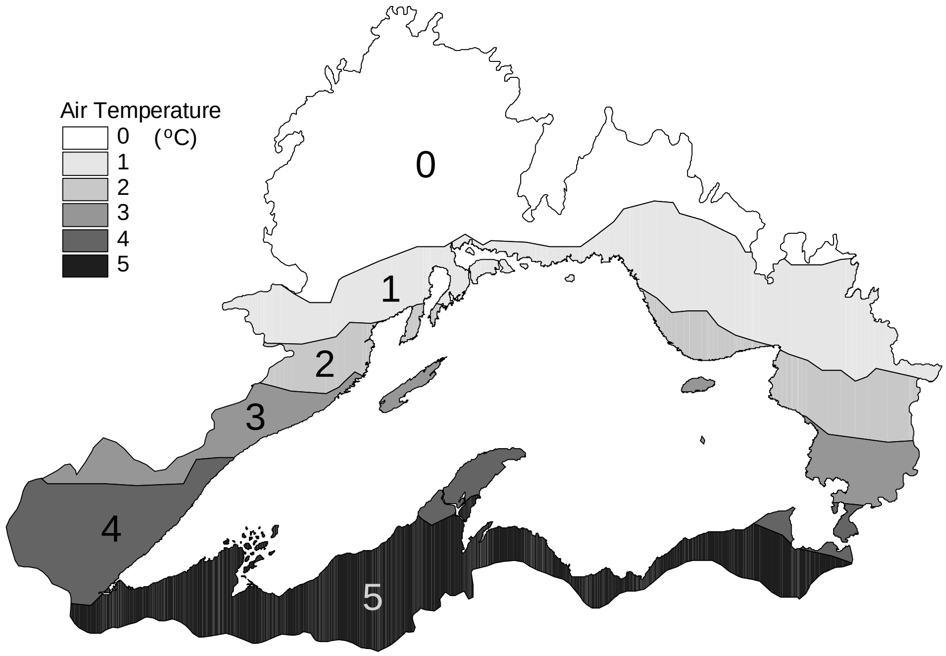


Figure 3. Mean annual temperatures calculated from monthly values (Lake Superior Decision Support Systems data). The numbers are mean temperatures in degrees Celsius.

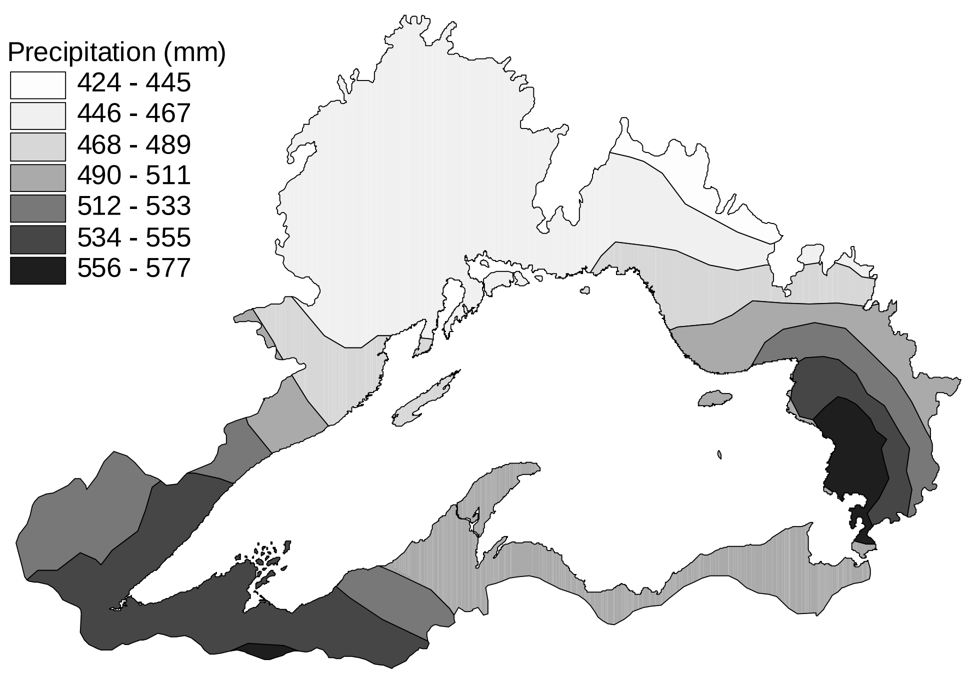


Figure 4. Growing season precipitation. (Lake Superior Decision Support Systems data).

1.4 Great Lakes Natural Regions and Seascapes

Great Lakes Natural Regions and Seascapes were developed as part of a classification system of enduring features for planning marine protected areas (World Wildlife Fund 1997). Natural regions and seascapes are equivalent to terrestrial ecoprovinces and ecodistricts respectively. Natural regions are delineated on the basis of light penetration and macrotopography. Lake Superior comprises 11 marine natural regions and 20 seascapes (Figure 5). The four benthic natural regions are subdivided into 13 seascapes on the basis of substrate type, slope and water motion (e.g., upwelling, stratification). The Photic Zone Natural Region #1 encompasses the entire benthic euphotic zone of Lake Superior, including significant offshore shoals. The West Slope Natural Region #2 lies on the windward side of the lake and is characterized by low relief at depth of about 150 m. The Central Basin Natural Region #3 is a deep basin (up to 400 m) with upwelling zones. The Southeastern Rise Natural Region #4 is characterized by very irregular bottom topography and depths from 100 to 300 m. The seven pelagic natural regions represent the euphotic (>20 m depth) and dysphotic-aphotic zones overlying the corresponding benthic natural region. Natural Region #1 has only one overly pelagic region (the euphotic zone), whereas the other three benthic natural regions each have two pelagic natural regions. The pelagic natural regions are not further divided so are also effectively seascapes.

Seascapes within the nearshore euphotic zone are defined on the basis of exposure to wave energy (i.e., exposed or protected), which is related to fetch direction and length, the presence or absence of offshore islands, and overall shoreline morphology. Offshore shoals and island shorelines are included with the adjacent mainland at this scale, even though they are often exposed to more wave energy. Seascapes in the offshore natural regions are delineated by water mixing and bottom substrate type (particle size).

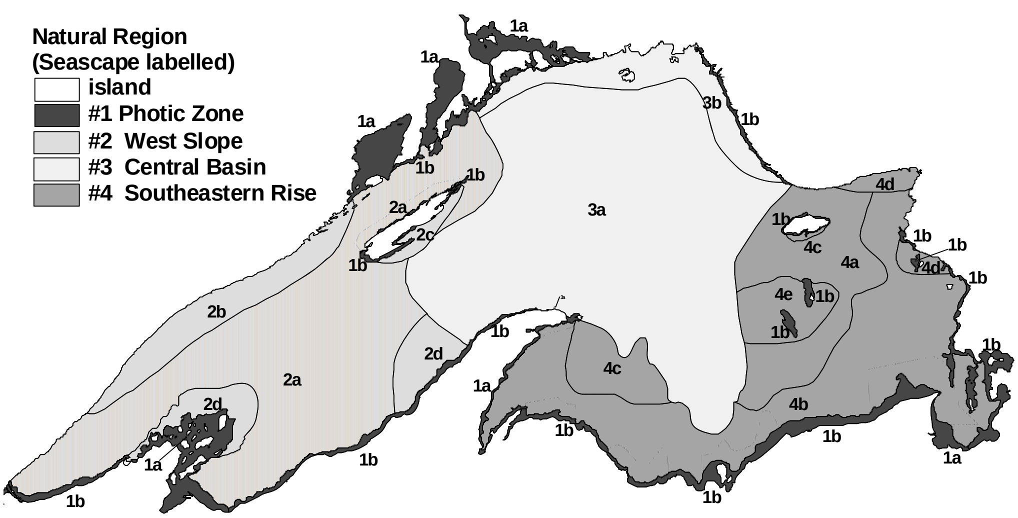


Figure 5. Seascapes of Lake Superior (World Wildlife Fund Canada 1999).

1.5 Bathymetry And Basin Morphology

Lake Superior averages 147 m in depth with a maximum depth of 406 m. The lake is divided into three main bathymetric basins by the Keweenaw Peninsula, which protrudes approximately 95 km into the lake from the southern shore (Figure 6). The eastern basin is characterized by a series of long, parallel, steep-sided troughs 100 to 300 m in depth which are oriented north-south. The central basin is comprised of very deep (up to 400 m), steep-sided sub-basins bounded on the north by extensive underwater cliffs which fringe a complex series of islands. The western basin encompasses relatively shallower offshore waters and a very deep channel, the Thunder Bay Trough, which separates Isle Royale from the adjacent mainland.

Water depths of less than 100 m are found in a narrow band paralleling the shore, with a rapid fall-off to deeper waters. In addition, water depths of less than 100 m are also found around islands and off shore shoals, especially in eastern Lake Superior. Shoals are numerous along the eastern shore and northern shore, and Superior Shoal is prominent midlake as an extension of the Keweenaw Sill. Along the north shore, the Sibley and Black Bay Peninsulas, and associated islands, delineate three large, sheltered bays, Thunder Bay, Black Bay, and Nipigon Bay.

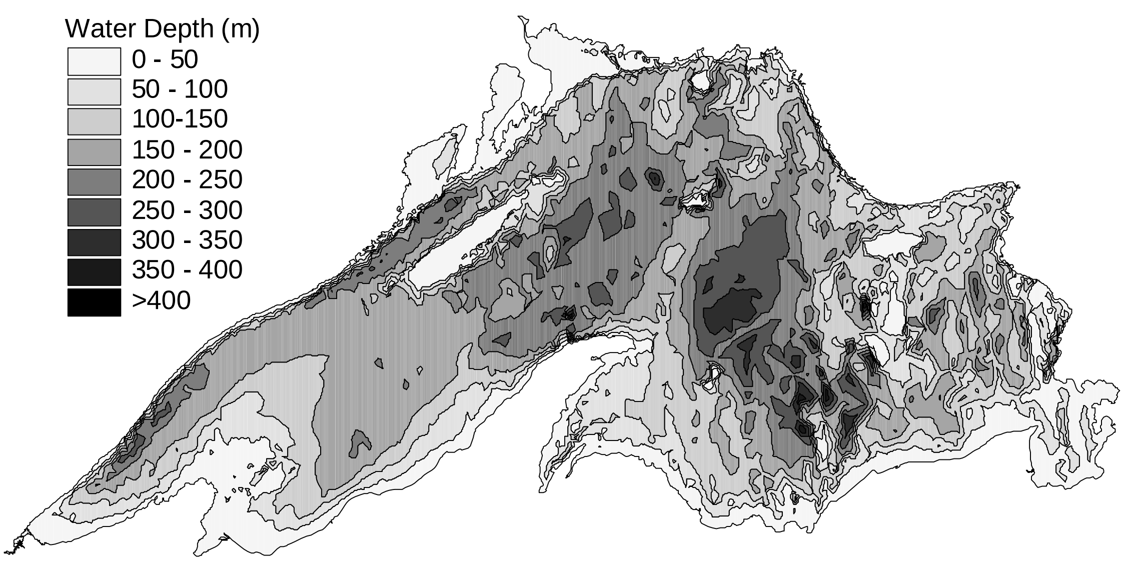


Figure 6. Lake Superior bathymetry.

1.6 Currents and Circulation

In Lake Superior, epilimnetic and hypolimnetic currents generally flow parallel to the shore in a counter-clockwise direction. There are also smaller gyres south of Isle Royale and around the Superior Shoal that reflect the bottom topography, temperature, and wind conditions of those areas. Currents are stronger along the south shore than elsewhere in the lake and are greatest adjacent to the north side of the Keweenaw Peninsula (Keweenaw Current). Currents are affected by wind conditions and internal pressure caused by density variations and the slope of the thermocline. Less dense, warmer water along the south coast where the thermocline is deeper show higher shoreline currents. Northerly hypolimnetic flows in the eastern portion of the lake may exceed five cm/sec compared to less than one cm/sec near Duluth and the Apostle Islands. The magnitudes of the currents also vary temporally, with the largest currents occurring in September (Lam 1978). Currents also flow during winter when the coldest and least dense water is confined on the periphery of the lake.

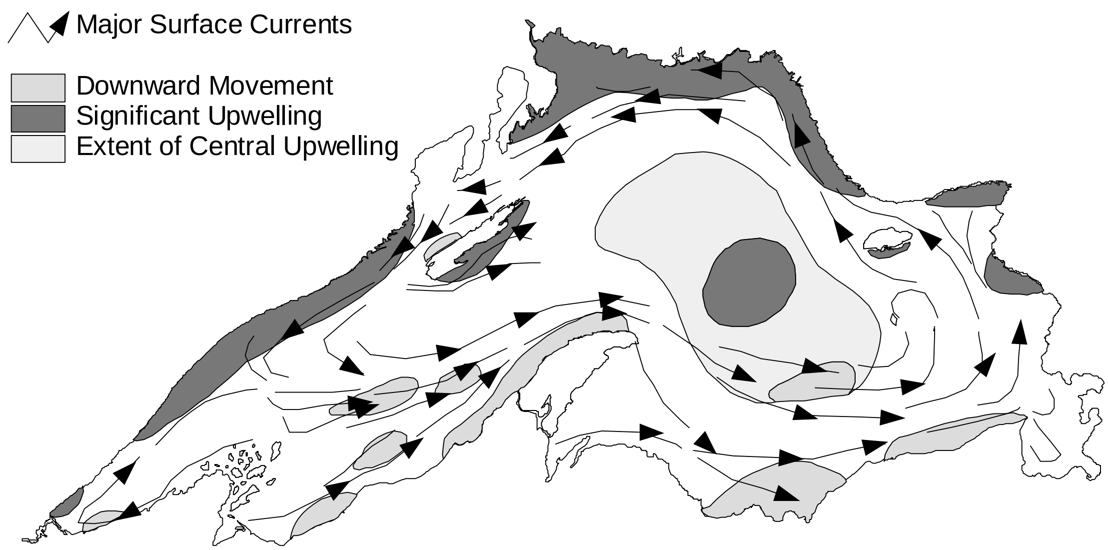


Figure 7. Major surface currents and upwellings. Downward water movement (cross-hatched), significant areas of upwelling (dark stipple), and extent of central upwelling (light stipple) are shown (after Harrington 1985 and WWF 1999).

Summer circulation is strongly influenced by the seasonal development and depth of the thermocline. During spring warming, current speeds are relatively constant, low, and uniformly distributed throughout the water column. After stratification, mean current speed rises in the epilimnion (at 10 m depth) and attains maximum values in early September, one or two weeks after surface temperatures peak (Bennet 1978). The thermocline restricts downward transport of heat and momentum from the surface, so current speeds in the hypolimnion decrease slightly because of frictional dissipation and are a seasonal minimum in August. Current speeds and temperatures rise in September due to enhanced vertical mixing which provides a downward flux of heat and momentum. Epilimnetic water temperature and current speeds have a corresponding decline in September and October.

Strong, modeled hypolimnetic currents in the vicinity of Superior Shoal, south of Isle Royale and east of the Apostle Islands, are likely related to upwelling and downwelling (Lam 1978). Upwelling occurs where sub-surface water is brought to the surface of the lake to replace surface water that has been forced to move laterally by wind or the temperature-density pressure gradient. During the summer, surface water tends to flow away from the nearshore upwelling zone along the north shore of Lake Superior and toward the nearshore downwelling zone along the southern shore (Bennet 1978). The general shoreward drift of surface water associated with anti-clockwise flow contributes to upwelling in midlake, as do bottom topography, rapid heating of the water, and winds. Upwelling enhances heat exchange by allowing more heat to enter the water during the summer and more heat to escape during the winter than if no upwelling occurred. Upwelling may bring nutrients and organic matter from the lake bottom and hypolimnium into more biologically active surface waters, which tends to increase productivity. See Figure 7 for major surface currents and upwellings in Lake Superior.

Currents and circulation are significant to the aquatic community because they influence water temperatures, sediment transport, ice cover, distribution of nutrients and oxygen, and dispersal of planktonic organisms.

1.7 Water Level Fluctuations

Lake Superior’s water levels undergo natural variation at the short-term, seasonal, and year-to-year scales (Edsall and Charlton 1997). Short-term variation takes place over the course of several hours, due to seiche activity (oscillation due to changes in barometric pressure or wind). The amplitude of variation is in the range of a few centimeters or tens of centimeters, but can exceed one meter under extreme conditions (Edsall and Charlton 1997).

Seasonal changes in water levels occur in response to the annual cycle of precipitation and runoff. Lake Superior’s levels typically peak in October and recede over the winter, reaching the lowest levels in early spring, followed by a steady rise through the spring and summer.

Year-to-year fluctuations in water level result from year-to-year fluctuations in precipitation and runoff. Table 2 and Figure 8 show the natural water level fluctuations (represented by the 1860-1887 period) compared to current conditions (represented by data from 1900-1986). Lake Superior levels are now higher than they were under natural conditions, but show a smaller range of variation between maximum and minimum values (1.01 m vs. 1.16 m) (Southam and Larsen 1990).

Water level fluctuations are important in maintaining healthy wetlands. Extreme low water levels allow cyclic, regenerative processes, such as oxidation of sediments and germination of submerged seed banks, to occur over a broad width of shoreline. High water levels prevent the encroachment of trees and shrubs in open wetlands (Wilcox and Maynard 1996). Effects of water level fluctuations on fish habitats in the Great Lakes are not well understood (Edsall and Charlton 1997). Effects of water level fluctuations in some basin inland lakes are well known.

Table 2. Mean water levels (m) under current and natural conditions (adapted from Southam and Larsen 1990).

	Current	*Natural*	*Difference*
Mean	183.00	182.91	+0.09
Maximum	183.46	183.43	+0.03
Minimum	182.45	182.27	+0.18
Range	1.01	1.16	-0.15

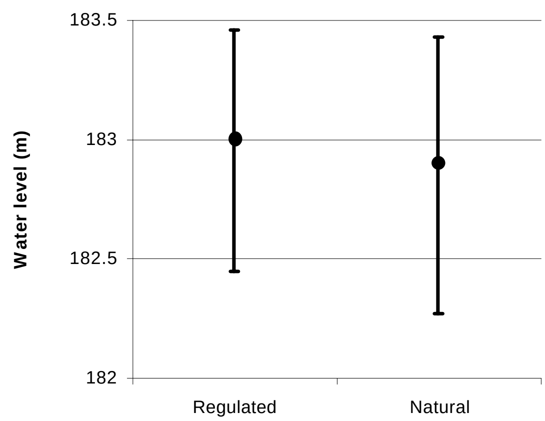


Figure 8. Annual water level fluctuations in Lake Superior, comparing present and natural values.

During the period from 1948-1999, the seasonal water level cycle decreased in amplitude by 20 percent (from 40 cm to 32 cm). The change is manifested as a downward trend in summer and autumn lake levels (where levels are typically highest). Summer and autumn trends reflect a large decrease in spring water influx and a nearly compensating influx in late autumn. These changes are primarily the result of trends in runoff and over-lake precipitation and are associated with variations in climate and land surface effects, rather than water level regulation (Lenter 2004).

1.8 Sediments

Sedimentation processes are important to aquatic life because they influence water clarity, nutrient availability, and benthic substrates, as well as shoreline habitats such as beaches and dunes. Sediment trap studies along the Keweenaw Peninsula demonstrated that sediment resuspension occurs even at depths of 120 to 220 m (9 to 21 km offshore) and that resuspended sediments contribute 10 to 30 percent of the organic carbon settling flux in offshore traps (Urban et al. 2004).

Lake Superior sediments reflect both glacial and post-glacial processes. Most of the sediments in Lake Superior were deposited approximately 11,000 to 9,200 before present during the last Wisonsinan glaciation (Thomas and Dell 1978). These glaciolacustrine sediments were derived directly from the melting ice front or from meltwater streams flowing into the lake. Till deposited during the last period of glaciation often underlies these glaciolacustrine sediments. The average thickness of glaciolacustrine sediments is approximately 1 m, but can be more than 18 m in northern parts of the lake (Thomas and Dell 1978). Massive red calcareous clays predominate in the lower strata and usually grade upward into red or grey carved calcareous clays. Red clays are derived from red tills from the southwestern portion of the basin, whereas grey clays reflect tills from the northeastern part of the basin exposed later as the glacier retreated. These sediments are comprised mainly of clay minerals, quartz, feldspars, calcite, and dolomite (Dell 1973). The calcite and dolomite are derived from calcareous Paleozoic rocks of the Hudson Bay lowland that were originally deposited as tills around the lake. In late glacial times, sedimentation rates in Lake Superior were so high (up to 13 cm per year) that carbonates were preserved in sediments beneath the top few cm (Thomas and Dell 1978). Unless the sediments are reworked by contemporary processes (e.g., currents), the carbonates remain in equilibrium with interstitial water and are preserved.

Postglacial sediments from deposition within the last 9,200 years overlie glaciolacustrine sediments in most of the lake. Little or no postglacial deposition has occurred in some parts of the lake, especially in nearshore areas, and glacial till or glaciolacustrine sediments are exposed or nearly so. For most of the lake, however, post-glacial deposits average three meters in depth, but may be as much as nine meters in local basin-like depressions (e.g., Thunder Bay Trough). These post-glacial sediments are primarily reddish brown or greyish-brown silty clays in the southern portion of the lake, grading to darker greys in the north. Postglacial sediments in Lake Superior are non-calcareous, even though they are derived from calcareous tills or glaciolacustrine sediments, since modern sedimentation rates are slow enough to allow complete dissolution of calcite and dolomite. Much of the Superior shoreline is rocky and, therefore, contemporary deposition rates average less than two millimeters (mm) per year (Bruland and others 1975). Much of the lacustrine sediment currently being deposited in Lake Superior may be reworked material derived from subaqueous erosion by currents.

Modern surficial sediment distribution in Lake Superior (Figure 9) is related to bathymetry, circulation patterns, and proximity of terrestrial sediment source. Deposition of very fine-grained muds occurs in deeper basins and local topographic depressions, resulting in exceptionally thick deposits in northern portions of the lake. Tills and glaciolacustrine clays are exposed and possibly eroded (Dell 1974) in non-depositional zones that occur around the lake periphery and in areas of high local topographic relief (even if they occur in deep water). Exposed bedrock occurs in a few locations close to shore, in island areas, and in regions of high lake bottom relief. Organic carbon in Lake Superior sediments ranges from only 0.01 to 3.85 percent reflecting the oligotrophic nature of the lake, and is greatest in depositional zones.

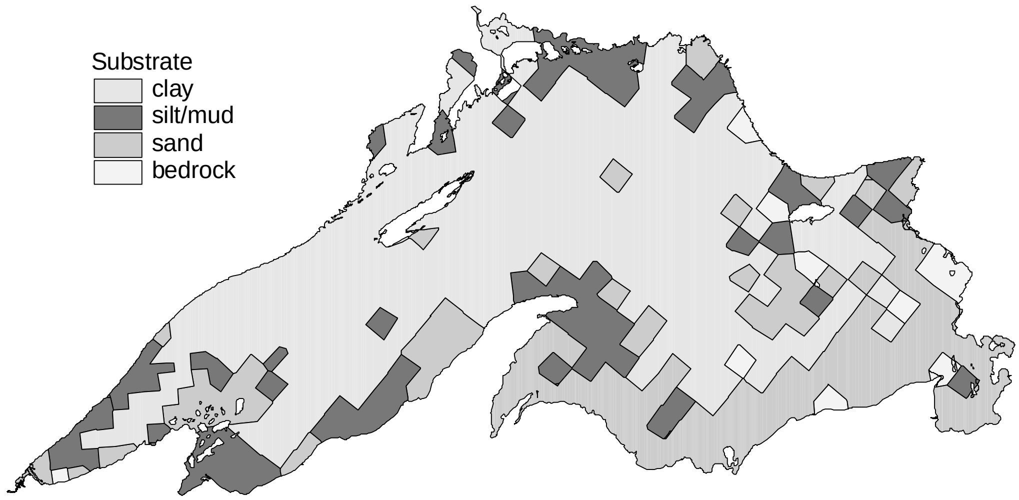


Figure 9. Surface sediment distribution in Lake Superior (after Thomas and Dell 1978).

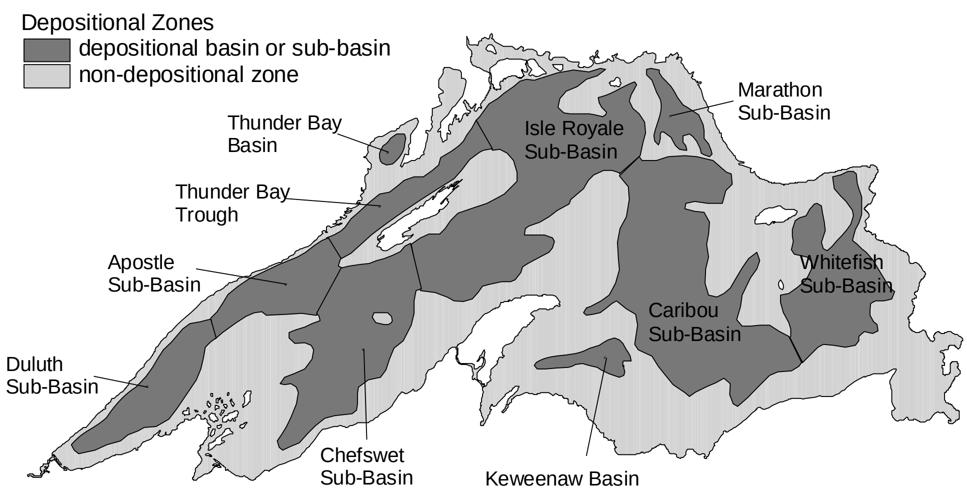


Figure 10. Depositional basins (shaded) (IJC 1977).

Modern sedimentation rates are generally half the magnitude of postglacial sedimentation rates and range from 0.1 to 2.0 mm per year. This is equivalent to approximately 6.029 million tonnes of fine sediment annually (Kemp and others 1978). Sedimentation rates vary with proximity to terrestrial source, circulation patterns, and bottom topography. The highest rates are found at locations closest to the edges of depositional basins and sub-basins and at the base of step-sided troughs, and lowest midlake in areas of gentle topography (Figure 10). Shoreline erosion is the largest external source of sediment (Figure 11), with the red-clay district on the western shore of the Keweenaw contributing up to 58 percent of annual inputs (Kemp and others 1978). Due to circulation patterns, suspension and deposition of these particles is likely to remain in the vicinity of the Duluth Sub-basin and western shore of the Keweenaw Peninsula. Approximately 37 percent of the current natural sediment load is deposited in the Duluth Sub-basin, followed by the Chefswet Sub-basin and Keweenaw basin (Kemp and others 1978).

Lake Superior tributaries are the second most important source of sediments with 30 percent of total inputs (IJC 1977). The St. Louis and Ontonagon rivers are the largest American sources, and the Nipigon, Kaministiquia, and Pic rivers are the largest Canadian sources, although much of this settles in Nipigon Bay and Thunder Bay (Kemp and others 1978). Erosion of taconite tailings from Silver Bay, Minnesota accounts for seven percent of the fine-grained sediment input. Although annual loading of airborne particulates is low relative to other sources, these particulates are of great importance because of their high concentrations of toxins and nutrients.

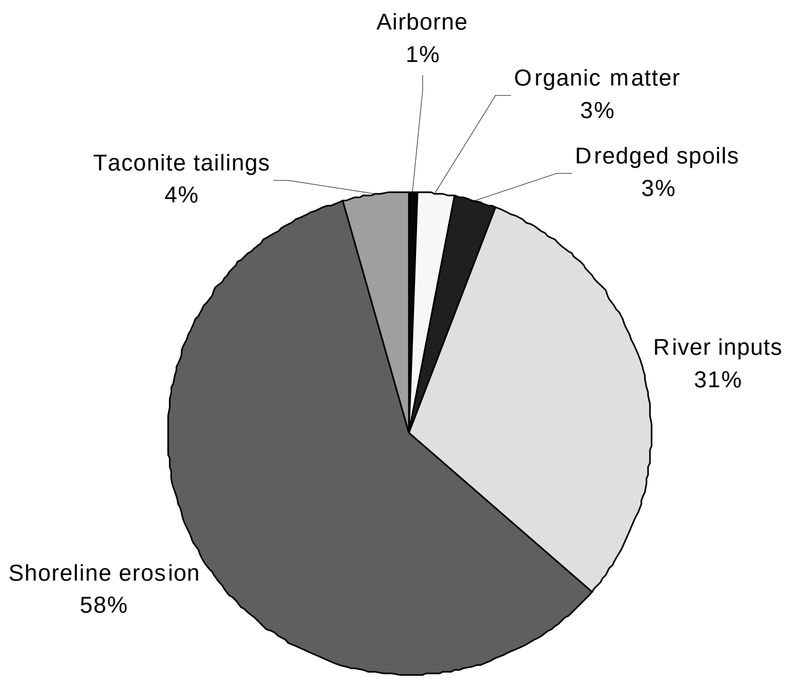


Figure 11. Estimated quantity of clay and silt-sized sediment inputs to Lake Superior from various sources (adapted from Kemp and others 1978).

Secchi depths range from 9 to 15 m in midlake and 5 to 11 m in nearshore areas. In southwestern Lake Superior, higher turbidity is due to increased suspended inorganic particulate concentration resulting from high erosion rates after ice break-up, agitation of sediments in the shallower nearshore, and associated sediments in water discharged as runoff from the surrounding basin (Stortz and others 1976). Secchi depths may be a low as 1.5 to 2.8 m under these conditions. Thunder Bay, Nipigon, and Black bays also have reduced water transparency.

1.9 Water Temperature

Water temperature is of paramount importance since it affects rates of chemical and biological processes and the thermal regime influences patterns of currents and density structure, as well as vertical and horizontal mixing. Lake Superior has a unique thermal regime due to its size and has the lowest summer surface temperature (13°C) and mean annual lake temperature (3.6°C) of the Great Lakes (Bennet 1978). Lake Superior has a semi-annual alternation between periods of stratification and of extensive vertical mixing typical of dimictic lakes (Figure 12). Although the annual heat income of Lake Superior is the second highest for any lake in the world, winter heat loss is the highest of the Great Lakes, and approximately half is used for spring warming of the lake to the temperature of maximum density (~3.8°C). As a result, the spring convective mixing period is the longest of the Great Lakes, the summer stratification period is the shortest, and the maximum surface temperature in the summer is the lowest. There is great year-to-year variation in the surface temperature of Lake Superior, especially in the summer months. The epilimnion is relatively deep in years when the mean surface temperature is relatively low and vice versa.

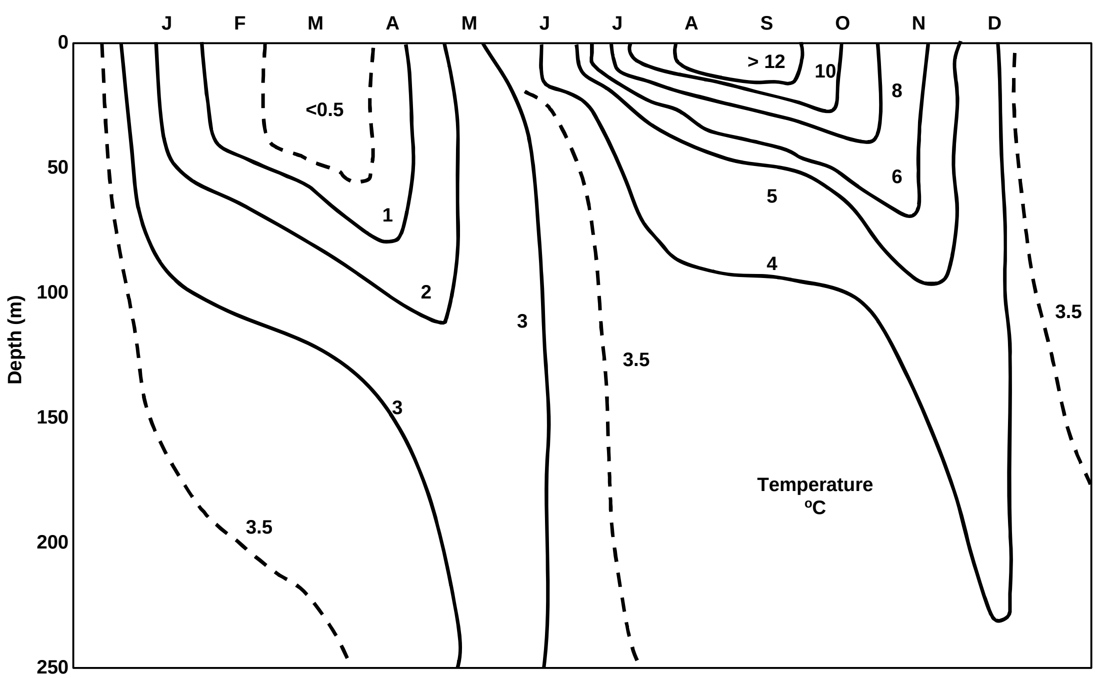


Figure 12. Seasonal changes in water temperature with depth for Lake Superior (Bennet 1978).

During winter stratification, the cooler (<1° C) waters of the epilimnion rest on denser, warmer water at a depth of 40 to 60 m. The lowest mean lake temperature of 1.4° C occurs at the beginning of April. Rapid warming from increased spring solar radiation raises surface water temperatures from 0° C at the end of March to 3.0° C by early June. The vigorous convective mixing results in a rapid downward flux of heat from the lake surface and the beginning of heating of the entire lake volume. This extends the epilimnion to a depth of 250 m or more by early June. By mid-July, surface waters have warmed past 4°C across the entire lake (including midlake), and initial summer stratification occurs. Surface temperatures then rise rapidly and the thermocline develops at a depth of approximately 10 m, which effectively reduces further transfer of heat and momentum to the hypolimnion. Surface temperatures continue to rise and reach a maximum of approximately 13° C in September, and mean lake temperature peaks at 5.8° C. Temperatures in the hypolimnion remain fairly constant throughout the summer at about 4° C. Beginning in mid-September, the epilimnion begins to extend downward due to autumnal cooling and enhanced vertical mixing and by the end of summer stratification in late November, the epilimnion has extended to 145 m. Convective mixing develops in November and slows the rate of decrease of surface temperature. By the end of December, surface water temperature has dropped to 3°C, and declines rapidly in January as the lake stratifies.

Horizontal temperature patterns (Figure 13) are due to differences in the local seasonal cycle of heating and cooling of the upper layer. Rapid inshore warming causes the formation of a thermal bar in the spring, which traps less dense warm water until it has reached 4° C. Surface temperature rises relatively rapidly and attains the highest values in Whitefish Bay, while spring warming is slowest and maximum summer temperature is relatively late and low in midlake (Irbe 1991). Coastal upwelling along the northwest coast maintains low temperatures until late June, similar to the midlake condition. As vertical stratification occurs in July, there is rapid warming along the northwest coast from 6° C to 14 to 16° C resulting from the formation and offshore movement of the thermal bar. During the winter, horizontal water temperature patterns are reversed, with cold water on the periphery of the lake, particularly along the south shore, and warm water located along the northwest coast and mid lake (Leshkevich 1975).

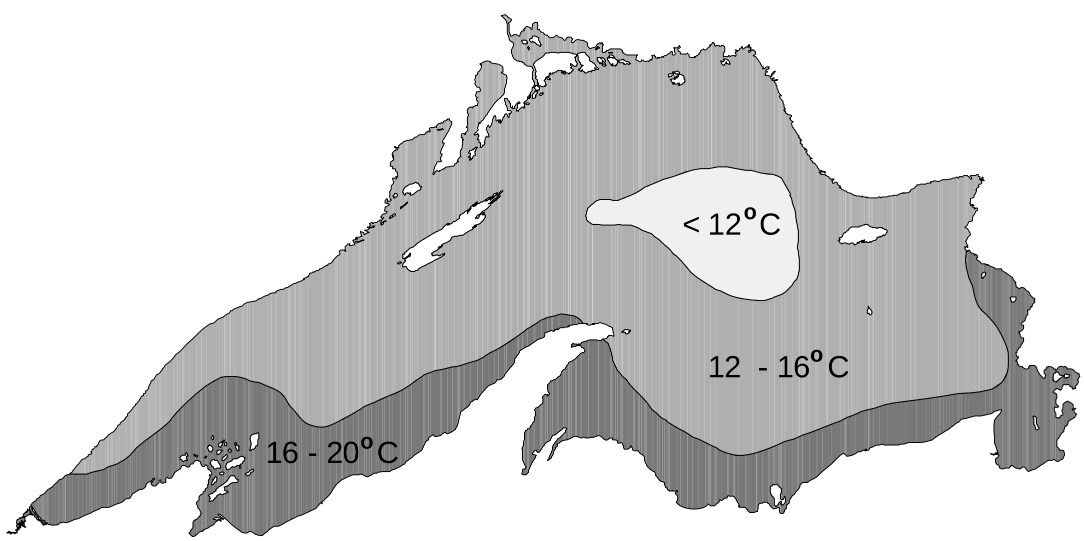


Figure 13. Mean August surface water temperature for Lake Superior.

1.10 Ice Cover

Ice cover has considerable environmental impacts, such as providing insulation between the atmosphere and relatively warm water, thereby reducing heat loss, evaporation, and the occurrence of lake-effect snowstorms. It may also impact fish reproduction (e.g., burbot) and dispersal of terrestrial mammals to islands (e.g., caribou and wolves on the Slate Islands). During a mild winter, approximately 40 percent of the lake surface is expected to become ice-covered, compared to 60 percent during a normal winter and 95 percent during a severe winter (Rondy 1971). Maximum ice cover normally occurs in late March (Figure 14). At this time, consolidated pack ice occurs in most of the shallow bays and along much of the north shore. Close pack ice (70 to 90 percent cover) exists over the middle portion of the lake and approximately 40 percent of the lake is open water, mainly in the eastern end around Caribou Island. Leads occur off Montreal Shoal, the Apostle Islands, the Keweenaw Peninsula, and between Isle Royale and the Slate Islands. These leads are used by gulls and bald eagles during migration or local movement.

Water circulation has a strong impact upon ice cover. Midlake upwelling that is present during the open-water season is maintained throughout the winter by rapid heat loss. This keeps the central area free of ice, which in turn results in a large integrated winter heat loss (Bennet 1978). The winter upwelling of relatively warm water is responsible for the lack of fast ice along the open part of the northwest shore (Marshall 1968).

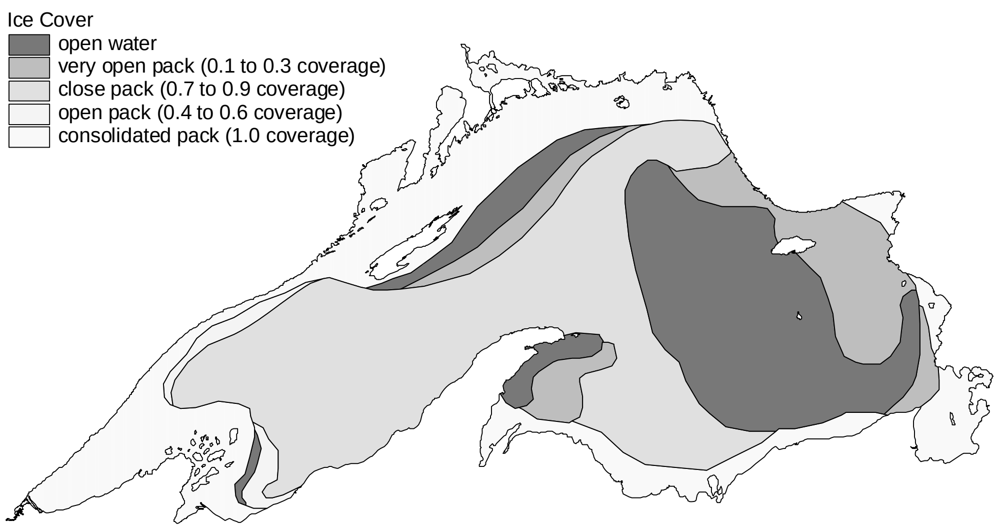


Figure 14. Normal winter maximum ice cover for Lake Superior (Rondy 1971).

2. SOCIAL ENVIRONMENT

2.1 Human Population

The human population of the Lake Superior basin was estimated at 607,121 people in 1996 (Environment Canada and U.S. EPA 1995). Most of the basin is sparsely populated with less than two people per square kilometer (km^2) in most of Ontario and the Minnesota north shore. Population density is greater on the south shore of the lake (Figure 15). Centers of population (i.e., cities with greater than 75,000 people) are at Thunder Bay, Duluth/Superior, and Sault Ste. Marie.

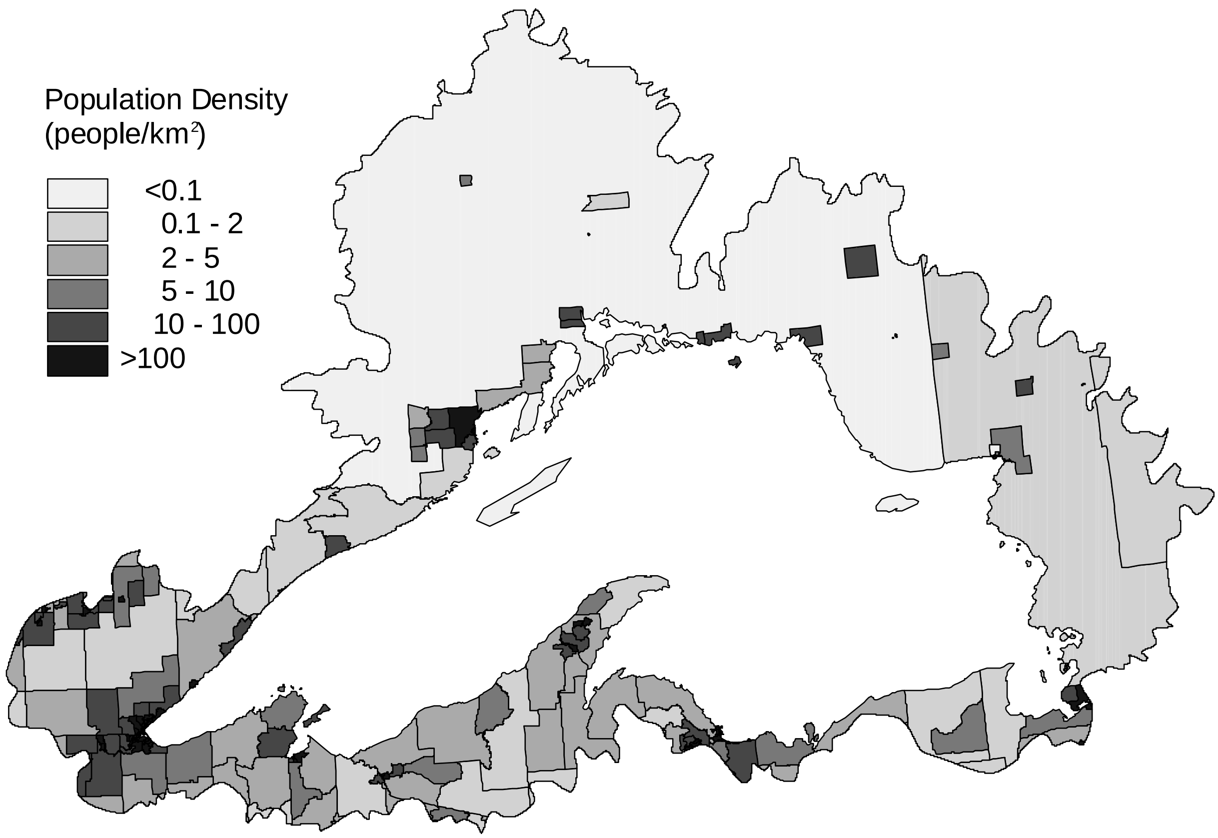


Figure 15. Population density of the Lake Superior basin in 1996 (people/km^2) (Lake Superior Decision Support Systems Data, based on U.S. and Canadian census data). Note that census areas partly overlap the basin and reflect population statistics from outside the basin.

Most of the basin experienced a small increase in population (zero to five percent) between 1991 and 1996. In contrast, the population of the Great Lakes basin increased by 8.7 percent between 1990 and 2000 (Kling et al. 2003). The greatest population growth was on the Minnesota north shore and adjacent Ontario, the Keweenaw Peninsula and the area west of Sault Ste. Marie, Michigan (Figure 16). The population density in most of these areas remains low, however. Other areas with increasing populations include the Duluth/Superior area and the Bayfield Peninsula. Areas with declining populations include Thunder Bay and other communities dependent on resource-based industries where job numbers have decreased.

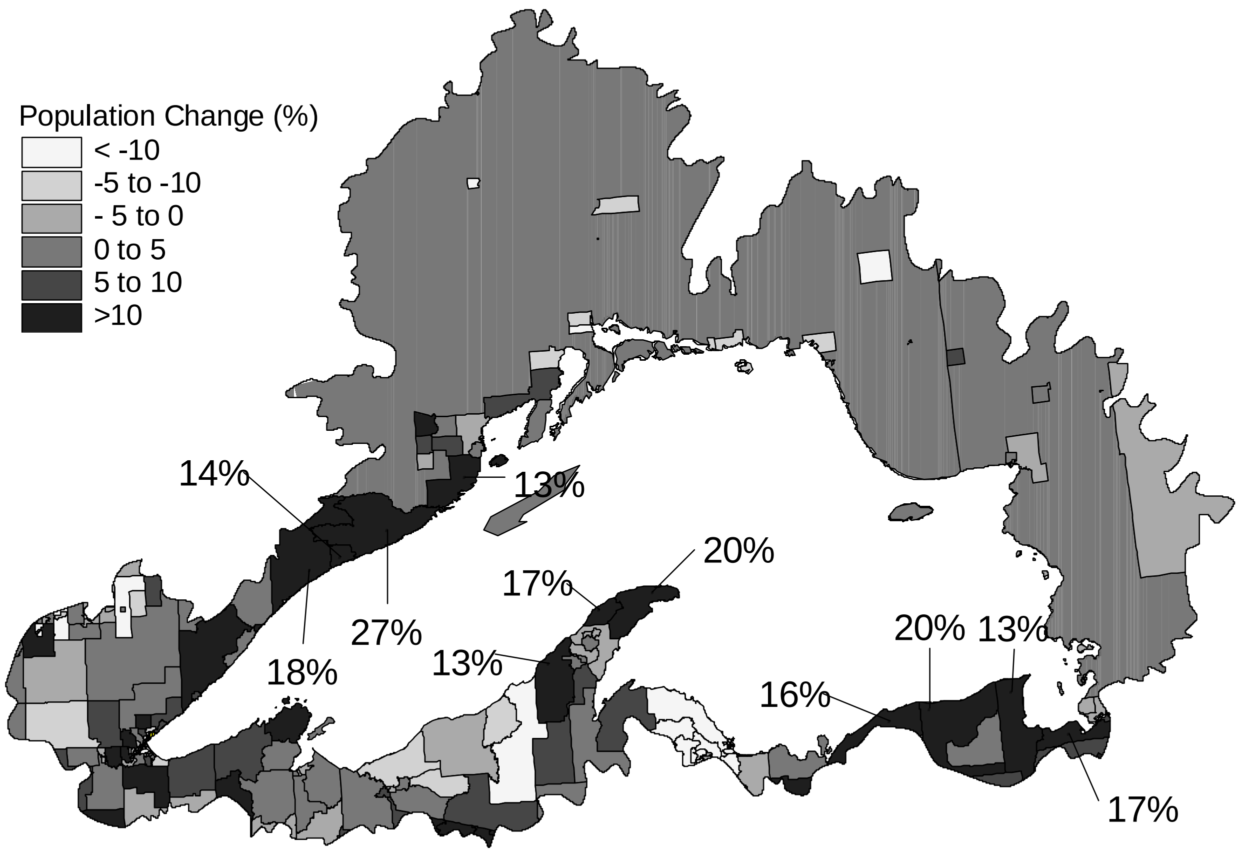


Figure 16. Population change (percent) between 1991 and 1996 (Lake Superior Decision Support Systems data, based on U.S. and Canadian census data).

House density (Figure 17) closely parallels population density (Figure 16), but also reflects the number of second homes, especially on the Michigan shore.

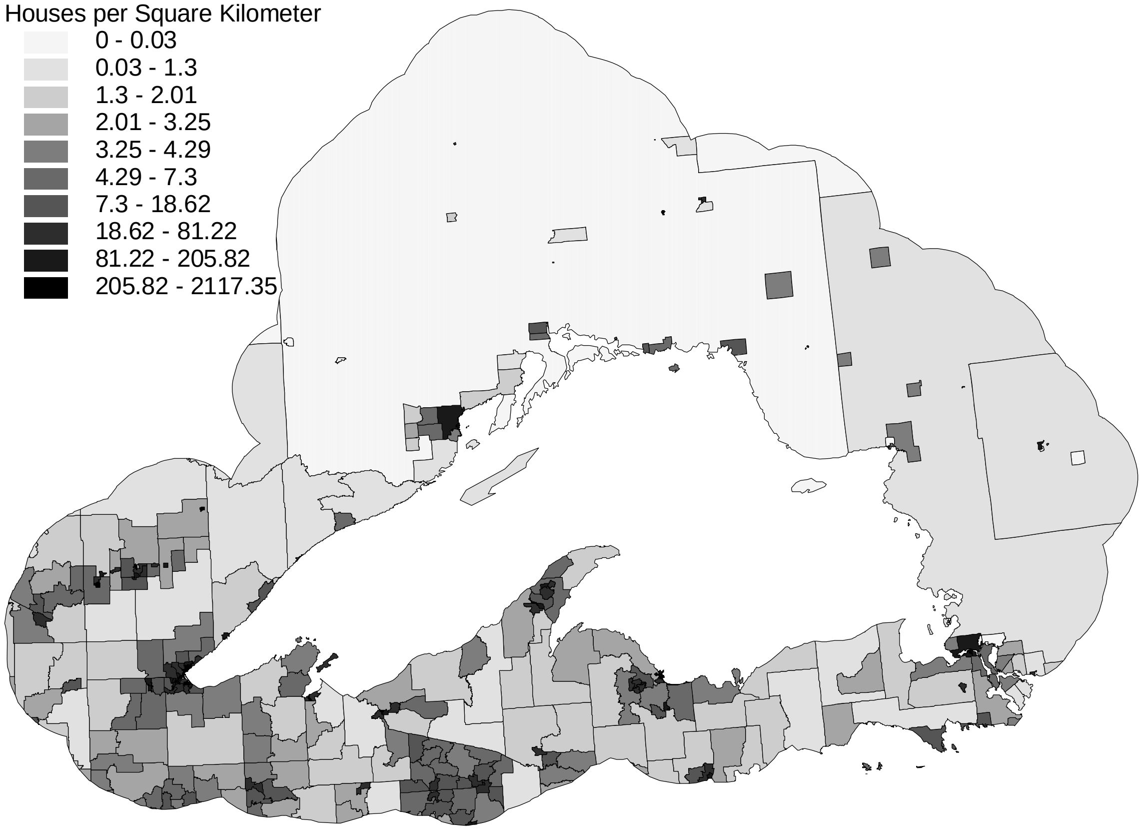


Figure 17. House density (Lake Superior Decision Support Systems data, based on U.S. and Canadian census data).

2.2 Urban Centers

Urban centers in the Lake Superior basin include Duluth/Superior, Thunder Bay, Sault Ste. Marie, Ashland, Marquette and Houghton (Table 3, Figure 18). About 60 percent of the human population of the basin lives in these cities. As described under *Basin Use and Economics*, the economies of these cities are based mostly on natural resources. Paper and saw mills are present in most of the communities. Shipping of grain, minerals, and manufactured goods also takes place. Universities and colleges, government offices, regional health care, and manufacturing contribute to the economic base.

Table 3. Urban centers in the Lake Superior basin with populations of greater than 5,000.

City	Population	Date of census
Thunder Bay, Ontario	121,968	2001
Duluth, Minnesota	86,918	2000
Sault Ste. Marie, Ontario	78,908	2001
Superior, Wisconsin	27,368	2000
Marquette, Michigan	19,661	2000
Sault Ste. Marie, Michigan	16,542	2000
Ashland, Wisconsin	8,620	2000
Houghton, Michigan	7,010	2000

2.3 Political Boundaries

The Lake Superior basin is divided between three states and one province (Table 4, Figure 18). Each of the states is divided into counties (7 in Minnesota, 5 in Wisconsin, and 11 in Michigan). The two districts in Ontario have no elected bodies or land management authority. A number of tribal reservations are also found within the Lake Superior basin including Grand Portage, Fond du Lac, Red Cliff, and Bad River. There are approximately 14 reserves in the Ontario part of the basin under the Robinson-Superior Treaty or Robinson-Huron Treaty.

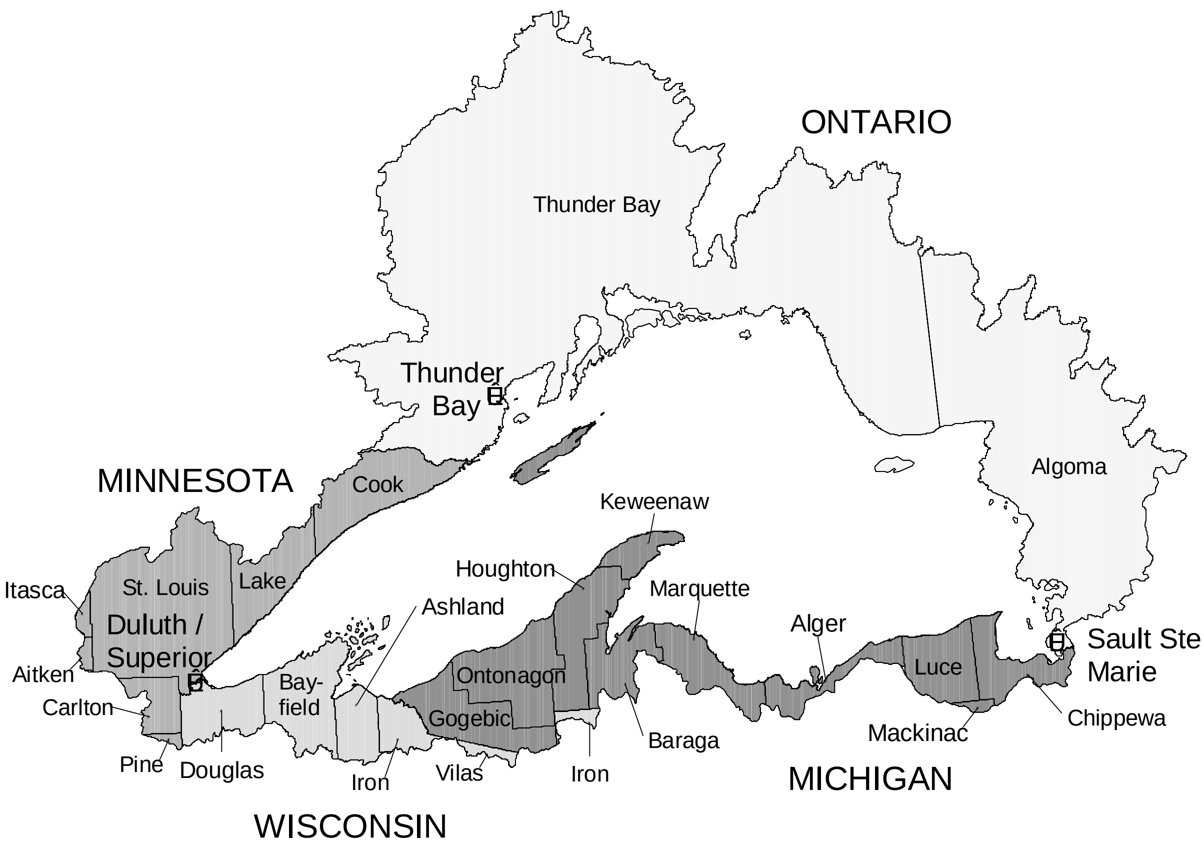


Figure 18. Counties and districts of the Lake Superior basin.

2.4 Basin Use and Economics

In the U.S., approximately 54 percent of the land base in the basin is privately owned. The remainder is public land held by various agencies of the federal (National Forest Service, National Parks Service), state (Department of Natural Resources), and county governments in Michigan, Minnesota, and Wisconsin (Table 4). Indian Reservations make up 0.6 percent of the land area in the U.S.

In Ontario, about 90 percent of the land is public, held by the Ontario Government as Crown Land and Provincial Parks. The remaining 10 percent is made up of relatively small holdings of farmland, city and rural residential lots, and mining developments (Figure 19, Figure 20). Some large consolidated blocks of land are privately held by railway and forest product companies. Tribal Land and Indian Reservations are included in the 10 percent. Reservations in the basin also contain lands that are not public.

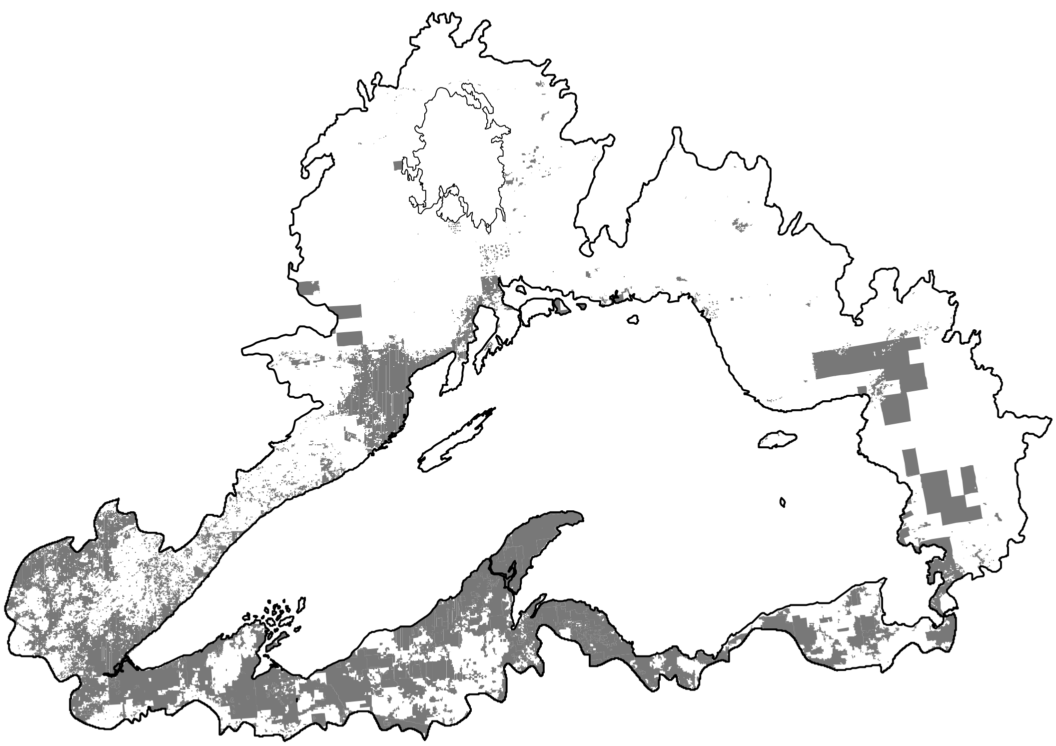


Figure 19. Private Land (shaded) in the Lake Superior Basin (derived from OMNR and Lake Superior Decision Support Systems data).

Table 4. Land ownership (percent) in the Lake Superior basin (derived from OMNR and Lake Superior Decision Support Systems data).

Ownership	Ontario	Michigan	Minnesota	Wisconsin	Lake Superior Basin
County Forest		1	22	19	4
National Forest		20	17	15	7
National Park	2	3	<1	2	2
Other Federal		<1			<1
Other Private*	12	41	38	55	22
Non-industrial Private Forest			<1		<1
Private Industrial Forest		22	3	5	4
Crown Land / State Forest	75	11	13	2	52
State / Provincial Park	4	2	1	<1	3
Conservation Reserve	6				4
State Fish & Wildlife			1	<1	<1
Other State			1		<1
Tribal			1	1	<1
Army Corps of Engineers			<1		<1
Bureau of Indian Affairs			<1		<1
Bureau of Land Management			<1		<1
Wilderness Area			3		1

** includes Patent Land in Ontario*

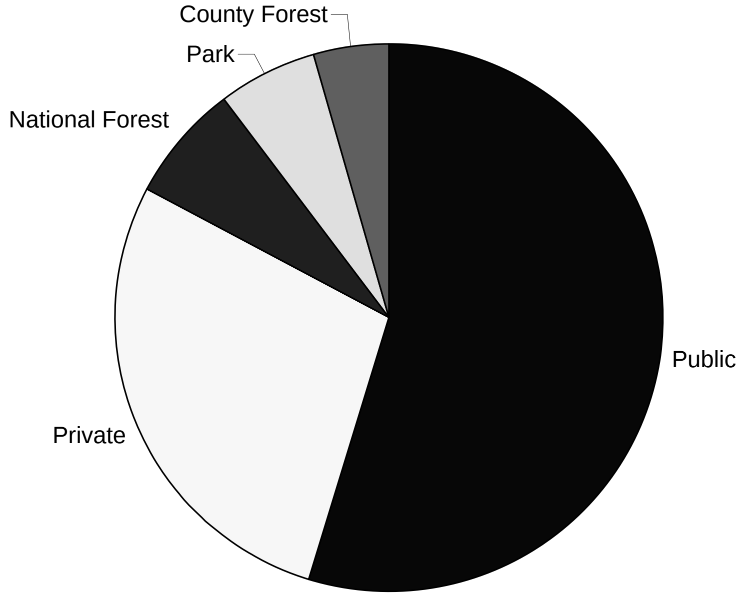


Figure 20. Land ownership in the Lake Superior basin. Most of the public land is in Ontario (see Table 4).

In general, family and household incomes in Lake Superior counties in the United States are well below the national and state medians (1979 and 1989 data). In 1990, average monthly mortgage payments within the watershed were considerably below those in the U.S. and the respective states, indicating slow or little economic growth.

The three principal industries in the Lake Superior basin are forestry, mining, and tourism (NWF 1993).

Administration of natural resources in Ontario (including forestry, fish and wildlife, and public lands) is the responsibility of the Ontario Ministry of Natural Resources (OMNR). Portions of two OMNR Regions and five OMNR Districts are found within the basin. District offices coordinate the local field delivery of OMNR programs including forest management planning and fish and wildlife inventories and allocation. Forest management occurs on a number of forest management units under Sustainable Forest Licenses across the commercially harvested Crown forests of Ontario. Individual Forest Management Plans are prepared by the forest management companies, in conjunction with OMNR staff, every five years. The two-year planning process involves a great deal of public and stakeholder consultation and is aimed at ensuring that sustainable forest management occurs. Planning and management follows an ecosystem approach in which timber harvesting attempts to follow natural disturbance patterns (e.g., fire) and retain important wildlife habitat features such as snags and winter habitat.

Fisheries management (i.e., sustainable use, protection, rehabilitation and restoration) is largely OMNR's responsibility, however, the federal Department of Fisheries and Oceans retains responsibility for fish habitat under the habitat provisions of the federal Fisheries Act through review and monitoring of activities near water.

Forty-seven percent of the timberland in the U.S. portion of the basin is in public ownership, which includes lands managed by the federal government (U.S. Forest Service), states (Departments of Natural Resources), and counties. The remainder is owned by the forest industry and private landowners. The U.S. Forest Service has a multiple-use mandate and follows a planning process that directly involves the public. State Natural Resources Departments and County Forestry Departments are beginning to encourage public involvement in their forestry planning. All lands, however, are open to recreation. Coordinated regional planning is seldom, if ever, done; however, the Wisconsin and Minnesota Departments of Natural Resources recently initiated a land use planning effort for the northwest sands region (locally referred to as the pine barrens), which is located on the edge of the Lake Superior basin. They are involving interested stakeholders, including towns, counties, landowners, the forest industry, and non-profit organizations.

Since the mid-1800s, mining has had a major impact on the economics and natural resources of the basin. During the 1870s, the Silver Islet mine east of Thunder Bay was the world's most productive silver mine. It closed in the early 1880s. The Keweenaw Peninsula in the Upper Peninsula of Michigan was the world's leading producer of copper during the early 1800s. One of the largest Superfund sites in the country is a result of this copper mining (NWF 1993). Iron ore mining in Minnesota began in 1884 on the Vermilion Range and in 1892 on the Mesabi Range. The eastern portion of the Mesabi Range is within the Lake Superior basin. Mining of taconite, a lower-grade iron ore, continues on the Mesabi Range, and Minnesota remains the largest producer of iron ore and taconite in the United States. In Wisconsin, brownstone was quarried in the late 1800s to early 1900s. Approximately 12 quarries were mined, and the brownstone was exported to large cities in the United States, including Chicago, St. Louis, and Minneapolis/St. Paul. Brownstone buildings remain in the basin in Wisconsin, but brownstone is no longer quarried. Old, unreclaimed quarries dot the landscape. Mining is still one of the other major land uses. Interest in mining and manufacturing is increasing in the basin. In 1984, one of the world's largest gold deposits was found near Marathon, Ontario. Currently, there are four active gold mines in that area. Two smaller gold mines are located near Wawa. A platinum-palladium mine is located approximately 100 km north of Thunder Bay, and zinc/copper mines are located in Manitouwadge and Schreiber. The Schreiber mine is slated for closure. Diamond mining and exploration are underway in the Wawa area. This area is also under development planning for an open pit trap rock mine at Michipicoten Harbour to supply material for road base, construction, and rock wool.

Approximately three-fourths of United States iron ore is produced in Minnesota, totalling about 40 million tons per year (NWF 1993). Most of the ore is shipped to Great Lakes steel mills. One active iron ore mine is located near Ishpeming, Michigan. A large copper mine and smelting operation in Ontonogon in the Upper Peninsula was recently closed. On the Canadian side, the major iron ore-producing mine was located in Wawa. This mine and its associated processing plant produced concentrated ore from 1960 until its closure in May 1998, supplying the Algoma Steel mill in Sault Ste. Marie, which is still in operation.

By the early 1830s, the Great Lakes were opened to international shipping with the completion of several canals that connected all the Great Lakes to the St. Lawrence Seaway. This allowed commodities harvested from the Lake Superior basin to be exported to growing cities farther east. Many cities on Lake Superior had burgeoning shipping industries in the late 1890s and early 1900s, but only a few major shipping docks now remain, including those at Duluth-Superior in the United States and at Thunder Bay, Marathon, and Sault Ste. Marie in Ontario.

Railways created additional accessibility and were important for transport of harvested timber, which was not readily transported by water. Numerous railroad companies and railroad spurs were prevalent in the late 1800s and early 1900s, providing transportation to and from the region.

There are currently five large and two medium-sized pulp and paper operations and four large, two medium, and four small sawmill operations located within the basin on the Ontario side. In addition, there are two veneer mills and two oriented strandboard/particle core board mills within the basin in Ontario. Four pulp and paper mills are found on the U.S. side of the basin, two in Minnesota and two in Michigan. Several mills located outside of the basin draw pulpwood from the basin's forests. A paper mill in Ashland, Wisconsin closed in 1998.

Tourism in the Lake Superior basin is related to outdoor recreation opportunities. The forests, streams, and lakes have attracted outdoor recreation enthusiasts throughout the 20th century. Since the mid-19th century, resorts and lodges have housed visitors from metropolitan areas who come for hunting, fishing, boating, camping, and other outdoor pursuits. Outdoor recreation interest remains high today and is increasing in popularity, especially in areas within driving distance of metropolitan centers, such as Minneapolis /St. Paul. Recreation pursuits have expanded to include skiing, snowmobiling, all-terrain vehicle riding, hiking, bicycling, wildlife watching, sailing, and others. Facilities for these activities have been developed in response to the interest and need. A significant draw is the large percentage of public lands and trails available for public use. Public lands that are set aside as parks include national parks such as Apostle Islands National Lakeshore in Wisconsin and Pictured Rocks National Lakeshore in Michigan, Pukaskwa National Park in Ontario, and state parks and natural areas such as Split Rock Lighthouse State Park in Minnesota. These areas not only provide outdoor recreation opportunities, but they also protect important habitats for wildlife and fish and provide opportunities for natural resource management that are not commodity-based. Local communities that serve as gateways to these protected areas and trails gain economic development opportunities by serving tourists and residents.

2.5 Parks and Protected Areas

Approximately 10 percent of the Lake Superior basin is in parks and protected areas (Figure 21). For purposes of this report, protection has been interpreted broadly. Areas included range from Wilderness Class National and Provincial Parks to national forest areas and state parks. There are at least 112 areas ranging in size from Wabakimi Provincial Park (<890,000 hectare (ha), only part of which is within the basin) to Baraga State Park (22 ha) in Michigan.

On the south shore of the Lake, there are two National Lakeshores, a National Park, many State Parks that provide protection for specific sites, and parts of five National Forests that are managed for forestry and recreation, as well as providing some wilderness representation. In addition, part of the Boundary Waters Wilderness Area is within the Superior National Forest (Table 5, Figure 21).

Recently, significant steps have been taken to increase the area under protection around the lake. "Ontario's Living Legacy" has identified many new areas for protection or additions to existing parks. In addition, policies are being put in place to recognize the Great Lakes Heritage Coast. This policy will recognize the "internationally significant natural, cultural, scenic, and recreational values of the Lake Superior shoreline." The Great Lakes Heritage Coast will apply to Crown lands, waters, lakebeds, Crown islands, and intervening coastal areas between the Pigeon River mouth and the St. Mary's River at Sault Ste. Marie. The policy does not apply to Indian Reserves or private land.

Lands designated under "Ontario's Living Legacy" include Provincial Parks, Conservation Reserves, and Enhanced Management Areas, totalling 3,856 km^2 of varying degrees of protection.

A proposed National Marine Conservation Area (NMCA) encompasses the waters and federal lands on the north shore of Lake Superior from Thunder Cape to Bottle Point. Negotiation of an NMCA establishment agreement between the Government of Canada and the Province of Ontario is ongoing.

World Wildlife Fund Canada (1999), concludes that there are "…significant gaps in the core protected areas system for the Lake Superior basin in both the terrestrial and aquatic portions in the United States and Canada." The study indicates that 12 of 29 seascapes have a marginal degree of protection, which includes five areas with at least 10 percent protection. The remaining 24 have less than 5 percent protection.

The Lake Superior Binational Program has developed a map entitled "Important Habitat Conditions in the Lake Superior Basin" (see Addendum 6-H). This map documents a number of sites – some that are protected, some that are not – that contain habitat important for the overall health of the Lake Superior basin.

Table 5. Parks and protected areas in the U.S. Lake Superior basin.

	Michigan	Wisconsin	Minnesota	Total
National Parks	1			1
National Monument			1	1
Wilderness (Forest Service)			1	1
National Lakeshore	1	1		2
National Historic Park	1			1
National Wildlife Refuge	1	1		2
State Parks	13	4	13	30
State Wayside			3	3
County Parks			2	2
Wilderness Area	1			1

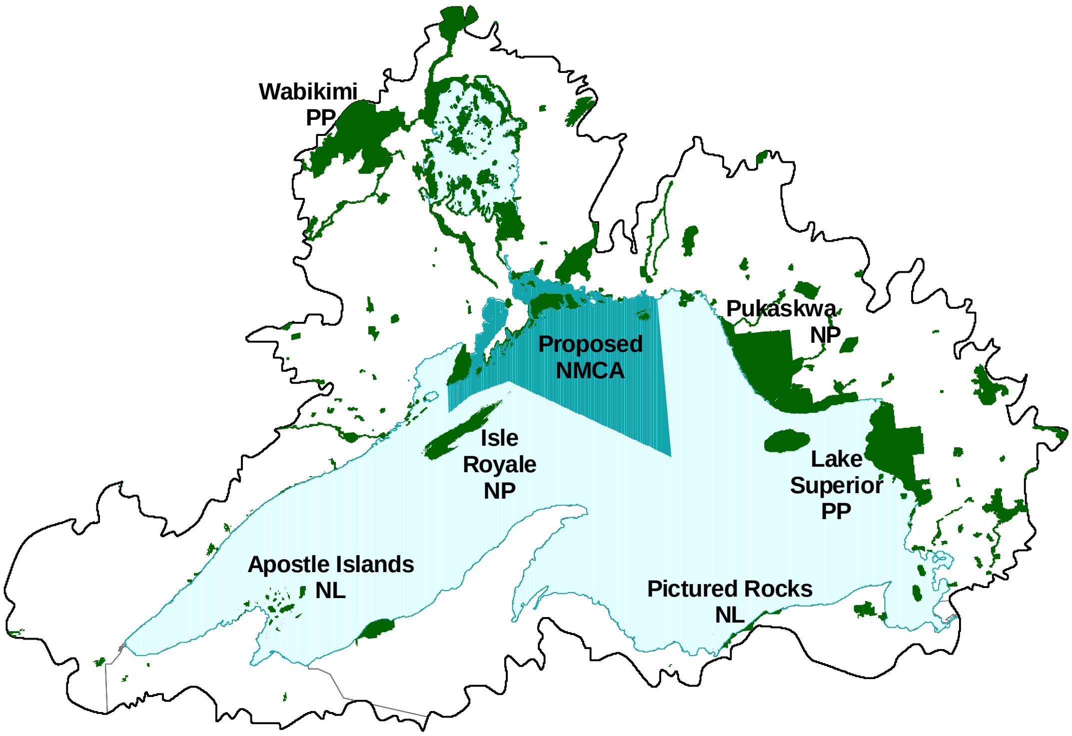


Figure 21. Parks and protected areas in the Lake Superior basin, including the proposed National Marine Conservation Area (NMCA).

3. LIVING ENVIRONMENT

3.1 The Terrestrial Environment

3.1.1 Ecological Units

The Lake Superior basin lies in a zone of transition from the mixed deciduous forests in the south to the boreal forest ecosystems of the north. This transition is apparent for many species and ecosystems. The Lake Superior basin represents the northern-most extent for many plant and animal species resident in the United States. It also represents the southern range extent for several other species native to Canada and points north. Because of the complexity of landforms within this region, it is useful to classify the land into ecological units. Often times these classification systems are hierarchical, with smaller units fitting underneath larger units. Different types of land classification systems are applied to the U.S. and the Canadian sides of the basin. Each system is useful and is described below.

Ecological land classifications are based on relationships between vegetation and the physical environment, especially soils, landform, and climate. They define "…useful and functional land units that differ significantly from one another in abiotic characteristics as well as in their related biotic components" (Albert 1995).

The Lake Superior basin is subdivided into 20 land units (called Sections) following the U.S. Ecological Subregions Classification (McNab and Avers 1994) and Ontario's Site Region classification (Hills 1959) (Figure 22). The U.S. system is based on climatic and physiographic features (i.e., bedrock features, glacial landforms, soils, and vegetation) (Albert 1995), while Ontario's classification is based mainly on climatic factors (Hills 1959). Another Canadian land classification, Ecoregions of Ontario (Wickware and Rubec 1989), closely parallels Hills's system, at least within the basin.

The entire Lake Superior basin on the U.S. side is contained in the Laurentian Mixed Forest Province (212), which stretches from New England to northeastern Minnesota. Most of this province has low relief, but rolling hills occur in many places. Lakes, poorly drained depressions, morainic hills, drumlins, eskers, outwash plains, and other glacial features are typical of the area, which was entirely covered by glaciers during parts of the Pleistocene. This province lies between the boreal forest and the broadleaf deciduous forest zones, and is therefore transitional. Part of it consists of mixed stands of a few coniferous species (mainly pine) and a few deciduous species (mainly yellow birch and sugar maple); the rest is a macromosaic of pure deciduous forest in richer soils and pure coniferous forest in poor soils. Mixed stands contain several species of conifer, mainly northern white pine, with an admixture of eastern hemlock.

The Northern Great Lakes Section (212H) makes up most of the eastern part of the U.S. basin. Gently rolling lowland and flat outwash of ground moraine and lacustrine plain predominate, with dune fields near Lake Superior. Local relief is generally less than three meters. Prevailing winds off Lake Superior result in cooler summers and milder winters than Sections to the west. Lake-effect snow and rain is common near Lake Superior. This Section is mainly forested, except the clay lake plains, which are often used for pasture and forage crops. Northern hardwood-fir forests dominate on moraines and stratified ice-contact hills with northern hardwoods on warmer than average sites. Great Lakes pine forests occurred on outwash and lacustrine sands, with jack pine forests occupying outwash and lacustrine sand plains. Conifer bogs occupy low-lying areas (Albert 1995, McNab and Avers 1994).

The Southern Superior Uplands (Section 212J) occupies the middle part of the south shore and consists of bedrock ridges and glacial moraines, lakebeds, outwash channels and plains (Albert 1995). Soils are relatively nutrient-poor, acidic, and rocky. The Lake Superior Lake Plain extends for approximately 322 km along the lakeshore from Duluth / Superior to the Keweenaw Peninsula. Soils are lacustrine clays and clayey till. Most of the Keweenaw Peninsula is a bedrock knob with sandy till. Climate is strongly continental, although considerable lake-effect snowfall occurs across this Section. Northern hardwoods occur on mesic landforms; with pines on drier sites and hemlock and white cedar on wetland landforms. Extensive clearcutting and slash burning in the late 19^{th} century have increased the proportion of paper birch and trembling aspens (Albert 1995, McNab and Avers 1994).

The Western Superior Section (212K) encompasses a small part of the western end of the basin. It is mostly poorly drained, flat to slightly rolling ground moraine and plain-pitted outwash, with kettles intermittently overlain by low, undulating ridges (glacial end moraines) and drumlins. Coniferous and deciduous forests dominate. Some jack pine and oak barrens are on the Bayfield peninsula. Logging and agriculture have significantly altered the environment (Albert 1995, McNab and Avers 1994).

The Northern Superior Uplands (Section 212L) constitutes most of the basin within Minnesota. It consists mainly of morainal landforms with shallow soils and low bedrock knobs. There is a prominent escarpment along Superior's shore. Numerous small lakes dominate the northern part of the Section. Climate is slightly drier and cooler than the Southern Superior Uplands, but winter precipitation is less. Forest composition shifts from northern hardwoods in the Southern Superior Uplands to more boreal pines and hardwoods in the Northern Superior Uplands. Dominant vegetation includes mixed pine with aspen-birch, white pine, red pine, jack pine, black spruce, balsam fir, and white cedar, with less common occurrences of northern hardwoods along the shore of Lake Superior. Due to the rugged terrain and cost of constructing transportation corridors, the area has remained relatively undeveloped (Albert 1995, McNab and Avers 1994).

Site Region 4W (Pigeon River), marks the transition between Great Lakes/ St. Lawrence forest and boreal forest. Along Lake Superior, the topography is rugged with shallow soils. West of Thunder Bay, deep, clayey, glacial lacustrine soils exist.

Site Region 3W (Lake Nipigon) and Site Region 3E (Lake Abitibi) contain boreal forests dominated by black spruce, jack pine, trembling aspen, and white birch. Topography is rugged with shallow morainal soils. Near Lake Superior, deep glacial valleys are filled with sandy outwash and varved lacustrine clays.

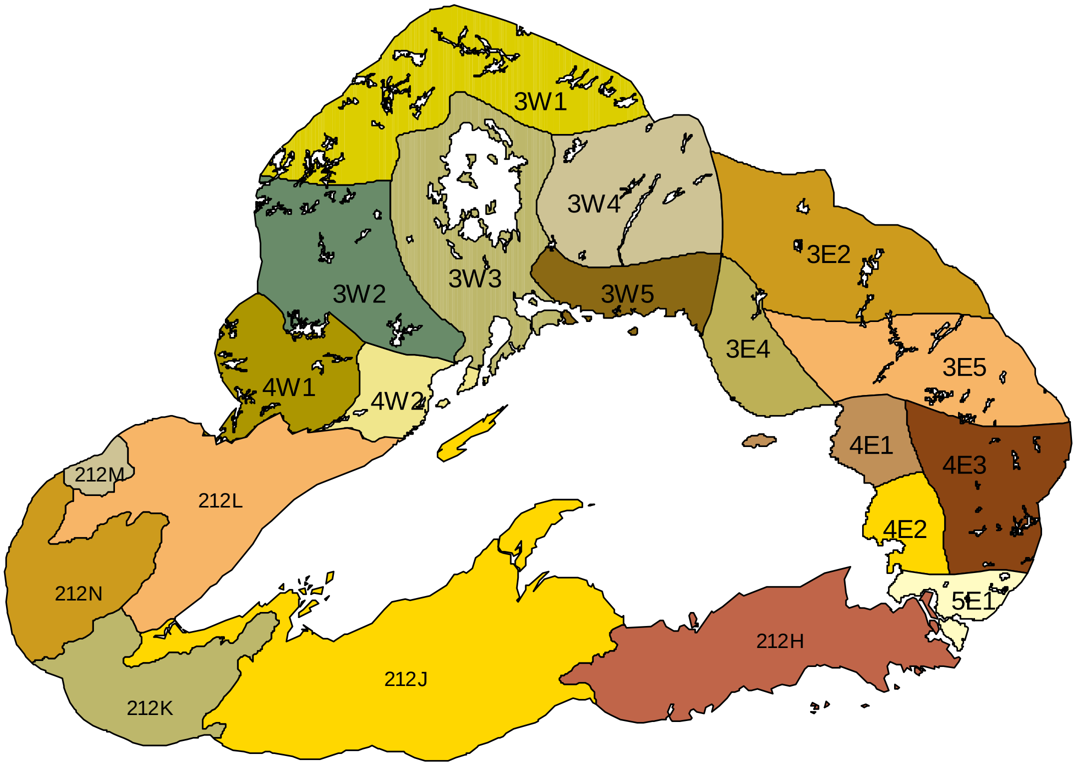


Figure 22. Ecological land classification of the Lake Superior basin (Hills 1959 and McNab and Avers 1994).

3.1.2 Forested Upland Ecosystems

The majority of the Lake Superior basin (approximately 88 percent) is forested, including conifer, hardwood, and mixed forests (Figure 23 and Figure 24). Early seral hardwoods comprise an additional 1.3 percent of the basin. Non-forested communities (grass and brush) make up only 4.5 percent of the basin. The remainder is inland lakes and rivers, agricultural land, and urban areas.

The character of the forests surrounding Lake Superior changes as one travels from south to north. Within ecological sections (described previously) deciduous, coniferous, or mixed deciduous/coniferous forest types can exist depending on soil fertility and soil moisture. Also, as one moves from the south to the north, the preponderance of conifer species increases, until one reaches the boreal system, in which most of the species are coniferous.

The species composition of forested stands depends on the ecological sections in which it is located, the relative soil fertility and moisture, and the stand's age. As forest stands are disturbed and new forests are regenerated, a predictable series of forest types appear, starting with the early seral stages and progressing to the later seral stages and ultimately to old growth forests. This series of progressions is referred to as succession.

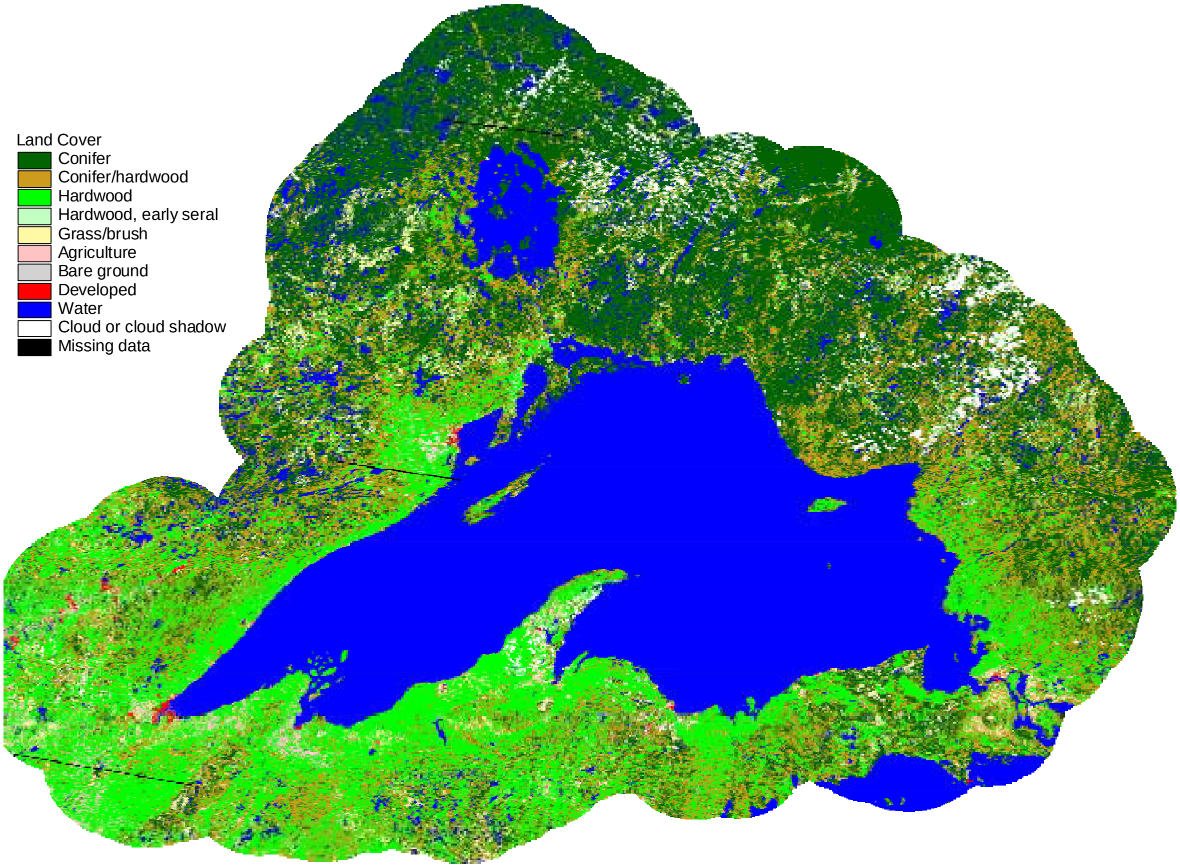


Figure 23. Land cover classes of the Lake Superior basin (derived from Landsat Thematic Mapper (TM) remote sensing).

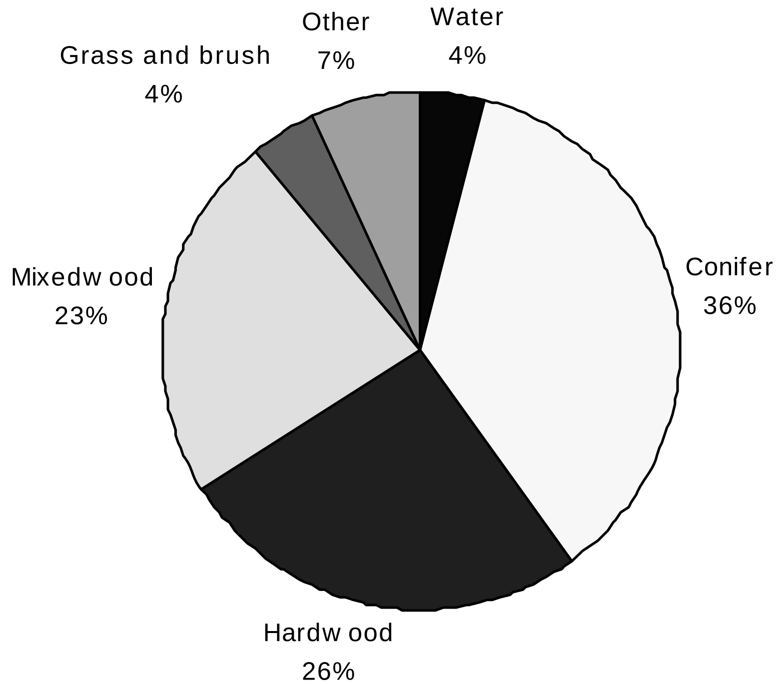


Figure 24. Land cover classes of Lake Superior basin (excluding the lake itself) (1999).

Succession

Following disturbances of the forests, early successional or seral forests form in most of the forested upland ecosystems within the basin. These forests are typically dominated by pioneer species such as jack pine, white birch, and trembling and big-toothed aspen, depending on site conditions. These seral forests have low to moderate shade tolerance and tend not to be self-replacing.

Succession in the hemlock and hardwood forests of the southern portion of the basin was historically characterized by gap dynamics. These multi-generational forests were dominated by shade-tolerant species such as sugar maple, beech, and hemlock that can reproduce without large canopy openings. Other mid-tolerant species such as yellow birch, green ash, and basswood could reproduce in gaps caused by the death of canopy trees (Frelich 1995).

Succession in the boreal system was generally initiated by large, stand-replacing disturbances. Succession was generally set back every 50 to 100 years by fire in these forests and every 150 to 200 years in red-white pine forests and oak forests (Heinselman 1981). Many of these forests were one-generational, in that many of the first trees to invade after the stand-originating fire lived until the next catastrophic fire (Frelich 1995). As long as intolerant hardwoods and jack pine form vigorous, fully-stocked stands, they restrict the development of shade-tolerant species. However, as canopy openings are created by the death of the short-lived hardwoods, more shade-tolerant species such as white spruce and balsam fir are able to succeed. In the continued absence of fire, shade-tolerant species, particularly balsam fir, will often persist on mesic sites. On more nutrient-poor sites in the boreal forest, black spruce is often the dominant species.

After these early successional stages of shade-intolerant species, such as aspen and birch, comes the mid-successional stages. There is a great deal of variation in the species composition of these mid-successional stages, depending on the location within the basin (boreal vs. Laurentian) and the soil characteristics (moist to dry, fertile to infertile). In deciduous stands of the Laurentian Mixed-Deciduous province, the mid-successional stages are characterized by red oak, basswood, and red maple while the coniferous stands contain red and white pine, white spruce, and balsam fir. In the boreal stands, white spruce and balsam fir stands form on the more productive sites, while black spruce stands form on the more hydric and less productive sites.

If no disturbance occurred on these forested upland areas, succession would lead to a more stable forest type, one that tended to be self-replacing. This is sometimes referred to as the "climax forest." It is usually composed of shade-tolerant species which can regenerate in shady conditions. If this forest type lives long enough without disturbance, it can evolve into a forest with closed canopy, large trees and much forest structure (dead and down woody material, complex canopy structure). These forests are referred to as old growth forests.

Disturbance

Three major disturbance regimes naturally occurred in the forests of the Lake Superior basin: fire, disease, and windthrow. In the hemlock and hardwood forests in the U.S. side of the basin, fire was relatively rare and the major disturbances were heavy or catastrophic windstorms and tornadoes that occurred at greater than 1000-year intervals (Frelich 1995). Catastrophic disturbances were relatively small (~100 ha) with an approximate maximum size of 4000 ha (Canham and Loucks 1984). Windstorms could remove 10 to 50 percent of the forest canopy in a given stand every 100 to 300 years (Frelich and Lorimer 1991). In contrast, fire, and to a lesser extent disease, are the most important landscape-level disturbances in the boreal forests and pine forest of the Great Lakes/St. Lawrence Region. Fire is essential to the regeneration dynamics of most boreal forest species, particularly early successional species such as jack pine. A site's long-term cumulative fire history plays an important role in determining present-day vegetation, since some areas are burned more frequently than others (Heinselman 1973). Fire in lowland conifer stands, for example, is less frequent than xeric (extremely dry) sites.

The fire return interval, or fire cycle, is the average period of time between stand-replacing fires in the same stands, assuming all stands in the forest burn once during the interval. The natural fire cycle for Quetico Provincial Park is 78 years (Woods and Day 1977) and approximately 122 years for the Boundary Water Canoe Area Wilderness (BWCAW) (Heinselman 1996). Based on a fire cycle of 70 years, the average annual burn fraction (i.e., the proportion of the total forest that would burn each year on average), was 1.5 percent for boreal forests in Ontario (Ward and Tithecott 1993). Since 1920, fire has burned approximately 1,212,135 ha or 16 percent of the Canadian portion of the basin (on average 0.2 percent per year), most of which is predominantly boreal (Figure 25 and Figure 26).

Figure 25. Fires in the Canadian portion of the Lake Superior basin 1920-1990.

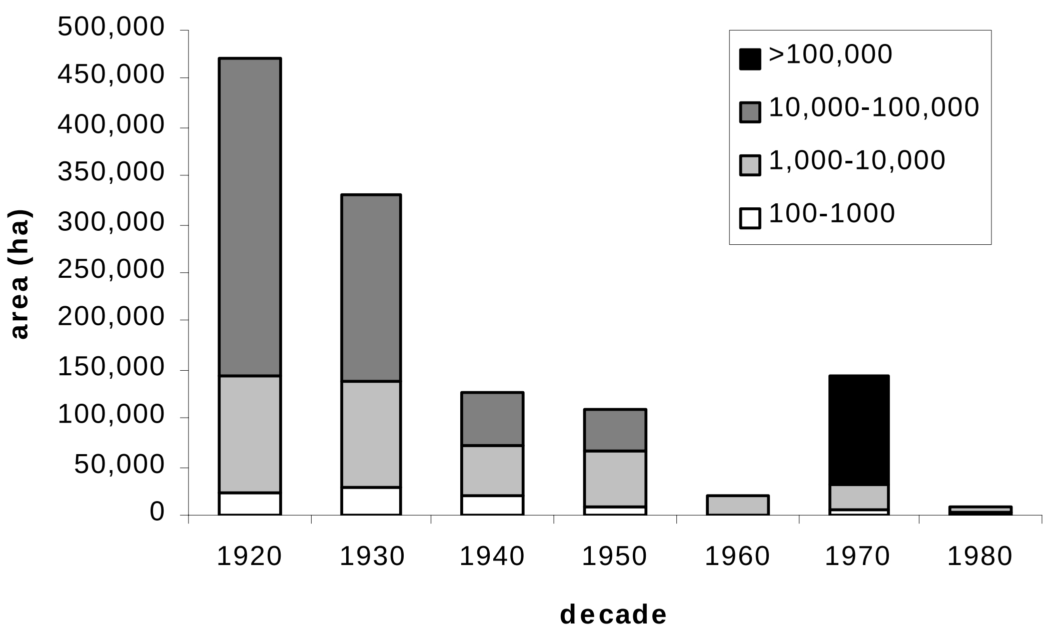


Figure 26. Area burned by wildfire in the Canadian portion of the Lake Superior basin by fire size class (ha) and decade.

The area burned in each decade has generally decreased due to more aggressive fire suppression, combined with improved detection and fire-fighting methods. With the exception of some islands, most of the Canadian Lake Superior basin is within the intensive fire management zone of the OMNR, which means that fires are actively suppressed. Despite this, a very large fire burned approximately 111,000 ha west of Lake Nipigon in the 1970s. With that exception, fewer large fires occur than would have occurred historically.

Historically, lightning was the main source of ignition. Lightning is more or less random, but ground strikes are more frequent on high ridges (Heinselman 1996) and lightning-induced fire is often associated with bedrock. First Nations or Native American people were another possible source of fire, but their role in fire cycles in northeastern North America is uncertain (Russell 1983). Habitat manipulation for large game would have been unlikely, since caribou was historically the dominant ungulate and they prefer mature forests. Burning to encourage blueberry production reportedly took place in northern Minnesota (Heinselman 1996).

Spruce budworm is the most important forest pest in the Lake Superior basin in terms of total area infested, length and frequency of outbreaks, as well as volume and numbers of trees killed (Candau and others 1998). It attacks primarily balsam fir, followed by white spruce, and to a lesser extent black spruce. Affected trees will die if exposed to three to five consecutive years of defoliation, and almost all the trees in dense, mature balsam fir stands are killed during uncontrolled outbreaks. Spruce budworm outbreaks are large-scale phenomena and usually consist of many infestations that occur in different localities within the basin at about the same time.

Outbreaks of high budworm densities and heavy defoliation occur every 20 to 100 years and usually last five to 15 years (Blais 1983). During the 18th and 19th centuries, outbreaks have occurred in the Lake Nipigon region at approximately 70-year intervals (Blais 1983, 1985). Lake Nipigon is one of three "hot spots" in Ontario for spruce budworm outbreaks with about 6,600,000 ha being frequently defoliated, i.e., in >1/3 of the years from 1941 to 1998 (Candau and others 1998). Extensive defoliation occurred in this "hot spot" in 1948, 1985, and 1992, with smaller peaks in other years, and an average interval of 38 years between outbreaks. Widespread mortality of balsam fir and white spruce results in a loss of valuable wood, increased risk of fire and windthrow, and associated public safety risks and degraded aesthetics.

Windthrow is relatively common in boreal forests, and is another major natural disturbance in the Lake Superior basin. Shallow-rooting species such as white spruce and white pine are particularly vulnerable (Foster 1988), as are forests heavily affected by spruce budworm. Wide-scale catastrophic windstorms occur infrequently in the basin, but may have significant impacts. Mineral soil exposed following windthrow may be important in boreal forest regeneration dynamics (Jonsson and Dynesius 1993).

Old Growth Forest

"Old growth" has been variously defined and applied, but typically is used to describe forest ecosystems with old trees and their associated plants, animals, and ecological processes. In the Lake Superior basin, old growth usually refers to forests that are dominated by long-lived species including red and white pine, oaks, northern hardwood species, and lowland conifers. The age at which this occurs depends on species composition, site variables, and stand conditions, but typically occurs at approximately 120 years for long-lived species (Frelich and Lorimer 1991, Heinselman 1973). Forests dominated by short-lived species (those that normally live from 60 to 100 years) such as aspen, paper birch, balsam fir, and jack pine are relatively old at age 80 and have been referred to as "old-seral" forests (Frelich 1995).

The age structure of pre-European settlement forests was determined largely by natural disturbance regimes. In the boreal forest, stand-regenerating fires usually occurred every 50 to 200 years (Heinselman 1981), so that old growth was a temporary phenomenon that was usually only attained by oak, and red and white pine stands (Frelich 1995). In contrast, fires were rare in the Great Lake-St. Lawrence Region / Laurentian Mixed Forest Province, and catastrophic windstorms and tornadoes occurred at greater than 1000-year intervals. Many of these forests were multigenerational and old growth conditions could last centuries.

Approximately five to eight percent of the forest in the Great Lakes basin is presently old growth (including old seral forest). Only about one percent of the pre-European settlement primary forest remains in the Lake States, of which more than 90 percent is located outside the Superior basin. Nearly all the primary forest within the U.S. side of the basin is retained in large wildernesses and parks. Very little red and white pine, river bottom northern hardwood, and oak-hickory forests remain. In contrast, it is estimated that 68 percent of pre-European settlement forests in the Lake States were old growth. The proportion of old growth varied among pre-European settlement forest types, with 20 percent of jack pine forests; 45 to 55 percent of red-white pine, spruce-fir-birch, swamp conifer, oak-hickory, and river bottom forests; and 89 percent of northern hardwood forests (Frelich 1995).

The only large, primary upland forests in the U.S. side of the Lake Superior basin are those of the Porcupine Mountains Wilderness State Park (14,164 ha) and the Northshore Highlands (600 ha within the Boundary Waters Canoe Area Wilderness). Porcupine Mountains Wilderness State Park and Pictured Rocks National Lakeshore (400 ha) contain most of the protected northern hardwoods in the basin. Isle Royale National Park has 38 percent of the Lake States' protected old growth spruce-fir. Over 90 percent of the forest in the Porcupine Mountains WSP is older than 120 years, compared to approximately only 10 percent in adjacent commercial forests (Frelich 1995). The Porcupine Mountains is the largest old growth northern hardwood forest in North America and is closest to presettlement condition of any upland forest remnant in the Great Lakes region. Minnesota has 13 old growth sites totalling 1600 to 2000 ha (Kershner 1999). The private Huron Mountain Reserve has 2600 ha of old growth (Kershner 1999). There are protected old-growth forests located on the Apostle Islands National Lakeshore which are older than 350 years. Four islands, each around 120 ha, contain important old-growth stands. They are especially significant because they have not been subjected to deer browse.

Most of the Canadian side of the basin is boreal and predominantly early-seral forest. A Conservation Strategy for Old Growth Forest Ecosystems in Ontario was developed in 1994 by the OMNR (Policy Advisory Committee 1994). Most of the inventory and study of old growth forests on the Canadian Side of the basin has focused on longer-lived red and white pine. Fire suppression has resulted in older ages for some stands, but widespread logging has removed other old growth stands. There are 123 old growth (>120 years) red and white pine stands identified on the Canadian side of the basin covering 3819 ha. Most of these stands are in the southeast or northwest portion of the basin (Figure 27).

Figure 27. Old growth red and white pine stands in the Ontario Lake Superior basin (OMNR data).

3.1.3 Non-forested Upland Ecosystems

Within the Lake Superior basin upland areas occur which are non-forested. Some of these areas are quite small and remain open due to weather patterns, often referred to as “frost pockets.” In these areas, cold temperatures persist late into the spring and prevent trees and shrubs from establishing and growing to maturity. In other areas, landscape-level processes (fire and disease) occur and result in an open savannah called pine barrens.

Barrens Ecosystems

Pine barrens are relatively large tracts of land in which frequent fires created a landscape mosaic of large openings, savannas, and forested patches. This landscape mosaic provides habitat for grassland birds and other open habitat species and is known as Pine Barrens. This community is characterized by scattered jack pines (*Pinus banksiana*), or less commonly red pines (*P. resinosa*), sometimes mixed with scrubby Hills and bur oaks (*Quercus ellipsoidalis* and *Q. macrocarpa*), interspersed with openings in which shrubs such as hazelnuts, (*Corylus* spp.) and prairie willow (*Salix humilis*) and herbs dominate. The flora often contains species characteristic of “heaths,” such as blueberries (*Vaccinium angustifolium* and *V. myrtilloides*), bearberry (*Arctostaphylos uva-ursi*), American hazelnut (*Corylus americana*), sweet fern (*Comptonia peregrina*), and sand cherry (*Prunus pumila*). Also present are dry sand prairie species such as June grass (*Koeleria macrantha*), little bluestem (*Schizachyrium scoparium*), silky and sky-blue asters (*Aster sericeus* and *A. azureus*), lupine (*Lupinus perennis*), blazing-stars (*Liatris aspera* and *L. cylindracea*), and western sunflower (*Helianthus occidentalis*). Pines may be infrequent, even absent, in some stands in northern Wisconsin and elsewhere because of past logging, altered fire regimes, and an absence of seed sources.

The 930,800 ha of pine barrens in the basin have changed enormously since European settlement. Originally a mosaic of fire dependent communities, today's pine barrens contain only a small fraction of the original acreage of the ecosystem's early seral stages. This open habitat is rated as globally rare.

3.1.4 Islands

There are 1,763 islands in Lake Superior, most of which are in Canadian waters (Figure 28). Lake Superior islands represent over 1,672 km^2 and 2,265 km of shoreline. They range from small barren rock outcrops to Isle Royale, which is 71 km in length (Figure 29). Most (71 percent) islands are less than 1 ha and represent only 0.2 percent of the total island area. The three largest islands, Isle Royale, St. Ignace I. (in the Black Bay Peninsula Archipelago), and Michipicoten I. represent 62 percent of the total island area. The Apostle Islands National Lakeshore (AINL) protects 21 of the 22 Apostle Islands archipelago. The islands of AINL range in size from 1 to 4,050 ha.

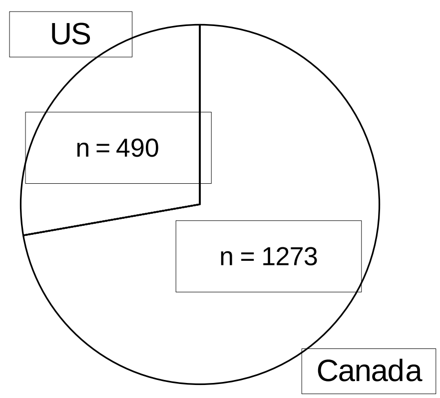


Figure 28. Lake Superior islands (compiled from U.S. EPA 1994 and Environment Canada 1993).

Island habitats contribute significantly to the biodiversity of the Lake Superior basin and provide important habitat distinct from most mainland sites. In 1995, a joint U.S.-Canada workshop to assess the State of the Great Lakes Islands, determined that the natural biological diversity of the islands of the Great Lakes is of global significance (Vigmostad 1999). At the 1996 State of the Lakes Ecosystem Conference, islands were also specifically identified as one of seven special ecological community types recognized within the Lake Superior basin (Reid and Holland 1997).

The cold, oligotrophic nature of Lake Superior and the harsh microclimates of exposed shorelines on many islands have created conditions suitable for scattered populations of plants normally only found in arctic or alpine regions. These species were present immediately after the last Wisconsin glaciation and have been able to persist because of these climatic refugia. Many of these plants, known as "arctic-alpine disjuncts," are well-represented in Lake Superior.

Island ecosystems are greatly influenced by their isolation from mainland communities. Their isolation tends to simplify wildlife communities and provide protection from predators (Reid and Holland 1997). Islands often serve as "living laboratories" where studies of the impact of herbivores, predator-prey relationships, evolution and extinction, population dynamics, animal cycles, dispersal, and rapid population growth can be conducted.

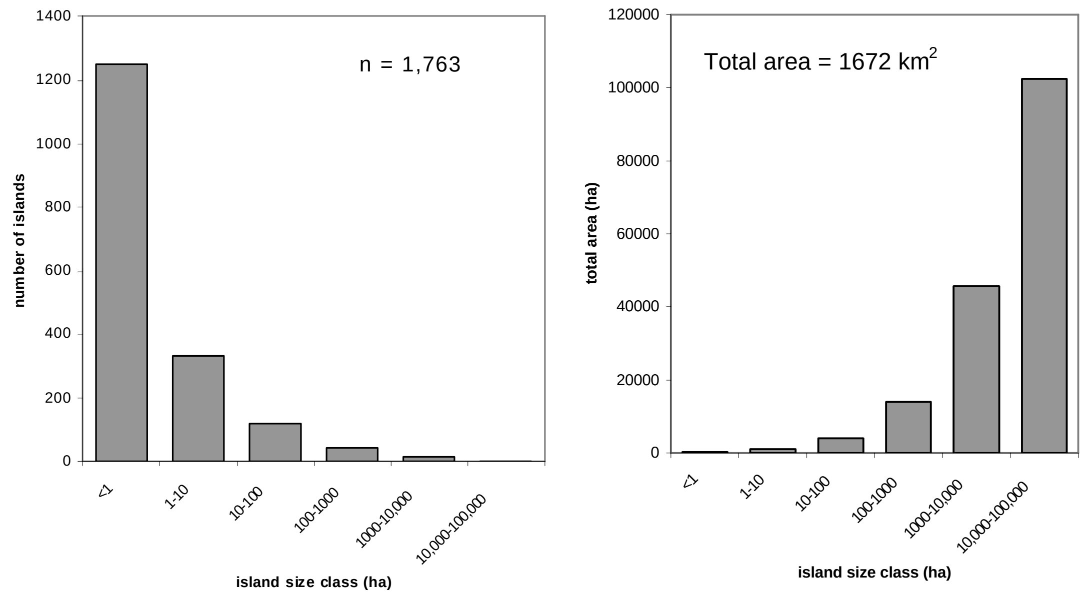


Figure 29. Lake Superior islands size distribution in terms of number of islands and total area (compiled from U.S. EPA 1994 and Environment Canada 1993).

Moose commonly calve on small islands and woodland caribou persist (naturally or by reintroduction) on some offshore islands due to the absence of predators. Lake Superior islands provide nesting sites for ring-billed and herring gulls, double-crested cormorants, and great blue herons (Blokpoel and Scharf 1999). Isolated island habitats have few mammals, reducing egg predation for ground nesting birds. Islands also provide stop-over refuges for birds flying over open water at night or form natural extensions to mainlands that follow critical migratory flight corridors.

Many of the islands in Lake Superior are encompassed in protected areas (Figure 30). Lake Superior islands may be particularly suited to serve as biosphere reserves especially in terms of sentinels to detect the long-range transport of toxic materials (Vigmostad 1999). They are under stress, however from increased recreational use particularly sea-kayaking and boating, and human manipulation of lake levels. These isolated islands are sensitive due to the limited potential for recolonizing with mainland species in the event of an extirpation. Islands are by their nature subject to human curiosity and regularly attract human visitation to their shores. Human intrusions can range from recreational visitation by boaters to housing development.

Isle Royale

Isle Royale is the largest island in Lake Superior (555 km^2) and is 22 km from the nearest mainland. Climax spruce-fir and yellow birch-sugar maples are the dominant forest cover. Isle Royale is well-known for its long-term studies of predator-prey relationships involving wolves and moose. Caribou were historically present, but white-tailed deer, black bear, raccoons and porcupines are notably absent. Isle Royale is perhaps the best known of the Lake Superior Islands because of its National Park and International Biosphere Reserve designation. It is the only island based national park in the United States and is a federally designated wilderness area (Vigmostad 1996).

Apostle Islands

The 22 Apostle Islands cover over 219 km^2 and comprise approximately 291 km of shoreline. Twenty-one of the islands are protected by Apostle Islands National Lakeshore, which is managed by the U.S. National Park Service. Apostle Islands include many important habitats including old-growth forest remnants, a wide variety of coastal features, sandstone cliffs with arctic remnant rare plants, and important habitat for nesting, migratory and colonial birds. The Apostle Islands are comprised of pre-Cambrian sandstone, the remnants of an old braided river channel that created a unique archipelago with almost grid-like spacing. The islands are largely comprised of northern hardwood forest with some pine forests and dune vegetation being found on sand spits and other coastal features. Outer Island has one of the largest remaining virgin hemlock hardwood forests in the Great Lakes region (Vigmostad 1999). This stand has an especially unique understory because it does not have a history of ungulate browsing.

Grand Island

Grand Island lies just offshore in Grand Bay, Lake Superior, near Munising, Michigan, west of the Picture Rocks National Lakeshore. This 55 km^2 island is managed by the Hiawatha National Forest as a National Recreation Area, and features sandstone cliffs on the northwest, north and western shorelines.

Outstanding features of this island include a tombolo (connecting sandbar) between two parts of the island and an expansive marsh on Murray Bay. The marsh includes wet meadow, shrub swamp and poor conifer swamp, features a diverse and unusual array of plants. Upland conifers dominate the northern ridges. The upland areas feature some rare plants, habitat for peregrine falcons, and a small, forested Research Natural Area. This is the only large island in Michigan's portion of Lake Superior that consists of sandstone bedrock (adjacent small islands are also sandstone), and second only to Isle Royale in size in Michigan's portion of Lake Superior. Peregrine falcons last nested on the island in 1906 but were reintroduced to the island in 1992.

Grand Island has very high biodiversity significance, primarily because of the excellent quality marsh. The Michigan Natural Areas Council has worked on developing a vegetation monitoring plan for the island in response to impact concerns that may arise from recreational uses.

Slate Islands

The Slates Islands are an archipelago of 58 islands, 13 km from the mainland shoreline near Terrace Bay. They range in size from small barren rocks to Patterson Island at 22 km^2. The Slate Islands have exceptionally interesting and significant geology. They are comprised of an array of metamorphic rocks indicative of an ancient volcanic cone or perhaps thought to be the remnants of a crater from a meterorite impact (Snider 1989). The Slate Islands were exposed approximately 3,000 years ago after slowly rebounding from the weight of glaciers.

The Slate Islands provide an example of how isolation from the mainland has affected wildlife communities. The islands support the southern most population of woodland caribou in North America. Caribou are present at extremely high densities (200 to 400 animals) due to the absence of predators. Other large mammals such as moose, deer and wolves have not become established on the Slate Islands (in 1997 two wolves are believed to have reached the island across the ice, but have not persisted). The Slate Is. are also notable for populations of arctic-alpine plants and devil's club, a western disjunct also found on Porphyry Island and Isle Royale. Herring gulls nest on at least seven locations, including the Leadman Islands.

The Slate Islands and surrounding waters within 400 m of shore are protected in the Slate Islands Provincial Park. There is a Canadian Coast Guard lighthouse and outbuilding on federal land on the south shore of Paterson Island.

Black Bay Peninsula Archipelago

Over 480 islands form an archipelago along the outer edge of the Black Bay Peninsula and Nipigon Bay along the north shore of Superior. They range from wave-washed rocks to a number of large islands over 1000 ha each including St. Ignace Island (274 km^2), Simpson I. (73 km^2), Wilson I. (19 km^2), Edward I. (16 km^2), Fluor I. (14 km^2), Vein I. (10 km^2) and Copper I. (9 km^2). These islands have numerous arctic-alpine communities and colonial nesting waterbirds. The archipelago is largely undisturbed by development and parts have recently been protected as a Provincial Conservation Reserve. The islands are also part of an area currently being considered for establishment of a National Marine Conservation Area.

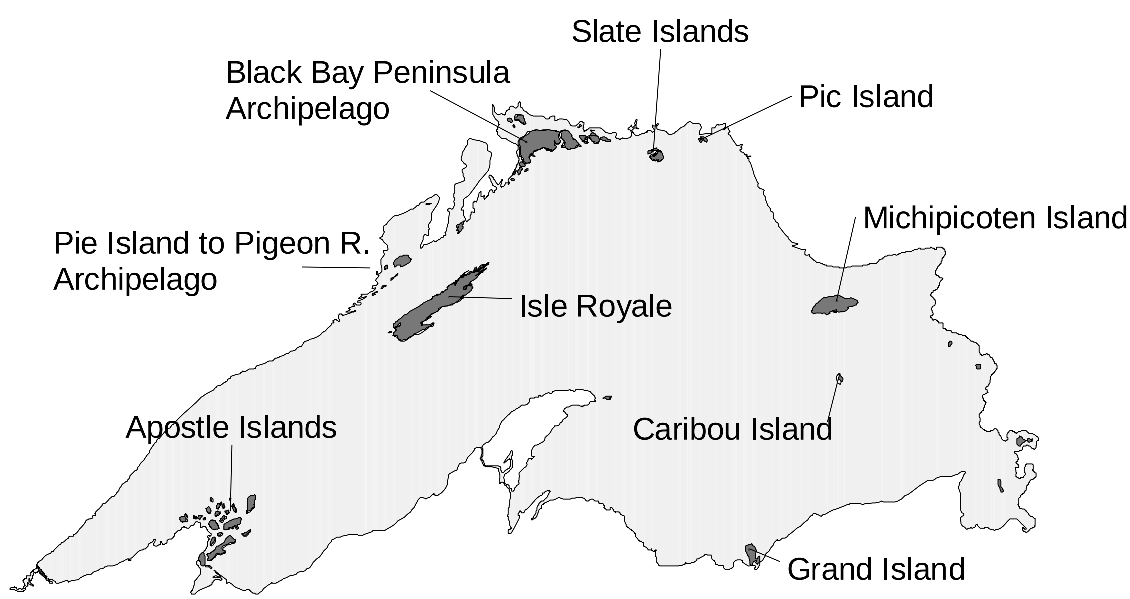


Figure 30. Major Lake Superior islands.

Michipicoten and Caribou Islands

Michipicoten is a large island (184 km^2) in eastern Lake Superior significant for its introduced woodland caribou population. Caribou Island (12 km^2) is due south of Michipicoten Island, approximately 65 km from the mainland and is notable for its isolation and as a rest stop for migrant birds. Michipicoten is a provincial park, and Caribou Island is largely protected from human disturbance by its extreme isolation.

Pic Island

Pic Island is a small island (11 km^2) on the north shore of Superior that historically had woodland caribou and still has suitable woodland caribou habitat. Together with three adjacent islands, they have arctic-alpine plants and colonial-nesting birds. They have recently been incorporated into the adjacent Neys Provincial Park.

3.1.5 Wildlife

The Lake Superior basin represents a transition zone for wildlife along with vegetation. Lake Superior represents a barrier to dispersal, as does the change in forest composition and climate. No terrestrial vertebrate species are endemic to the Lake Superior basin. Although the term “wildlife” can be defined variously, here it will be used to describe mammals, birds, herptiles, and some invertebrates. See Addendum 7-C for scientific names of non-fish species included throughout this chapter.

Mammals

Fifty-nine species of mammals are native to the Lake Superior basin. Many of these have wide-ranging distributions, but approximately 25 percent are predominantly boreal and 20 percent are species primarily from more southerly deciduous forests (Burt 1975, Dobbyn 1994). In addition to this ecological transition, a social transition exists. Canada (and the Provinces) treat individual species differently than does the U.S. (and the States). For example, the lynx is classified as a Threatened species in the U.S., while classified as a game animal in Canada. This dichotomy of mammal status makes describing the mammal community in the Lake Superior basin complicated.

The mammal community of the Lake Superior basin has been significantly affected by land use change, particularly within the U.S., during the past century. Large carnivores were largely eliminated or greatly reduced in abundance. Some species (e.g., fishers) are making recoveries. Some herbivores have benefited from these land-use changes. Beavers have increased in abundance to the point of causing damage to roads and impacting forested stands. White-tailed deer populations are high in some portions of the southern basin, causing damage to people (e.g., automobile collisions) and forests. A few species, such as coyote, have benefited from habitat change and expanded their ranges and numbers (Hazard 1982, Frelich and Lorimer 1985). It is necessary to place the mammal community in the context of these changes.

Deer
White-tailed deer reach the northern extent of their continental range in the Lake Superior basin. Their population densities range from less than two to 15 deer/km^2, from northern Ontario to Wisconsin,

respectively. Deep snows, cold temperatures, and lack of cover prevent deer from ranging much beyond the northern boundary of the basin. Deer are an important species for several reasons. They are an integral part of forested ecosystems, sometimes referred to as a keystone species. They can have negative impacts on people and forests when they reach over-abundant levels. Deer also provide food for large carnivores such as timber wolves. Deer provide various social benefits, such as hunting and viewing opportunities and the associated economic stimulus.

Moose

Moose are more common in the northern part of the basin, become less common to the south, and are relatively common in Ontario and Minnesota. Michigan conducted moose translocation projects to estimate the moose population. Only a handful of moose exist in Wisconsin, with those few animals finding their way to the western part of the state from populations in Minnesota and to the eastern part of the state from moose in the Upper Peninsula of Michigan. Although moose are another large herbivore, they have not been associated with damage complaints, as deer have, because they tend to occupy land removed from human populations. Moose is a big-game species that is hunted over most of the basin.

Caribou

Caribou are absent from the south side of the basin, but a few populations occur in Ontario. Woodland caribou population trends are discussed in the *Status and Trends* section of this report.

Beaver

Beavers benefited from land use changes in the last century and have recovered from heavy exploitation during the trapping era. They remain a trapped species within the U.S. and Ontario but harvests have declined since the heyday of trapping. Beavers are found throughout the Lake Superior basin occupying the lakes, streams, and wetlands of the region. They are one of the few animals that can alter the habitat to meet its needs. Unfortunately, beaver dams occasionally cause damage to roads and forest lands. Beavers have caused declines in some cool-water fish populations because of their dam building. (Dams back up water, which then warms to a temperature too high for some fish.) On the other hand, beavers create many hectares of wetlands which have benefits to many bird and herptile species.

Coyote

Coyotes have benefited from land-use changes and are present at varying densities throughout the basin. They are harvested through hunting and trapping for their fur. With the reductions in wolf populations, coyotes have increased in abundance, occupying areas from which they were once absent. The potential cascading effects of this change have not been investigated.

Wolves

Wolves are present at various levels of abundance throughout the Lake Superior basin. They are classified as a game animal and are harvested for their pelts in Ontario. Wolves are a federally listed Threatened species in the U.S., having been recently down-listed from Endangered. Population recovery goals have largely been met and the process is underway to de-list wolves in the U.S. Wolves are a top-level predator and can impact prey populations. They also can cause depredation to some livestock and game farm operations.

Medium sized carnivores (marten, fisher, bobcat, lynx, , red fox, grey fox, mink, otter, badger)

Martens and fishers are now present throughout the basin, although they were both extirpated from Wisconsin and Michigan. Populations in these states are the result of reintroduction efforts. They are trapped in Ontario, Minnesota, and Michigan but are classified as state Endangered in Wisconsin, with only a few hundred individuals present. Densities vary among populations in Ontario, Minnesota, and Michigan. Bobcats are more common in the southern portion of the range and become rare to the north. Lynx are just the opposite, being more common in Ontario where they are trapped, and becoming so rare as to be classified as Threatened in the U.S. Red fox, like coyotes, are well established throughout the basin while grey fox is rare in the south basin area and absent from the north. Mink, otters, and badgers are relatively common throughout the basin. The status of many of these species has not been monitored over the years and so population estimates are unavailable.

Small mammals
Little has been reported about the small mammal populations (including bats) of the Lake Superior basin, including species that reach the northern part of range, e.g., southern flying squirrel, and species that reach the southern part of range, e.g., northern bog lemming. Many small mammal populations are cyclic and so vary from year to year. No long-term monitoring projects of small mammal populations have been undertaken, so little is known of these species. Some agencies have conducted inventories or other periodic sampling of small mammal populations. Apostle Islands N. L. has surveyed small mammals on 4 of the 22 islands.

Birds

The bird species of the Lake Superior basin also reflect a north-south transition. In the northern portion of the basin, boreal species such as the great grey owl, spruce grouse, and three-toed woodpecker are common. Farther south, species typical of the Great Lakes/St. Lawrence and northern hardwood forests, such as rose-breasted grosbeak, scarlet tanager, and red-headed woodpecker are found. Widespread species, such as the American crow, black-capped chickadee, and red-tailed hawk, are found throughout the basin. A few species with western affinities (e.g., yellow-headed blackbird) are found locally.

Of the approximately 200 species of birds that nest in the Lake Superior basin, 130 to 150 species migrate south for the winter (Cadman and others 1987). A smaller number of species (<30) are permanent residents (e.g., most owls, woodpeckers, and grouse). A few species, such as the snowy owl, northern shrike, and common redpoll, breed farther north and are only winter residents in the basin. Although not on a major flyway, relatively large numbers of migrants pass through on the eastern and western sides of Lake Superior. Three well-established, introduced bird species inhabit the basin: rock dove (now reclassified by the American Ornithologists' Union (AOU) as rock pigeon), house sparrow, and European starling. Other introduced species including mute swan, ring-necked pheasant, and house finch have established local populations.

Lake Superior provides important habitat for migratory waterfowl, especially diving ducks. Coastal wetlands also provide important habitat for both breeding and migrating birds. Although Lake Superior is not a center of waterfowl production in North America, large numbers of migratory waterfowl pass over and around the Lake each spring and fall during migration.

Neotropical migrants
Neotropical migrants include most of the forest warblers of the region. These birds are sensitive to forest fragmentation and the associated adverse impacts (primarily predation and nest parasitism) of forest edges. Multiple species of neotropical migrants nest in the basin. Some species are showing indications of population decline, while others are either stationary or slightly increasing.

Colonial nesting birds
Colonial nesting birds (i.e., gulls, terns, and cormorants) are found throughout the basin at varying levels of abundance. Some of these species are sensitive to environmental perturbations and have undergone large population changes. Cormorants, for example, had been classified as a Threatened species in the U. S. However, due to reduction in mortality factors and increased reproductive success due to pesticide restrictions, cormorants have recovered enough to be de-listed. In some areas of the basin, these birds are seen as a nuisance because of their impacts on some fish populations.

Birds of prey
Bald eagles are found throughout the basin. Listed as Endangered for many years in the U.S., their population has recovered sufficiently to be down-listed to Threatened. Bald eagle population trends are discussed in the *Status and Trends* section of this report. Peregrine falcon population trends are also discussed in the *Status and Trends* section of this report.

Reptiles and Amphibians

A recent survey of institutional collections, atlas projects, and monitoring efforts found records of 37 species of reptiles and amphibians in the Lake Superior basin (Casper 2002), including seven salamander, 12 frog and toad, six turtle, two lizard, and 10 snake species. An additional 10 species of herptiles occur near the margins of the basin or were erroneously reported. Generally, the abundance and diversity of amphibians and reptiles is dependent on climatic conditions. The short growing season and cold, severe winters limit the number of species that can survive in the Lake Superior basin, especially in the north.

Blue spotted and red-backed salamanders are found throughout the basin (Casper 2002; Cook 1984, Conant and Collins 1991). Common frog and toad species throughout the basin include American toad, spring peeper, green frog, wood frog, and leopard frog. Turtles found throughout the basin include the snapping turtle and the painted turtle. No lizard species are common in the basin. Widely distributed snakes include garter snake, red-bellied snake, and ring-necked snake. Most other species found within the basin are restricted to the south (Casper 2002). The mink frog is a northern species, with the southern border of the basin representing its southern range limit.

Few monitoring programs occur in the region, thus population data are lacking (Casper 2002). Frogs and toads are monitored by some state and local governments or organizations using calling surveys. However, the majority of herptile species remain unstudied and unmonitored.

Invertebrates

About 90 percent of the nearly one million species of animals in the world are terrestrial or aquatic invertebrates (animals without backbones). In the Great Lakes region, the larger, more easily seen invertebrates include mollusks, such as snails and clams, and insects. Insects are the most diverse animal group and may have the largest collective biomass of all terrestrial animals.

Within the Lake Superior basin, however, little information exists on status and trends of the insect or other invertebrate populations. The groups are too large to encompass, and taxonomic problems have impeded the development of status and trend information. Although invertebrates can be sensitive to environmental conditions, in a recent review of soil invertebrate species (Mallik 2002) concluded that monitoring of these species would be unduly intensive and would not yield beneficial results. Some have suggested that aquatic invertebrates, such as mussels and clams, can be indicators of water quality, but similar conclusions have not been reached for terrestrial invertebrates.

Some recent research has shown that most earthworm species in the Lake Superior basin are exotics, introduced after the most recent glaciations eliminated earthworms from the region. These non-native earthworms have negative impacts on forest flora. Earthworms increase decomposition rates of the duff on the forest floor. Herbaceous plant species adapted to this forest duff layer (e.g., Canadian shield plants) are adversely impacted by this decomposition.

3.2 The Transitional Environment

3.2.1 Shorelines

The most comprehensive classification of Lake Superior shorelines are the Environmental Sensitivity Atlases compiled by Environment Canada (1993) and the United States National Oceanic and Atmospheric Administration (U.S. EPA 1994). Although primarily designed to assist in response to oil spills, these Canadian and U.S. atlases also provide data on Lake Superior's shoreline characteristics and features.

This classification system established a number of distinct shoreline habitat types. The U.S. approach to this shoreline classification strategy offered a slightly finer level of detail by providing a greater number of categorized shoreline types. However, both the Canadian and U.S. atlases share a number similar physical themes that, when merged, provide an overview of shoreline habitat for the entire basin. Shoreline types are summarized in Figure 31and Figure 32, and Table 6.

Cliff

This feature includes bedrock cliffs of various heights comprised of resistant or impermeable bedrock surfaces. This is the most extensive shoreline habitat type of Lake Superior, comprising 32 percent of the shore. Most cliff shores are in Canada, making up the predominant shoreline type on the outer islands and along the eastern shore (Figure 31 and Figure 32). In the U.S., cliffs are common in the Pictured Rocks area, Isle Royale and along the Minnesota north shore. Many rare plant species grow along exposed, shallow soil cliff tops.

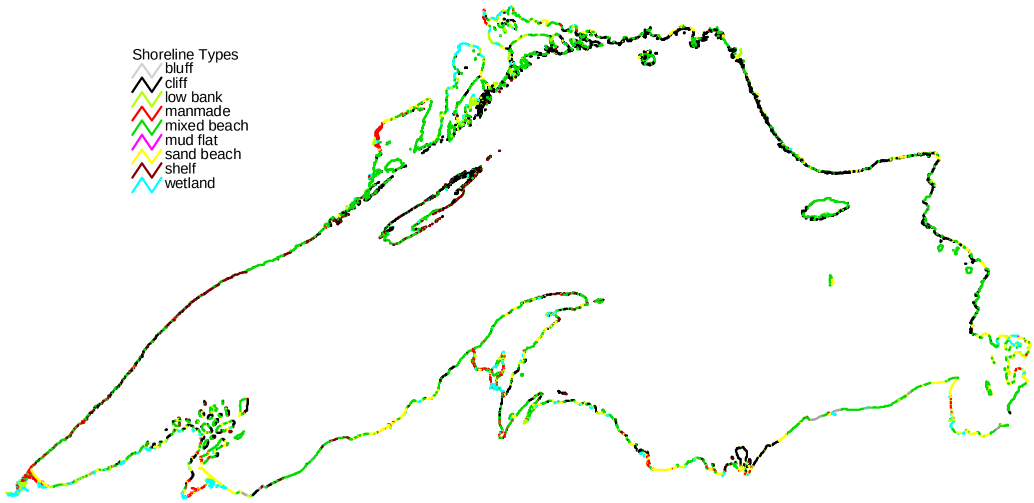


Figure 31. Lake Superior shoreline types (Environment Canada 1993 and U.S. EPA 1994).

Shelf

Shelf shoreline consists of flat expanses of bedrock, often extending below water levels. Bedrock shelves are often influenced by wave action. Shelving bedrock shoreline is found mainly in the U.S., particularly on Isle Royale and the Minnesota north shore. Exposure, cool temperatures, and shallow soils provide conditions suitable for arctic-alpine disjunct plant species.

Bluff

Bluffs, or scarps, are unconsolidated soil banks in an erosional state from wind, wave, and surface water action. They represent a source of sand and other mineral soil that is transported and deposited to form sand beaches. Bluffs are uncommon on Lake Superior, making up only one percent of the shoreline.

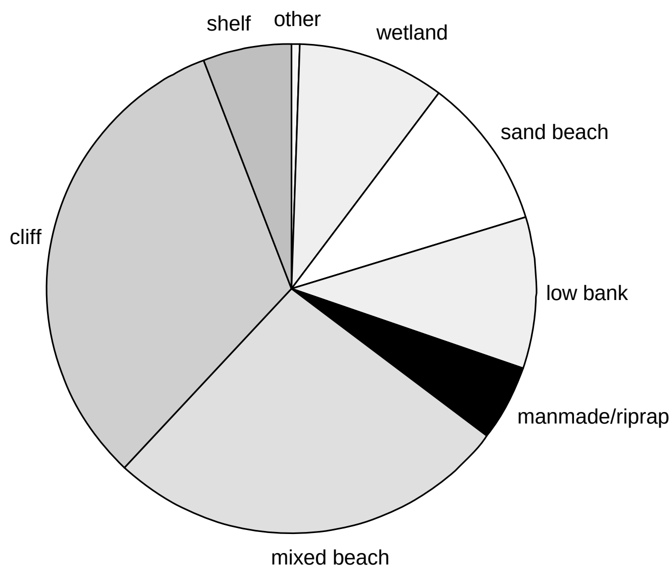


Figure 32. Lake Superior shoreline types (compiled from U.S. EPA 1994 and Environment Canada).

Table 6. Physical features of Lake Superior shoreline (compiled from U.S. EPA 1994 and Environment Canada 1993).

Shoreline Type	U.S.		Canada		Total	
	km	%	km	%	Km	%
Cliff	607	18	1,533	46	2,140	32
Bedrock Shelf	344	10	36	1	380	6
Bluff	30	1	4	-	35	1
Sand Beach	409	12	256	8	665	10
Mixed Beach	980	30	797	24	1,777	27
Low Bank	175	5	491	15	666	10
Mud Flat	2	-	1	-	3	-
Fringing Wetland	173	5	154	5	327	5
Extensive Wetland	294	9	25	1	319	5
Artificial Structure	112	3	22	1	134	2
Riprap	157	5	40	1	197	3
Total	**3,283**		**3,359**		**6,643**	

Sand Beach

Sand beaches are formed where waves and wind and littoral drift deposit sand particles. Most sand beaches are on the eastern and southern shores of the lake, particularly in sheltered bays where wave action is lessened. Beaches are important areas for migrating shorebirds that feed on a variety of invertebrates. They also provide habitat for a number of rare species dependent on the beach environment. Artificial shoreline structures and the hardening of shorelines can interrupt the process of longshore sediment transport that naturally erodes and replenishes beaches.

Mixed Beaches

Mixed beaches are a combination of sand, gravel, cobbles, and boulders, the proportions of which depend largely on the degree of exposure to wave energy. Cobble and boulder beaches are more common on wave-washed shores and sand/gravel beaches are more common in more sheltered sites. Mixed beaches make up 27 percent of the Lake Superior shoreline. Exposed cobble beaches are largely devoid of vegetation, but in more protected areas they support mosses and lichens. Herbs, graminoids, and woody plants are found above the limit of wave action. The spaces between cobble and other beach materials provide habitat for a variety of terrestrial and aquatic insects. Below the wave wash zones cobble beaches serve as lake trout spawning habitat. Perhaps the most spectacular of this habitat type are the raised cobble beaches resulting from a combination of glacial rebound and receding lake levels. One of the more notable sites for raised cobble beaches is Cobinosh Island near Rossport, Ontario.

Low Banks

Low banks are shorelines with vegetation extending to the waterline. They make up only 10 percent of Lake Superior's shoreline. These are typically found in protected bays where they are sheltered from wind and wave scouring.

Mud Flats

Mud flats are typically found near the mouths of rivers where suspended sediments are deposited upon reaching the waters of Lake Superior. Less than one percent of Lake Superior's shoreline is mud flat.

Wetland Shorelines

Wetland shorelines include fringing wetlands and extensive wetland. Fringing wetlands are marsh communities, characteristically found in shallow water coves protected from wind and waves. They closely border the shore to form a narrow belt of aquatic vegetation. Because urban and cottage sprawl also tend to focus lake front developments in sheltered coves, wetlands tend to be a shoreline habitat particularly susceptible to human impacts. Extensive wetlands are larger (up to one to two km long) and occupy shallow coves with stream outlets. On Lake Superior, marsh communities are the most common type of broad wetland. These two wetland shoreline types make up five percent of the Lake Superior shoreline, with most of the extensive wetlands on the south side of the Lake.

Artificial Structures

This category includes retaining walls, harbour structures, sheet piling, breakwaters, and riprap. This type of shore is usually found in close proximity to urban areas. Riprap is comprised of rock material placed to protect shoreline property. Solid, straight-line artificial structures provide little habitat for terrestrial or aquatic life. In some instances, riprap can enhance fish habitat by providing a suitable spawning substrate, but habitat for plants and animals dependant on soft substrates is lost. Gulls frequently use breakwaters for resting, feeding, and nesting. Collectively, artificial shorelines make up five percent of the Lake Superior shore, mainly in the U.S.

3.2.2 Wetlands

Wetlands often form the link between the terrestrial environment and Lake Superior. They provide habitat for fish and wildlife, protect shoreline areas from erosion, buffer runoff following storm peaks, and contribute to the diversity of habitat types in the basin.

Wetlands can be classified in different ways. One of the most widely accepted classifications recognizes five major categories of wetlands. Bogs are peatlands (i.e., wetlands with more than 40 cm of organic soil) where the surface is isolated from contact with mineral rich ground water. They are acidic and nutrient-poor. Fens are peatlands nourished by groundwater flow and are therefore richer than bogs. Swamps are dominated by trees or tall shrubs and have standing or gently moving waters. They have organic or mineral soil. Marshes are flooded by standing or slowly moving water for all or part of the year and are usually associated with lakes or streams. Shallow open water wetlands are also flooded by water, but are dominated by submergent and floating-leaved plants (NWWG 1988).

Wetlands can also be classified by type of aquatic system (lacustrine, riverine, estuarine, palustrine) and site type (e.g., open embayment, barrier beach lagoon, dune and swale complex, etc.) (Chow-Fraser and Albert 1998).

About 15 percent of the U.S. basin is made up of wetland (excluding marshes and shallow water) (Table 7). An alternative estimate of Minnesota's wetland area using National Wetland Inventory (NWI) data puts the total for the basin at 31 percent of the land base (MPCA 1997). Differences in estimates of total wetland area are due to different techniques and definitions of wetlands. Digital NWI data are unavailable for Wisconsin and Michigan.

Table 7. Wetland area for the U.S. Lake Superior basin (exclusive of open water and deep marsh wetlands) (data from Lake Superior Decision Support Systems).

Wetland Class	Total Area (km^2)	Percent of Basin
Michigan		
Forested	1935	10
Non-Forested	366	2
Subtotal	2301	**11**
Minnesota		
Forested	3067	19
Non-Forested	312	2
Subtotal	3379	**21**
Wisconsin		
Forested	699	9
Non-Forested	82	1
Subtotal	781	**10**
Total U.S.	**6461**	**15**

Minnesota's wetlands are mostly bog, fen, and swamp, typically in palustrine environments. Marshes and shallow open water are mostly found on inland lakes and streams (Wright and others 1992, MPCA 1997) (Figure 33).

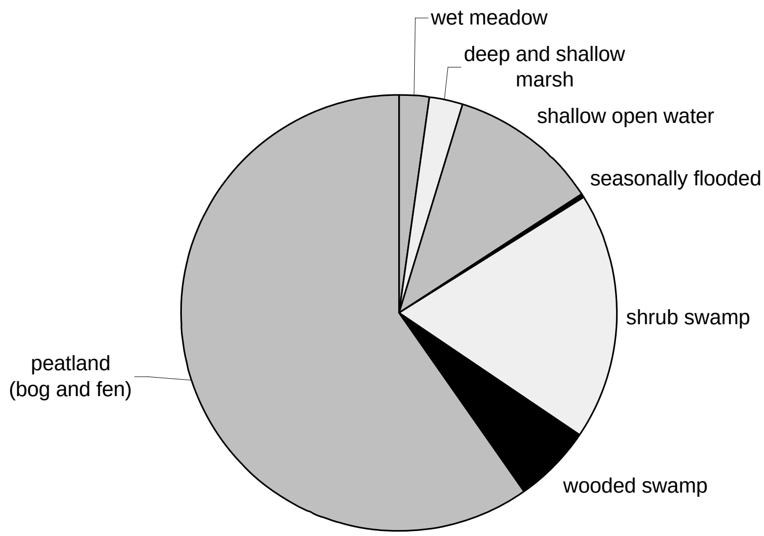


Figure 33. Proportions of wetland types for the Minnesota Lake Superior basin; "bog" includes bog and fen (MPCA 1997).

The most heavily concentrated areas of wetland in the U.S. basin are in western Minnesota and eastern Michigan (Figure 34). The St. Louis River watershed is 41 percent wetland, with extensive peatlands in the central watershed (MPCA 1997). Large peatlands in Luce and Chippewa counties in Michigan are also noteworthy (Crum 1988).

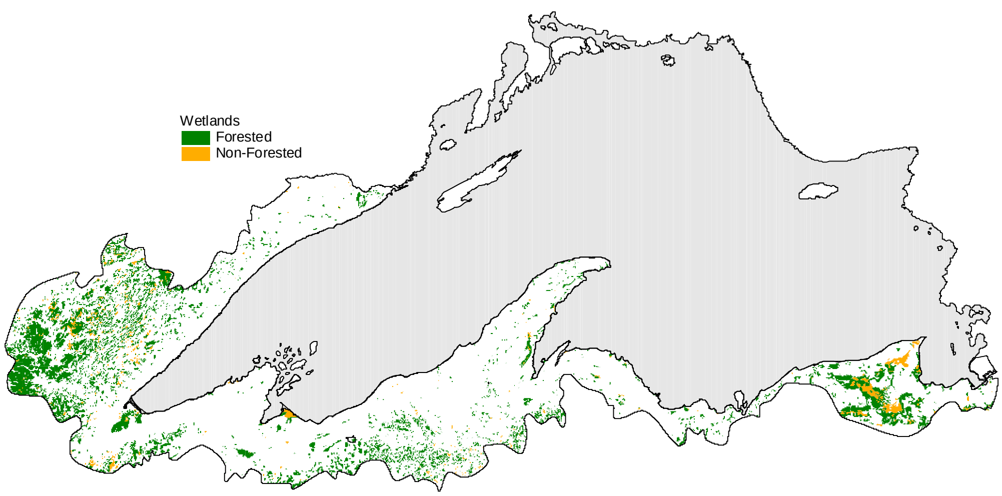


Figure 34. Forested (green) and non-forested (orange) wetlands in the U.S. Lake Superior basin (Lake Superior Decision Support Systems data).

Detailed data are unavailable for Ontario, but the area surrounding the basin is estimated at 6 to 25 percent wetland cover by area (Figure 35) (NWWG 1988). Wetlands in Ontario are concentrated in the eastern and western ends of the basin. The Ontario basin is within the "Low Boreal" and "Humid Mid-Boreal" wetland regions, where the most common wetland types are bogs, fens and coniferous swamps.

Figure 35. Wetlands in the Ontario Lake Superior basin (OMNR data).

3.2.3 Coastal Wetlands

Coastal wetlands make up 10 percent of the Lake Superior shore (Table 7, Figure 36) mostly associated with protected bays, estuaries and barrier beach lagoons (Chow-Fraser and Albert 1998). Lake Superior coastal wetlands consist of small lacustrine marshes dominated by spikerush and hardstem bulrush with richer submergent communities in more sheltered estuaries. Narrow bands of wet meadow with bluejoint grass and sedges and thicket swamp with willows and alder occupy the seasonally-flooded zone. Fens are found above the level of contact with lake water, where organic soil accumulates. Sphagnum moss and ericaceous shrubs are the dominant plants.

In Ontario, coastal wetland development is restricted by high wave energy. Extensive coastal wetlands are confined to Thunder Bay, Black Bay and Nipigon Bay (Figure 36). Fringing wetlands are associated with Black Bay Peninsula and Nipigon Bay. There is very little coastal wetland on the eastern half of the Ontario shore. Ontario's coastal wetlands cover approximately 4,400 ha (Wilcox and Maynard 1996). Because of their scarcity, Ontario's coastal wetlands are very important to fish and wildlife (Maynard and Wilcox 1996). Only about 10 coastal wetlands have been evaluated on Lake Superior, mostly near Thunder Bay and at least 3,500 ha of coastal wetland remains to be evaluated (Wilcox and Maynard 1996).

The U.S. side of the lake has approximately 17,400 ha of coastal wetland (Wilcox and Maynard 1996). Coastal wetland is rare on the Minnesota northshore due to the smooth steep shoreline. The stretch of shoreline from Duluth to Marble Point, Wisconsin has perhaps the most abundant and richest coastal wetlands on Lake Superior. Most are associated with the Lake Superior Clay Plain where estuaries and barrier beaches offer shelter from waves and wind (Epstein and others 1997). Wisconsin's coastal wetlands have been thoroughly inventoried and described (Epstein and others 1997).

Michigan's coastal wetlands are scattered at stream mouths from the Keweenaw Peninsula to Sault Ste. Marie. Extensive dune and swale and barrier beach wetlands are along the sandy shore between Whitefish Bay and Sault Ste. Marie (Chow-Fraser and Albert 1998).

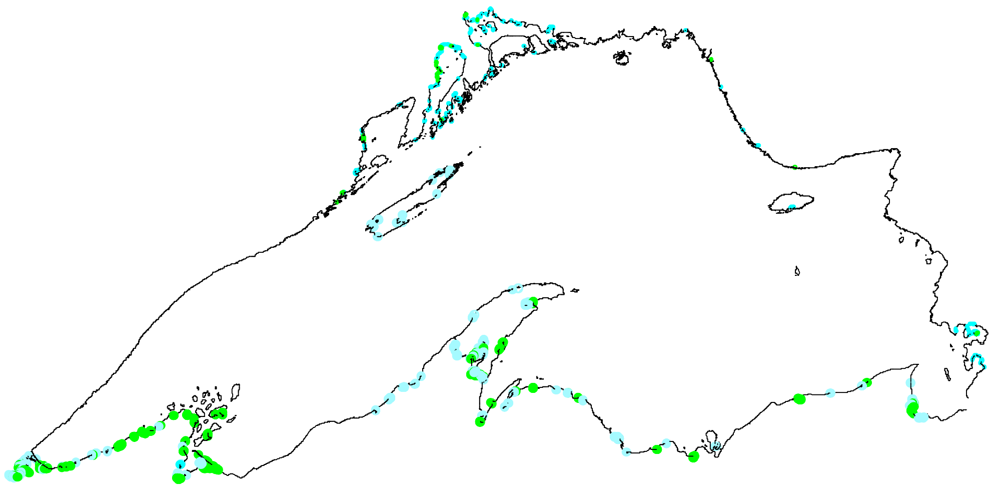


Figure 36. Lake Superior shoreline wetlands: extensive (green) and fringing (blue) (compiled from U.S. EPA 1994 and Environmental Canada 1993).

3.3 The Aquatic Environment

Four habitat categories have been described for Lake Superior by the Lake Superior Committee (Busiahn 1990). They are offshore habitat in waters deeper than 80 m, nearshore habitat in open waters less than 80 m, embayment and estuary habitat protected from the open lake energy, and tributary habitat utilized by migratory fish. Additionally, aquatic habitat is provided by thousands of inland lakes, ponds, and streams within the Lake Superior watershed.

3.3.1 Offshore Habitat

This habitat makes up about 80 percent of the surface area of Lake Superior (Figure 37). Offshore habitat is less productive and diverse than nearshore habitat. The vast majority of this habitat area is dark, due to lack of light penetration to deep water, with a constant temperature of 4^{o} C. The substrate is homogeneous, consisting primarily of silt and particulate detritus. The bottom topography is comprised of peaks, valleys and large troughs.

The fish community is relatively simple, composed of a few pelagic and benthic (bottom dwelling) species. The species include three recognized forms of lake trout (lean, siscowet, and humper), burbot, deepwater ciscoes, lake herring, and deepwater sculpins. In addition, non-native Pacific salmon and sea lamprey now utilize this habitat area. This area contains nearly all of the important and critical habitat for siscowets, humpers, chubs, and deepwater sculpins. See Addendum 8-A for further detail on habitat requirements for lake trout, whitefish, lake herring, and walleye.

Limnological conditions were measured at 19 offshore sample stations in spring and summer 1998. Isothermal conditions were present in spring, while summer samples were collected under stable stratified conditions. In summer stratification, the thermocline, a relatively narrow zone of rapid thermal change that separates warmer epilimnion (upper water layer) from the hypolimnion (cold, deep water) was present at a depth of 23.5 m (Barbiero and Tuchman 2001). Physical and chemical parameters averaged across all sample stations by season show little seasonal difference. Epilimnetic temperature increased from 3^{o} C to 10^{o} C from May to August. In the offshore zone, alkalinity was 41 mg/L, chloride was 1 to 2 mg/L, total soluble phosphorus ranged from >1 to 3 ug/L, pH remained stable around 8, dissolved silica was just over 1 mg/L, conductivity remained stable at 100 umhos, chlorophyll was around 0.5 ug/L, and nitrogen fluctuated from about 290 to 350 ug/L (Barbiero and Tuchman 2001).

3.3.2 Nearshore Habitat

Nearshore open water habitat consists of areas where the water depth is less than 80 m (Busiahn 1990, Lake Superior Technical Committee 1999). Along with embayments, the nearshore habitat makes up about 20 percent of Lake Superior's surface area.

A subset of the nearshore zone is the area where the thermocline intersects with the lakebed in late summer. In other words, this is the zone where the entire water column and the substrate are subject to seasonal warming and cooling. In Lake Superior, this is marked by about the 10 m depth (Edsall and Chalton 1997).

Nearshore waters consist of a narrow band along the north shore, but is generally wider along the south shore (Figure 37). The most extensive areas of nearshore habitat are at the southeast and southwest ends of the lake. Nearshore habitat is also found around Isle Royale and other islands and includes offshore shallow waters, such as the Superior Shoal and the Caribou Island Reef complex.

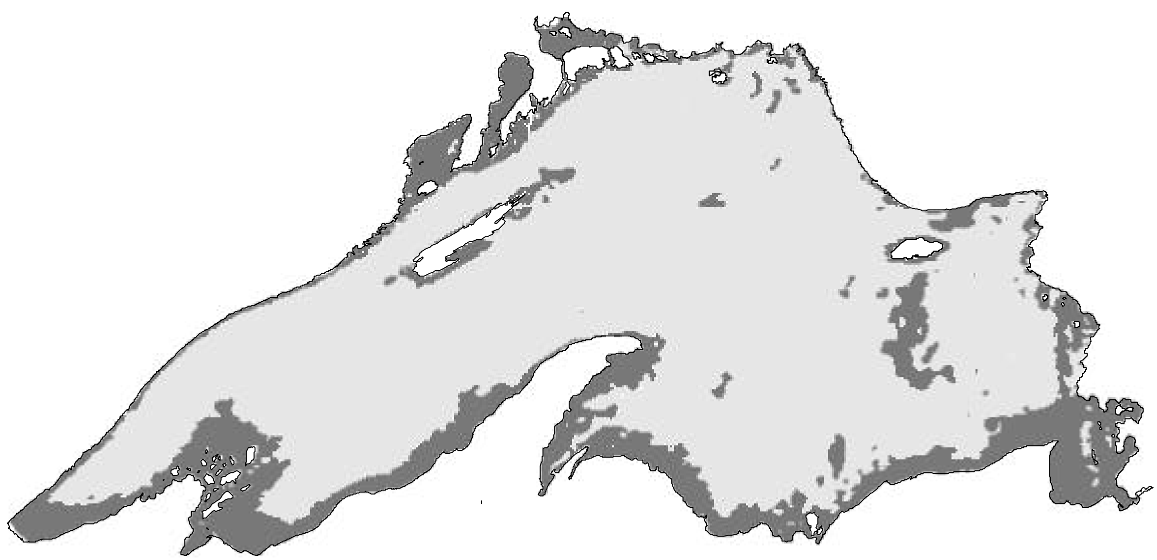


Figure 37. Nearshore (dark) and offshore (light) habitats.

Most of Lake Superior's aquatic plants and animal species use nearshore waters at some stage of their life cycle (Edsall and Charlton 1997). Nearshore habitats have warmer temperatures and greater diversity of substrate types than offshore areas. In exposed stretches, waves and currents clean the substrate of sediment, maintaining suitable spawning and nursery habitat for fish species (Figure 38) and providing ideal habitat for aquatic invertebrates typical of riverine habitats (Barton and Hynes 1976). Aquatic vegetation is found in nearshore habitats.

Most of the important and critical habitat for lean lake trout, lake herring, and lake whitefish is found in the nearshore habitat. The nearshore habitat has a greater assemblage of fish species than the offshore habitat. The native fish community is composed mainly of lake trout (both lean and siscowet), burbot, lake herring, lake whitefish, round whitefish, ninespine sticklebacks, trout-perch, pygmy whitefish, and longnose and white suckers. This habitat may also be important to coaster brook trout, however, populations have declined significantly and they are considered extirpated in most nearshore waters. Primary non-native species include Pacific salmon, rainbow and brown trout, rainbow smelt, and sea lamprey.

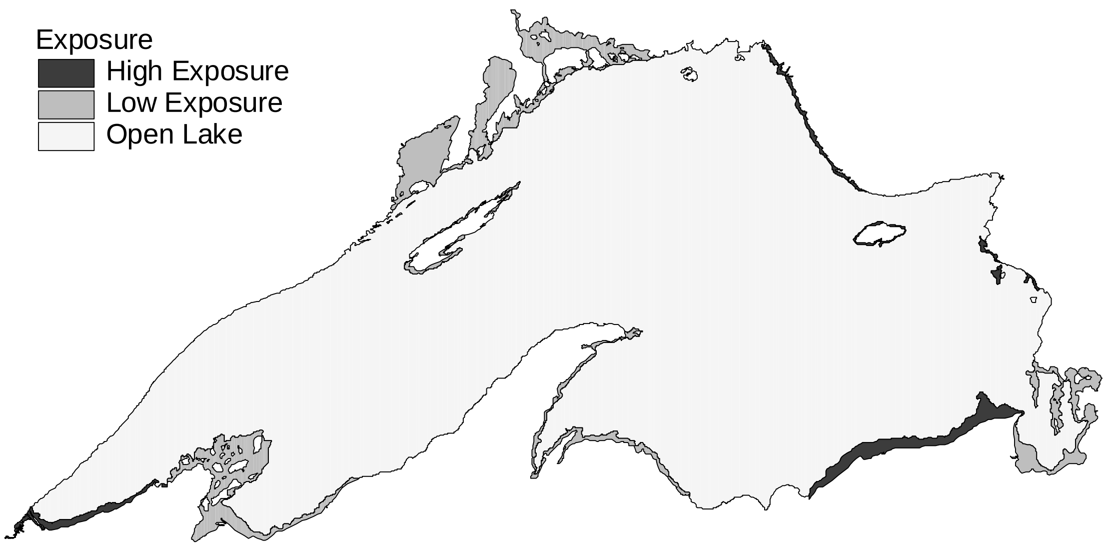


Figure 38. Wave exposure zones (WWF data).

3.3.3 Embayments

Embayments are a subset of the nearshore habitat that are connected to Lake Superior, but exhibit unique physical properties because they are partially protected from the physical dynamics that occur in the open lake. Embayments can be natural or artificial and include coastal wetlands, bays, harbors, and estuaries that are subject to lake seiche.

Major embayments include Black Bay, Nipigon Bay, Thunder Bay, Batchawana Bay, Goulais Bay, Whitefish Bay, Keweenaw Bay, and Chequamegon Bay.

Fish communities living in the embayment habitat are more complex than in the offshore and nearshore habitats because Lake Superior's embayments are warmer, more productive, and more physically diverse than the remainder of the lake. Fish living in the embayments include many of the same fish that live in the nearshore habitat, but also warm and cool water fish species such as walleye, smallmouth bass, yellow perch, rock bass, northern pike, lake sturgeon, johnny darters, longnose dace, bullheads, carp, and numerous species of sculpins, shiners, and minnows.

Table 8 shows nearshore areas and bays that have been identified as Aquatic Biodiversity Investment Areas (Koonce and others 1998). These sites are especially productive, support exceptionally high biodiversity, support rare species or habitats and contribute significantly to the integrity of the whole ecosystem (Koonce and others 1998).

Table 8. Nearshore waters and embayments nominated as Aquatic Biodiversity Investment Areas (adapted from Koonce and others 1998).

Site Name	Features	High biodiversity	High productivity	Critical for economically important species	Rare habitat features	Critical for rare species	Critical for endangered species	High habitat diversit y
Allouez Bay	Embayment	X		X	X			
Batchewana Bay	Embayment	X	X			X		
Big Bay Reef	Nearshore reef, offshore reef		X	X			X	
Black Bay	Embayment	X	X	X				
Caribou Island Reef Complex	Offshore reef	X	X					X
Eagle River Shoals	Offshore reef		X	X	X			
Huron Islands	Offshore reef		X	X				X
Huron River Reef	Nearshore reef		X	X	X			
Isle Royale Nearshore Waters	Nearshore reef, embayment	X				X		X
Manitou Island	Nearshore reef			X	X	X		
Nipigon Bay	Embayment	X		X		X		
Otter Cove	Embayment	X	X		X			
St. Louis River	Embayment		X			X	X	
Thunder Bay	Embayment, nearshore reef	X			X			
Traverse Island Reef	Offshore reef		X	X				X

3.3.4 Tributary Streams

Lake Superior has an estimated 1,525 tributaries (840 in the U.S. and 685 in Canada) (Lawrie and Rahrer 1973). These include permanent as well as intermittent streams. There are over 3,300 km of tributaries available to Lake Superior fish. In addition, there are thousands of tributaries that flow into inland lakes or other streams rather than directly into Lake Superior) (Figure 39). Collectively, these streams add up to over 30,000 km of habitat (Figure 40). The largest tributaries are the Nipigon, St. Louis, Kaministiquia, and Pic rivers (Figure 41, Table 10). The length of accessible tributary stream habitat is a limiting factor for Lake Superior's migratory fish populations. Accessible stream length can be limited by natural (e.g., falls) or artificial (e.g., dams, water crossings, excessive water velocities) barriers. Of 118 streams listed in the Brook Trout Rehabiliation Plan for Lake Superior (Newman et. al. 2003), 65 have barriers to fish passage. A discussion of the number and impact of dams is found in the *Status and Trends* section of this report.

On the Canadian side, there is an estimated 1,091 km of stream available to anadromous fishes (Steedman 1992). The U.S. side has an estimated 3,171 km of accessible stream. The method of determining the length probably differs between jurisdictions.

In general terms, many streams are high gradient, cold-water environments supporting brook trout, sculpins, dace and introduced salmonids. Slower-moving, low-gradient streams support cool and warmwater fish communities. Wisconsin has the most exhaustive stream inventory (Turville-Heitz 1999). Most Wisconsin streams that have been classified are coldwater trout streams (Figure 42). Minnesota north shore streams are numerous and short with steep gradients. They are "…deeply entrenched and characterized by swift flows, many rapids and waterfalls, and especially steep gradients in the lower five to eight kilometers before entering Lake Superior…" (MPCA 1997). Streams in the St Louis River watershed have shallower gradients.

Many fish that live in the embayment, nearshore, and offshore habitat types spend part of their life in tributaries. The fish community of tributaries varies greatly based on the water temperature and quantity. Cold water tributaries support brook, lake, brown, and rainbow trout, Pacific salmon juveniles, and mottled sculpin. Cool and warm water tributaries support a large number of species including walleye, yellow perch, northern pike, lake sturgeon, burbot, bullheads, longnose, white and redhorse suckers, darter species, native and sea lamprey, and many species of minnows. Since tributaries provide spawning and nursery habitat, they are the critical habitat for nearly all of the species listed above. Rainbow trout and brook trout are found in more tributaries of Lake Superior than the other major fish species, while lake trout and lake whitefish are found in the fewest number of tributaries. The number of tributaries known to contain important fish species in Lake Superior is described below (Table 9) based on creel surveys, some published literature (Moore and Braem 1965, Goodyear and others 1981), and personal communications with area managers and biologists.

Table 9. Lake Superior tributaries with a record for resident or penadromous fish species.

Fish species	**Minnesota**	**Wisconsin**	**Michigan**	**Ontario**	**Total**
Lake trout	0	0	3	2*	5
Lake sturgeon	2	3	2	8	13
Pink salmon	10	8	65	7	90
Brown trout	2	76	29	3	110
Chinook salmon	6	15	27	14	62
Coho salmon	8	59	56	20	131
Walleye	2	9	29	40	80
Brook trout	52	90	93	61	254
Rainbow trout	65	74	112	52	270

** other tributaries are also used, but confirmed locations are lacking*

Figure 39. Perennial streams in the Lake Superior basin (Lake Superior Decision Support Systems and OMNR data). Note that stream mapping standards differ between jurisdictions.

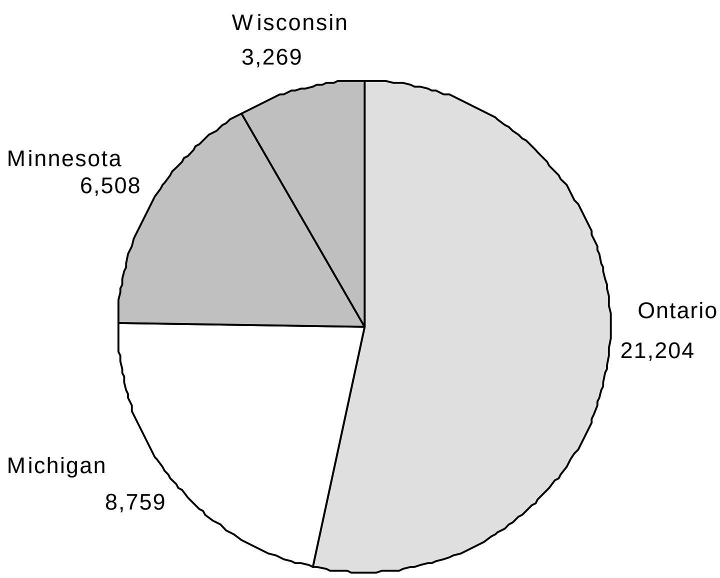


Figure 40. Perennial stream lengths (km) in the Lake Superior basin (derived from OMNR and Lake Superior Decision Support Systems NRRI data). Note stream mapping standards differ between jurisdictions.

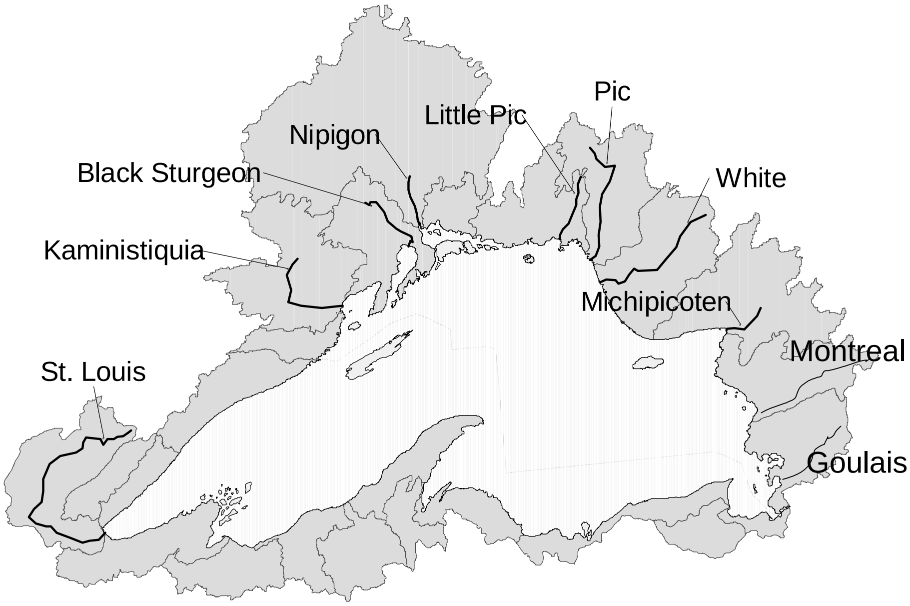


Figure 41. Major watersheds and rivers (Lake Superior Decision Support Systems data).

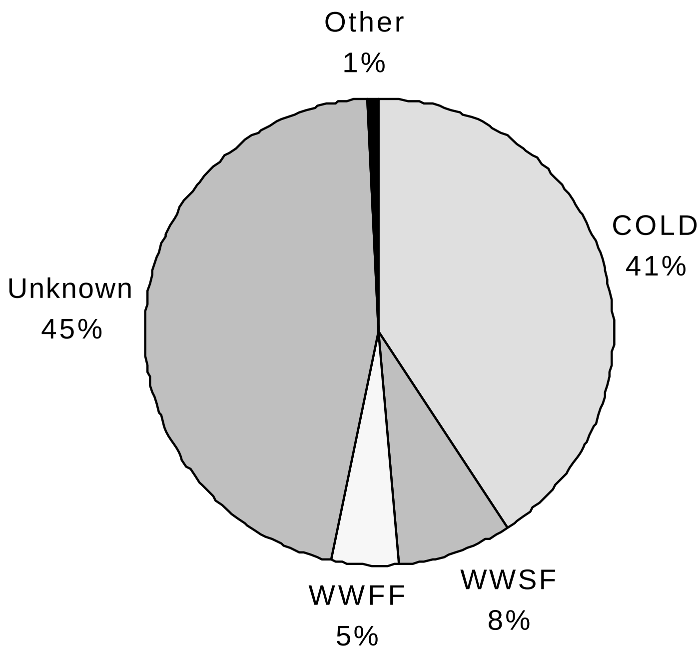


Figure 42. Classification of Wisconsin streams in the Lake Superior basin. Percent values are the proportion of total stream length in the basin. COLD is cold water fishery including trout stream; WWSF is warm water sport fishery; WWFF is warm water forage fishery; “Other” includes limited forage fishery and limited aquatic life (from Turville-Heitz 1999).

Table 10. Some major Lake Superior tributaries (OME 1992, MPCA 1997, OMNR, NRVIS 2003).

River	Mean Annual Flow (m^3/s)	Length (km)
Nipigon	331	50
St. Louis	258*	288
Pic	65	-
Kaministiquia	61	93
Montreal	42	70
Michipicoten	36	128
Goulais	19	153
Little Pic	19	158
Black Sturgeon	19	90

** approximate value determined downstream from confluence of Cloquet River*

The wide diversity of geology and soils around the basin contribute to a diversity of stream habitats. Due to the steep gradient throughout most of the Lake Superior watershed, discharge tends to fluctuate dramatically related to precipitation and surface water runoff. Discharge is typically greatest during spring due to melting snow and rainfall.

In Ontario, the complex geology of the north shore, north and east of Thunder Bay generates isolated but significant amounts of groundwater discharge into some of the big and small watersheds discharging into Lake Superior. These discharges occur in areas with drifts of glacio-fluvial outwashes, gravel/till moraines, and drifts along the base of escarpments. These deposits in conjunction with steep valley gradients drive significant amounts of groundwater into these watersheds, especially in the last several kilometers before the lake.

Throughout most of the rest of the basin, with the notable exception of tributaries in the central section of Wisconsin, surface water is the primary source of flow. These surface-runoff streams typically experience wide fluctuations in physical and chemical parameters. For example, in the Big Garlic River, Marquette County, Michigan, discharge ranged from 0.3 to 3.3 m^3/sec from late spring through winter. Discharge rates are even higher during spring runoff. Temperatures ranged from 0 to 21^o C, conductivity ranged from 40 to 124 micro-mhos, total alkalinity ranged from 14 to 62 ppm, and total hardness ranged from 20 to 66 ppm (Zimmerman 1968).

These fluctuations in stream parameters influence the fish community in a number of ways. Fluctuating discharge and temperature extremes reduce the availability of suitable habitat (e.g., anchor ice) and lead to increased mortality. Stream resident fish and juveniles of migratory fish that require an extended nursery period are adversely affected by the fluctuating conditions. Shrinking habitat forces anadromous juveniles to migrate into Lake Superior at less than optimum size and age. In surface water dominated tributaries, spring spawning migratory fish such as rainbow trout, walleye, and suckers have more reliable access to tributaries than fall spawning fish such as brook and brown trout and the Pacific salmon.

Many Lake Superior tributaries receive some groundwater input, however, groundwater is the predominant source of discharge in tributaries of Wisconsin's Bayfield Peninsula. The high quality, spring-fed streams of this region provide stable flow and constant water temperature, which makes them ideally suited for trout and salmon.

Many of the low gradient tributaries along the south shore of Lake Superior have small coastal estuaries. These estuaries are influenced by both downstream river flow and periodic reverse flow caused by a seiche. Due to their connection to both the riverine and lake environment, these coastal estuaries provide excellent habitat for a wide range of fish and wildlife species.

Western and southeastern Lake Superior tributaries are generally short due to small watershed size (Figure 41). Along the Minnesota shore, stream gradient is steep and flow is heavily dependent upon surface water runoff. These tributaries are harsh environments for salmonine fish in comparison to tributaries around the rest of the lake. Nearly all Minnesota tributaries have natural barriers a short distance upstream from Lake Superior. These barriers limit movement of anadromous fish within tributaries and reduce juvenile salmonine habitat. Minnesota tributaries have very little groundwater intrusion.

Tributaries on the southeastern shore in Michigan are also short, but gradient is generally more gradual. Discharge depends mostly on surface runoff, but numerous streams receive substantial groundwater input. While the north and northeastern shoreline has many small, steep gradient tributaries, most of the large tributaries to Lake Superior are located in Ontario (Table 10). The diverse nature of tributaries along the north shore provides for both cool and coldwater fish communities.

Wisconsin is the only jurisdiction that has a detailed inventory of habitat conditions of streams in the Lake Superior Watershed (Table 11) (Turville-Heitz 1999).

Table 11. Wisconsin Lake Superior tributaries (from Turville-Heitz 1999).

	Watershed	**No. Streams**	**Total Stream Length (mi)**	**Watershed Area (mi^2)**
LS01	St. Louis and Nemadji rivers	78	284	159
LS02	Black and Upper Nemadji rivers	52	180	126
LS03	Amnicon and Middle rivers	107	384	289
LS04	Bois Brule	72	165	195
LS05	Iron River	36	147	218
LS06	Bayfield Peninsula Northwest	56	172	236
LS07	Bayfield Peninsula Southeast	56	142	302
LS08	Fish Creek	35	115	157
LS09	Lower Bad River	18	129	124
LS10	White River	67	271	360
LS11	Potato River	46	160	140
LS12	Marengo River	85	261	218
LS13	Tyler Forks	46	124	79
LS14	Upper Bad River	62	194	135
LS15	Montreal River	80	264	226
LS16	Presque Isle River	53	91	108
	Total	**949**	**3083**	**3072**

3.3.5 Inland Lakes

The Lake Superior basin has almost 7,000 inland lakes (Figure 44), covering over 10,000 km^2. These lakes range in size from less than 1 ha to Lake Nipigon at 448,000 ha (Table 12). Inland lakes are an important link in the hydrological cycle since much of the water that enters Lake Superior flows through lakes. They contribute to the diversity of aquatic habitats in the basin.

Inland lakes exhibit a wide range of habitat conditions and contain a variety of fish communities. Habitats in these lakes vary from small, shallow winter-kill lakes to deep, cold-water lakes, and as a result of the morphometry of the lakes, fish assemblages vary from warm- to cold-water fish communities.

The morphology and water chemistry of the inland lakes are dictated by the geology of the Lake Superior basin that includes granite, sandstone, and sandy-loam shoals. Most lakes are found on the shallow soils of the Precambrian Shield in Ontario and northern Minnesota (Figure 43). Another concentration of lakes is in the Presque Ile River watershed in Vilas County, Wisconsin and Gogebic County, Michigan.

Inland lakes in Ontario and Minnesota tend to be cool, clear, and low in dissolved solids and nutrients (MPCA 1997). South of Lake Superior, inland lakes tend to be warmer and richer. The number of oligotrophic (nutrient-poor) lakes ranges from 15 to 54 percent in Michigan, Minnesota, and Ontario (Figure 45).

Secchi depth is a measure of lake transparency, reflecting the amount of suspended material and algae in the water. Secchi measurements are available for over 700 lakes in the basin. Over half the lakes in Ontario and Minnesota are in the one to three meter Secchi depth range (Figure 46). Unpolluted lakes show a range of transparencies due to naturally-occurring differences in nutrient availability and turbidity. However, changes in Secchi transparency can indicate a change in the trophic state of a lake due to pollution.

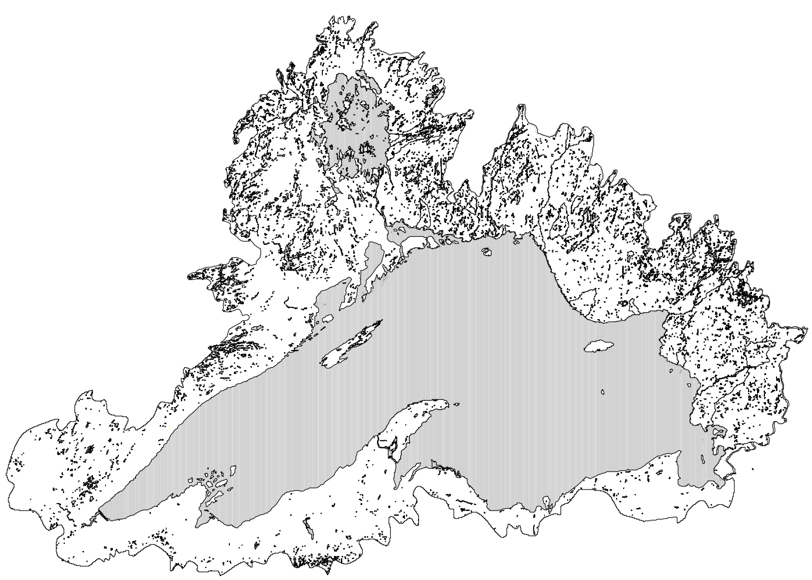


Figure 43. Inland lakes of the Lake Superior basin (Lake Superior Decision Support Systems and OMNR data).

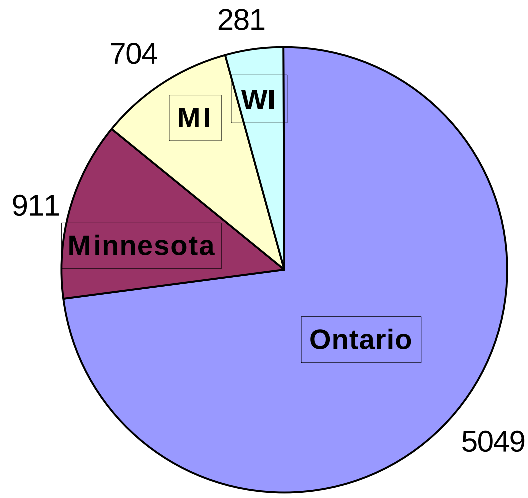


Figure 44. Inland lakes and reservoirs in the Lake Superior basin (derived from OMNR and NRRI data).

Fish communities in Ontario and Minnesota are dominated by cool and coldwater species (Figure 47). Oligotrophic lakes often support lake trout, lake herring and lake whitefish, but are relatively species poor. About 100 lakes in the Minnesota North Shore support lake trout (Waters 1987). Some lakes in the southern part of the basin provide warmer and more nutrient-rich habitat than Lake Superior. Warmwater species, such as sunfishes and catfishes, dominate the fish community of these lakes.

Table 12. Major Inland Lakes (>20 km^2) in the Lake Superior Basin.

Lake Name	Area (km^2)	Max. Depth (m)	Mean Depth (m)	Littoral Area (%)	Trophic Status*	Secchi Depth (m)
Lake Nipigon, ON	4,481	137	55		Oligotrophic	6.5
Dog Lake (Thunder Bay), ON	148	117	30	29	Oligotrophic	2.5
Onaman Lake, ON	108	19	2	97	Eutrophic	1
White Otter Lake, ON	83	56	22	91	Oligotrophic	4.8
White Lake, ON	59	49	9	54	Eutrophic	2.7
Shebandowan Lake, ON	59	38	8		Oligotrophic	2.9
Lake Gogebic, MI	52	-	-	-	-	-
Dog Lake, (Wawa) ON	52	75	13	-	Oligotrophic	4.4
Black Sturgeon Lake, ON	48	49	12	23	Oligotrophic	2.5
Esnagi Lake, ON	46	22	5	47	Eutrophic	3.7
Windermere Lake, ON	38	30	8		Oligotrophic	4.8
Wabatongushi Lake, ON	38	53	7	59	Eutrophic	2.9
Obonga Lake, ON	36	72	17		Oligotrophic	3
Muskeg Lake, ON	35	12	5	66	Eutrophic	2
Island Reservoir, MN	34	22	-	-	Eutrophic	2
Arrow Lake, ON	33	55	18	23	Oligotrophic	4.7
Manitowik Lake, ON	31	119	38	19	Oligotrophic	3.7
McKay Lake, ON	31	49	9	62	Eutrophic	4
Greenwater Lake, ON	31	55	18	14	Oligotrophic	4
Whitefish Lake (Th. Bay), ON	30	6	2	100	Eutrophic	3
Forgan Lake, ON	30	44	13	35	Mesotrophic	4

Lake Name	Area (km^2)	Max. Depth (m)	Mean Depth (m)	Littoral Area (%)	Trophic Status*	Secchi Depth (m)
Cedar Lake, ON	29	15	6	100	Eutrophic	2.1
Cliff Lake, ON	27	34	9	50	Eutrophic	4.3
Kagiano Lake, ON	24	-	-	-	-	2
Barbara Lake, ON	24	56	10		Oligotrophic	3
Kashabowie Lake, ON	23	35	7	58	Oligotrophic	2.6
Whiteface Reservoir, MN	23	10	-	-	Eutrophic	1.2
Holinshead Lake, ON	23	17	5	-	Oligotrophic	2
Wildgoose Lake, ON	17	16	4	-	Eutrophic	4
Roslyn Lake, ON	17	45	10	-	Oligotrophic	4
Loch Lomond, ON	17	71	21	-	Oligotrophic	4
Brule Lake, MN	17	18	-	34	Oligotrophic	4.9
Helen Lake, ON	16	61	13	-	Mesotrophic	3

**Trophic status for Ontario lakes is based on morphoedaphic Index (MEI). MEI values between 6 and 7 are mesotrophic, higher are eutrophic, lower are oligotrophic (Leach and Herron 1996). Trophic status for U.S. lakes are determined using the Carlson method.*

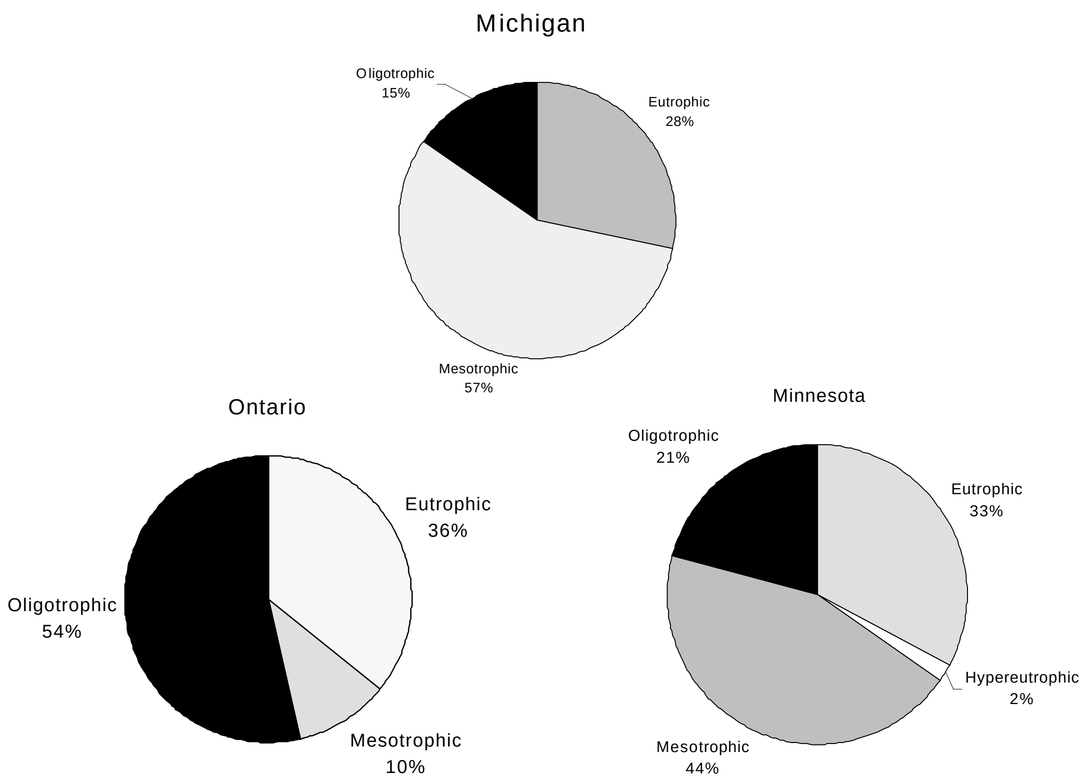


Figure 45. Trophic status of inland lakes in the Lake Superior basin. (a) Ontario (n= 516), (b) Michigan (n = 78), (c) Minnesota (n = 208). (Data from Ontario Ministry of Natural Resources, Michigan Dept. of Environmental Quality, and Minnesota Pollution Control Agency data.)

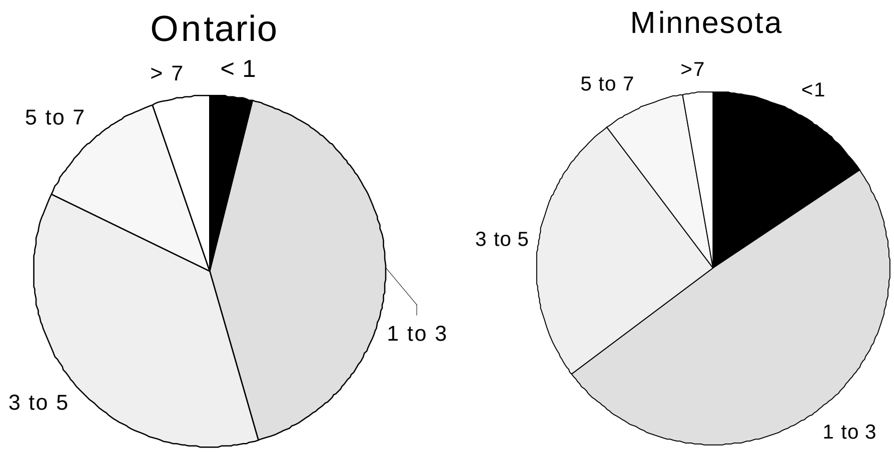


Figure 46. Secchi depth (m) for 1,128 Ontario and 147 Minnesota lakes within the basin (Ontario Ministry of Natural Resources and MPCA Data).

Ontario

Ontario's portion of the Lake Superior watershed contains numerous inland lakes supporting lake trout, brook trout, walleye, and northern pike fisheries (Figure 47). The majority of the lakes are undeveloped and the shorelines are managed as public lands. Lake Nipigon is the largest inland lake in Ontario's portion of the Lake Superior watershed; with a surface area of 448,060 ha it is approximately one quarter the size of Lake Ontario. Lake Nipigon supports trophy sports fisheries for brook trout and lake trout as well as commercial fisheries for whitefish, lake trout, walleye, and more recently rainbow smelt.

Ontario lake survey data are available from 1,251 lakes within the basin, but there are thousands of unsurveyed lakes. Surveyed lakes tend to be large, accessible, and support sport fishes. Many of the lake survey data are over 20 years old.

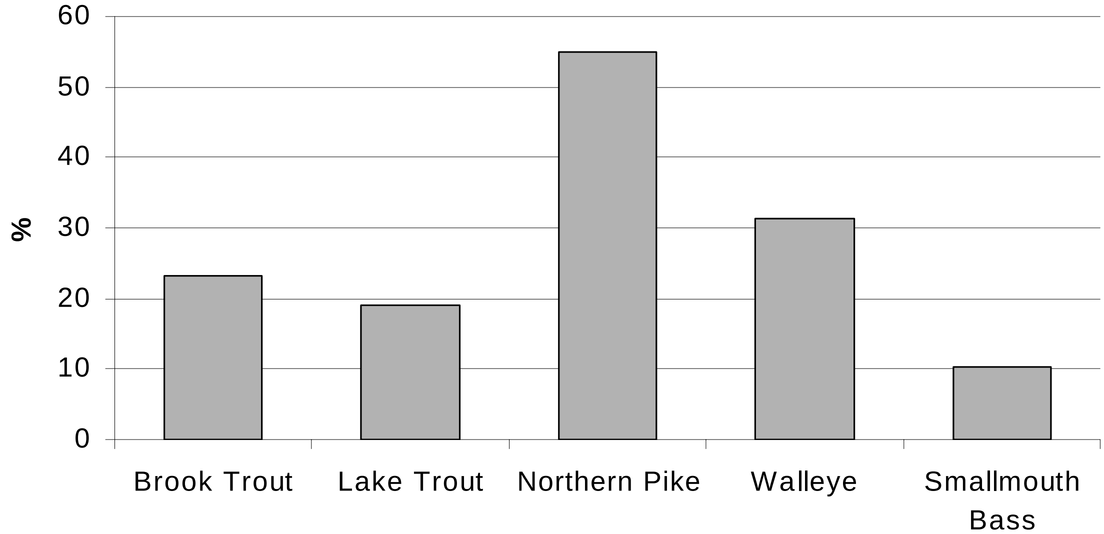


Figure 47. Major sport fish species in 612 Ontario lakes in the Lake Superior basin (Ontario Ministry of Natural Resources data).

Wisconsin

The soft water seepage lakes are most commonly found in the Wisconsin portion of the Lake Superior basin. These lakes are typically clear, slightly acid, and relatively infertile. The principal fishery resources pursued by anglers in the Wisconsin basin include muskellunge, northern pike, walleye, largemouth and smallmouth bass, and panfish.

Most lakes in the Wisconsin basin have basic, descriptive data. Five Wisconsin lakes in the basin were identified as priority sites from a biodiversity perspective (Epstein and others 1997). These are Anodanta Lake, Bad River Slough, Hoodoo Lake, Rush Lake, and Smith Lake. Most of these lakes have rich invertebrate communities or support rare invertebrate species.

Michigan

The MI DNR, U.S. Forest Service, U.S. Fish and Wildlife Service, Bay Mills Indian Community, and Keweenaw Bay Indian Community have assessed many of the 200 to 300 lakes in the Lake Superior drainage of Michigan. Most of these lakes support a cold or cool water fishery. The cold-water lakes have brook trout or rainbow trout as the dominant predator, while the cool-water lakes have walleye, northern pike, or perch as the dominant predator. A few lakes are characterized as warm-water and have a largemouth bass/bluegill fish community. A compliment of various prey species also exists in these lakes, dominated by minnows (cyprinids) and suckers (catostomids).

In general, Michigan inland lakes within the Lake Superior basin receive minimal fishing pressure because of the sparse human population in their region, and their remote locations. A few lakes are storage reservoirs used for hydroelectric power; associated lake level fluctuations negatively impact those fisheries. These lakes include: Gogebic, Prickett, Bond Falls, Victoria, McClure, and Autrain. The storage reservoir known as Silver Lake, located in Marquette County, was lost as a result of dam failure in spring 2003.

Minnesota

Minnesota's portion of the Lake Superior watershed contains over 900 inland lakes. These areas are extremely important for both recreation and tourism. Much of the aquatic resource in Minnesota is in very good condition. High quality pristine areas in the watershed include portions of the Boundary Waters Canoe Area, natural heritage lake trout lakes that are supported only by wild populations, state parks, and state and federal forests.

There are five major hydroelectric dams on the St. Louis River system creating two of the largest impoundments in the basin: Island Reservoir and Whiteface Reservoir (MPCA 1997). These are headwater reservoirs that store water during the spring run off and release it to augment low flows at other times of the year. Other impoundments (Two Rivers Reservoir and Whitewater Reservoir) are used for mine processing water and recreation.

3.3.6 Nutrients and Oxygen

Lake Superior is an "ultra-oligotrophic" lake on the basis of its very low nutrient availability and cold temperature. Water chemistry is determined by the geology and climate of its drainage basin, anthropogenic inputs, bottom topography, circulation patterns, thermal regime, and biological processes. Most of its watershed is on the nutrient-poor Precambrian shield. Compared to the other Great Lakes, Lake Superior is characterized by high concentrations of total nitrogen and reactive silicate but very low concentrations of total phosphorous, which limits productivity (IJC 1976). Nutrient levels are quite uniform horizontally and vertically in the open lake, with the exception of areas with restricted circulation, notably near Duluth, Thunder Bay, and in Whitefish Bay. Nearshore areas, near Duluth in particular, exhibit generally elevated levels of total phosphorus and silica that are linked to artificial and riverine inputs (Weiler 1978). Locally elevated nutrient concentrations have also been identified in Thunder Bay, the Carp River mouth, and Munising. Nitrate and silica have well-defined seasonal cycles correlated with biological uptake and release. They usually reach a minimum during August and September when phytoplankton biomass peaks. Current nitrate concentrations in Lake Superior are higher than historical levels, and are increasing at approximately 3 µg/L per year (Dobson 1972).

Lake Superior is saturated with dissolved oxygen most of the year. During the spring, convective mixing to nearly 300 m depth brings nearly all of the lake water in contact with the atmosphere (Bennet 1978). Some oxygen depletion can occur locally, but dissolved oxygen levels generally remain over 80 percent (Matheson and Munawar 1978). A small loss of oxygen from the hypolimnion is caused by the oxidation of organic matter that has settled through the thermocline. However, the great depth, large volume of the hypolimnion, low productivity, and persistence of vertical mixing through June means that oxygen depletion is generally not limiting for deep water species.

3.3.7 Primary Production – Chlorophyll *a*

Chlorophyll *a* concentrations are a measure of phytoplankton biomass and reflect the levels of nutrients, particularly total nitrogen and phosphorous. In offshore areas, chlorophyll *a* levels seldom exceed 1 µg/L, except in the western end of the lake near Duluth. Higher chlorophyll *a* concentrations are found in nearshore areas, averaging 0.6 to 2.5 μg/L, with Duluth-Superior Harbour showing the highest levels (3.6 μg/L). If greater quantities of phosphorous become available, there is the potential for a significant increase in productivity due to the overabundance of nitrate and reactive silicate in offshore waters (IJC 1976).

Primary production by phytoplankton is strongly related to the depth of the euphotic zone (depth which photosynthetically active radiation penetrates the water surface) (Fee 1971). The euphotic zone averages 20 to 30 m depth in offshore areas, and less than 20 m where water is more turbid in coastal areas near Duluth, Thunder Bay, Nipigon Bay, Black Bay, Marathon, Whitefish Bay, Apostle Is., and the southwest red clay portions of the lake. Near Duluth, the euphotic depth may be only two meters deep. Lake Superior has similar water transparency to Lake Huron, but higher transparency than the other Great Lakes (Schertzer and others 1978).

The deep chlorophyll maximum (DCM), a common feature in summer in the offshore waters of Lake Superior, was observed in the upper hypolimnion between 23 and 35m. Chlorophyll *a* concentrations in the DCM were 1.5 to 2.5 times epilimnetic concentrations and were associated with minimal or no increases in particulate organic carbon concentration. Carbon to phosphorus ratios were consistently lower in the DCM, indicating increased phosphorus content in the phytoplankton. Community structure in the phytoplankton of the DCM was distinguishable from that of the epilimnion, with the most notable difference being a relative reduction in the abundance of Cyclotella species in the DCM (Barbiero and Tuchman 2004).

Lakewide chlorophyll *a* concentration decreases in mid-October due to the decline in solar radiation and decreased water temperatures associated with deep vertical mixing. Seasonally, surface water chlorophyll dynamics were characterized by an increase from late-winter concentrations in late April and early May, a continued increase in the nearshore and a decrease/stabilization at offshore sites from late May through July, a summer minimum in late July and August, and an increase in September and October with the approach to turnover (Auer and Bub 2004).

3.3.8 Phytoplankton

The Lake Superior phytoplankton community represents a unique assemblage of approximately 300 species. Over 160 taxa have been been found in the offshore habitat (>80 m) (Barbiero and Tuchman 2001). Nannoplankton (<60 μm) dominate the phytoplankton biomass and primary production, but most surveys have focused on diatoms and other larger plankton (>60μm) (Munawar et al. 1978). Phytoflagellates (cryptomonads, chrysomonads, dinoflagellates) comprise approximately 35 percent of the species, followed by diatoms (31 percent) and Chlorophyta (22 percent).

Lake Superior is divided into six phytoplankton regions based on taxonomic and biophysical data (Munawar and Munawar 1978) (Figure 48). With the exception of the Duluth region, species composition is broadly similar among regions. Common phytoflagellate species typical of oligotrophic lakes (e.g., *Cyclotella* spp. and *Fragilaria crotonensis*) characterize the open lake. There are also a large number of rare species, some of which are indicative of cold, oligotrophic conditions (e.g., *Stelexmonas dichotoma* and *Chrysolykos planctonicus*). The phytoplankton community in the Duluth region has fewer species and is dominated by diatoms, in particular *Melosira ranulata*, which is associated with eutrophication.

In 1998, two non-indigenous phytoplankton species were collected. This is believed to be the first documentation of the centric diatoms, *Thalassiosira baltica* and an organism identified as *Stephanocostis*, in Lake Superior (Barbiero and Tuchman 2001).

Most of the lake has very low (0.1 to 0.2 g/m^3) phytoplankton biomass. Biomass is homogeneously distributed with little inshore/offshore differentiation with the exception of Western Lake Superior, which has relatively high biomass concentrations (Munawar and Munawar 1978). Nannoplankton comprise approximately 65 percent of the total phytoplankton, and smaller organisms (<10 µm) account for 32 percent of the biomass. Diatoms and phytoflagellates, especially cryptomonads and chrysomonads, dominate the lakewide phytoplankton biomass. Dinoflagellates, green and blue-green algae contribute little to the total biomass. The Duluth, Thunder Bay, and Whitefish Bay regions are unique environments and show relatively high biomass concentrations during the summer (July to September).

No clear seasonal trends in biomass are apparent for most of the lake, although biomass is lowest when Lake Superior is unstratified (May to June, November to December) and highest from July to September when it is stratified. The overall cold temperature regime of Lake Superior is not conducive to rapid and sudden changes in the phytoplankton community (Munawar and Munawar 1978). Uniform vertical distribution of biomass appears to be typical of offshore conditions in most of the lake although at some offshore stations, phytoflagellate biomass is highest below the thermocline. In temperature-stratified nearshore conditions, there are peaks of diatom and phytoflagellate biomass near 10 m depth. In general, the size and composition of the phytoplankton community has apparently changed little in the past fifty years (Barbiero and Tuchman, in press).

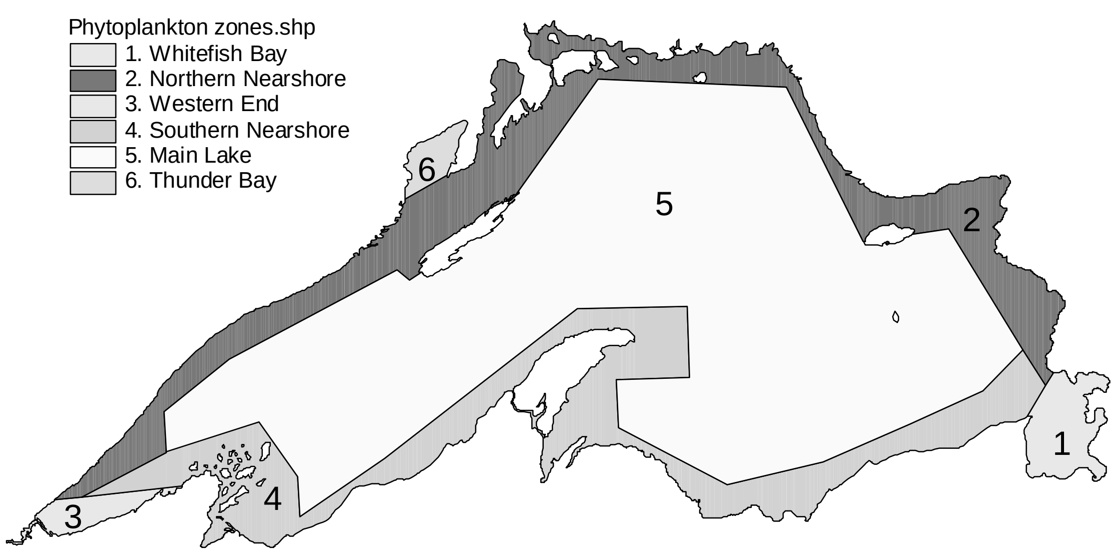


Figure 48. Phytoplankton zones of Lake Superior based on taxonomic data. (1) Whitefish Bay, (2) Northern Nearshore, (3) Western End, (4) Southern Nearshore, (5) Main Lake, (6) Thunder Bay (Munawar and Munawar 1978).

3.3.9 Zooplankton

Zooplankton distribution and abundance (Table 13) is strongly associated with surface water temperature, and highest concentrations are found inshore, especially in the major embayments. The offshore open water community has low species richness, dominated by large, calanoid copepods found at substantial depths. The summer cladoceran population is small. Overall, abundance is generally low in comparison with the lower Great Lakes, and little variation in abundance is evident throughout the ice-free season.

The lakewide zooplankton community is relatively homogenous in the spring and summer, and offshore as well. During the early summer local clusters appear in many inshore areas, and by early fall the zooplankton community varies in different parts of the lake. Seasonal concentrations peak at 45,000 individuals/m^3 in some inshore areas (Whitefish Bay) compared to only about 3000 to 3,500 individuals/m^3 in the open lake (Watson and Wilson 1978, Barbiero et al. 2001). Abundance has remained stable in offshore waters for the past 30 years.

The zooplankton community of the open lake is generally dominated by herbivorous filter feeders such as calanoid copepods and cladocera, although low numbers of raptorial cyclopoid copepods that feed on other zooplankton are also present. The zooplankton community of the open lake, and the lakewide average, is dominated by large calanoid copepods such as *Diaptomus sicilis, Limnocalanus macrurus,* and *Senecella calanoides.* The dominant species appear to be present year-round, with a single reproductive pulse during the fall or early winter. Upwellings along the northern shore push warmer inshore water and its entrained zooplankton offshore.

The exotic, spiny water flea, *Bythothrephes longimanus* (formerly *B. cederstroemi*), a predatory cladoceran, was found in modest numbers at most stations across the lake, but accounted for only 0.5 percent of total biomass (Barbiero et al. 2001).

Major embayments and inshore areas along the southern and eastern shore have communities dominated by cladocera and smaller diaptomids. These communities tend to have a bimodal seasonal pattern, with a spring-summer peak dominated by calanoid nauplii and copepodites, and a fall peak of calanoid adults, cladocerans, and cyclopoids. Inshore species gradually extend into the offshore waters during the late summer and early fall and mix with the offshore assemblages. Homogenous lakewide conditions return quickly with the turnover in late fall (Watson and Wilson 1978).

In three ecoregions of western Lake Superior (Duluth-Superior, Apostle Islands, and the open lake), copepods were far more abundant than cladocerans in all ecoregions. Mean zooplankton size was larger in the open lake due to dominance by large calanoid copepods. Zooplankton abundance was three times higher in the Duluth-Superior and Apostle Islands regions than in the open lake due to the large numbers of rotifers. Forage fish abundance and biomass were highest in the Apostle Islands and lowest in the open lake with lake herring, rainbow smelt and deepwater ciscoes comprising over 90 percent of the abundance and biomass. Growth and condition of fish was good, suggesting they were not resource limited. Fish and zooplankton assemblages differed among the three ecoregions of western Lake Superior, due to a combination of physical and limnological factors related to bathymetry and landscape position (Johnson et al. 2004).

Zooplankton biomass distribution patterns in Lake Superior are strongly influenced by the differential heating of surface water, which is in turn influenced by lake morphometry, and upwellings and currents. During the spring and early summer, biomass values are similar across the lake at approximately 4 mg/m^3. Inshore biomass peaks at approximately 60 mg/m^3 in August and September as cladoceran populations develop. Offshore and lakewide biomass is primarily related to the growth and maturity of large calanoid copepods and peaks approximately one month later at 30 mg/m^3. Total biomass nearly doubles from spring to fall in offshore waters (Barbiero et al. 2001), and, overall, biomass increases five-fold between May and September (Watson and Wilson 1978).

Table 13. Dominant zooplanton species in Lake Superior (Watson and Wilson 1978).

Taxa	Numbers (%)	Biomass (%)
Calanoid copepods		
Diaptomus sicilis adults	11	20
Diaptomus ashlandi adults	3	3
Diaptomus spp. copepodites	18	17
Diaptomus spp. nauplii	44	7
Limnocalanus macrurus	5	32
Senecella calanoides	1	5
Calanoid Total	**83**	**84**
Cyclopoid copepods		
Cyclops bicuspidatus thomasi adults	1	1
Cyclops spp. copepodites	7	2
Cyclops spp. nauplii	5	1
Cyclopoid Total	**13**	**3**
Cladocerans		
Bosmina longirostris	1	<1
Daphnia galeata mendotae	3	8
Holopedium gibberum	<1	<1
Cladoceran Total	**3**	**8**
Total	**99**	**95**

3.3.10 Benthic Communities

The benthic community of Lake Superior is dominated by the amphipod *Diporeia hoyi* (formerly known as *Pontoporeia affinis),* followed by the oligochaetes, especially the Enchytraeidae and the lumbriculid worm *Styoldrilus heringianus* (Cook 1975). Molluscs (primarily the sphaeriid pea clam *Pisidium conventus)* and insects (primarily the chironomid *Heterotrissocladius oliveri)* account for less than 10 percent of the total biomass.

The relatively simple benthic community of Lake Superior reflects the low diversity of habitat rather than impaired water quality. Sediment size, depth and therefore temperature are the major factors controlling the distribution of individual species. Sphaeriids and chironomids are associated with shallow water, on sandy and finer substrates respectively. *Diporeia* is most abundant in relatively shallow water (40 to 80 m) compared to the mean depth of Lake Superior (160 m) (Freitag and others 1976; Dermott 1978). Tubificid worms (*Rhyacodrilus)* are associated with relatively shallow water depths and are replaced by *Phallodrilus* in deeper oligotrophic sites having sediments with lower organic matter. *Stylodrilus* and Sphaeriidae were negatively associated with the sediment zinc levels.

In a study along three transects off the Keweenaw Peninsula that each had shelf, slope, and profundal habitat, *Diporeia* (48 percent) was the most abundant invertebrate, with chironomids, oligochaetes and sphaerids representing 21, 19, and 8 percent of the community, respectively. All major groups were most densely distributed in the slope region, with chironomids and oligochaetes exhibiting more fine-scale density differences over the slope. Peaks in the abundance of invertebrate organisms in the slope region of Lake Superior suggest that this area may provide critical habitat, offering an important region for resource acquisition by these and other members of the Lake Superior food web (Auer and Kahn 2004).

A probability-based survey of 27 sites was conducted in 1994 and 2000 to ascertain the status of *Diporeia* in Lake Superior. In 1994, *Diporeia* abundance in the nearshore ranged from 550 to 5,500 /m^2 and the Great Lakes Water Quality Agreement objective of 220 to 320 /m^2 was met for the entire nearshore. In 2000, abundance ranged from 10 to 2,800 /m^2 and the objective was not met in 11 percent of the nearshore area. There was no significant trend in *Diproeia* abundance among years and populations observed at present are higher by a factor of seven than those reported in the 1970s (Scharold et al. 2004).

In deep water communities and much of western Lake Superior, mollusc and insect populations are extremely sparse, and in mid-lake locations with extremely low productivity, only the stenotherms *Diporeia* and *Stylodrilus* are present. The benthic community is richest in terms of abundance and diversity in the area south and east of Michipocoten Island, especially Whitefish Bay (Figure 49), due to shallower mean depth (63 m) and higher algal populations. In contrast to the lakewide mean, oligochaetes were dominant and Sphaeriidae comprise 12 percent of the biomass. Thunder Bay also has a relatively diverse benthic community where Sphaeriidae and Chironomini are more abundant than in the main lake. Benthic abundance and diversity was lowest in the Duluth area and often restricted to *Diporeia,* despite abundant phytoplankton populations (Munawar and Munawar 1978, Rao 1978).

Figure 49. Benthic biomass diversity. Numbers represent Shannon's diversity index. Higher numbers indicate greater species diversity (Dermott 1978).

3.3.11 Fish Communities

The native fish community of Lake Superior is dominated by lake trout and corregonines (whitefish, lake herring and deepwater ciscoes), as is typical of post-glacial oligotrophic lakes in North America. Approximately 80 fish species belonging to 19 families occur in Lake Superior and its tributaries. Of these, twenty are non-native species that have been deliberately (e.g., chinook salmon, rainbow trout) or accidentally introduced (e.g., ruffe, sea lamprey) since the late 1800s. Commercial and sport fishing pressure, introductions of non-native species, and changes in the physical environment (e.g., logging, dams, mine tailings) have resulted in a fish community somewhat different and less stable than it was in the mid 1800s (Hansen 1994, Paloheimo and Regier 1982). See Addendum 6-F for further detail on the presence of fish species observed during 1953-1996 and Addendum 6-G for fish species names.

Commercial fishing for lake whitefish and lake trout began in the mid 1800s in Lake Superior to provide food for fur trading posts and other settlements (Waters 1987). By the late 1800s, increased human population and improved transportation resulted in intensified fishing effort, and improved boats and gear resulted in a more efficient harvest. Typically, the most accessible stock was fished heavily until the population declined, and then effort switched to another stock or species (Lawrie and Rahrer 1972, Regier and Loftus 1972). Records of depleted stocks date back as early as the 1870s and there was a general pattern of decline for many commercial species between the mid 1940s and early 1970s (Lawrie and Rahrer 1972). Declining populations of lake trout, burbot, whitefish and other species were further decimated during the 1940s and 1950s by sea lamprey (Hansen 1994), which were first recorded from Lake Superior in 1938. During the time of highest sea lamprey abundance, up to 85 percent of fish in commercial catches exhibited sea lamprey wounds (Scott and Crossman 1973). Commercial fish yields from 1979 to 1983 in Lake Superior were significantly lower than historical yields (Table 14) mainly due to the collapse of the lake herring and lake trout, species that have not yet fully recovered lakewide, although lake trout are approaching historical levels in most areas of the lake with the exception of Whitefish Bay. Angling has had less impact on fish populations, but contributed to the decline of some populations of lake trout and brook trout, especially in tributaries, embayments and shallow nearshore waters.

Control of commercial fishing has also contributed to the difference between early and more recent yields. Michigan closed lake trout fishing in 1962 and lake herring fishing in 1974. Although commercial fishing rights have been restored to Native American tribes, there are some Michigan waters of Lake Superior that have been closed even to tribal fishing as described.

Since 1983, lake herring have produced periodic large year classes that have provided pulsed recruitment to the forage base and fishery. However, the boom or bust status of lake herring reproduction is a concern for fishery managers and a project is underway to review the current status of lake herring stocks and evaluate management options. Millions of lake trout were stocked from the 1960s up to the present. The abundance of stocked and wild fish has increased to the point that many lake trout stocks have been restored to pre-crash numbers. In areas of Lake Superior where assessment surveys have shown that lake trout stocks are supported primarily by natural reproduction stocking has been discontinued.

Table 14. Mean annual fish yield (kg/ha/yr) and percent of total yield for Lake Superior contributed by different species or species groups (from Loftus and others 1987).

Species	Early (1913-50)		Recent (1979-83)	
	Yield	**%**	**Yield**	**%**
Lake herring	0.651	66.4	0.139	36.6
Other ciscoes and chubs	0.018	1.8	0.041	10.8
Lake whitefish	0.048	4.9	0.080	21.1
Lake trout	0.240[a]	24.5	0.046	12.1
Rainbow smelt	0.000	0.0	0.041	10.8
Other species	0.021	2.1	0.028	7.4
Total	**0.980**		**0.380**	

[a]*Based on the years 1920-45 only.*

Historically, the fish community of the main lake was comprised of lake trout, coregonines (whitefishes and ciscoes), burbot, sticklebacks, sculpins, and suckers. Lake trout, and to a lesser extent burbot, were the dominant predators. Today, the predator mix has been expanded by the introduction of non-native salmonines, but lake trout remains the dominant predator. Lake trout made up about 93 percent of the predator biomass in western Lake Superior in the early 1990s (M. Ebener, personal communication). Lake Superior contains three forms of lake trout referred to as leans, sicowets and humpers, but some discrete lean stocks are believed to have disappeared. The main forage of lean lake trout historically was lake herring. Lake herring was largely replaced by non-native rainbow smelt as forage in the1960s and 1970s, but re-emerged as major forage species in the 1980s following a decrease in rainbow smelt and abundance and production of several strong lake herring year classes (Selgeby and others 1994). Coregonines (mainly deepwater ciscoes), burbot, and sculpins are principal forage fish for siscowets.

Lean lake trout, rainbow trout, coho and chinook salmon are most abundant in nearshore waters less than 80 m depth. Brown trout and splake are less widely distributed than other naturalized salmonines. Brook trout were formerly more abundant in nearshore areas but have been reduced by overfishing, competition with introduced species and loss of access to and destruction of spawning habitat in tributaries. Lake whitefish are less pelagic than other coregonines and are most abundant at depths of 20 to 50 m. Rainbow smelt are also abundant in nearshore waters, however, their numbers have declined dramatically over the past 40 years.

The fish community of bays, harbors, and estuaries is comprised mainly of perches (walleye and yellow perch), suckers, sculpins, and minnow species (Table 15). Walleye is most abundant in mesotrophic waters less than 15 m depth, although they may be found deeper. Both walleye and lake sturgeon were formerly more abundant and exist mostly as suppressed localized populations. The recent introduction of exotic ruffe, white bass and round gobies may have profound impacts on these warmwater communities. Approximately 20 species (e.g., catfishes and sunfishes) are restricted to the warmest weedy shallows of protected bays and estuaries. Tributaries are critical spawning and nursery habitat for many species, including walleye, sturgeon, burbot and salmonines. Various minnow species, native lamprey, and the central mudminnow are generally confined to tributary waters.

Shoals and spawning areas for lake whitefish, lake herring, round whitefish, and lake trout are shown in Figure 50.

Table 15. Principal fish species in the four main habitat zones of Lake Superior. "X" denotes presence of species during different life stages, i.e., adult (A), juvenile (J), and/or spawning (S).

Principal Species	Adult Diet	Offshore (>80 m deep)			Nearshore (<80 m deep)			Bays, Harbours, Estuaries			Tributaries		
		A	J	S	A	J	S	A	J	S	A	J	S
sea lamprey	fish				X							X	X
lake sturgeon	macroinvertebrates				X	X		X	X				X
pink salmon	fish, macroinvertebrates	X			X							X	X
coho salmon	fish	X			X							X	X
chinook salmon	fish	X										X	X
rainbow trout	fish				X							X	X
brown trout	fish		X	X									
brook trout	macroinvert./ fish				X	X		X	X	X	X	X	X
lake trout	fish	X	X	X	X	X	X	X	X				X
lake whitefish	macroinvertebrates				X	X	X						
lake herring	plankton	X	X		X	X	X						
Bloater	plankton	X	X	X									
Kiyi	macroinvertebrates	X	X	X									
rainbow smelt	plankton				X	X		X	X	X			X
Burbot	fish				X		X			X			X
ninespine stickleback	macroinvertebrates	X			X						X		
Ruffe	macroinvertebrates				X			X	X	X	X	X	X
Walleye	fish				X			X	X				X
slimy sculpin	macroinvertebrates	X									X		
deepwater sculpin	macroinvertebrates	X											

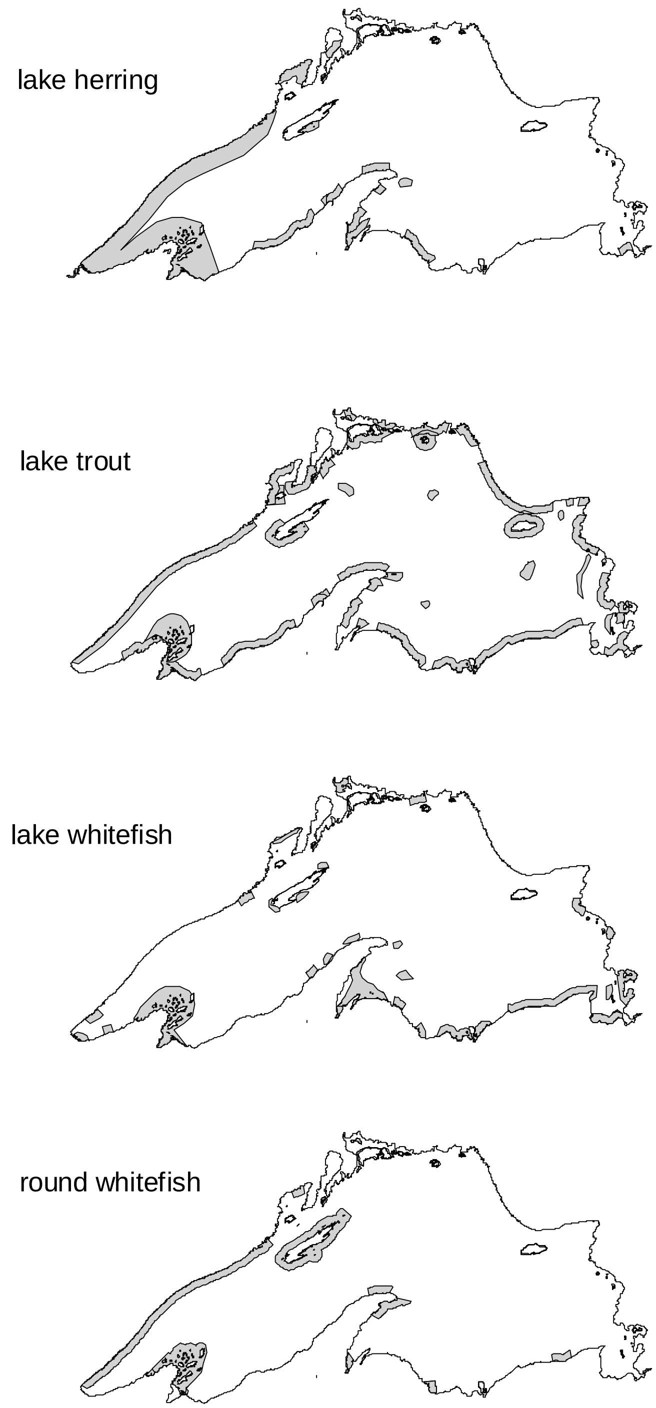


Figure 50. Spawning habitat for major fish species (from Goodier and others 1981).

III. STATUS AND TRENDS OF LAKE SUPERIOR ECOSYSTEMS

4. THE TERRESTRIAL ENVIRONMENT

4.1 Changes in Forest Composition

On the U.S. side of the basin, the forests were almost entirely cut-over between the mid-1800s and early-1900s. Early logging concentrated on white pine; individual trees could reach 61 m in height and produce slightly over 14 cubic meters (m^3)of lumber (TNC 1994). Red pine was harvested to a lesser extent. Early logging practices greatly reduced the seed source for many of the conifer species. In addition, burning of the slash from timber harvest further eliminated reproduction. Hemlock was removed during a later wave of logging when the bark was used for the tanning industry (WI DNR 1995).

After railroads and logging roads were built, hardwoods were harvested by both clearcutting and high-grading (cutting only the most valuable trees). Many hardwood species regenerated, especially sugar maple, beech, basswood, yellow birch, and ash.

Pre-settlement forests on the U.S. side of the basin were predominantly spruce-fir (41 percent) in Minnesota and northern hardwood (39 percent) in Wisconsin and Michigan (Figure 51). Fire-dependent forests of white, red, jack pine combined accounted for 14.8 percent and aspen-birch represented only 1.4 percent. Since logging, pioneer species such as aspen have became more abundant than before settlement (Frelich 1995). For example, in the protected Porcupine Mountains and Sylvania Wilderness northern hardwoods predominate as in historical times, and aspen-birch stands represent only about 1.4 percent of the forest. However, in surrounding commercial forests, approximately 23 percent is aspen-birch dominated (Frelich 1995). Increased browsing of hemlock by deer has contributed recruitment failure and a gradual conversion of hemlock stands to northern hardwoods and spruce-fir where white-tailed deer numbers are well above historic levels (Frelich and Lorimer 1985).

Clearing of presettlement forests not only eliminated the forest ecosystem locally and regionally, but it also created other massive problems when cut logs were floated down the closest stream for transport to Lake Superior or other locations. Riparian vegetation was removed, stream banks were trampled, and stream bottoms were scoured or disrupted. The loss of vegetation created erosion of soils and sheet runoff into streams. Water quality was degraded, and fish habitat was often lost (TNC 1994).

In the Canadian boreal forest, logging began later than in the U.S. portion of the Lake Superior basin, mostly because the forest contained fewer timber-quality trees. The trees were harvested mostly for pulpwood (National Wildlife Federation [NWF] 1993). The pre-settlement forests of the Canadian part of the basin have not been mapped. However trembling aspen, white birch, balsam fir, and balsam poplar have increased due to poor regeneration of shade-intolerant conifers following logging and fire suppression (Carleton 2000). In particular, black spruce has declined following logging.

Red and white pine have been much reduced in abundance on both sides of the border due to selective timber harvest near the turn of the century, blister rust, and fire suppression (see White Pine).

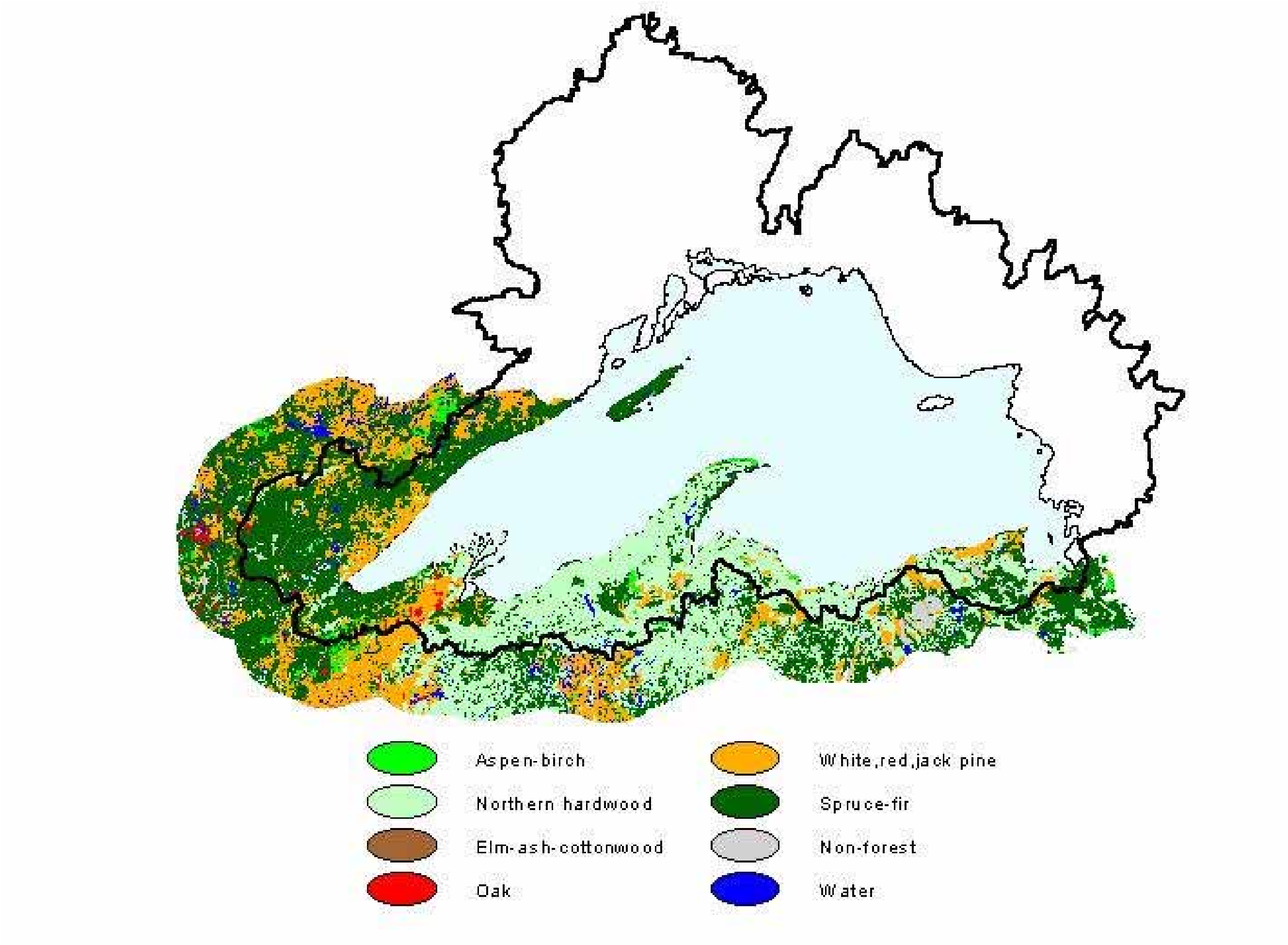


Figure 51. Historic forest cover in the U.S. portion of the Lake Superior basin.

The age structure of forests in the Lake Superior basin has also changed since pre-settlement times. In the predominantly boreal forests of the Canadian portion of the Lake Superior basin, there are fewer very young forests than expected under natural conditions. Fire suppression since the 1930s lengthened the fire interval from approximately 65 years to over 500 years and shifted the age class distribution (Ward and Tithecott 1993). Under natural fire regimes, a more or less negative exponential age class distribution is expected on a landscape scale, with most of the area in very young age classes i.e., <20 years (Van Wagner 1978). In contrast, 40- to 80-year age classes now dominate commercial forests in Ontario (Figure 52) (OMNR 1986). In comparison, there is less old forest, and more young and mature northern hardwood, hemlock and oak forests within the Lake Superior basin than in pre-settlement times due to clearing of forests for timber, agriculture and development.

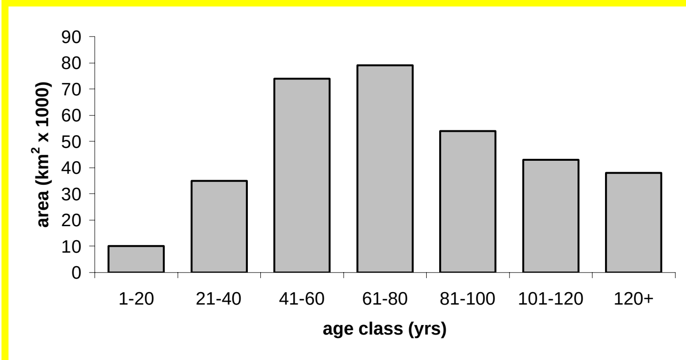


Figure 52. Age class structure of the Ontario commercial forest (OMNR 1986).

4.2 Forest Fragmentation

Forest fragmentation is a landscape-level process in which forested areas are subdivided into smaller, geometrically more complex, and increasingly isolated patches (Harris 1984). Forest fragmentation results from natural processes such as wildfire, wind, insects and climate effects. Urbanization, clearing for agriculture, and logging also contribute to forest fragmentation and affect patterns of natural disturbances.

Forest fragmentation is one of the most prevalent landscape changes occurring within the Lake Superior basin. It is recognized as a major cause in declining biodiversity (Whitcome and others 1981). For example, habitat loss as a result of forest fragmentation was a factor in extirpating species such bison, elk, cougar, wolverine and black bear from all or much of their range in the Lake Superior basin (Matthiae and Stearns 1981). The target for forest fragmentation identified in *Ecosystem Principles and Objectives* is:

> *No further increase in forest fragmentation in the Lake Superior basin as measured by several complementary indices of landscape composition and pattern. A decrease from the current level of fragmentation is desirable.*

Forests in the basin are often fragmented by roads. Forest that is at least 1 km from all roads accounts for 3,444,635 ha or approximately 44 percent of the Canadian portion of the basin (excluding Lake Nipigon). Most patches of roadless areas are less than 1000 ha, but the vast majority (80 percent) of the total area is comprised in several large patches >10,000 ha each. These tracts are located around Pukaskwa National Park, east of Lake Superior Provincial Park, in the Schreiber Highlands, and west of Lake Nipigon (Figure 54). Mean and median patch size is 1750 ha and 20 ha respectively, indicating a disproportionate amount of area in large patches. Much of the forest has been fragmented by recent clear cuts and logging roads which encompass at least 1,229,416 ha (Figure 53). Much of the forest around the city of Thunder Bay that has historically been logged is not reflected in Figure 53.

No estimates are currently available for roadless wilderness on the U.S. side, but the area and proportion of roadless wilderness are probably considerably less. Large blocks of unbroken mature mesic forest are rare in Wisconsin (WI DNR 1995).

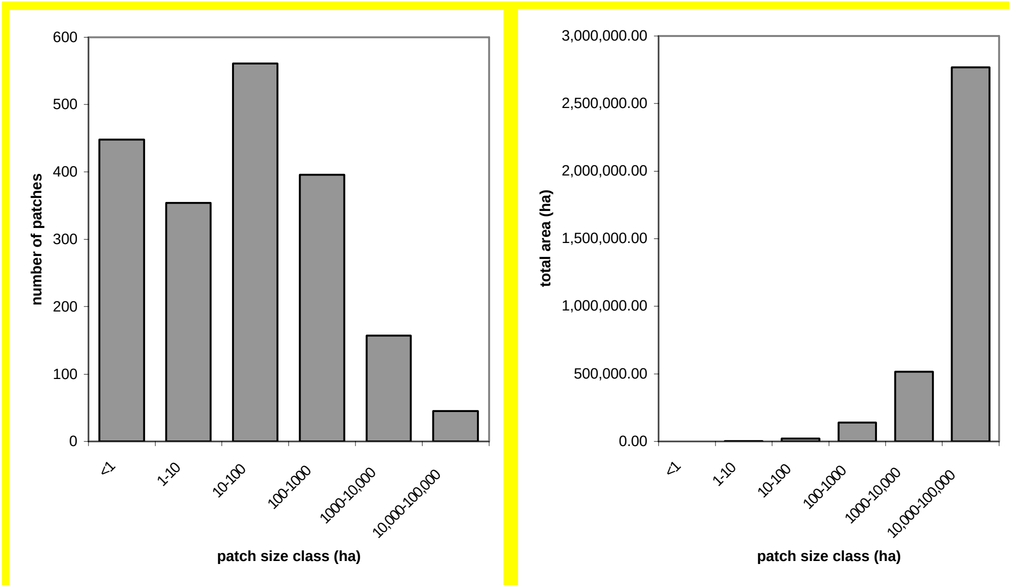


Figure 53. Number and area of roadless wilderness patches (>1 km from nearest road) in the Canadian portion of the Lake Superior basin.

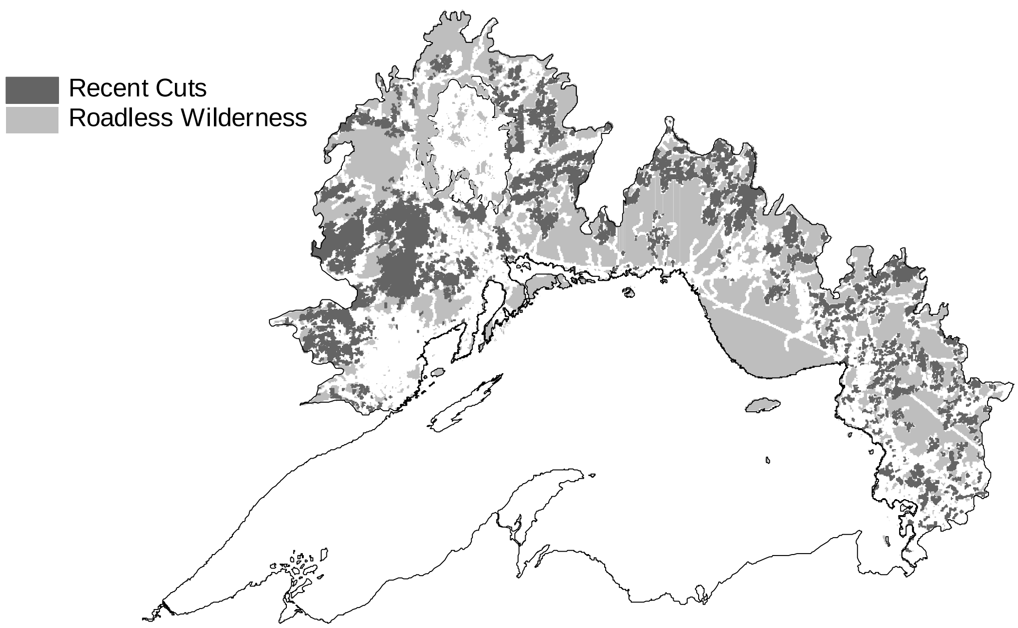


Figure 54. Roadless wilderness (>1 km from nearest road) and recent cuts in the Canadian portion of the Lake Superior basin.

4.3 Old Growth White Pine

White pine is of special significance in the Lake Superior basin due to concerns about logging in "old growth" stands, its commercial importance, biodiversity, and cultural significance. The present white pine range in the Lake Superior basin includes all of the lake states and the southern part of the Ontario basin. Approximately 3,500,000 ha or 1.9 percent of the forest in northwestern Ontario has at least 10 percent white pine in the overstory (Simpson 1996).

In much of the basin, white pine is an uncommon component of the forest and found in small, widely distributed stands that are isolated from each other and vulnerable to loss (Simpson 1996). In Ontario, white pine typically occurs in mixed wood stands in association with black spruce, balsam fir, jack pine, trembling aspen, white birch and red pine (Perera and Baldwin 1993).

Red and white pine forests are generally restricted to four physiographic site groups (Carleton and Arnup 1993):

1) Conifer-dominated stands on dry, infertile, very shallow soils over bedrock.
2) Conifer-dominated stands on dry to fresh, deep, sandy soils of glaciofluvial origin.
3) Mixed conifer-hardwood stands on dry to moist shallow, coarse loamy soils of morainal origin, often on slopes.
4) Mixed conifer-hardwood stands on deep, coarse loamy, fine loamy or silty soils of morainal or lacustrine origin, usually with level topography.

Mature white pine forests have been replaced by spruce-fir forests due to selective harvesting of white pine in the early 20th century and fire suppression. White pine harvest reached a peak between 1890 and 1910. In the Boundary Waters Canoe Area, white pine decreased from 37.5 percent of the presettlement forests to 10 percent currently, and from 29.5 percent to 5.9 percent in adjacent commercial forests (Heinselman 1973; Frelich 1995). The age class distribution of white pine in northwestern Ontario is skewed to the older age classes. For example, all white pine stands on the Thunder Bay Crown Unit are greater than 80 years, with 3 percent greater than 121 years of age (Bowling and Niznowski 1996). The scarcity of younger age classes is a result of poor regeneration due to fire suppression (Heinselman 1973). In the absence of fire, balsam fir, spruce, and shade-tolerant hardwoods replace old white pines. The lack of forest fires discourages successful white pine regeneration and is a major factor in its slow recovery in Ontario mixedwoods (Bowling and Niznowski 1996). In the absence of fire, the pine component will continue to decline and be replaced by shade-tolerant species.

4.4 Future Trends In Forest Cover

The Wisconsin Department of Natural Resources (WI DNR1995) projected the following trends for northern forest management in Wisconsin:

- The total forested area will probably remain the same or increase slightly.
- Aspen-birch type forest will gradually decrease as forest succession progresses. The area in aspen has declined 728,450 ha since 1936.
- Portions of current aspen-birch forests will be replaced by various mixtures of white pine, red maple, and locally, red oak. A significant proportion will succeed to mixed stands of mesic hardwoods, with sugar maple playing the largest role.
- All forests currently dominated by mesic hardwoods will remain so, but species composition will vary greatly depending on geographic location, site type, and management practices. Sugar maple will become more dominant on many mesic sites.
- Red pine plantations are likely to dominate local areas, particularly on forest industry lands. Jack pine acreage is decreasing, while acreage of red pine plantations is increasing.

- Because of great disparity between economic and biological maturity of most tree species, an increase in old-growth forests, in a biological sense, is unlikely. Increased utilization prevents development of old-growth characteristics in managed mature forests.
- Clearcuts and plantations will continue to fragment large, uniform blocks of mature mesic hardwoods. Temporary edges caused by forest cutting will continue to dominate the northern landscape.
- Small, permanent grassy openings will continue to decline to less than one percent of public and forest industry lands. Wildlife that are dependent on grassy, open areas will decline.
- Balsam fir and tag alder will continue to dominate the former white cedar forests. White cedar and Canada yew reproduction will be restricted to scattered, local areas.
- The scattered relict stands containing hemlock and yellow birch will continue to decline. Reproduction of these species will be restricted to scattered, local areas.
- Fire will not play a significant role as an ecological agent in the northern forest.
- Road networks will continue to be improved and expanded.

The demand will continue to increase for forest products such as pulpwood and sawlogs, game species such as white-tailed deer and ruffed grouse, and aesthetic characteristics such as wild country and solitude.

The WI DNR also made the following observations. Under current management practices, only selected economic tree species, a few forest game species, and selected endangered or threatened species receive funding and management attention. The result is a mosaic of many small stands of different forest age classes. Temporary edges are abundant. Fire as a natural process is rare and is not currently used as a management tool in most areas. National, state, county, and local public land units currently plan management strategies independently, but development of ecologically sound, cost-effective techniques that encourage natural processes on the forest landscape will require partnerships with the forest landowners, including the forest industry. Public pressure to pay more attention to maintaining complete and functional forest ecosystems will surely continue.

In Ontario, forest management guidelines have recently changed to better simulate the way fire disturbs the forest in terms of the size and distribution of cutovers. New guidelines are also in place for protecting old growth forests (OMNR 2003).

4.5 Exotic Species

Numerous non-native insects and plant species have been introduced to the Lake Superior basin. Most of these are largely restricted to urban and agricultural areas. The following species are some of the most likely to have significant impacts in terrestrial habitats.

Gypsy Moth

Gypsy moth is one of North America's most devastating forest pests (USDA 1998). It was deliberately introduced to the U.S. in the late 1800s and had spread to the eastern part of the Lake Superior basin by the early 1990s (USDA 1998).

Widespread defoliation of forest stands occurs in peak years. Oaks are the preferred larval food, but other hardwood trees are also eaten. The impacts of defoliation on the forest ecosystem are not well understood, but probably cause reduced growth and survival of oaks, perhaps eventually leading to a shift in forest composition to less vulnerable species (USDA 1998).

Gypsy moths have been recorded in all of the Lake States and have infested the Upper Peninsula of Michigan. In Minnesota and Wisconsin, infestation is restricted to mainly urban areas but is now spreading to rural forests (Joe Meating, personal communication). There was a major outbreak in the Sault Ste. Marie, Ontario area in the late 1990s. Oaks are absent in most of the Ontario basin, and extensive infestation is unlikely north and west of Sault Ste. Marie. Suppression means preventing buildup of populations to protect recreation areas, forested communities, and high-value timber stands in the established infestation in the northeast. This work is carried out by state agencies with help from USDA's Forest Service. All the states have monitoring programs. Control efforts have focused on slowing the spread by eradicating isolated colonies with pesticides and biological control methods (USDA 1998).

Asian Longhorned Beetle

The Asian Longhorned Beetle is native to China, and is a hardwood tree pest. It is believed to have been imported to the U.S. in untreated wood used for pallets and packing materials. It was first discovered in the U.S. in 1996 and in a Chicago neighborhood in 1998. These beetles spread rapidly from tree to tree, killing trees by boring deep holes in them. There is no known method of eradicating the beetles short of destroying the infested trees. Due to its recent introduction into the Great Lakes basin, the extent of potential damage due to this non-native nuisance beetle has not yet been assessed, although hundreds of trees have already been destroyed in the Chicago area. At present this species does not occur in the Lake Superior basin, but may pose a threat in the future.

Hemlock Woolly Aphid

Introduced into the Pacific Northwest in the 1920s, the hemlock woolly aphid was first reported in eastern Virginia in the early 1950s. Since then it has spread primarily northeastward and now occurs as far north as Connecticut and Rhode Island. The primary host is hemlock, with spruce being a possible secondary (alternative) host.

Immature nymphs and adults damage trees by sucking sap from the twigs. The tree loses vigor and prematurely drops needles, to the point of defoliation, which may lead to death. If left uncontrolled, the aphid can kill a tree in a single year. When not at serious risk to the tree, presence of the dirty white globular masses of woolly puffs attached to the twigs or base of needles reduces the value of ornamentals.

Application of insecticides is currently recommended for controlling the hemlock woolly aphid. Tree fertilization can result in more damage, as aphid populations are known to flourish on such trees. It is believed that this species originally came from Japan. Currently, researchers are investigating the prospects of identifying and importing natural enemies for use against this pest. At present this species does not occur in the Lake Superior basin, but may pose a threat in the future.

Pine Shoot Beetle

The pine shoot beetle, a serious foreign pest of pines, was discovered at a Christmas tree farm near Cleveland, Ohio in July 1992. A native of Europe, the beetle attacks new shoots of pine trees, stunting the growth of the tree. The USDA's Animal and Plant Health Inspection Service (APHIS) has taken steps to prevent this insect from moving to major pine-tree production areas. APHIS, in cooperation with state officials, has quarantined 43 infested counties in Michigan, Indiana, Ohio, New York, Illinois, and Pennsylvania. Most of the beetle finds have been at Christmas tree farms and pine tree nurseries. The beetle prefers Scotch pine but will feed on most, if not all, species of pine. Although the beetle is slow moving, it could spread to other areas through the movement of Christmas trees, nursery stock, and pine logs.

In cooperation with state officials, APHIS is requiring the inspection of cut Christmas trees, pine nursery stock, and pine logs, stumps, and lumber with bark attached before these regulated articles can move out of quarantined areas. Lumber and logs without bark attached are not regulated. Additionally, APHIS and cooperating officials are conducting wide-ranging detection surveys for the pest. State and federal scientists are working with the affected industries to develop appropriate control strategies. This beetle species presently occurs in many counties in the Michigan portion of the Lake Superior basin.

Exotic Buckthorns
Exotic buckthorn *(Rhamnus cathartica* and *R. frangula)* has invaded plant communities from state parks to back yards. European or common buckthorn invades woodlands. Glossy or columnar alder-buckthorn is generally found on moist soils. In the Lake Superior basin, both species are established in the Duluth area, Michigan, and Wisconsin. These species are not yet known to be invasive in the Ontario part of the Lake Superior basin.

Exotic Honeysuckles
Exotic honeysuckles *(Lonicera tatarica, L. morrowii, L. maackii,* and the hybrid *L.* x *bella)* have been used as ornamentals for decades. Birds carry their seeds from formal landscapes to natural habitats, including grasslands, marshes, and woodlands. Once established, often with European buckthorn, honeysuckle can dominate the understory of woodlands. In the Lake Superior basin, *Lonicera tatarica* is established in Duluth and Michigan. In Ontario, *Lonicera tatarica* is restricted to scattered occurrences near human habitation. The other species have not yet been documented in the basin, but are spreading and are expected to occur here.

Garlic mustard
Garlic mustard spreads and dominates the ground flora in forests, replacing native woodland plants. Seedlings of this biennial herb germinate in early spring and by midsummer form a cluster or rosette of three or four leaves. In the spring of its second year, it flowers, sets seed, and then dies. Floodwaters, wildlife, human footwear, and off-road vehicles carry seeds to new sites. Management methods include hand removal, herbicide treatments, and repeated burning, though none can control large infestations. A long-term control using biological agents is being sought. In the Lake Superior basin, garlic mustard is apparently restricted to Marquette County, Michigan.

Leafy spurge
Leafy spurge is a plant that has roots that can extend nearly 11 m, grows through asphalt, and flings its seeds almost 5 m. It invades prairies, roadsides, and pastures. Its deep root system enables it to survive dry conditions and resprout even after the foliage is destroyed. Control usually combines use of herbicides, prescribed fire, and mowing. Insects for biological control have been released at several hundred sites in the state of Minnesota by the U.S. and Minnesota Departments of Agriculture. In the

Lake Superior basin, leafy spurge is fairly widespread, but largely restricted to roadsides and other highly disturbed sites.

Spotted Knapweed

Spotted knapweed probably arrived in the Lake Superior basin in alfalfa or hay seed from Europe and Asia. It reproduces solely by seed. Dry prairies, oak and pine barrens, and sandy ridges are likely natural habitats. Chemical control can be fairly effective, but cost is prohibitive. The USDA is conducting a biological control program, involving a root-mining beetle, two root-mining moths, and a flower moth, which has produced varying levels of success. Two species of seed-head-attacking flies have reduced seed production by 95 percent in experiments. In the Lake Superior basin, spotted knapweed is known from Isle Royale and Grand Sable Dunes in Michigan and northern Wisconsin. In Ontario, its status is uncertain, but it has been reported from the east side of the basin.

4.6 Status and Trends of Terrestrial Organisms

Wildlife populations in the Lake Superior basin have undergone continuous changes since before Europeans settled the area. Native Americans influenced terrestrial wildlife communities through habitat manipulation and harvests. Harvest of beaver and large ungulates could have indirectly affected the forest community through reduction in browsing and lowland flooding (Stearns 1995). The effects, however, were likely localized and minor and have never been quantified (Stearns 1995).

The first European explorers and settlers were attracted to the Lake Superior basin by the abundance of furbearing animals. A series of forts and settlements were established along the Great Lakes to protect the fur trade (The Nature Conservancy [TNC] 1994). Many populations of furbearing mammals were depleted as a result of unregulated fur harvest. Once the stocks were depleted, the fur trade moved west to more productive areas.

Pursuit of wildlife-related recreation is important for residents of the basin. In 1996, Michigan had the highest number of hunters of all states in the United States, with 934,000 (U.S. Dept. of Interior and U.S. Dept. of Commerce 1998). This was an increase from 1991, when 826,000 people hunted in Michigan (U.S. Dept. of Interior and U.S. Dept. of Commerce 1993). In 1996, Wisconsin was fourth in the United States with 665,000 hunters, which was a decrease from 747,000 in 1991 (U.S. Dept. of Interior and U.S. Dept. of Commerce 1998, U.S. Dept. of Interior and U.S. Dept. of Commerce 1993). The total number of days that Ontario residents spent on non-consumptive wildlife-related recreation increased from 1981 to 1991, but the total number of days spent hunting decreased (Filion and others 1993).

Wildlife watching is important to both residents and nonresidents of the basin. In 1991, more than 7 million Ontario residents aged 15 years and over (91.9 percent of the population) participated in one or more wildlife-related activities (Filion and others 1993). In 1996, residents of Ontario spent $4.3 billion on nature-related activities, of which $410.9 million was spent on wildlife viewing (Environment Canada 2000). In 1996, almost $1.6 billion was spent in Wisconsin for wildlife watching, the fifth-highest of the 50 states. Michigan supported slightly more than 16 million days of nonresident wildlife watching, which was second in the nation (U.S. Dept. of Interior and U.S. Dept. of Commerce 1998).

Habitat changes on the landscape, as well as harvest and management of select species, have created some dramatic changes in wildlife communities over the past 150 years. Table 16 shows how some species and bird communities have changed since European settlement. Populations have fluctuated from common to rare or from rare to common, and community structures have shifted as a result of large-scale logging in the late 1800s and early 1900s. Species such as the gray squirrel, porcupine, and beaver were rare in the early 1900s, but populations increased as the forest began to mature. Other species, such as raccoon, eastern cottontail, and striped skunk, became more abundant as young forests, forest edges, resorts, small towns, and agriculture provided favorable habitat. Birds such as ruffed grouse and woodcock increased as young forests became available. However, forest bird species, such as the pine warbler, barred owl, and scarlet tanager, decreased in numbers as forests were converted to brushlands; current trends from young to mature forests are again providing habitat for these species (Wisconsin Department of Natural Resources 1995).

Table 16. Changes in the Relative Abundance and Distribution of Selected Wildlife in Wisconsin's Northern Forests: 1850-1994.

	Relative Abundance and Distribution			
Species	**Mid-1800s**	**Early 1900s**	**Mid-1900s**	**1994**
White-tailed deer	Low Clumpy	Low Clumpy	Abundant Continuous	Common Continuous
Coyote	Low Clumpy	Common Clumpy	Abundant Continuous	Common Continuous
Bobcat	Low Clumpy	Low Clumpy	Common Continuous	Rare Continuous
Moose	Low Clumpy	Rare Isolated	Gone Gone	Rare Isolated
Snowshoe hare	Low Clumpy	Common Continuous	Abundant Continuous	Low Clumpy
Gray wolf	Common Continuous	Common Continuous	Gone Gone	Rare Clumpy
Fisher	Common Continuous	Rare Isolated	Gone Gone	Common Continuous
American marten	Abundant Continuous	Rare Isolated	Gone Gone	Rare Isolated
Elk, wolverine	Low Clumpy	Gone Gone	Gone Gone	Gone Gone
Bald eagle, osprey	Common Common	Common Continuous	Low Clumpy	Common Continuous
Ruffed grouse	Low Clumpy	Common Continuous	Abundant Continuous	Common Continuous
Woodcock	Low Clumpy	Common Clumpy	Abundant Continuous	Common Clumpy
Sharp-tailed grouse	Low Clumpy	Abundant Continuous	Common Clumpy	Rare Isolated
Beaver	Common Continuous	Rare Isolated	Low Clumpy	Abundant Continuous

Table 16. Changes in the Relative Abundance and Distribution of Selected Wildlife in Wisconsin's Northern Forests: 1850-1994.

	Relative Abundance and Distribution			
Species	**Mid-1800s**	**Early 1900s**	**Mid-1900s**	**1994**
Grassland birds	Rare Isolated	Common Continuous	Common Clumpy	Rare Isolated
Young-forest birds	Rare Isolated	Common Clumpy	Common Continuous	Common Continuous

Source: Wisconsin Department of Natural Resources 1995
In order of abundance, from least to most abundant: gone, rare, low, common, abundant. In order of distribution, from extirpated to widely distributed: gone, isolated, clumpy, common, continuous.

Direct human interference and harvest also dramatically affects species abundance. Species that rely on large blocks of wild land with little human presence, such as timber wolf, Canada lynx, wolverine, and spruce grouse, were extirpated from a portion of their range (WI DNR 1995). Some of these species can be recovered with careful management and reintroduction. Many species were harvested or exploited until they nearly disappeared from the basin. For example, herring gull populations in the early 1900s were almost extirpated from the entire Great Lakes basin as a result of persecution at nesting sites and demand for bird feathers for the millinery trade during the late 1800s. The Migratory Bird Convention of 1916 provided protection, and herring gull populations began to increase in the 1940s (Ryckman and others 1997).

Environmental quality also plays a significant role in wildlife communities. Environmental contaminants from toxic chemicals that humans introduced into the environment in the mid-1900s nearly eliminated top carnivores such as bald eagles and double-crested cormorants. The effect of chemical pollutants on amphibian populations has also been noted. Species such as bald eagle, herring gull, and river otter are indicators of the quality of the environment, and some monitoring is taking place in the basin to determine contaminant levels and their effects.

The landscape, its environmental quality, and human-imposed regulations and actions are reflected in the current status and health of terrestrial wildlife communities. Tough decisions are being made and will need to be made in the future regarding restoration and management of terrestrial wildlife. As a society, we have begun to understand what needs to happen in the Lake Superior basin to provide a native, healthy, and sustainable wildlife community. But there is also much we do not know. Adaptive management and strategic decision-making may aid in moving toward our goals.

The following summaries are provided for groups of species: mammals, birds, amphibians and reptiles, invertebrates, and plants. We generally provide a broad overview of changes that have taken place in these communities and their current status. Some larger groups are broken down into smaller groups of species, depending on our knowledge.

The status and trend information helps to define the overall problems and opportunities for terrestrial wildlife communities in the Lake Superior basin and to define broad strategies for the Binational Program and its partners.

This work is not a detailed account of status and trends of all wildlife in the Lake Superior basin. There are two reasons for this. First, the time frame given to the working committees was very tight and did not allow for complete compilation of existing data or knowledge. Second, the Binational Program is not a wildlife management entity; rather it is a partnership of agencies from two countries trying to improve the integrity and health of the Lake Superior basin. The work is focused at the strategic level to identify broad goals and strategies. Individuals and organizations may investigate the details at the specific level as they develop and implement programs to meet the Binational Program's broad strategies.

4.6.1 Mammals

Mammalian populations have seen greater fluctuations and changes than any other group of terrestrial vertebrates. Furbearers were exploited during the fur trading years, which caused dramatic decreases of most species and nearly wiped out some. Ungulates were hunted for food and hides; carnivores, such as wolves, were feared and harvested to near oblivion in the southern portion of the basin. As regulations were enacted to control the harvesting of such animals, however, many populations rebounded. Wildlife management agencies have successfully reintroduced certain species, such as American marten, to their historic range. Other species, such as white-tailed deer, have become so abundant in certain areas that they may be damaging their environment.

Some species, however, remain in peril. The woodland caribou has been nearly pushed out of the basin. Canada lynx is nearly gone from the southern part of the basin. There is very little we know about the trends of many small mammals, such as voles, mice, and bats.

There are differences in abundance and diversity of species from south to north. Many of the species that were lost in the U.S. portion of the basin in the early 1900s persisted in the Canadian portion. Species such as white-tailed deer moved into the Canadian portion of the basin in the late 1800s. Because of these differences, habitat and population management and recovery efforts are different between Canada and the United States. For example, Ontario is managing habitat to protect woodland caribou and needs to understand and monitor the effect that deer, moose, and wolf have on caribou. The states have and continue to actively reintroduce some mammalian species, such as moose, which was not necessary in Ontario. It is unlikely that any work to protect and manage mammalian species has focused on the Lake Superior basin specifically. Most work has been limited by political boundaries. Therefore, no information has been specifically compiled for the basin. This report can provide a starting point.

Ungulates

Within the Lake Superior basin and surrounding area, the ranges occupied by large ungulates (woodland caribou, moose, white-tailed deer, and elk) have been substantially altered from presettlement patterns. Harvesting, human disturbance, and habitat changes have nearly eliminated species such as woodland caribou and elk. Elk have been reintroduced into northern Wisconsin and northeast of Sault Ste. Marie Ontario, but they are found nowhere else in the basin. Conversely, white-tailed deer populations in the southern part of the basin are high, largely due to favorable habitat conditions, mild winters, hunting regulations, and decline of natural predators, such as wolf. The white-tailed deer brought with it the parasitic brain worm, which is fatal to both caribou and moose. Minnesota's moose population has remained relatively stable since the early 1990s (Mark Lenarz, MN DNR, personal communication). Ontario has seen stable to increasing populations of moose since 1992 (Timmermann and Buss 1997).

Michigan successfully reintroduced moose into the Upper Peninsula in 1985 and continues to manage the population to increase its range.

Woodland Caribou
Woodland caribou historically ranged throughout most of the Lake Superior basin, but they currently can be found only in the northern edge of the basin in Ontario and in remnant populations on islands and in parks. A discussion of their status appears in the section on *Species and Ecosystems of Concern*.

White-Tailed Deer
Current deer numbers in the Upper Peninsula of Michigan are estimated to be approximately double the presettlement numbers, based on a habitat suitability model (Doepker and others 1996). Deer moved northward into northwestern Ontario in the late 1890s (Snyder 1938). McCaffery (1995) estimated presettlement populations of deer in northwestern Wisconsin to be approximately 7.5 deer/km^2 and peak populations in the 1940s to be 15 to 19 deer/km^2. The 1995 population in northern Wisconsin was about 10.3 deer/km^2, largely due to mild winters and opposition to liberal harvests (McCaffery 1995). Minnesota's deer population increased steadily from 1980 to 1995, but severe winters in 1995-96 and 1996-97 caused the population to decline more than 40 percent. Their numbers have increased in the last few years, however, due to mild winters since 1997 (Mark Lenarz, MN DNR, personal communication). Three primary factors that affect deer numbers in northern Minnesota, in order, are: 1) winter weather, 2) human harvest, and 3) wolf predation (Mark Lenarz, MN DNR, personal communication). A discussion on the ecosystem effects of and approach to deer management is provided as Addendum 7-B.

Increasing numbers of deer have resulted in several impacts to the ecosystem within the basin and elsewhere. Waller and Alverson (1997) suggest that chronically high deer numbers are having substantial, deleterious ecological impacts across many regions. We do not know the overall extent of the problem in the basin, but several studies have shown negative impacts on certain plant species and plant communities in this region (Stoeckeler and others 1957; Frelich and Lorimer 1985; Mladenoff and Stearns 1993; Balgooyen and Waller 1995). Stoeckeler and others (1957) identified a direct negative impact on hemlock seedlings from deer browse in northeast Wisconsin, and Frelich and Lorimer (1985) identified negative effects in the western Upper Peninsula of Michigan. Mladenoff and Stearns (1993) point out that hemlock used to be a regional dominant, but now only occupies 0.5 percent of the landscape. Hemlock requires very specific microhabitat conditions for germination and seedling establishment, and the right conditions occur only in specialized locations. Mladenoff and Stearns agree that deer browsing has a negative effect, but it is only one of many current conditions that suppress regeneration. Climate, dominant forest type (which is now hardwood), and herbivory are all factors that affect hemlock. The ecosystem approach to conservation would require a look at more than deer numbers to re-establish healthy hemlock communities.

Herbaceous plants constitute the bulk of deer summer diets (McCaffery and others 1974), so certain sensitive plants can be negatively affected by deer browsing, especially the species that might be selected by deer as most palatable. In the Apostle Islands and northern Wisconsin, Balgooyen and Waller (1995) showed declines in several woody species, overall herbaceous species diversity, and specific declines in wild sarsaparilla, Canada mayflower, and blue bead lily. The impacts to herbaceous diversity had persisted for over 30 years, with blue bead lily apparently extirpated from Madeline Island.

Other studies have suggested that an overabundance of deer affects other animal species in the ecosystem. In Pennsylvania, for example, a study showed that intermediate canopy-nesting birds declined 37 percent in abundance and 27 percent in species diversity at higher deer densities. Five species completely dropped out at very high densities (14.7 deer/km^2), and two dropped out at highest deer densities (24.6 deer/km^2) (DeCalesta 1994). In New Hampshire, deer were browsing on lupine plants, which are host plants for the endangered Karner blue butterfly (Miller and others 1992). This, in turn, decreased populations of the butterfly.

Increased white-tailed deer populations are thought to have contributed to the decline of some moose and caribou populations through the spread of brainworm.

Human interaction with overabundant deer is also seen in increased vehicle collisions, loss of crops and landscape plants, and increased nuisance occurrences.

Furbearers, Including Mid-Sized Carnivores

Beaver, river otter, American marten, bobcat, fisher, mink, and other furbearers were intensively trapped in the mid- to late-1800s, some to the level that they were extirpated from significant portions of the basin. Fishers, for example, were extirpated from Wisconsin and Michigan due to overharvest and habitat destruction (Racey and Hessey 1989a).

Furbearer populations were also severely reduced in Ontario, and species such as beaver, marten, and fisher were extirpated from portions of their historic range. Season closures and other regulations, along with the establishment of a number of Crown Game Preserves in the 1920s, helped reverse the declines and allowed populations to recover. Individual traplines were first established in the 1930s, and in 1950 it became a requirement for traplines to be registered. The registered trapline system, which licensed a trapper to a specific trapping area, stabilized a chaotic industry and allowed distribution of the harvest, eliminated competition among trappers, and encouraged trappers to manage their trapline areas on a long-term basis (Novak 1987). During the period of the 1940s through the 1950s, beaver, marten, and, to a limited extent, fisher, were transplanted from remaining populations to areas of their former occurrence. In 1950 both marten and fisher were generally absent or uncommon in most of the basin. They were common only in the eastern portion of the basin between Wawa and Chapleau (de Vos 1952). Since that time both fisher and marten numbers have increased, and they now reinhabit their former range. In the case of marten, current harvest levels are higher than at any time in over 100 years. Marten from Ontario were also used as source stock for an introduction into the Lower Peninsula of Michigan in 1985 and 1986 (Ludwig 1986).

In Minnesota, raccoon, fisher, American marten, red fox, and black bear populations have all recovered substantially over the past 20 or more years (Bill Berg, MN DNR, Grand Rapids, personal communication). Fisher and marten were closed to harvest in the late 1920s and reopened in 1977 and 1984. Both species have increased their ranges west and south in Minnesota (Bill Berg, MN DNR, Grand Rapids, personal communication). A long series of mild winters and general climate change have allowed many of these species to increase in abundance and range.

Populations of bobcats, fishers, martens and otters can be estimated using a population model developed by Bill Berg of the MN DNR. The model is used widely throughout the Midwest, including Minnesota, Wisconsin, and Michigan. The Wisconsin and Minnesota DNR used the model to estimate populations for their states, and this information is presented below. Unfortunately, little published information is available for population levels of Michigan furbearer species.

Harvest seasons have been established in all three states for otter, bobcat, and fisher. Marten harvest is permitted only in Minnesota. Martens, fishers, and otters have been expanding their ranges in all three states. Martens are designated as a sensitive species by the U.S. Forest Service in the Chequamegon and Nicolet National Forest Land Management Plans.

Beaver

Beaver have increased in abundance and regained a continuous distribution since the trapping-induced population plunge of the early 1900s. The favorable habitat conditions resulting in the overabundance of white-tailed deer have also resulted in record high beaver populations. Beaver impact both the terrestrial and aquatic ecosystems of the basin. When they harvest trees and build dams, they change the aquatic community structure and open riparian canopies, which creates a positive impact to some species and a negative impact to others.

Beaver can be harmful to the cold-water migratory fish communities. Beaver dams may create a barrier to anadromous migratory fish that use tributary streams for spawning. In addition, cold-water streams in Minnesota's portion of the basin exist and support trout by virtue of climate alone. Summer water temperatures of the surface water driven stream systems are often the limiting factor for healthy fish populations. Riparian forest cover is essential for moderating stream temperature conditions. The removal of riparian forest cover by abundant beaver populations and loss of stream shade results in thermally degraded aquatic trout habitat. Increased water temperatures are also found in ponds above beaver dams. However, beaver ponds offer many benefits to a variety of wildlife species such as waterfowl, reptiles and amphibians.

Bobcat

Bobcat populations in Minnesota are estimated at around 1,500 animals. This population level has been maintained for 20 years. The Wisconsin bobcat population is also estimated at 1,500 animals, which represents a 20 percent increase in population during the past five years. Bobcat harvests in all three states range from 100 to 300 animals. These harvests are regulated to provide for a size-stable population. Bobcats are very rare in the Ontario portion of the basin, with less than 50 animals harvested in the entire province each year.

Fisher

The fisher population in Minnesota has been increasing for about 20 years since the lows of the mid- to late-1970s and is currently estimated to be 10,000 animals. The fisher population in Wisconsin peaked in 1992 at 9,500, declined to 7,500 in 1997, and is now estimated to be nearly 8,000 animals. Both Wisconsin and Minnesota are trying to stabilize the population growth of this species through harvests at about current levels. Ontario fisher populations have experienced an increase over the last decade.

Otter

Otter populations in Minnesota, currently estimated at 13,000 animals, have also been increasing for nearly 20 years. The Wisconsin otter population is estimated at 14,000 animals, which represents a decline from the peak population in 1992 of 15,500. Wisconsin harvest regulations were liberalized in

1992 to take advantage of high population levels. While no population estimates are available, Ontario populations are believed to be stable based on annual trapper questionnaire responses.

American Marten
American marten populations in the U.S. portion of the basin declined in the late 1800s, and the species was thought to be extirpated from Minnesota and Wisconsin by the 1920s. Marten became reestablished in northern Minnesota by the 1950s and are relatively common there now. American marten are listed as a game species in Minnesota, and a trapping season has been in effect in that state for many years. The population is estimated at 12,000 animals. The marten population has been increasing steadily since 1980 with only small dips when trapping conditions are good and harvests unexpected large. Martens are classified as an endangered species by the State of Wisconsin. They were extirpated from the state in the early 1900s and were reintroduced in the 1970s and 1980s (Wisconsin Dept. of Natural Resources 1999). The marten population continues to be small and isolated, centering on the two release sites. Reasons for the lack of expansion of this species are unknown.

In Ontario, marten are relatively common and widespread

Small Mammals

Small mammals include mice, voles, bats, cottontail rabbits, and snowshoe hares. Little population information is available for any of these species, except perhaps on a site-by-site basis. This group of mammals plays a very important role in providing a prey base for other mammals and birds and for preying on invertebrates.

Stressors of Mammals

Overabundant Populations
The recovery of some species from near extirpation to overabundance has resulted in stresses to other species (see Addenda 7-A and 7-B). The management of overabundant deer, however, also provides opportunities to focus on ecosystem management principles and to manage wildlife communities as a whole.

Habitat
Habitat changes on the landscape have been a factor in the composition of mammalian communities (see Table 16). Habitat changes created by certain species, especially white-tailed deer, alter the composition of all mammalian communities.

Beaver also have a significant impact on the surrounding environment, especially riparian vegetation and adjacent aquatic communities. The long-term management of beaver populations can be addressed through management of their riparian food source. The dominant aspen/alder riparian community we see today can be steered toward less palatable coniferous stands. The restoration of coniferous old-growth riparian forest will benefit both terrestrial and aquatic ecosystems.

Some species of particular concern have specific habitat requirements that must be met for their survival. For example, American marten and fisher require blocks of mature forest, and marten seem to prefer forests with a coniferous component. These requirements are an important consideration in timber management (Racey and Hessey 1989b). Standing hollow trees must be present for den sites for both species, and coarse woody debris is critical for winter rest sites for marten (Gilbert and others 1997). Loss of mature, coniferous forest habitat related to logging and human settlement, as well as over-trapping, probably contributed to their decline (Coffin and Pfannmuller 1988). Recently introduced marten habitat guidelines call for maintaining large contiguous blocks of "core habitat" consisting of mature coniferous forest.

Contaminants
Mammals that are top predators accumulate toxic chemicals in their bodies, which may affect their individual health and reproductive capability. Most contaminant monitoring in the Lake Superior basin, however, has focused on birds and fish.

Concern has been expressed about cadmium levels in liver and kidney tissue of deer and moose that exceed recommended daily intake levels for humans. While negligible amounts of cadmium have been found in Ontario deer and moose muscle (Glooschenko and Burgess 1987), the OMNR recommends that people do not eat the liver and kidneys of moose and deer because of the concerns about cadmium levels in these internal organs. Kronberg and Glooschenko (1994) suggested that cadmium could serve as a proxy for other heavy metals of concern, such as lead and mercury, and that analyzing moose tissues on a regular basis could be useful for monitoring changes in environmental levels of these elements.

Studies begun on fisher (Gerstenberger and others 1996) found elevated levels of chlordane, but much work remains to be done. Mink and otter are good indicators of contaminant effects on mammals in the Great Lakes; they are carnivores, consume significant amounts of fish, and have been found to be very sensitive to PCBs and mercury (Ensor and others 1993). PCBs negatively affect mink reproduction (Heaton and others 1992; Kubiak and Best 1991). A study to develop baseline contaminant data in wildlife in Minnesota (Ensor and others 1993) found elevated levels of PCBs in mink collected along Lake Superior, with the three highest levels of mercury observed in mink. The study's authors suspect that high mercury levels in combination with PCBs may be impacting mink populations.

Public Demands
Many mammalian species were historically stressed by overharvest, but many populations have recovered with the implementation of hunting laws and regulations. Recent demands from the public have resulted in agencies also managing wildlife populations for non-consumptive uses. Conflicts can arise with how an agency manages certain wildlife species or communities.

Management Efforts for Mammals

Management and recovery of mammalian populations is done by the state, provincial, tribal, or federal agency that has authority.

Current Monitoring Efforts for Mammals

Management agencies usually monitor mammal populations, either through population indices or harvest surveys.

Ontario initiated a Wildlife Assessment Program to monitor representative wildlife species that may be affected by forestry activities. Eighty-two species were selected as a measure of sustainable forest management; 23 of these species are mammals. Small mammals (mice and voles) are monitored as part of a pilot study at a number of sites within the basin. Annual trapper questionnaires also allow the calculation of a Population Level Index and Population Change Index for furbearers and a number of other wildlife species.

National forests in the United States are monitoring some mammalian species, especially those that are indicators of the impacts of forest management activities. A few programs are monitoring contaminant levels in top predators.

Gaps in Mammal Information

None of the monitoring information on any mammal species has been compiled for the Lake Superior basin.

Very little research is being conducted on contaminants in mammalian predators in the Lake Superior basin.

A significant amount of research needs to be conducted on the long-term effects of herbivory on plants and animals. We need to better understand whether population management programs can reverse some of the negative trends that are seen. This type of monitoring and research should be done in conjunction with adaptive management strategies.

Challenges for Mammals

One of the biggest challenges concerning management of mammals is understanding what mammalian community structure represents a "healthy, sustainable terrestrial wildlife community." As noted above, the current community profile of ungulates has changed drastically from what it was pre-European settlement. Do current conditions represent a healthy terrestrial wildlife community, or is the current community simply the one that will be most accepted by human society? Mammalian communities can have a substantial effect on habitat structure, which in turn affects other terrestrial wildlife and ecosystem functions.

The Binational Program is not, and should not be, in the position of defining a healthy, sustainable mammalian community at the population level. It can, however, help define healthy ecosystems in terms of habitat structure, landscape patterns, and disturbance regimes. The appropriate agencies, however, need to become more actively engaged on a landscape scale to address overlapping goals and objectives. If this is done, the Binational Program can advance those programs where goals overlap.

4.6.2 Birds

Songbirds

Trends in songbird populations can be measured on the basis of individual species, communities, habitat guilds, or migratory status. Populations can be reviewed nationally, regionally, or locally, depending on the data set that is available. The North American Breeding Bird Survey allows us to look at continent-wide trends, as well as regional trends. Local trends are available only if individual studies or monitoring programs have been established. The Lake Superior basin has abundant information at all levels, but it has not been compiled on a basinwide basis. Therefore, we can only provide some relative trend information that is currently compiled at the national and regional level.

Portions of the Lake Superior basin have some of the highest species richness for breeding birds in North America, especially the southern and northwestern shores (Sauer and others 1997; Green 1995). Certain forest species appear to be more abundant, widespread, or productive in northern Wisconsin than in other regions. For these species, the Lake Superior basin could provide source populations. Some species include American woodcock, broad-winged hawk, black-billed cuckoo, winter wren, veery, blackburnian warbler, black-throated green warbler, and scarlet tanager (Howe and others 1992). The Minnesota portion of the basin also has some of the highest woodland species richness in North America (Sauer and others 1997).

Recent concerns have been raised about the decline of neotropical migrant bird populations (those birds that breed in North America and winter in Central or South America). Neotropical migrant birds include 143 species (Thomson and others 1992), approximately 70 percent of which breed in the Lake Superior basin. About 43 percent of the forest birds in Minnesota are neotropical migrants (Green 1995). Some neotropical migrants that are characteristic of Lake Superior forests have shown significant declines on a continent-wide basis, including eastern wood-pewee, wood thrush, veery, and indigo bunting (Peterjohn and Sauer 1994). The decline can be attributed to several factors, including habitat loss on their wintering range, changes in forest habitat in their breeding range, and migration obstacles, deforestation on neotropical wintering grounds, and increased levels of brood parasitism by cowbirds (linked with habitat fragmentation) (Terborgh 1989). Many area-sensitive neotropical migrants that are found in the basin e.g., veery, black-and-white warbler, ovenbird, and northern waterthrush, are particularly vulnerable to forest fragmentation (Robbins and others 1989). Concurrently, several species of neotropical migrants have shown an increase since 1966 on a continent-wide basis, including red-eyed vireo, solitary vireo, ovenbird, and pine warbler (Peterjohn and Sauer 1994). Thomson and others (1992) evaluated the status of neotropical migrants from the midwest (3 provinces and 14 states) based on breeding ground threats, population trends and the importance of the region to the species. The species of most management concern whose ranges encompass most or all of the basin included the chestnut-sided, bay-breasted, Connecticut, Nashville and Canada warblers. The Lake Superior basin represents a significant portion of the breeding habitat, and although they are still relatively common in the basin (Cadman and others 1987), their populations show a long-term decline. Current and past timber extraction may be differentially affecting the breeding success of these and other neotropical migrants. Connecticut and Nashville warblers are most abundant in mature conifer forests, whereas chestnut-sided, and Canada warblers commonly use younger successional hardwood and mixedwood forests, which have increased in extent within the basin. In a northern hardwood forest in New York, numbers of both chestnut-sided and Canada warblers increased in response to logging (Webb and others1977).

Local surveys, especially those that are done in forest interior, show finer trends in woodland birds. For example, the Ontario Forest Bird Monitoring Program indicates that based on analysis of 69 species, 35 showed an increasing trend (11 significant) and 34 showed a decreasing trend (9 significant). In the Boreal Ecozone, significant declines were seen for brown creeper, golden-crowned kinglet, eastern wood-pewee, winter wren, and ovenbird. Significant increases were seen for yellow-bellied sapsucker, great-crested flycatcher, white-breasted nuthatch, northern waterthrush, red-eyed vireo, pine warbler, and chipping sparrow (Cadman and others 1998).

A regional analysis of Breeding Bird Survey (BBS) data was conducted for northeastern Minnesota, specifically the Great Lakes transition forest and the spruce hardwood forest regions (Niemi and others 1995). The analysis compared data in these regions of Minnesota with statewide trends. Table 17 summarizes the findings.

Table 17. Summary of Breeding Bird Survey Analysis in Northeastern Minnesota, 1966-1993.

Species that showed a decline statewide, as well as in both regions:	Species that showed a decline statewide, but not in the two regions:	Species that showed a decline in the two regions, but not statewide:
American Bittern	American Redstart	Blue-winged Teal
Ruffed Grouse	Red-headed Woodpecker	Brown Thrasher
Belted Kingfisher		Field Sparrow
Northern Flicker		Vesper Sparrow
Eastern Wood-pewee		Eastern Meadowlark
Least Flycatcher		
Ruby-crowned Kinglet		
Grasshopper Sparrow		
Western Meadowlark		
Brown-headed Cowbird		
Species that showed an increase in the state and in both regions:		**Species that showed an increase in the two regions, but not statewide:**
Common Loon	Red-breasted Nuthatch	Black-billed Cuckoo
Pied-billed Grebe	White-breasted Nuthatch	House Wren
Canada Goose	Sedge Wren	Marsh Wren
Wood Duck	Eastern Bluebird	Warbling Vireo
Mallard	Swainson's Thrush	
Red-tailed Hawk	Yellow-throated Vireo	
Wilson's Snipe	Yellow-rumped Warbler	
Downy Woodpecker	Black-throated Green Warbler	
Hairy Woodpecker	Scarlet Tanager	
Pileated Woodpecker	Swamp Sparrow	
Eastern Phoebe	Baltimore Oriole	
Blue Jay	Evening Grosbeak	
Common Raven		
Black-capped Chickadee		

Source: Niemi and others 1995

Trends from this analysis indicate:

- Some bird species of mature forests are increasing (e.g., downy woodpecker, Swainson's thrush, pine warbler) and some are decreasing (e.g., least flycatcher, eastern wood-pewee).
- Species associated with fragmented forest landscapes are increasing (e.g., American kestrel, yellow-throated vireo, warbling vireo).
- Species associated with human habitation and human-dominated landscapes are increasing (Canada goose, wood duck, blue jay, black-capped chickadee, house wren, eastern bluebird). Some of these increases are a direct result of recovery programs for specific species, such as wood ducks.
- Four of the species that are increasing are highly associated with lakes and ponds (common loon, pied-billed grebe, double-crested cormorant, and great egret). These are fish- and aquatic-feeding

species that were likely affected by chlorinated organic compounds in the 1950s and 1960s. Their increases parallel those of bald eagle and osprey.

- Several species of agricultural, rural landscapes have decreased (e.g., upland sandpiper, red-headed woodpecker, northern flicker, field sparrow, vesper sparrow, and meadowlark). Possible reasons for the decline include reduction and fragmentation of native grasslands, reductions in hayfields and pastures, and changes in agricultural practices.
- Several species associated with shrub/sedge wetlands are increasing (e.g., common snipe, sedge wren, LeConte's sparrow, and swamp sparrow). Wetlands in northern Minnesota remain in a relatively natural state when compared to other parts of Minnesota.[1]

Although the Lake Superior basin is not on a major migratory flyway, significant numbers of birds migrate through the basin. Lake Superior represents a considerable obstacle, so many birds follow either the eastern or western shore, or use the Slate Islands, Isle Royale, Michipicoten and Caribou islands as they hop cross from the north to south shore (particularly the Keweenaw Peninsula). Bird observatories at Thunder Cape (on the Sibley Peninsula) and Whitefish Point (50 km NW of Sault Ste. Marie) are well located for monitoring migrating songbirds, raptors, owls and waterbirds. At Thunder Cape, the most commonly banded species include black-capped chickadee, dark-eyed junco, yellow-rumped warbler, Swainson's thrush and palm warbler. Black-capped chickadee, Swainson's thrush, golden-crowned kinglet, yellow-rumped warbler, Nashville warbler, and Tennessee warbler are commonly sampled at Whitefish Point. Nine sites along the north shore of Lake Superior have been identified as potential Important Bird Areas (IBAs) by Birdlife International. Many of these sites are important migration staging or stopover areas.

Bald Eagles

Populations of bald eagles declined sharply in the 1950s and 1960s as a result of contamination by toxic chemicals that accumulated in the food chain and affected reproductive success of eagles and other carnivores. A discussion of their status appears in the section on *Species and Ecosystems of Concern*.

Migratory Raptors

Migrating raptors seek thermals to make their flights more efficient. Because thermals rarely form over water, raptors prefer to migrate around Lake Superior. Several locations around the lake provide other physiographic features (such as ridges) that concentrate raptors during migration. These locations provide excellent sites for monitoring raptors and other birds during migration (Ryan Brady, Northern Great Lakes Visitor Center, Ashland, WI, personal communication). Hawk Ridge in Duluth, Minnesota, and Whitefish Point, Michigan, are two well-known hawk migration viewing areas on Lake Superior.

Colonial Waterbirds

Colonial waterbirds are good bioindicators of contaminant levels. Herring gulls and other long-lived fish-eating birds show the effects of prolonged exposure to toxic chemicals and help us understand wildlife health. Herring gull monitoring has occurred for more than 25 years in the Great Lakes. Two annual monitoring sites are located in Lake Superior (Mineau and others 1984; Pekarik and Weseloh 1988; Hebert and others1999).

---

1) It is important to note, however, that coastal wetlands are threatened and of concern in the entire Great Lakes region.

Most colonial waterbirds had nearly disappeared in the early 1900s before the Migratory Bird Convention of 1916 provided some protection. Birds like herring gulls were valued for their feathers and were persecuted at nest sites. After they were protected through federal laws, their numbers began to increase in the 1940s. But by the early 1970s, herring gull populations had once again decreased. Contaminants were blamed, especially persistent chemicals such as DDE, PCBs, and dioxin, which affected eggshell thickness and embryonic growth and caused other problems (Gilbertson 1974; Mineau and others 1984). The mid-1970s saw the greatest concentrations of these toxic chemicals in herring gull eggs, but the levels have decreased since then (Bishop and others 1992a, 1992b; Pettit and others 1994a, 1994b; Pekarik and others 1988a, 1988b). Herring gull populations are recovering in the Great Lakes, but numbers in Lake Superior have shown declines (Table 18). Declines could be due to a smaller food base in Lake Superior (Weseloh and others 1999). Also, contaminants remain in the Lake Superior ecosystem and can continue to cause problems in certain areas (Ryckman and others 1997). The Apostle Islands N. L. has two large colonial bird colonies that include approximately 80 percent of all nesting herring gulls along Wisconsin's Lake Superior shoreline (1,010 nests in 1999).

Table 18. Number of Herring Gull Pairs (colonies) on Lake Superior in 1976, 1989, and 1998.

	1976		1989		1998	
	Pairs	Colonies	Pairs	Colonies	Pairs	Colonies
Canada	6,410	149	12,181	299	11,115*	301*
Percent change from last survey			90.0%	100.7%	<-8.7%	<1.0 %
U.S.	7,106	90	13,263	187	7,715	134
Percent change from last survey			86.6%	107.8%	-41.8%	-28.3%

**Preliminary data, some sites missing; Compiled from: McKearnan, personal communication; C. Pekarik and C. Weseloh, personal communication; Cuthbert and McKearnan 1999.*

Double-crested cormorants have also seen unnatural fluctuations in their populations. It is believed that cormorants did not historically breed in Lake Superior and the Great Lakes. The first suspected nesting occurred on the western end of Lake Superior in 1913 (Weseloh and Collier 1995). This was likely an eastward expansion of the Lake of the Woods population.

There was a continual expansion of cormorants into the Great Lakes, and by the late 1940s and 1950s, the cormorant had become so common that control measures began, especially on the lower Great Lakes. People suspected that cormorants competed with commercial and sport fisheries. There were both sanctioned and unsanctioned control measures, including annual destruction of colonies by shooting adults and destroying eggs and young. Control measures largely ended by 1960.

Cormorant populations declined drastically throughout the 1960s and early 1970s. By 1973, breeding cormorants had completely disappeared from Lake Superior (Weseloh and Collier 1995). One of the leading reasons for the decline – if not the leading reason – was contamination by toxic chemicals. Cormorants, like many fish-eating birds, were producing thin eggshells because they had accumulated DDE in their system. They were breaking their eggs by lying on them. Deformities were also noted, probably caused by agents such as PCBs (Weseloh and others 1995).

In the mid-1970s, with decreased use of toxic chemicals, cormorants began a dramatic recovery. They increased by 300-fold between 1971 and 1995 in the entire Great Lakes region. Lake Superior saw a slower growth (Figure 55), mostly because it is less productive than the lower lakes, so it has a reduced food base. The rate of bill deformities also decreased (Weseloh and Collier 1995; Ryckman and others 1998).

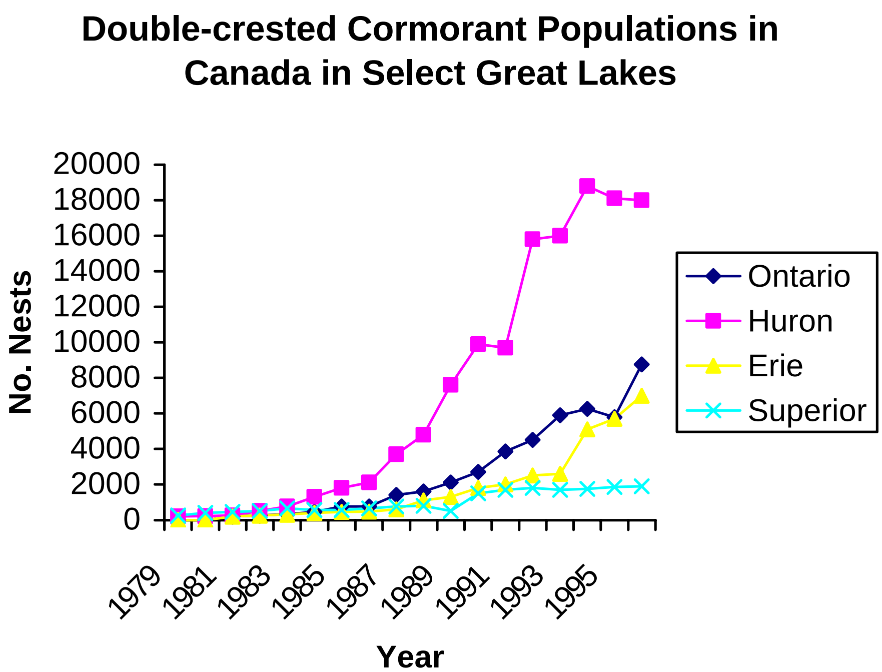


Figure 55. Double-Crested Cormorant Populations (Weseloh and others 1999).

The American white pelican, generally considered a bird of the great plains/prairie regions of North America, has become established in the Lake Superior basin. Breeding colonies were discovered in the early 1990s on Lake Nipigon. These birds are believed to have come from breeding colonies on Lake of the Woods, which is located along the Manitoba/Ontario/Minnesota border (Bryan 1994 and Escott 1991).

Shorebirds

Some information is available on the status of shorebirds east of the Rocky Mountains (Harrington 1995). Most information was gathered from migratory bird surveys and some from breeding bird surveys. Population trends were evaluated for 27 of 41 shorebird species. Of these, 12 showed no change, 1 increased, and 14 decreased. Some species that are of interest to the basin are: spotted sandpiper – no change; common snipe – significant decline; piping plover – endangered; American woodcock – significant decline.

Migration habitat is critical for many shorebirds. A high proportion of them migrate by visiting one or a small number of "staging sites," areas where the birds can accumulate fat. These staging sites are often productive areas with highly predictable but seasonally ephemeral "blooms" of invertebrates. The St. Louis River estuary at the Duluth-Superior Harbor and the north end of Black Bay in Ontario are used by many species of shorebirds and could be a significant staging site for Lake Superior (Pat Collins, MN DNR, Two Harbors, personal communication). We are not aware of other heavily used sites on Lake Superior.

Common Loons

Most common loon pairs use inland lakes in the basin for breeding sites. Lake Superior is used by loons as a staging area, including Whitefish Point in Michigan. Isle Royale has a large loon population for its size, and some of these loons nest on Lake Superior (Michigan Loon Recovery Program 1992).

Loon reproductive success in Ontario decreased between 1981 and 1997. Loons breeding on acid lakes declined more rapidly than those on more alkaline lakes (Weeber 1999). In the upper Great Lakes, loons nesting on acid lakes were more susceptible to mercury contamination (Evers and others 1998).

Minnesota has the largest summer population of loons in the lower 48 states, with northeastern Minnesota serving as an important area for loons (Strong and Baker 1991). Michigan had only about 300 pairs in 1988, and about 165 of these were in the Upper Peninsula (Michigan Loon Recovery Program 1992). Wisconsin saw an increase in its loon population from 1985 to 1995, probably due to good reproduction from 1986 to 1990, which was mostly weather-related (Daulton and others 1997).

Waterfowl

Lake Superior and the basin is not a hot spot for waterfowl production. The lake provides important habitat for migratory waterfowl, especially diving ducks. Coastal wetlands also provide important habitat for both breeding and migrating birds.

Waterfowl information has not been compiled for the Lake Superior basin. Most waterfowl indices for North America are created from surveys done outside the basin. However, trend data for Minnesota, Wisconsin, and Michigan (Figure 56) shows that waterfowl numbers are increasing, except for a few select species, such as the American black duck, lesser scaup and greater scaup. The increase in numbers in North America is mostly due to ideal conditions in the prairie region and Alaska. Increase in abundance is also reflected in the data from Minnesota (U.S. Fish and Wildlife Service 1998). The degree to which Lake Superior contributes to waterfowl production is unknown.

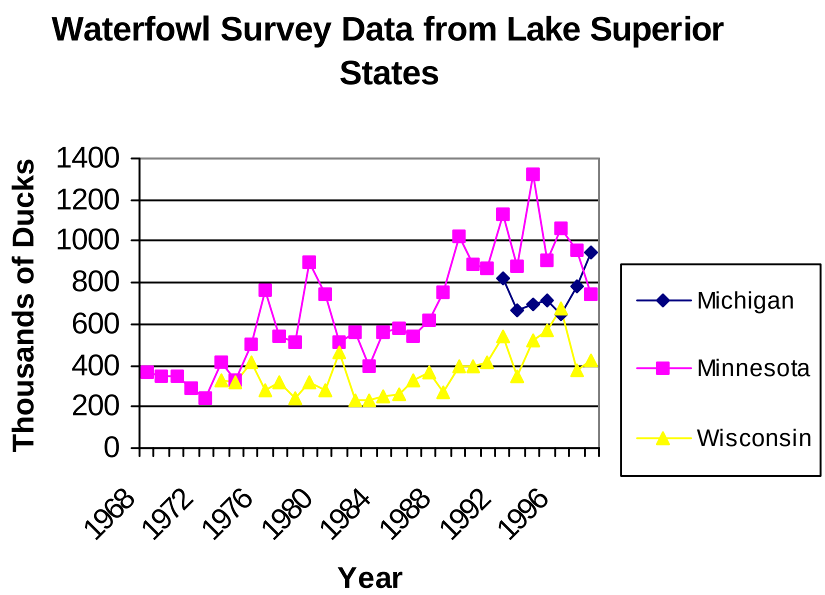


Figure 56. Waterfowl survey data (U.S. Fish and Wildlife Service 1998).

Stressors of Birds

Chemical Contaminants

The presence of elevated levels of toxic chemicals coincides with poor health, reproductive impairments, and other physiological problems in herring gulls, as well as ring-billed gulls, double-crested cormorants, black-crowned night-herons, bald eagles, common terns, Caspian terns, and Forster's terns. This is related to reduced hatching success, eggshell thinning, abnormal adult behavior, deformed embryos, biochemical changes, endocrine disruption, and suppressed immune function (Fox and others 1998).

Currently, contaminants are being released or recycled by atmospheric deposition, agricultural land runoff, slow leaching of discarded stocks of pesticides and other chemicals from landfill sites and agricultural soils into the Great Lakes via groundwater and resuspension of contaminated lake and river sediments. On Lake Superior, up to 90 percent of toxic contaminants entering the lake comes from the atmosphere in the form of precipitation (Eisenreich and others 1981). Table 19 summarizes contaminant-related effects in fish-eating waterbirds.

Table 19. Summary of Some Contaminant-related Effects Observed in Herring Gulls and Other Fish-eating Waterbirds Inhabiting the Great Lakes (Ryckman and others 1997).

Contaminant Effect	Evidence in the Great Lakes	Current Status
Eggshell Thinning - caused by high DDE levels in the 1950s, 1960s, and 1970s.	Resulted in widespread eggshell breakage, causing population declines of fish-eating waterbird species including double-crested cormorants, ospreys, bald eagles, black-crowned night-herons, and herring gulls.	Due to regulatory controls and banning of DDT, eggshell thinning is no longer a problem, resulting in improved reproductive success of affected species.
Reproductive Failure -causes include early embryonic death, embryo toxicity, and abnormal parental behavior during incubation.	Herring gulls, double-crested cormorants, and bald eagles were not reproducing during the late 1960s and 1970s when highest levels of organochlorines were present.	Due to significant declines in organochlorine levels, reproductive success has improved in most fish-eating waterbird species.
Biochemical Changes	Abnormal liver functions and low levels of Vitamin A may increase susceptibility to infectious diseases, possibly affecting the survival and development of young chicks.	Biochemical measures indicate that herring gulls are still chemically stressed. Full effect of biochemical changes on the reproduction or life span of waterbirds is not known at this time.
Suppressed Immune Function -several contaminants (e.g., PCBs and TCDDs) suppress important immune functions and can increase susceptibility to infectious diseases.	At highly contaminated sites, herring gulls and Caspian terns have suppressed T-lymphocyte function, atrophy of the thymus gland, and altered white blood cell counts.	Research is underway to determine the extent and significance of suppressed immune function in fish-eating waterbirds.
Congenital Deformities	Crossed bills, jaw defects, extra limbs, and malformed feet, joints, and eyes were found in herring gulls and at least eight other species of fish-eating waterbirds.	Waterbirds continue to display higher rates of deformities compared to clean sites outside of the basin. Studies continue on the links between contaminants and developmental problems in certain waterbird species.

Habitat

Habitat changes and landscape patterns have very strong effects on birds, especially migratory songbirds. Because the Lake Superior basin is primarily forested, the composition, size, and structure of forests strongly affects songbird species diversity, abundance, and productivity. For example, some songbirds prefer to nest in forest interiors (ovenbird), and others prefer disturbed, open habitats (indigo bunting). Some require dead, standing trees (pileated woodpecker), and some prefer dense shrubs under a canopy (black-throated blue warbler). Others prefer a mix of hardwood and conifer forests (black-throated green warbler). Therefore, habitat changes and forest management policies affect each species differently. However, the following habitat changes are known to be negative for forest birds in general and have caused stresses to populations:

- Even-aged stands of hardwoods with little understory decrease bird species diversity (Howe and Mossman 1995, Green 1995).
- Some bird species are dependent on conifers (Green 1995) or prefer conifers (Howe and Mossman 1995), and loss of conifers affects abundance of those species.
- Neotropical migrant birds often increase in diversity and abundance as woodland size in fragmented landscapes increases (Friesen and others 1995).
- Shape of woodlands also plays an important role. A woodland with minimal edge is likely to have greater bird production than one with maximum edge. Edge creates many problems, including

increased predation, intrusion of invasive species, and human disturbance. Edges have the effect of increasing temperature and wind, and lowering humidity in the forest interior.

- Neotropical migrant birds consistently decrease in diversity and abundance as adjacent home development increases, regardless of forest size. This study was conducted in a heavy agriculture landscape in southwest Ontario with about 14 percent of the landscape wooded (Friesen and others 1995).
- Hard edges have a detrimental effect on most species of concern, even disturbance-dependent species such as indigo bunting (Suarez and others 1997). Soft edges and residual habitat in clearcuts are preferred (Merrill and others 1998, Suarez and others 1997).
- Large gaps without cover between woodlands are detrimental to some forest birds. The creation or preservation of woodland corridors for these species is important (Desrochers and Hannon 1997).

Even non-native plant species can decrease bird productivity. For example, buckthorn, which replaces native hawthorn, lacks sharp thorns that might deter predators. A study showed that productivity of robins and wood thrushes decreased for birds nesting in non-native shrubs (Schmidt and Whelan 1999).

Habitat changes created by shoreline development affect many species of birds and create dramatic changes in avian community guilds. A study by Gillum and others (1998) showed that ground-nesting birds decrease in numbers as development increases, probably due to vegetation alteration, increased predation, and nest disturbance. Insectivorous species are less common along developed shoreline. The proportion of omnivores, nectivores, frugivores, or seed eaters is two times greater at developed lakes than at undeveloped lakes. Concerns are mostly related to forest interior species of northern Wisconsin, such as ovenbird, hermit thrush, black-and-white warbler, black-throated green warbler, and brown creeper, because they are displaced by development. Intensive shoreline development also eliminates habitat for certain water-dependent species such as herons and kingfishers (Gillum and others 1998).

Human Disturbance

Species such as loons can be negatively affected by direct human disturbance. Unsuspecting recreational users sometimes chase birds off their nest, leaving eggs or chicks susceptible to heat or cold. Loons also become entangled in commercial trap nets, fishing lines and hooks, and ingest lead fishing sinkers (Michigan Loon Recovery Program 1992). Songbirds that nest on or near the ground are susceptible to predation by domestic cats and dogs.

Invasive and Nuisance Species

Brown-headed cowbirds parasitize the nests of songbirds, laying their eggs in the nests of other species. The adult songbirds raise and feed the cowbirds to maturity, reducing their own nesting productivity. Cowbirds thrive in edge habitat, especially if the edge habitat is near to mowed grass or pasture, which is where they feed. In the Lake Superior basin, cowbirds are a problem where human habitation is the greatest and in agricultural landscapes, but they are not a major concern in the basin overall.

Non-native plants can degrade habitat structure, resulting in decreased biodiversity. Schmidt and Whelan (1999) showed the effect of non-native shrubs on robin and wood thrush productivity. Predation of both species was higher in non-native shrubs than in native shrubs and trees, likely due to structural differences in non-native plants that provided easier access for predators.

Management Efforts for Birds

In general, states, tribes, and the Province of Ontario have regulatory authority and management responsibility for resident wildlife, which includes resident birds. Federal governments have regulatory authority and management responsibility for migratory birds. Federal agencies that manage federal lands have management responsibility for both resident and migratory birds. However, many responsibilities for migratory birds are shared between states and the federal government. Some example programs include the following:

North American Waterfowl Management Plan – Recognizing the importance of waterfowl and wetlands to North Americans and the need for international cooperation to help in the recovery of a shared resource, the Canadian and United States governments developed a strategy to restore waterfowl populations to 1970s levels through habitat protection, restoration, and enhancement. The strategy was documented in the North American Waterfowl Management Plan signed in 1986 by the Canadian Minister of the Environment and the United States Secretary of the Interior, the foundation partnership upon which hundreds of others are built. The Plan is implemented through cooperative partnerships called "Joint Ventures." In 1994, the Mexico Secretario de Desarrollo Social signed the Plan, expanding the efforts to protect wetlands and improve waterfowl populations. The Lake Superior basin is included in Canadian Eastern Habitat Joint Venture (EHJV) and the U.S. Upper Mississippi River / Great Lakes Joint Venture (UMR/GLJV).

U.S. Shorebird Conservation Plan – The U.S. Shorebird Conservation Plan is a collaborative effort among researchers, land managers, and education specialists from the United States who cooperate with colleagues from Canada and Mexico to advance effective conservation of North American shorebird species. The plan was initiated in 1997. Canada and Ontario Shorebird Conservation Plans have been published and no significant shorebird sites have been identified on the Ontario side of the basin.

North American Colonial Waterbird Conservation Plan – This effort was initiated in 1998. The mission is to create a cohesive, multinational partnership for conserving and managing colonially-nesting waterbirds (seabirds, wading birds, terns, gulls) and their habitats throughout North America. A plan will be implemented to maintain healthy populations, distributions, and habitats of colonial-nesting waterbirds in North America, throughout their breeding, migratory, and wintering ranges.

Partners In Flight (PIF) – PIF is a coalition of countries, government agencies, conservation groups, academic institutions, industry, and concerned citizens who share a common vision: to maintain the health of landbird populations and their habitats. While international in its scope, Partners In Flight advocates a grassroots approach where regions develop their own goals and strategies to keep common birds common. Partners In Flight landbird planning within Ontario is currently underway for all four of Ontario's Bird Conservation Regions (BCRs) and fit into the broader PIF Continental Plan. Priorities for the Lake Superior basin on the Ontario side have yet to be determined. Priorities on the U.S. side have been described in PIF Physiographic Region 20 Plan: http://www.blm.gov/wildlife/pl_20sum.htm

North American Bird Conservation Initiative – NABCI was initiated in 1999 by representatives of federal, state, and provincial agencies, as well as nongovernmental organizations, to create a framework that would foster coordination among the four bird initiatives (Partners in Flight, the North American

Waterfowl Management Plan, the North American Waterbirds Conservation Plan, and both the U.S. and Canada Shorebird Conservation Plans) with the aim of conserving all birds and their habitats.

Circle of Flight – This program provides funding and technical assistance to lake state tribes for wetlands protection, restoration, enhancement, and management projects. Many tribes have reseeded and now manage wild rice beds under this program. Thousands of hectares of wetlands have been restored or enhanced since the program's inception in 1991. The program is administered by the U.S. Bureau of Indian Affairs and U.S. tribes. It involves many partners.

Current Monitoring Efforts for Birds

Songbirds

North American Breeding Bird Survey – Established in 1966, this program is a joint effort of Canada and the United States. Volunteers and natural resource agency employees complete selected roadside counts once a year. This program provides long-term trend data over a broad geographic area. The information is not currently compiled or analyzed for the basin.

Ontario Forest Bird Monitoring Program – This program began in 1987. Its goals are to: 1) compile a habitat-specific baseline inventory of forest songbirds, 2) describe changes over time in the numbers of forest songbirds in relation to habitat and landscape characteristics, and 3) contribute to an understanding of population trends for forest birds in Ontario. This information supplements breeding bird survey data (Cadman and others 1998). OMNR's Wildlife Assessment Program began a similar forest bird monitoring program in 2000, greatly expanding coverage in northern Ontario. A number of these forest bird monitoring sites are located within the basin.

Ontario Landbird Monitoring Strategy – This program encompasses all landbird monitoring, including breeding and migration monitoring. It is part of the Canadian Landbird Monitoring Strategy.

Marsh Monitoring Program – The Marsh Monitoring Program began in 1994 in order to monitor the condition of marshes in the Great Lakes basin, using marsh birds and amphibians as indicator species. Volunteers survey marsh birds, amphibians, or both. The Marsh Monitoring Program is a cooperative venture of Environment Canada and Bird Studies Canada. Migration monitoring is done at Thunder Cape, Ontario; Whitefish Point, Michigan; and Hawk Ridge, Duluth, Minnesota.

Songbird monitoring is conducted on many public lands to measure the effect of management on avian populations. Lands that are monitored in the basin include: U.S. national forests (Chequamegon Nicolet, Superior, Ottawa), U.S. National Parks (Apostle Islands and Isle Royale), tribal lands (Red Cliff and Bad River), and national wildlife refuges (Whittlesey Creek).

Colonial Waterbirds

Herring gulls are monitored for contaminants, populations, and productivity. The herring gull is considered one of the major indicator species for environmental contamination in the Great Lakes. This program has been in place for more than 25 years and is one of the longest running wildlife monitoring programs for contaminants in the world. Two of the 15 monitoring sites are on Lake Superior: at Granite Island, east of Thunder Bay, and at Agawa Rocks, south of Wawa. Populations of cormorants, gulls, terns, and herons are monitored in the entire Great Lakes on both the Canadian and United States sides at varying intervals.

Waterfowl
Breeding pair and brood surveys are conducted in Minnesota, Michigan, Wisconsin, and Ontario, but a large area of the basin is not included in these surveys.

Loons
State and provincial agencies along with various loon watch programs monitor breeding pairs and productivity. Work was recently initiated by the BioDiversity Research Institute to monitor contaminants in loons.

Bald Eagles
Nesting pairs are monitored along the Great Lakes and inland lakes in the basin by the states and Ontario. Productivity is monitored in select areas.

Habitat
Habitat changes at the landscape level are being monitored using computerized geographic information system (GIS) software. Satellite photographs, starting from the late 1980s, have been interpreted (at 200 x 200 m resolution) and entered into GIS data layers.

Gaps in Bird Information

Little information has been compiled specifically for the Lake Superior basin, but a significant amount of general information is available, particularly for breeding birds, loons, bald eagles, and colonial waterbirds. Once the information is compiled for the basin, an analysis should be conducted to determine where the information gaps are.

Monitoring was initiated on contaminants in tree swallows, but work has slowed due to lack of funds.

The ongoing GIS data could be developed at a finer resolution (50 x 50 m) and interpreted every ten years to allow comparison over time. Linkages need to be made with landscape-scale habitat changes to songbird communities.

Challenges for Birds

Lake Superior forests provide very important habitat for migratory songbird populations, some of which probably serve as source populations for other areas. With concerns expressed nationwide over the decline of neotropical migrants, the Lake Superior basin should be considered a critical region for migratory songbird conservation. Significant work continues on population monitoring; some of this is being linked to habitat changes at the landscape scale. The Binational Program would be a logical organization to work toward compiling this information for the Lake Superior basin and providing it to project partners. The Binational Program should also provide recommendations for habitat conservation strategies to its project partners and to local units of government in the throes of land use planning.

Conservation of migratory songbirds remains uncertain because of the complex interactions between birds and their landscapes. However, Howe and others (1995) provide some recommendations that can be used to help guide conservation and management efforts. They include: 1) establish realistic conservation goals at several administrative levels, 2) select species that can be used as guidelines, 3) identify specific populations where priority species occur and implement appropriate management in these locations, 4) coordinate planning strategies among forest management units, and 5) design monitoring strategies to track populations and management actions.

Contaminant levels are being monitored in colonial waterbirds. This work needs to continue and should be coordinated closely with other contaminant studies being conducted in the basin. This is especially critical considering the goal of zero discharge for the Lake Superior basin.

4.6.3 Amphibians and Reptiles

Status and Trends of Amphibians and Reptiles

Little work has been done on amphibians and reptiles in comparison to other vertebrates. Until 10 to 15 years ago, few agencies and organizations even considered them in conservation efforts. Therefore, historical population data are mostly incidental. Species ranges are often derived from museum collections and records. Current efforts to monitor populations and to study the effects of anthropogenic influences have given us an increased awareness and concern for amphibian and reptile communities.

Populations of amphibians and reptiles are affected by many factors, and the overall trend for any species is not known. As with many vertebrates, the widespread changes in habitat cover across the landscape have had a dramatic effect on the community composition of amphibians and reptiles. For example, areas in the southern part of the basin that were historically mixed forest probably included species such as redback and blue-spotted salamander and species that are dependent on logs and downed branches, such as American toads, wood frogs, and redbelly snakes (Oldfield and Moriarty 1994). If those areas are logged and converted to agricultural lands, the amphibian species composition changes to those tolerant of human disturbance. Even then, the habitat must contain cover, a prey base, and water. Where these are present, American toads, garter snakes, and painted turtles might be present (Oldfield and Moriarty 1994).

It is important to understand how amphibians respond to changes in the ecosystem. Most amphibians are secretive, so it isn't readily obvious that they constitute a large percentage of the biomass of terrestrial ecosystems. Because amphibians and reptiles are often in the middle of the food chain, their presence or absence causes a shift in patterns of predation. (Stebbins and Cohen 1995).

It is also important to consider metapopulations (a metapopulation is a network of semi-isolated populations with some level of regular or intermittent migration and gene flow among them, in which individual populations may become extinct but may be recolonized by other populations). This is especially important in areas that are being quickly developed because amphibian populations are becoming isolated (Casper 1998). Even where they are not isolated, conservation efforts need to keep in mind that individuals of many reptiles and amphibian species travel between sites, which increases genetic viability. This is also important where certain conditions (such as drought) might temporarily create population sinks.

Estimates of population trends for amphibian species in Wisconsin and Minnesota are available (Table 20). Local population declines of many amphibians are becoming a concern worldwide. Many possible reasons exist for these declines (see stressors section). Monitoring programs have been initiated to document trends.

Table 20. Status of Amphibian Species Found in the Lake Superior Basin in Minnesota and Wisconsin.

Species	Minnesota	Wisconsin
Wood frog	Relatively stable	Increasing
Northern leopard frog	Relatively stable or decreasing	Decreasing
Pickerel frog	N/A	Decreasing
Mink frog	Unknown	Unknown
Green frog	Relatively stable	Relatively stable
Chorus frog	Unknown	Relatively stable
Northern spring peeper	Relatively stable	Decreasing quickly
Eastern gray treefrog	Relatively stable	Relatively stable
Cope's gray treefrog	Unknown	Decreasing
Blanchard's cricket frog	Special concern	State endangered
American toad	Relatively stable	Relatively stable
Blue-spotted salamander	Relatively stable	Relatively stable
Eastern tiger salamander	Decreasing?	N/A
Spotted salamander	N/A	Relatively stable
Four-toed salamander	Unknown	Special concern
Redback salamander	Relatively stable	N/A
Mudpuppy	Unknown	Unknown

Compiled from Casper 1998; Moriarty 1998; Mossman and others 1998.

Some specific examples of species found in the basin and their estimated status are listed below.

Blue-Spotted Salamander

This is a relatively widespread species, which is tolerant of both cold temperatures and human habitat disturbance. They may be common in woodlands with the required breeding ponds. They are tolerant of selective logging and low-density residential development, as long as the critical parts of the habitat remain intact. Local populations are threatened by clear-cuts and roads that separate breeding ponds and terrestrial habitats (Harding 1997).

Northern Spring Peeper

Spring peepers are common in the Lake Superior basin. They require temporary and permanent ponds, marshes, or ditches for breeding. After breeding, they disperse to old fields, woodlands, and shrubby areas. They remain abundant, but their wetland habitats must be conserved to ensure they do not become a species of concern (Harding 1997).

Northern Leopard Frog

The leopard frog is probably one of the best-known frogs, largely because it was often dissected in school biology labs. It is a widespread, ubiquitous species, but there have been significant declines in parts of its range, including Minnesota, Wisconsin, and Ontario (Mossman and others 1998; Casper 1998; Moriarty 1998; Seburn and Seburn 1997). Leopard frogs were completely absent from a large area of northern Ontario in 1997, indicating a major population decline there (Seburn and Seburn 1997). Collections by biological supply houses have been suggested as a potential problem, but there could be other reasons for the decline, such as disease, weather, and exposure to ultraviolet radiation (Seburn and Seburn 1997).

Snapping Turtle

The common snapping turtle is a large freshwater turtle that can live 100+ years. They are fairly common in the southern part of the basin, but they are at the edge of their range in Ontario. They are omnivorous, and because they eat mainly animal matter, they may be exposed to higher concentrations of contaminants than most other turtle species, which are mainly vegetarian. Their eggs, which are laid in sand next to water, are often eaten by skunks, foxes, and raccoons, and hatchlings are often eaten by avian predators. The adults are harvested for their meat. Snapping turtles are often thought of as common, but all the factors listed here make them vulnerable to population declines (Shirose and others 1996).

Unique Characteristics of Amphibians and Reptiles

Blaustein and Wake (1995) did a good job of describing the special characteristics of amphibians:

> "*Amphibians are valuable as gauges of the planet's health for a few reasons. First, they are in intimate contact with many components of their natural surroundings. For example, as larvae, frogs live in water, but as adults most find themselves at least partially on land. Their moist, delicate skins are thin enough to allow respiration, and their unshelled eggs are directly exposed to soil, water and sunlight. As larvae, they are herbivores and as adults, carnivores. Because amphibians sample many parts of the environment, their health reflects the combined effects of many separate influences in their ecosystems. Second, these animals are good monitors of local conditions because they are homebodies, remaining in fairly confined regions for their entire lives. What happens to frogs and their brethren is happening where humans live and might affect our species as well*."

A unique characteristic of turtles is their longevity. Certain turtle species, such as wood turtles, can live as long as 40 years. This is very important given the fact that their annual productivity is often low and they do not reach maturity until they are 12 to 20 years old (Harding 1997). They lay eggs in sandy beaches, and these are often completely destroyed by predators. When adult turtles are harvested, the remaining adults cannot replace the population with enough young to keep it viable. Collection of turtles for contaminant analysis has been discontinued for this reason (Brooks and others 1988 and Galbraith and others 1987). Tissue from their eggs provides sufficient information to analyze contaminant levels.

Concerns about amphibian abnormalities have been in the news for the past five years, since the highly publicized 1995 discovery of deformed leopard frogs by middle school students in Minnesota. Since then, reports of abnormalities have surged, and a North American database and reporting system was established through the U.S. Geological Survey. The North American Reporting Center for Amphibian Malformations is now a repository of data about amphibian deformities. A web site has also been established to make this information easily accessible.

Experts have been conducting studies to try to determine the causes of these deformities, looking mainly at parasites, chemical contaminants, ultraviolet light, temperature, and other environmental factors. According to a recent report by Jamie K. Reaser (U.S. Dept. of State) in FROGLOG (a newsletter published by the International Union for the Conservation of Nature [IUCN] Declining Amphibian Population Task Force), it is unlikely that any one particular factor can be singled out as the cause. Different factors, such as chemical contamination, UV light, and parasites, operate by similar mechanisms, impacting similar ecological and developmental pathways to cause abnormalities.

Stressors of Amphibians and Reptiles

Stressors to amphibian and reptile populations are not clearly defined for the Lake Superior basin, but the problems noted for the Upper Midwest and Canada are probably reflected in the Lake Superior basin. Stressors can be related to global problems and to local problems. Global problems include the increase of ultraviolet radiation from depletion of the ozone layer, acid precipitation, and bioaccumulation and transport of toxic chemicals such as DDT. Local problems are related to habitat loss and fragmentation, direct impact from chemical applications such as pesticides and herbicides, infectious diseases, and invasive species.

Habitat

Degradation and loss of habitat is a concern for many species, especially those dependent on wetland habitats. Degradation of wetlands is caused by eutrophication, pollution, addition of non-native fish, and loss of surrounding upland habitat. Loss of plant diversity due to invasion of exotic, invasive species can affect invertebrate populations, which can in turn affect the health of amphibians and reptiles (Casper 1998). Changes in land use surrounding wetlands and aquatic habitats may increase sedimentation rates (Casper 1998; Lannoo 1998). Clear-cutting may affect amphibians by changing soil moisture and acidity (Blymyer and McGinnes 1977). Woodlands that are managed by removing mature trees before they fall would not be suitable habitat for species that require litter and downed logs. Habitat fragmentation also causes loss of migration corridors and loss of the mosaic of wetland types that are often critical for amphibian life cycles, especially during drought years. Some species move from a seasonal pond to a permanent pond during dry years (Lannoo 1998). Migration corridors for reptiles are often disrupted by roads and trails, which can directly cause mortality of turtles (Oldfield and Moriarty 1994).

Ultraviolet Radiation (UV-B)

Ambient UV-B radiation can directly or indirectly kill some amphibian eggs under both field and laboratory conditions (Blaustein and others 1994, 1995, 1997). The depletion of the ozone layer has increased the amount of UV-B radiation striking the earth, which might be one of the reasons why amphibian populations in relatively pristine habitats are declining. The increase in UV-B radiation might have a synergistic effect, by making amphibians more susceptible to diseases.

Invasive Species

Zebra mussels and rusty crayfish alter the native prey base of areas they invade. Zebra mussels are voracious consumers and can drastically reduce the zooplankton population, leaving other native invertebrates little to eat. This can result in a drop in native invertebrate populations and less food for amphibian larvae. Rusty crayfish can wipe out native plants, which are used by invertebrates for food and shelter. The result is similar to zebra mussels, with a lower invertebrate population and less food for amphibians and reptiles.

The non-native plant, purple loosestrife, invades and dominates wetlands. These wetlands lose many microhabitats that are needed by invertebrates, causing a decrease in invertebrate diversity, which can negatively affect amphibians and reptiles in their aquatic stage.

Contaminants
Many studies have been done on contaminants and their effects on amphibians and reptiles, but most were laboratory studies, so little information is available about direct and indirect effects. More research needs to be done to better understand the direct, indirect, and cumulative effects of contaminants on reptiles and amphibians. Agricultural chemicals could be a significant cause of toxic effects, but this needs to be better investigated. Habitat fragmentation and destruction, compounded by pollution of some of the remaining, otherwise suitable habitat, as well as loss of the corridors between suitable areas, may have a devastating impact on the viability of amphibian metapopulations (Diana and Beasley 1998).

Some turtle species are long-lived and consume animal matter, making them especially susceptible to contamination by toxic pollutants (Shirose and others 1996).

Infectious Diseases and Parasites
Outbreaks of infectious diseases may be an important indicator of stress and environmental mismanagement. The effects of a disease might not be as dramatic if the population were not already stressed. The protection of suitable habitat and maintenance of a diverse gene pool are of critical importance in limiting the ultimate impact of a range of infectious agents (Faeh and others 1998).

Other
Introduction of fish, crawfish, and bullfrogs into naturally fishless ponds and wetlands can cause several problems. Introduced species may provide direct competition for food, and they may prey on the larval or fledgling stages of native amphibians and reptiles.

Management Efforts for Amphibians and Reptiles

All states within the Great Lakes basin and Ontario have protective laws and regulations that affect amphibians and reptiles (Harding 1997).

In Ontario, the Fish and Wildlife Conservation Act (FWCA) of 1997 lists all reptile species, with the exception of the common snapping turtle, as specially protected reptiles. The snapping turtle may be harvested within specified seasons and bag limits under the authority of an angling license. Of the 15 amphibian species found within the Ontario portion of the basin, only the salamander species and the gray treefrog are listed as specially protected under the FWCA. The frog species are not offered special protection, and, with the exception of the bullfrog, there are no harvest seasons in place. Bullfrogs may be harvested only within specified areas, seasons, and bag limits in Ontario.

The MN DNR keeps track of turtle harvest (those harvested for food). Turtles and frogs are collected by biological supply houses, under license by the MN DNR, without restriction. Minnesota law protects wood turtles and Blanding’s turtles. A bounty system for rattlesnakes was removed in 1989. Minnesota

Herpetological Society and the Nongame Wildlife Program are attempting to raise the awareness of conservation needs, to conduct inventories, and to protect important habitats.

The WI DNR regulates the taking of amphibians and reptiles. They specify seasons for some species of frogs and turtles and regulate the method of capture. They also limit the size of some species, such as snapping turtles. State threatened or endangered species may not be collected except by special permit.

The MI DNR protects species that are listed as threatened or endangered. Reptiles and amphibians that are listed as special concern by the MI DNR require a permit for collection (Lori Sargent, personal communication).

The IUCN established a Declining Amphibian Population Task Force (DAPTF) in 1991. The DAPTF includes a network of over 3,000 scientists and conservationists belonging to national and regional working groups, which cover more than 90 countries around the world. Ultimately, the DAPTF hopes to understand why populations are declining and develop conservation programs to stabilize them. A Great Lakes working group was established, which covers Minnesota, Michigan, and Wisconsin. Canada has established a Canadian Amphibian and Reptile Conservation Network as part of DAPTF.

Partners in Amphibian and Reptile Conservation is a public-private network that was established in 1999 to facilitate greater conservation efforts for amphibians and reptiles in North America, encouraging the use of partnerships to facilitate successful work. Modeled after the successful Partners In Flight program, its focus is to protect amphibian and reptile populations and habitats to "keep common species common." A Midwest Working Group formed in September 1999 includes the Lake Superior basin.

Current Monitoring Efforts

North American Amphibian Monitoring Program
This program was established by the Declining Amphibian Populations Task Force. It encompasses Canada, the United States, and Mexico. The purpose of the program is to collect information to monitor populations on a global basis. It includes frog calling surveys and terrestrial salamander monitoring. Monitoring protocols along random routes are established and conducted mostly by volunteers. Surveys in the Great Lakes region are coordinated by state and provincial agencies. Routes are included in the Lake Superior basin, but the data has not been compiled for the basin.

Ontario has several surveys that monitor amphibian populations, mostly frogs and toads. These programs are: *Backyard Survey*, *Road Call Count Survey*, Marsh Monitoring, and *Adopt-A-Pond/Frogwatch*. Backyard Surveys are conducted by volunteers who record species and calling intensity from their backyard or cottage on a daily basis. This program and the Road Call Count Survey are coordinated by the Canadian Wildlife Service. The Road Call Count Survey establishes routes that have stations from which observations are made. These surveys are also conducted by volunteers who run the route three times during the spring and summer. The Marsh Monitoring Program's purpose is to monitor the health of wetland ecosystems in the Great Lakes basin, including 43 Areas of Concern around the Great Lakes. Marsh Monitoring includes an amphibian roadside survey, following the same protocols as the Road Call Count Survey mentioned above. Routes are also conducted outside of the Areas of Concern. This is coordinated by Bird Studies Canada.

Frogwatch USA is a new program established in February 1999. It is modeled after Frogwatch Ontario. Volunteers across the United States submit observations on their local amphibian populations by choosing and periodically monitoring a wetland site for calling frogs and toads. Adopt-A-Pond/Frogwatch in Ontario is coordinated by the Toronto Zoo and is similar to the Frogwatch USA program. This data is submitted to the Natural Heritage Information Centre of the OMNR. Both U.S. and Canadian programs allow citizens an opportunity to learn about the amphibian community in their area, as well as an opportunity to become involved in monitoring.

Various agencies, including the U.S. Fish and Widlife Service and National Park Service, have implemented calling frog and toad surveys within the Lake Superior basin. Some tribes and First Nation groups have also initiated frog and toad surveys on native lands and project areas, including Bad River and Keweenaw Bay.

Gaps in Information about Amphibians and Reptiles

More routes and surveys are needed for all amphibian and reptile monitoring programs in the Lake Superior basin.

Monitoring protocols should be agreed to for amphibian and reptile surveys. Existing information for the Lake Superior basin has recently been compiled (Casper 2002) and work toward development of standardized basin-wide monitoring protocols began at a workshop held in Duluth in June, 2003.

Few surveys are being conducted for reptiles, and those are usually very local or incidental. OMNR's Wildlife Assessment Program has been undertaking a pilot study on the use of artificial cover objects to monitor redbacked salamander populations. Monitoring programs should be established and followed.

Causes of population changes for both amphibians and reptiles need to be identified.

Challenges for Amphibians and Reptiles

Most conservation and management actions have focused on vertebrate species that are either visible or harvested. Amphibians and reptiles can be highly observable at certain times of the year and are also harvested, yet they have been ignored in management plans in the past. An ecosystem approach to conservation should encompass habitat for all species, as well as all ecosystem functions. If the Binational Program is concerned with overall ecosystem health, then we need to pay closer attention to amphibians and reptiles in our inventories, planning work, actions, and monitoring efforts.

4.6.4 Invertebrates

About 90 percent of the nearly one million species of animals in the world are terrestrial or aquatic invertebrates (animals without backbones). In the Great Lakes region the larger, more easily seen invertebrates include insects and mollusks, such as snails and clams. Insects are the most diverse group and globally may have the largest collective biomass of all terrestrial animals. Yet, within the Lake Superior basin, we have little information on the status and trends of the insect or terrestrial invertebrate populations. The groups are too large to encompass, and taxonomic problems have impeded the development of status and trend information.

Along with an appreciation of the interaction between plants and animals, the role of soil invertebrates, fungi, and microorganisms in ecosystem functioning must be understood. Interdependencies of every part of the biotic community, including the decomposers, must be taken into account. The complex spatial and temporal heterogeneity of habitats and species response to disturbance has to be understood. We have very little information on this, and new research must be initiated in this area.

4.6.5 Plants

Green plants form the base for all animal life, and yet protection of plants in the ecosystem has not been associated with the protection of wild animals. The term wildlife has been traditionally used to refer to wild animals only. This gross misconception must be corrected. It is evident from the long list of rare and endangered plants in the Lake Superior basin (see habitat committee section) that the number of endangered plants far exceeds that of wild animals. For every threatened animal there are two or more endangered plants. This connection between wild plants and animals must be clarified and highlighted to the professionals and to the public. The importance of plants to the survival and well being of wild animals must be recognized and factored into the equation of wildlife conservation.

A discussion of the status of some rare plants species appears in the section on *Species and Ecosystems of Concern*.

4.7 Species and Ecosystems of Concern

The species discussed in this section are considered to be rare or declining in at least one of the states/provinces in the basin. Species can be listed at the federal, provincial, or state levels.

The U.S. federal categories are as follows:

> **Endangered:** The classification provided to an animal or plant in danger of extinction within the foreseeable future throughout all or a significant portion of its range.
>
> **Threatened:** The classification provided to an animal or plant likely to become endangered within the foreseeable future throughout all or a significant portion of its range.
>
> **Species of Concern:** “Species of concern” is an informal term that refers to those species which might be in need of concentrated conservation actions. Such conservation actions vary depending on the health of the populations and degree and types of threats. At one extreme, there may only need to be periodic monitoring of populations and threats to the species and its habitat. At the other extreme, a species may need to be listed as a Federal threatened or endangered species. Species of concern receive no legal protection and the use of the term does not necessarily mean that the species will eventually be proposed for listing as a threatened or endangered species.

THE CANADIAN FEDERAL CATEGORIES ARE:

Endangered: A species facing imminent extirpation or extinction.

Threatened: A species likely to become endangered if limiting factors are not reversed.

Vulnerable: A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.

Ontario, Minnesota, Wisconsin, and Michigan have slightly differing definitions for the state / provincial level listings, but are similar in intent to the federal listings.

4.7.1 Key Mammals of Concern

Gray Wolf

The gray wolf was formerly distributed throughout the Lake Superior basin but declined after the early 1800s due to extermination efforts in both Canada and the U.S. Wolf populations never declined to low levels in Ontario, but were extirpated in most of the U.S. portion of the basin by the early 1970s. Remnant populations persisted in northern Minnesota and on Isle Royale. Wolves were listed federally as Endangered in the U.S. in 1967, offering them full protection. Wolf numbers and range increased in Minnesota and they repopulated Wisconsin and the Upper Peninsula of Michigan through immigration from Ontario and Minnesota. All three states now have breeding populations (Figure 57).

Recovery programs have been initiated in all three states, and recovery goals are nearly met. The U.S. Fish and Wildlife Service is drafting a proposal to change the status to threatened in Wisconsin and Michigan. A new issue with regard to wolves in the basin is their species status. White et. al. (2001) suggest that, based on DNA evidence, the wolves inhabiting the basin are not a sub-species of gray wolf (*C. l. lycaon*) as previously thought but are actually a separate species of wolf, the eastern wolf (*Canis lycaon*).

Wolf habitat consists of a relatively large land area with an adequate prey base. Major prey species are white-tailed deer in the southern part of the basin and moose in the north. Beaver and small mammals are important summer food. Habitat management to maintain or improve habitat for moose and deer is undertaken in all of the states and Ontario, mainly through timber management. Timber management can improve habitat for deer and moose by creating interspersion of mature forest with younger successional forest and, therefore, have a positive effect on wolves (Michigan Gray Wolf Recovery Team 1997, Wisconsin Wolf Advisory Committee 1999).

Wolves are most successful where there is limited human access (Michigan Gray Wolf Recovery Team 1997, Wisconsin Wolf Advisory Committee 1999). Road densities greater than 0.6 km/km^2 have been implicated in wolf declines due to collisions with vehicles and access by hunters and trappers. On the other hand, in areas of deep snow in Ontario, ploughed roads and packed snowmobile trails may make it easier for wolves to find and kill prey. Wolves can tolerate greater road density where humans do not kill or harass wolves (Michigan Gray Wolf Recovery Team 1997).

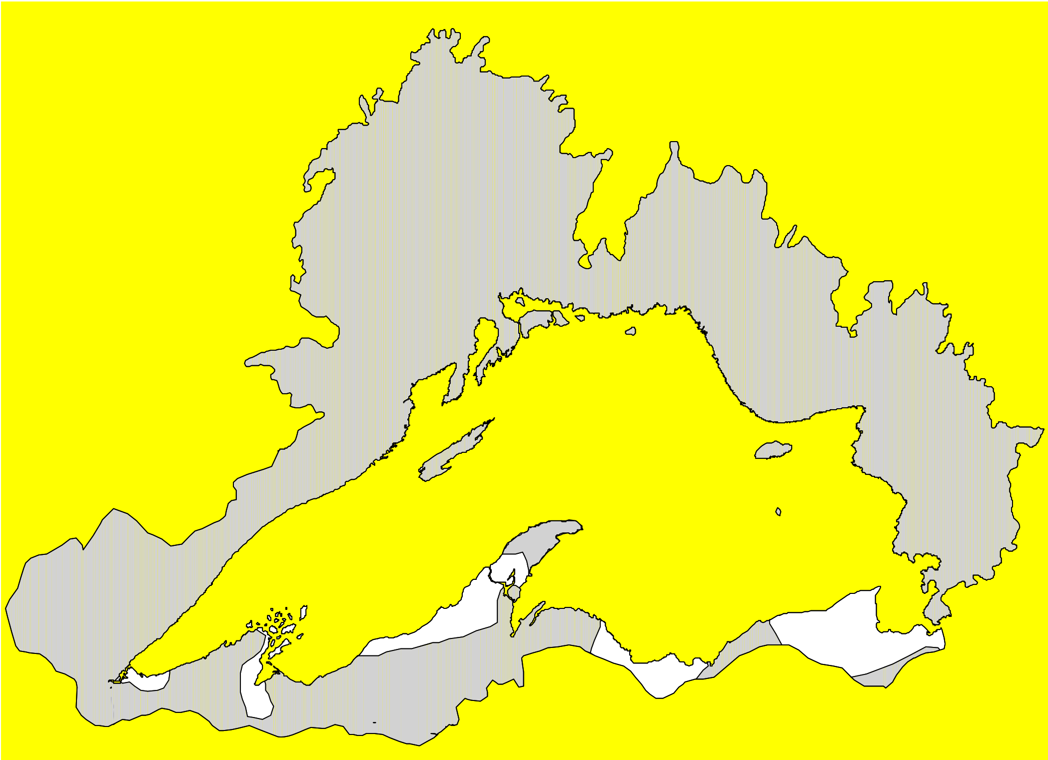


Figure 57. Wolf range in the Lake Superior basin in 1997 (shaded) (Michigan Gray Wolf Recovery Team 1997, Wydeven 1999, Coffin and Pfannumller 1988, Dobbyn 1994).

Human disturbance at den and rendezvous sites can cause abandonment of these areas. The area required for protection from disturbance has been estimated at approximately 0.05 percent of the pack's territory (13 ha for an average home range of 259 km^2) (Michigan Gray Wolf Recovery Team 1997).

Habitat corridors linking wolf populations may be important to allow wolves to move through landscapes fragmented by human activities (Michigan Gray Wolf Recovery Team 1997).

Wisconsin

Wolves returned to Wisconsin in the mid-1970s, and in 1975 was listed as Endangered. Management and recovery plans introduced in 1989 set goals of a population of 80 or more animals for more than three consecutive years (Wisconsin Wolf Advisory Committee 1999). In 1999, the wolf population reached 197 animals and has been at 80 or more animals since 1995. The Wisconsin Department of Natural Resources has now reclassified wolves as Threatened and is working on a management plan that will eventually delist the species. This plan would delist the wolf to a non-game species when the population reaches 250 or more animals across the state outside of Tribal Lands. A management goal of 350 is recommended.

Since 1979, the State has been monitoring the wolf population by radiocollaring one or two members of each pack. This method has been the most precise method of monitoring the population. Other survey methods include snow tracking and summer howling surveys.

Wolf habitat in Wisconsin has been assessed as primary or secondary (Mladenoff and others 1995). Based on computer models, primary habitat represents areas with a 50 percent or greater chance of supporting a wolf pack and secondary habitat represents areas with a 10 to 50 percent chance of supporting a wolf pack. Most of the primary and secondary habitat is in the northern third of the State, including much of the Lake Superior basin (Wisconsin Wolf Advisory Committee 1999).

Michigan

The gray wolf is considered Endangered in Michigan. Wolf populations have recovered from near extinction in the mid 1970s to at least 174 animals in 30 or more packs in 1999. This compares to 140 wolves located in 1997-98. In 1991, wolves reproduced in Michigan (other than on Isle Royale) for the first time in 40 years. All of the wolf packs are located in the Upper Peninsula (including much of the Lake Superior basin) and Isle Royale.

Monitoring for wolves is conducted by the Department of Natural Resources by using radio telemetry and snow track counts. There has also been a continuous monitoring program of wolves on Isle Royale since 1958. Two wolves first arrived on the island in the late 1940s, and the population of wolves is dependent on the local moose population. As moose numbers fluctuate (500 to 2,500), so have the wolf numbers fluctuated between 12 and 50 animals. Habitat supply analysis suggests that the Upper Peninsula could support over 800 wolves (Mladenoff and others 1995).

The Michigan Recovery Plan for the gray wolf will consider the animal recovered when there is a winter population of 200 animals for five consecutive years. At that time, the wolf will be recommended for removal from the Michigan Endangered Species List.

Minnesota

In 1978, Minnesota reclassified the gray wolf from Endangered to Threatened and plans to delist the animal in 2000. The 1978 Grey Wolf Recovery Plan set a population goal of 1,251 to 1,400 wolves by the year 2000. This goal was achieved when a statewide survey in 1989 estimated the population at 1,550 to 1,750 animals. Surveys estimate the population to be about 2,450 animals in the winter of 1998-1999 (Mike Don Carlos, personal communication).

A wolf management group consisting of 35 groups and individuals has been working on a revised plan for wolf management in Minnesota. This management plan has been produced, but the state has not implemented the plan.

In 1999, there were four projects using radio collars to monitor wolves in the state. The Department of Natural Resources also conducts winter snow tracking surveys.

Suitable habitat is located throughout most of the Lake Superior basin in Minnesota (Hazard 1982), but a population estimate for the basin is not available.

Ontario

In Ontario there is no evidence to suggest that wolves are threatened or endangered on either a regional or provincial basis. Observations by field staff and trappers suggest that wolf numbers are stable or increasing over nearly all of their historic range in the Province. The gray wolf population in Ontario is estimated at 8,000 to 9,000 animals (Buss and de Almeida 1997). Within the Ontario portion of the basin, wolf hunting and trapping is permitted year-round; however, wolves are essentially protected during the months of June through August, because the provincial small game-hunting license is not valid during that period. Hunting is prohibited in provincial and national parks, and trapping is prohibited, or minimal, in most provincial parks (Buss and de Almeida 1997). During the 1990s, the annual harvest of wolves has varied from 500 to 800 animals.

There have been two recent studies on wolf habitat use and population dynamics within the Lake Superior basin. In 1994, Pukaskwa National Park initiated a six-year predator-prey research initiative called "The P5 Project." This project investigated the predator-prey dynamics and landscape change in the Greater Pukaskwa Ecosystem. Twenty-seven wolves were radio-collared and data were collected on prey base, home ranges and territories. Habitat analysis was also investigated but most of the data collected were related to moose and woodland caribou requirements (Keith Wade, personal communication). A second project based out of Marathon radio-collared wolves from Neys Provincial Park to White Lake. This research examined habitat use and home ranges related to roads and landscape parameters and also the influence of garbage dumps (Krizan 1997).

Canada Lynx

Canada lynx was formerly found throughout the Lake Superior basin, but its range has receded northward and it is now largely restricted to Ontario within the basin. The U.S. Fish and Wildlife Service officially listed the Canada lynx population in the contiguous United States as threatened under the Endangered Species Act on March 24, 2000. The Service plans to establish a Lynx Recovery Team and prepare a recovery plan, however a court order to reconsider its final rule has delayed these activities. On July 3, 2003, the status of lynx populations in the contiguous United States was confirmed as Threatened under the Endangered Species Act.

Habitat is associated with cool coniferous forest in southern extensions of boreal forest into the U.S. (McKelvey and others 1999). Young, dense forest stands, where snowshoe hares are abundant, are critical, but lynx home range typically also includes mature forest with large woody debris for denning (Aubry and others 1999).

Lynx populations fluctuate widely in response to snowshoe hare numbers. Following declines in prey, lynx wander from their core Canadian range into Minnesota, Michigan and Wisconsin. Particularly large incursions from Ontario into the states happened in the early 1960s and again in the early 1970s (McKelvey and others 1999).

The recession of lynx range in the U.S. is related to changes in forest conditions, loss of coniferous forest cover, trapping, and roads. Timber management practices and fire suppression that lead to poor snowshoe hare habitat is detrimental to lynx. Increased roads threaten lynx due to increased access for trappers (Koehler and Aubrey 1994).

Michigan
Lynx were formerly widely distributed in the Upper Peninsula and Isle Royale but virtually extirpated by 1938 (McKelvey and others 1999). The last record in the state was a trapping record from the early 1980s in Mackinac County. Lynx are now listed as Endangered in Michigan.

There is good habitat consisting of a large continuous mixture of boreal and hardwood forest in the Upper Peninsula (Kevin Dorn, personal communication), but habitat availability has not been quantified (Ray Rustem, personal communication). The Department of Natural Resources monitors trapping records, but does not conduct annual surveys.

The National Forest Service initiated a three-year monitoring program for cat species in 1999. The survey covered the West Block of the Hiawatha National Forest and was expanded into the East Block of the Hiawatha Forest and the Ottawa National Forest in the winter of 1999-2000. Monitoring involved placing scratch pads marked with catnip oil and collecting hair samples for DNA sampling (Kevin Dorn personal communication).

Wisconsin

Lynx were listed as Endangered in Wisconsin in 1973 but removed from the list in 1997 due to lack of evidence of a breeding population (Wydeven and others 1999). Two lynx were killed in 1992, the first specimens collected since 1974 (Adrian Wydeven, personal communication). Between 1991-1997, there were 10 reports of lynx with three observations in both 1992 and 1993. The Wisconsin DNR monitors lynx by conducting furbearer snow track surveys, wolf track surveys, reports of rare carnivores by the public, and surveys of bobcat hunters and trappers. Lynx are considered to be very rare and probably not breeding in the state.

There has been no quantitative habitat survey, but habitat may be marginal with limited areas of boreal forest. Competition for prey with coyotes and bobcats may limit lynx distribution (Adrian Wydeven, personal communication).

Minnesota

The status of lynx in Minnesota in the late 1800s and early 1900s is unclear due to possible confusion of early records with bobcats (McKelvey and others 1999). Lynx are a protected furbearer in Minnesota and the trapping season has been closed since 1984. Predator scent station and snow track surveys are conducted annually.

Lynx numbers in Minnesota reflect irruptions from Ontario and many records are assumed to be transient animals from Ontario, rather than a resident population. There were peaks in fur harvest returns in 1930, 1940, 1952, 1962, and 1973 (McKelvey and others 1999). In 1973, four hundred lynx were harvested in the state; in 1982, 42 lynx were harvested; and in the 1990s there has only been one record in Minnesota. These irruptions followed the snowshoe hare peak in each decade (Mike DonCarlos, personal communication).

Canada lynx are being studied in Minnesota. USFS, USFWS, USGS, and NRRI initiated the lynx ecology project over a year ago. There have been 14 lynx captured thus far. Several of these lynx have been fitted with GPS collars (the first study of lynx using GPS collars). Lynx appear to be most highly concentrated on the Laurentian Divide (between Lake Superior Watershed and Rainy Lake Watershed) where the snow accumulation is higher. The USFS has currently identified about 40 individual lynx from DNA collected from scats, hair, or tissue collected from the Superior National Forest. This study also was the first to document lynx-bobcat hybrids in the wild from three different hybrids.

Potential habitat for a resident, breeding population within the Lake Superior basin is restricted to portions of Cook, Lake, and St. Louis counties (published and unpublished data collected by L. David Mech; cited in DonCarlos 1994). Habitat consists of areas with snowshoe hare and no bobcats.

Ontario

Lynx are distributed throughout the Ontario portion of the Lake Superior basin. Populations fluctuate with snowshoe hare numbers, but range has apparently been stable (Dobbyn 1994). Lynx have no official protection status, except their classification as a fur-bearer.

Trapping records are the only quantitative population data available in Ontario (Neil Dawson, personal communication). In 2002, a survey was sent out to trappers in Ontario asking them to assess the population of furbearers, including lynx, during the 2001-02 trapping season. In the five districts that border Lake Superior, 228 trappers responded to the questionnaire. Thirty-nine indicated that lynx were not present, 67 said lynx were scarce, 79 stated lynx were common, and 43 reported lynx as abundant. Overall, lynx were considered common in all areas except the Sault Ste. Marie area where they were considered scarce.

Lynx habitat supply has not been quantified, but is probably not limiting (Neil Dawson, personal communication).

Woodland Caribou

Woodland caribou formerly inhabited most of the Lake Superior basin. By the late 1800s, their numbers were declining and their range was receding northward. Caribou disappeared from the U.S. part of the basin by the early 1940s (Hazard 1982) and they are now extirpated from Michigan, Wisconsin and Minnesota. In Ontario, the southern limit of caribou range receded from the north shore of Lake Superior in 1900 to northern Lake Nipigon at present (Figure 58). North of this line, caribou are more or less continuously distributed. Remnant populations are on the Slate Islands (several hundred animals), Pic Island, Neys Provincial Park, Pukaskwa National Park, and Michipicoten Island (introduced) (Harris 1999). Forest-dwelling woodland caribou are ranked as Threatened in Ontario (Harris 1999). The boreal population of woodland caribou was designated as Threatened at the federal level in Canada (COSEWIC May 2002). A recovery team was established in Ontario in 2001 and a recovery strategy is currently being prepared and scheduled for completion in spring 2004. Subsequently, recovery action plans will have to be developed in order to implement the recovery strategy.

Reasons for the decline include hunting, fire, land clearing, logging, increased predation, disease, and human disturbance (Darby and others 1989). Logging and human settlement caused forest fragmentation and loss of mature coniferous forest cover. Populations of moose and white-tailed deer increased with the changes in forest landscape. In Ontario, at least, wolves increased in response to the increased prey availability. Increased wolf predation, combined with increased hunting pressure, caused greater mortality for caribou. Their relatively low reproductive rate meant that caribou could not compensate for the increased mortality. Today, caribou within the Lake Superior basin are restricted to islands and other areas where they can avoid wolves, and where logging has not fragmented the landscape.

Forest management guidelines have recently been implemented in Ontario to protect caribou habitat by reducing forest fragmentation, protecting calving areas and minimizing human disturbance (Racey and others 1999).

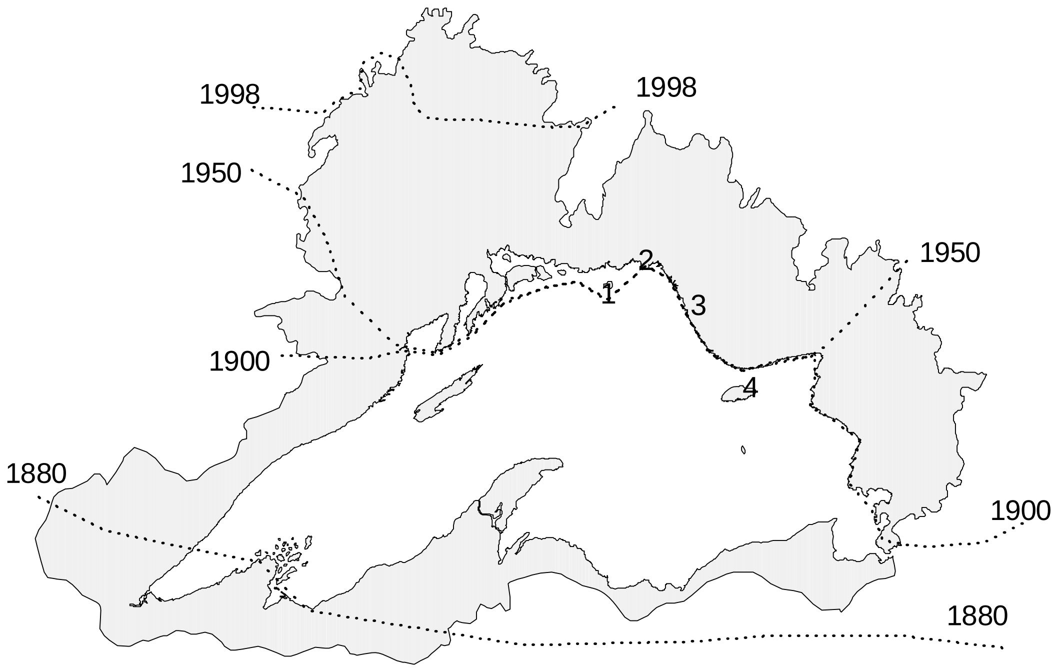


Figure 58. Historical and present distribution of woodland caribou in the Lake Superior basin. Dotted lines indicate southern limits of caribou distribution at various periods. Numbers indicate remnant herds: 1 – Slate Islands, 2 – Neys, Pic Island, 3 – Pukaskwa, 4 – Michipicoten Island (adapted from Darby and others 1989 and Armstrong 1998).

4.7.2 Key Birds of Concern

Bald Eagle

Populations of bald eagles declined sharply in the 1950s and 1960s as a result of contamination by toxic chemicals that accumulated in the food chain and affected reproductive success of eagles and other carnivores. Along the Lake Superior shoreline, bald eagles were nearly absent through the 1970s, but the population began to increase as the use of DDT was halted and DDE concentrations began to decrease. (DDE is a byproduct of DDT. It inhibits the action of the enzyme that is needed to transfer calcium carbonate to the eggshell.) Since the ban of DDT in the late 1960s, bald eagle numbers have increased throughout their range. In 1999, they were downlisted to Threatened in the U.S.

Within the Lake Superior basin, eagle numbers appear to have followed the same pattern of decline and recovery, but little specific data are available. Reproductive rates of eagles nesting along the Lake Superior shoreline are significantly lower than those nesting on inland lakes (1.0 vs. 1.3 young per active territory) (Dykstra and others 1998). Depressed reproduction rate was likely caused by low food availability and inclement weather. In Wisconsin, populations are increasing inland, but remain stable on the lake (Dykstra and others1998). Michael Hoff (U.S. Geological Survey, personal communication) suggests that burbot population dynamics play an important role in food availability, as well as the role of commercial fishermen in casting off unused catch.

Nesting habitat for Bald Eagles includes trees that are large enough to hold their massive nests. Red and white pine supercanopy trees are preferred in Minnesota (Coffin and Phannmuller 1988). Many of these nests are close to lakes or rivers, areas where the eagles scavenge for fish.

Figure 59 shows an assessment of bald eagle nesting habitat based on percentage of forested area and proximity to the shoreline, potential human disturbance, shoreline irregularity, available foraging habitat, and availablity of perching and nesting trees (Bowerman 1993).

Wisconsin
About 1,500 bald eagle pairs nest in Minnesota and Wisconsin, but less than five percent of these are along the Lake Superior coast (Bill Bowerman, personal communication). The number of occupied territories along the Wisconsin Lake Superior coastline tripled between 1983 and 1991 (Meyer 1992).

Figure 59. Potential bald eagle nesting habitat within 1.6 km of Lake Superior. Unshaded areas are considered unsuitable (Bowerman 1993).

Nesting habitat is considered good to excellent within the Lake Superior basin. However, housing construction is occurring at a record pace along lakeshores and riparian lands in northern Wisconsin, and it is not known what this threat poses for eagle nesting. Contaminant levels have declined dramatically in recent years and are no longer considered a threat to reproduction. Productivity of nesting eagles along the Lake Superior coast fluctuates from year to year depending on ice conditions and prey availability (Mike Meyer, Wisconsin DNR, personal communication).

On the Apostle Islands, there has been a fairly stable population of about five pairs for the last few years (Julie Van Stappen, Apostle Islands National Lakeshore, personal communication). Food shortage appears to limit population growth since there are many adequate nesting trees available and blood analysis indicates that contaminants are probably not impairing survivorship or reproduction. Spring ice packs restrict access to fish and the absence of deer on the islands limits late winter food availability.

Bald Eagles were delisted in Wisconsin in 1998. There have been annual surveys since 1985 but the future of these surveys is in doubt due to declining funds from the Adopt an Eagle Nest Fund.

Minnesota
The Minnesota population of bald eagles has increased dramatically since the 1970s and is now estimated at about 700 pairs. The last statewide survey was conducted in 1995, the same year that the birds were delisted. Based on current information (1999) in the Minnesota Heritage data, there are 41 eagle nests located in the Lake Superior basin. Most of these nests are in the interior away from Lake Superior (Maya Hamady, personal communication).

Habitat availability is probably the main factor limiting the number of eagles. Lake Superior probably offers poor foraging opportunities compared to inland lakes.

Michigan
The bald eagle is Threatened in Michigan. A state-wide survey is conducted each year to monitor breeding success. The state goal is to have 300 nesting pairs. The 1997 survey located 298 nests, of which 166 nests were in the Upper Peninsula. An estimate for the Lake Superior basin was not available and will be included in the final habitat report. The Michigan Department of Natural Resources also conducts mid-winter bald eagle surveys. In 1999, there were 235 eagles reported in the Upper Peninsula. The status of eagle habitat in the basin appears to be stable (Ray Rustem, Supervisor of the Natural Heritage Unit, Wildlife Division, MI DNR, personal communication).

Ontario
In Ontario, bald eagles are Endangered. The number of eagle nests along the north shore has been fairly stable for the last few years, although new nests are established as old ones are abandoned (Foster and others 1999).

In the Thunder Bay District, most of the larger inland lakes have established nesting pairs and there are a few nests along the Lake Superior coastline. There have been no recent surveys, but the population probably has not changed in the past few years (Steve Scholton, Thunder Bay District OMNR, personal communication).

The Lake Superior shore between Black Bay and Pukaskwa Park appears to consist of good habitat. The population has been fairly stable with 15 to 16 nests. Spring runs of rainbow trout and suckers are common and food supply should not be a limiting factor. Lake Nipigon has not been surveyed in a few years, but numbers have probably not changed dramatically in recent decades (Rosemary Hartley, Nipigon District OMNR, personal communication).

Seven active nests are in the White River to Montreal River portion of the watershed. Numbers appear to be growing and habitat does not appear to be a limiting factor (Joel Cooper Wawa District OMNR, personal communication).

The shoreline south of the Montreal River to Sault Ste. Marie has fewer than ten active nests. Habitat is adequate and there is room for more pairs (Jim Saunders, Sault Ste. Marie District ONMR, personal communication).

Eagle nest sites are recognized in timber management, and guidelines for their protection are applied in Ontario.

Peregrine Falcon

Peregrine falcon populations declined across North America due to nesting failure resulting from bioaccumulation of DDT and its metabolites. They disappeared as a nesting species from most of the Lake Superior basin by the mid 1960s.

Following the ban of DDT, efforts were initiated to re-establish peregrine falcons as a breeding species within the Lake Superior basin. Between 1988 and 1996, Minnesota released 40 young peregrines on the North Shore, and Michigan released 50 young birds on Isle Royale and 46 birds in the Upper Peninsula. Ontario released 87 birds in the Thunder Bay area and 38 near Sault Ste. Marie (Bud Tordoff, Ted Armstrong, personal communication). These efforts have succeeded in establishing nesting pairs (Table 21). In the Lake Superior basin, 90 young peregrines were banded in Ontario and 59 young were banded in Minnesota between 1996 and 1999.

The peregrine falcon was removed from the United States Endangered Species List in 1999. Michigan and Wisconsin list peregrines as Endangered, while Minnesota lists peregrines as Threatened. In Canada, peregrines are classified as Threatened at the federal level, but are considered Endangered in Ontario.

Peregrines nest on cliff ledges, often adjacent to water, but inland sites are also used. Artificial structures such as buildings, bridges, smokestacks, and quarries, are sometimes used. The best peregrine habitat in the Lake Superior basin is associated with the numerous large cliffs between the Pigeon River and the Nipigon River in Ontario (Ratcliff 1997, 1998, 1999). Almost half of the nests in the basin are in this area.

Current and potential peregrine territories are shown in Figure 60. “Potential” territories include historical nest sites that are not currently used and other cliffs that have been surveyed and assessed as being suitable (Ratcliff 1997, 1998, 1999; Bud Tordoff, personal communication). Due to the large amount of potential habitat available, and inaccessibility of most of this area, the estimate is a minimum number.

Overall, the status of peregrine falcon habitat is stable or increasing. Artificial structures increase the number of potential nest sites in the Lake Superior basin over historical levels.

Ontario
In 1998, there were 17 known territories occupied by peregrine falcon pairs and 3 territories held by single birds. In 1999, 12 territorial pairs and six single bird territories were located in the Lake Superior basin. In addition, there are at least six confirmed and suspected historical sites that probably could support peregrine falcon pairs (Ratcliff, 1997, 1998, 1999) (Table 21). In 2003, there were 38 territories comprised of 34 territorial pairs and 4 single birds on territory. Thirty-one nests were confirmed and 70 chicks were estimated to have fledged (Ratcliff 2003).

Minnesota
Historically, peregrines nested on five cliff sites along the northshore. As of 1998, there were eight pairs of peregrines along the North Shore, of which two used bridges within the city of Duluth and two nests were on mining structures (Bud Tordoff, personal communication). In 2003, surveys found 10 successful pairs within the basin as well as at least one non-breeding pair. Nineteen young were fledged by the 10 adult pairs (Tordoff et al 2003). There is potential for four more cliff nesting sites (Bud Tordoff, personal communication). Annual surveys are conducted throughout Minnesota checking both cliff sites and artificial structures.

Wisconsin
The small cliffs within the Wisconsin portion of the Lake Superior basin are not suitable for breeding peregrines. Except for artificial structures, habitat is very limited (Bud Tordoff and Sumner Matteson, personal communication). There are no historical records for this area and any future nesting sites will probably be on artificial structures. Wisconsin conducts annual surveys for peregrines, and, to date, all nesting sites have been on artificial structures, none of which are in the Lake Superior basin.

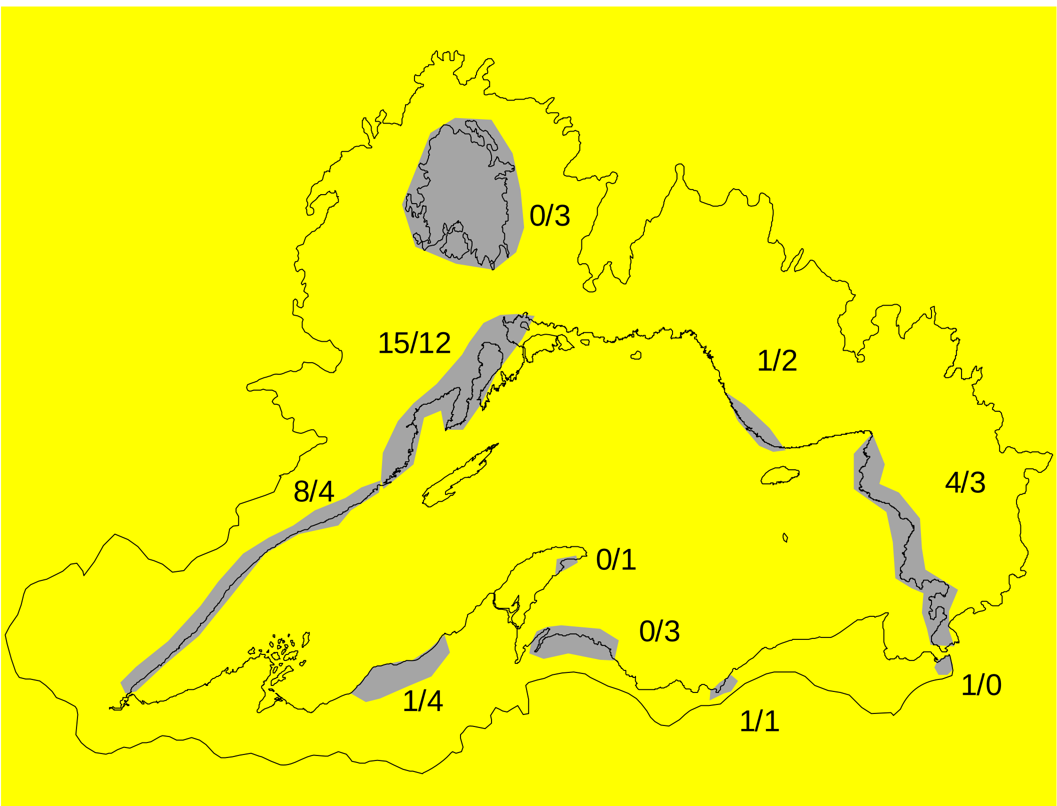


Figure 60. Peregrine Falcon Habitat in the Lake Superior basin. Numbers of current and additional potential territories are given (current number / potential number).

Michigan
Historically, peregrines nested at 13 cliff sites in the Upper Peninsula. There are four known cliff sites where peregrines nested during the 1990s (Bud Tordoff, personal communication), and in 1999 birds nested at two of these sites (Joe Rodgers, personal communication). In 2003, only one pair successfully fledged at least one young in the basin. A pair at the International Bridge at Sault Ste. Marie laid eggs

but were unsuccessful at raising young for the second year in a row. Two non-breeding pairs were also found within the basin (Tordoff et al 2003). Annual surveys for peregrines are conducted. There is good potential habitat in the Upper Peninsula (Joe Rodgers, personal communication) (Table 21).

Table 21. Current and potential peregrine falcon territories in the Lake Superior basin.

Location	Current Territories	Other Potential Territories
Ontario		
Pigeon River to Nipigon	15	12
Lake Nipigon	0	3
Pukaskwa to Michipicoten	1	2
Lake Superior P.P. to Sault Ste. Marie	4	3
Minnesota		
Northshore	6	4
Duluth	2	-
Wisconsin	-	-
Michigan		
Sault Ste. Marie	1	0
Porcupine Hills/Bergland	1	4
Pictured Rocks/ Grand Island	1	1
Bete Grise Bay	0	1
Huron Mountains/Champion	0	3
Total	**31**	**33**

4.7.3 Key Plants of Concern

Ginseng

Ginseng is at the northern edge of its range in the Lake Superior basin. Although relatively widespread in the southern parts of Ontario, Minnesota, Wisconsin and Michigan, its range within the basin is confined to Gogebic County in Michigan and adjacent Vilas County in Wisconsin (Argus and White 1984, Coffin and Pfannmuller 1988, Michigan Natural Features Inventory 1996). Ginseng is Threatened in Michigan, Special Concern in Wisconsin and Minnesota, and Rare (S3) in Ontario. At the federal level, ginseng is Threatened in Canada and Special Concern in the U.S.

Ginseng has declined throughout its range due to overharvest as an herbal medicine. This has resulted in loss of local populations and contraction of range.

Preferred habitat is rich hardwood forest with loamy soil, especially on slopes and ravines (Coffin and Pfannmuller 1988, Michigan Natural Features Inventory 1996).

Habitat related concerns include forest fragmentation (which inhibits natural reestablishment after harvesting), logging, heavy grazing by deer, and cattle grazing in woodlots (Michigan Natural Features Inventory 1996, Coffin and Pfannmuller 1988).

Ginseng export is regulated by the Committee on International Trade in Endangered Species (CITES). It is also protected by legislation in Michigan and Ontario.

Pitcher’s Thistle

Pitcher’s thistle is a Great Lakes endemic plant. Most of its range is on Lake Huron and Lake Michigan shores in Ontario, Michigan and Wisconsin. Habitat is open sandy beaches and dunes (White and others 1983).

On Lake Superior, Pitcher’s thistle is known from two locations: Oiseau Bay in Pukaskwa National Park (White and others 1983) and Grand Sable Dunes in Michigan (Voss 1996). A thorough search of other suitable habitat on the Michigan shore failed to find any additional populations (Voss 1996).

Threats to Pitcher’s thistle habitat include shoreline development, succession, shoreline modifications that change sand accumulation, and overgrazing from deer. A long term monitoring program in Pukaskwa National Park, Ontario, found that the population dropped from a maximum of over 700 plants to less than 200 plants following the failure of an upstream beaver dam, causing a creek to re-route its channel. The population remained low for five years, but then rebounded in 1996 (Promaine 1999). Periodic disturbances of this sort may in fact improve habitat conditions for the species by reducing competition from other species. This population is relatively secure from human trampling and overgrazing from deer.

A U.S. recovery plan for Pitcher’s thistle was released in 2002 (USFWS 2002). A Recovery Team has also been established in Ontario.

Lake Huron Tansy

Lake Huron tansy range extends from Maine and the Maritime Provinces, to Hudson Bay and northern Alberta. In the Great Lakes Region, it is found in northern Michigan, the Door Peninsula in Wisconsin, and eastern Lake Superior shore in Ontario (Soper and others 1989, Voss 1996).

Its preferred habitat is active sand dunes and upper sand or cobble beaches within the wave zone during high water. It occasionally grows in limestone crevices. Depauperate plants sometimes persist on older stabilized dunes (Voss 1996).

Lake Huron tansy is known from the Michigan portion of the Lake Superior basin from Alger, Luce and Chippewa counties in the Upper Peninsula (Voss 1996). In Ontario, it is found at the Sand River mouth on the eastern side of the lake (Bakowsky 1998). Ontario authorities (Argus and others 1982-1987) consider Lake Huron Tansy to be a subspecies of *T. bipinnatum*, which is common and widespread on the James Bay-Hudson Bay coast and therefore not considered to be rare in the province.

Houghton's Goldenrod

Houghton's goldenrod is another Great Lakes shoreline endemic. It typically grows in interdunal shoreline wetlands and low dunes and moist sandy beaches (Voss 1996). Fluctuating water levels of the Great Lakes play a role in maintaining its habitat. During high water, plants are submerged, but some plants survive the inundation and new seedlings establish on the moist sand (USFWS 1999).

Its primarily range is the northern shores of Lakes Michigan and Huron. In Michigan, it is found in the Lake Superior basin in Chippewa County (Voss 1996). Houghton's goldenrod is rare in Ontario, but is not known from the Ontario part of the basin (Oldham 1998, Semple and Ringius 1983).

Threats to Houghton’s goldenrod include trampling from foot and vehicular traffic associated with increased human activity on shorelines (USFWS 1999). Conservation efforts in Michigan include landowner contacts, monitoring, habitat protection in parks and reserves (USFWS 1999).

4.7.4 Other Rare Animals and Plants

Numerous other plants and animals in the Lake Superior basin are rare at the state or provincial level. These include species with fewer than 100 occurrences in the state/province (i.e., “S1,” “S2,” or “S3” following The Nature Conservancy rankings). Species that are rare in at least one state or province are listed in Addendum 6-A. It is important to note that some species listed here as rare are on the list because of habitat loss or population declines elsewhere in one or more of the states or the province. In some cases, such as with the kiyi, habitat in the Lake Superior area and populations of the species here are neither declining nor particularly degraded at the scale of the watershed. In these cases, habitat protection in the Lake Superior watershed is critically important.

Mammals

Three rare bat species: eastern small-footed bat, northern myotis and eastern pipistrelle are known from the basin, but are at the northern and western limits of their ranges. Suitable caves for hibernating may be a limiting factor (Coffin and Pfannmuller 1988).

Cougar and wolverine may have once inhabited the Lake Superior basin, but are apparently extirpated now. Occasional sighting of both species are reported, but these probably represent wandering individuals rather than a resident population. A 34 lb male wolverine was killed just outside of the basin boundary west of Thunder Bay in November 1996 and there have been a few credible, but unconfirmed, reports from within the northwestern portion basin in recent years. While reports of cougars within the basin are numerous, confirmations are lacking. A small number of cougars have been killed in Minnesota over the last decade and a few have been caught on film/video but these have been from outside the basin. Some cougar sightings may be escaped pets. Cougar and wolverine require large tracts of habitat with low human disturbance. Persecution by humans and large-scale changes in forest habitat probably contributed to their decline.

Birds

Over 50 bird species are considered rare in at least one state/province. This includes species that are rare in the southern portion of the basin, but abundant in Ontario (yellow-bellied flycatcher, Tennessee warbler, Swainson’s thrush).

American white pelican, although listed as endangered in Ontario, is increasing in numbers and expanding its range eastward. Pelicans now nest on Lake Nipigon in the Lake Superior basin, and may further expand their range since non-breeding birds are frequently seen on Lake Superior throughout the summer (Escott 1991, Bryan 1994).

Forest fragmentation and loss of mature forest cover threaten forest-dwelling birds, such as cerulean warbler and red-shouldered hawk (WI DNR 1999). Protection of extensive mature forested tracts, especially mature floodplain habitats in Wisconsin and Minnesota, will benefit these species.

Other threats to bird species include loss of wetlands (yellow rail, black tern), chemical contamination (merlin, osprey), and destruction of shoreline habitat (common tern).

Reptiles and Amphibians

Two rare species of reptiles are known form the Lake Superior basin. Wood turtle and Blanding's turtle are Threatened in Wisconsin and Minnesota. Wood turtle is Special Concern in Michigan and Vulnerable in Ontario. A Recovery Team has been established in Ontario. They are at the northwestern limit of their range in the Lake Superior basin.

Wood turtles inhabit small, clear fast streams with sandbars and meadows. In Michigan, they are distributed throughout much of the Upper Peninsula, but are restricted to small pockets of suitable habitat (Lee 1999). Wood turtles may be found in Ontario near Sault Ste. Marie. Overall, wood turtles are rare and declining in the basin. They are long-lived but do not reach maturity in northern latitudes until 14 to 18 years of age. A female lays one clutch of eggs, many of which are quickly taken by mammalian predators. A significant threat to wood turtles is the disturbance of nesting areas by recreational use of sandbars and sandy banks by off-road vehicles, canoeists, and anglers. Other threats include stream degradation, loss of forest cover along streams, and overcollecting for the pet trade and for food (Coffin and Pfannmuller 1988). The wood turtle's home range can be very small (0.25 ha) to relatively large (100 ha) (K. Smith, personal communication), making it vulnerable to habitat loss and direct exploitation. (Harding 1997; Oldfield and Moriarty 1994).

Blandings turtles live in rich wetlands near sandy uplands for nesting. Loss of wetland habitat, river channelization and dams are among the factors threatening populations (Coffin and Pfannmuller 1988).

Invertebrates

Rare invertebrates of the basin include 34 insect species and three molluscs. The distribution and abundance for some of these species is poorly understood and may be more common than their rankings suggest. Conversely, other rare species may be present, but not yet documented.

Several rare insects are associated with sand dunes and beaches. Beach dune tiger beetle inhabits sand beaches in the Ontario and Wisconsin parts of the basin. It is extirpated from some historical Ontario sites, possibly due to loss of habitat to shoreline development (Marshall 1999). Lake Huron locust is endemic to the Great Lakes region. It occurs on sand dunes along the Lake Superior coast in from Chippewa to Alger counties in Michigan and in northeastern Wisconsin (Rabe 1999). Preferred habitat is extensive, sparsely vegetated dunes with unstable sand and blowouts (Rabe 1999). Habitat loss from shoreline development and habitat degradation due to invasive weeds or disruption of sand movement cause populations to decline (Rabe 1999). Dune cutworm is a moth known from Whitefish Point in Michigan. It inhabits similar habitats and is threatened by similar factors as the Lake Huron locust (Cuthrell 1999a).

Plants

About 300 species of plants are considered rare at the state or provincial level in the Lake Superior basin. This represents approximately 10 percent of the total number of plant species growing in the basin (Thunder Bay Field Naturalists 1998, Coffin and Pfannmuller 1988). Many of these species are at the periphery of their range and have always been rare here. Some species are rare in one of the states/province, but common in others.

A breakdown of Minnesota's rare plants by habitat consists of 40 percent wetland species, 17 percent cliff/bedrock species, 15 percent prairie species, and 13 percent upland forest species. The rest are found in successional or transitional habitats. Most (78 percent) rare plant populations in Minnesota occur outside of protected areas (Coffin and Pfannmuller 1988).

Threats to rare plant populations include, logging, plowing native prairies, and water quality changes.

Some areas have higher concentration of rare plant habitats because of unusual features of climate, geology, and glacial history (Coffin and Pfannmuller 1988). Areas with concentrations of rare plant habitats are shown in Figure 61 and described in Table 22.

The moonworts (*Botrychium spp.*), consisting of several species of small ferns, deserve special mention. The majority of the global range of three of these species falls within the Lake Superior basin. They are false northwestern moonwort (*B. pseudopinnatum*), pale moonwort (*B. pallidum*), and pointed moonwort (*B. acuminatum*) (Wagner and Wagner 1993). Habitat for these species is primarily open sandy areas, dunes, and old fields.

Table 22. Rare plant habitats. Refer to Figure 61 for locations (Argus and others, Coffin and Pfannmuller 1988, Epstein and others 1997, Soule 1993).

	Area	Description	Example species
1	Northshore Islands and shorelines	Arctic-alpine disjunct species	*Oplopanax horridus, Carex atratiformis*
2	Sibley Peninsula	Cliff communities, calcium-rich bedrock	*Malaxis paludosa, Arnica cordifolia*
3	Stanley Prairie	Relict prairie community	*Erigeron glabellus, Stipa comata*
4	Nor'Wester Mountains and Minnesota Border Lakes	Open cliff base and rim communities	*Calamagrostis purpurescens, Senecio eremophilus*
5	Minnesota Northshore	Arctic-alpine disjunct species	*Sagina nodosa, Draba norvegica*
6	St. Louis River Estuary	Wetland communities	*Sparganium glomeratum, Petasites sagittatus*
7	Bayfield Peninsula	Boreal species, wetlands	*Armoracia lacustris, Huperzia selago*
8	Apostle Islands	Boreal and sub-arctic species	*Senecio indecorus, Pinguicula vulgaris*
9	Isle Royale	Arctic-alpine disjunct species	*Calamagrostis lacustris, Phacelia franklinii*
10	Keweenaw Peninsula	Coastal communities, arctic- alpine species	*Arnica cordifolia, Chamaerhodos nuttallii var. keweenawensis*
11	Eastern Michigan shoreline	Sand dune species	*Cirsium pitcheri, Tanacetum huronense*

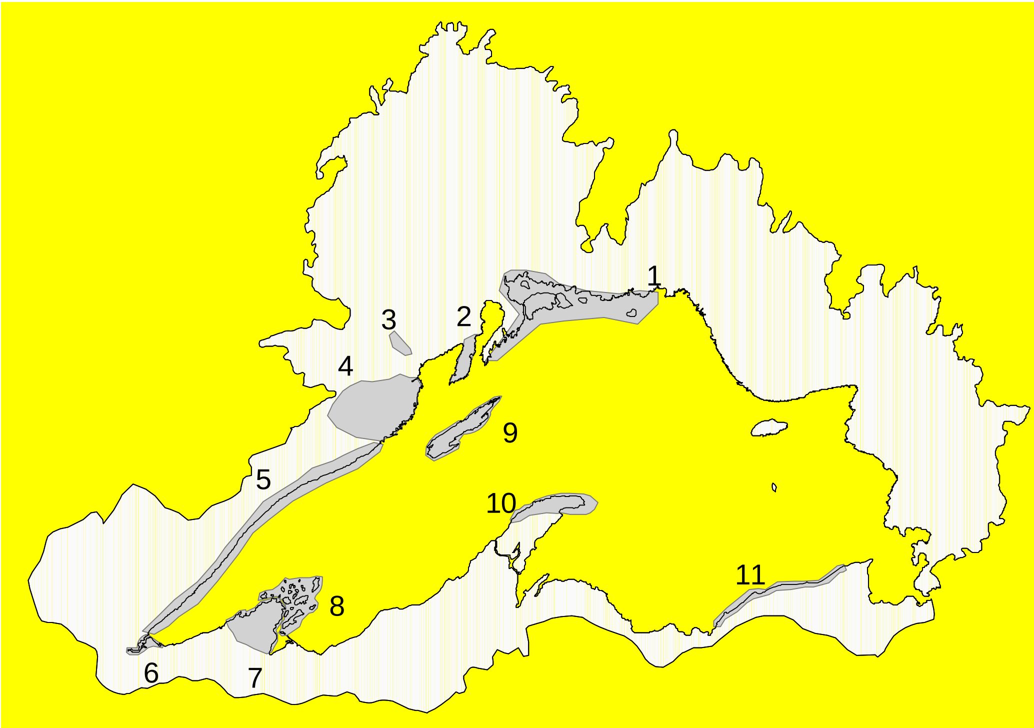


Figure 61. Rare plant habitats. Refer to Table 22 for descriptions.

4.7.5 Rare Communities

The Lake Superior basin is home to several globally rare vegetation communities. Many are directly dependent on lake processes for their existence and support many of the rare species that inhabit the basin (Reid and Holland 1997). In addition to some of the more prominent rare community types described in this section, the basin includes Oak Savannas and Alvars. A list of globally rare communities known from the Lake Superior basin is in Addendum 6-B. This list continues to be revised and updated as inventory work by the state and provincial agencies progresses.

Sand Dunes
Several communities associated with Great Lakes sand dunes are ranked as globally rare by the Nature Conservancy. Dunes form as sand is eroded from glacial sediments by waves and streams, moved along the coast, and deposited. Wind continues to move the sand, maintaining a continuously changing environment.

Coastal dunes have a characteristic series of zones. Foredunes develop closest to the beach, where vegetation such as marram grass and American dune grass forces the winds to drop sand. Other plants such as beach pea and wormwood are established as the foredune grows. Trees and shrubs such as white spruce, trembling aspen, sand cherry, dogwood, and willows eventually gain a foothold (Reid and Holland 1997).

Interdunal areas lie protected from wind and waves behind the foredunes. These areas include globally imperiled communities called interdunal wetlands (pannes) which are calcareous, depressions kept moist by the water table. Vegetation in interdunal wetlands includes shrubby cinquefoil, twig-rush and baltic rush (Michigan Natural Features Inventory 1999a).

Wooded dune and swale community complexes develop as postglacial uplift causes the lake level to recede, leaving dunes outside the direct influence of the lake and allowing new foredunes to form. Over several thousand years, this eventually results in a series of ridges and swales. Streams and groundwater keep the swales moist. Forest eventually develops on the older dunes. Jack pine, red pine and white pine are the dominant tree species, with white cedar and wet meadow in the swales (Michigan Natural Features Inventory 1999b).

The largest and most extensive dunes on Lake Superior are at Grand Sable Dunes National Lakeshore. Some dunes here are in the range of 100 m high (Reid and Holland 1997). Ontario's dunes are small, scattered cove dunes that develop in rocky coves of irregular coastlines. The largest examples are in Neys Provincial Park (0.9 km^2), at the mouths of the Pic and Sand rivers (0.4 km^2 each) (Bakowsky 1987).

Rare species found in dune habitats include Lake Huron Tansy, Houghton's goldenrod, Pitcher's thistle, Lake Huron locust, piping plover and dune cutworm.

Dunes are threatened by shoreline development that displaces native species and disrupts natural sand migration. A breakwall near Grand Sable Dunes was expanded in the 1950s and may be interfering with long shore drift and altering dune-forming processes (Loope 2003). Elsewhere, off-road vehicles and other recreational use increase erosion. Sand mining, logging of forested dunes, and exotic plants are other threats (Michigan Natural Features Inventory, 1999a, 1999b).

Sand Beaches
Great Lakes sand beaches are considered globally rare by the Nature Conservancy (Addendum 6-B).

Lake Superior has a total of 665 km of sand beach (Canada 256 km; U.S. 409 km), predominantly on the southern shore (Figure 62). The longest sand beach is a sand spit at the mouth of Chequomegon Bay in Wisconsin at 21 km in length. There are 161 sand beaches greater than 1 km long (Canada 60; U.S. 101), but most are short, narrow stretches. The Apostle Islands National Lakeshore has a very diverse collection of sandscapes, including sandspits, cuspate forelands, tombolos and a barrier spit. On Madeline Island there is a significant barrier beach in Big Bay State Park.

Sand beaches typically consist of a series of zones. The *lower beach* is scoured by waves and devoid of vegetation. The sparsely vegetated *middle beach* collects debris deposited by storms. The *upper beach* is vegetated with biennials and perennials such as wormwood and beach pea (Reid and Holland 1997). On Lake Superior, sand beaches are often associated with sand dunes, river mouths, and sheltered bays.

A number of rare flora and fauna are associated with sand beaches, many of which are shared by sand dune communities. These include Pitcher's thistle, Lake Huron Tansy, and piping plover. Many smaller beaches may be too small and isolated to support many of the plants and animals characteristic of the larger beaches.

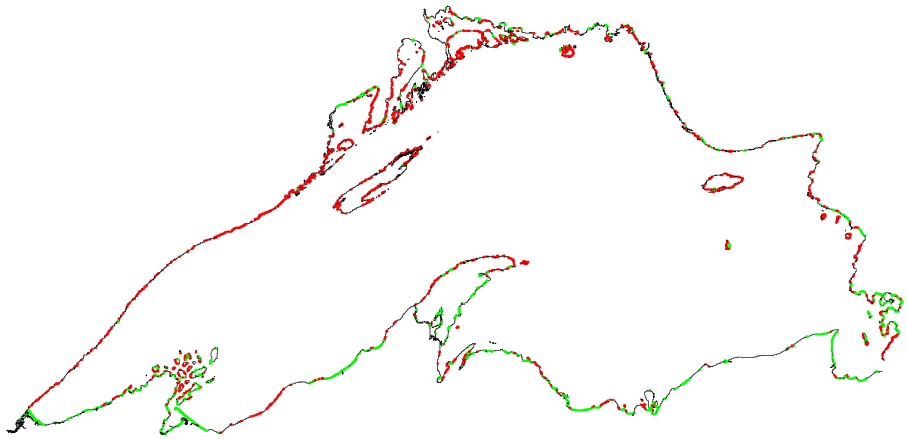


Figure 62. Sand (green) and cobble / gravel (red) beaches (compiled from U.S. EPA 1994 and Environment Canada 1993).

Most sand beaches depend on the natural processes of erosion, longshore sediment transport and sand deposition. When groins and other artificial shoreline structures interrupt these processes, the beach habitat is altered. Specialized beach plants can be out-competed by other species as the environment becomes more stable (Reid and Holland 1997). Increased recreational use threatens piping plover and other sensitive species on some beaches.

Cobble and Gravel Beaches

Cobble and gravel beaches are common along rocky shorelines. Cobbles are rock fragments 7.5 to 25 cm in diameter; gravel is 2 mm to 7.5 cm in diameter. Little vegetation is present due to exposure to severe wave and ice action and lack of soil. Great Lakes cobble and gravel beaches are considered to be globally rare by the Nature Conservancy (Addendum 6-B).

Cobble and gravel beaches are most common along the Minnesota north shore, Isle Royale, the Keweenaw Peninsula, the Sibley Peninsula, and islands along the Ontario coast (Figure 62). These beaches make up 958 km of the Lake Superior shore (Canada = 541 km – includes “cobble,” “pebble,” and “pebble and cobble” classes; U.S. = 417 km – includes “gravel” class).

Arctic-Alpine Communities

Arctic-alpine disjunct communities consist of plants that are isolated from their primary range in the far north or in alpine tundra. These communities are associated with the cold rocky shores of Lake Superior, where they have persisted since the retreat of the Wisconsin glacier.

Typical species include yarrow, bearberry, bluejoint grass, rocky mountain fescue and spreading juniper. Other arctic-alpine disjunct species include mountain avens, alpine chickweed, rock cranberry, butterwort, wild chives, Norwegian whitlow grass, northern eyebright, and alpine bistort (Bakowsky 1998, Reid and Holland 1997). Over 400 species of lichen are associated with this environment. Two lichen species, *Coccocarpia cronia* and *Umbilicaria torrefacta*, are found only on the Susie Islands in western Lake Superior (Reid and Holland 1997).

Arctic alpine communities are usually associated with base-rich rocks such as basalt or diabase (Bakowsky 1998). Some of the best examples can be found at Sleeping Giant Provincial Park Ontario, the Slate Islands Ontario, the Susie Islands Minnesota, and Passage Island Michigan (Bakowsky 1998, Givens and Soper 1981, Judziewicz 1997).

Glaciere talus is another environment supporting arctic-alpine flora (Bakowsky 1996). This community is known from several canyons near Thunder Bay, Ontario. The steep walls block sun from reaching the canyon floor and allow ice to persist beneath talus boulders for most of the summer. The cold microclimate allows a number of arctic-alpine species to persist.

Arctic-alpine disjunct communities are generally protected from disturbance because they are inaccessible, but second-home development, recreational use, and trampling of vegetation have the potential for significant vegetative impact (Reid and Holland 1997).

Pine Barrens

Pine barrens are defined as areas of deep sands with scattered, pine trees, and a ground layer of sedges and forbs. ,They have poor, sandy soils and frequent fires (Reid and Holland 1997). The flora often includes prairie species. Pine barrens are closely associated with oak barrens, sand barrens, savannahs, dunes, and prairies.

In the Lake Superior basin, pine barrens are found in the Western Superior Section (212K) (see Figure 22). Pine barren vegetation consists of jack pine, red pine, junipers, shrubs such as sand cherry, little bluestem and other grasses, sedges and forbs. Soils are sandy glacial outwash (Albert 1995).

Less than one percent of northern Wisconsin's jack pine barrens remain today (Reid and Holland 1997). Large areas are managed as jack pine plantations for pulpwood. Fire suppression has allowed non-native species to invade and permitted the forest to succeed to more closed conditions. Recreational development is another threat (Albert 1995).

4.8 Areas of Quality

The Binational Program's Habitat Committee has developed ecological criteria for identifying components of the Lake Superior system that warrant special attention. Areas of quality include significant ecosystems, communities, and species habitat. Addendum 6-D is an inventory of important habitat sites in the Lake Superior basin.

5. THE TRANSITIONAL ENVIRONMENT

5.1 Shorelines

Shoreline Development

Compared with the other Great Lakes, the Lake Superior shoreline is still relatively undeveloped. On the U.S. side, substantial portions of the eastern shoreline and some sizable tracts in the western basin are under federal or state ownership. About 90 percent of the Ontario shoreline is owned by the provincial government. A significant portion of the Lake Superior shoreline is protected in parks and protected areas. However, shoreline development is an increasing concern on Lake Superior.

Shoreline habitats represent the fragile interface between the land and the lake and are particularly sensitive to human stresses. Stresses associated with shoreline development include disruption of natural erosion and sedimentation processes by groynes and other structures, water level regulation in the basin, filling wetlands, increased human disturbance of wildlife, and increased pollution from wastewater, stormwater runoff, and septic fields (Thorp and others 1997).

Lake Superior is increasingly viewed as a desirable location for residential use in both rural and urban settings. Large parcels of privately owned land are now regularly subdivided for potential residential development as the market demand increases for waterfront homes. Shoreline development is increasing most quickly along the North Shore in Minnesota, the Bayfield Peninsula in Wisconsin, and the Keweenaw Peninsula in Michigan, largely because they are within a half-day drive from large metropolitan areas. For example, Bayfield County in Wisconsin, which has more than half its land base in the Lake Superior basin, has seen significant land price increases in the last few years. Property values increased 21.64 percent from 1998 to 1999, which was the second highest increase in Wisconsin (Wisconsin Department of Revenue 1999). The Keweenaw Peninsula on Michigan's Upper Peninsula has seen unprecedented growth in the past 20 years, mainly as the result of recreational home building. Over 50 percent of the homes in Keweenaw County are now classified as second homes. Some of the most scenic lakeshores, home to unique ecological communities and rare plants, are frequently the same areas being subdivided or subject to other development proposals. The placement of raised sand septic fields in shallow soiled rocky headlands and the filling of sensitive wetland habitats are specific concerns. In Ontario, this trend is greatest along the shorelines east and west of Thunder Bay and north of Sault Ste. Marie. Development is not yet as extensive as in Minnesota and Wisconsin.

Most of Superior's shores are rocky and exposed to heavy wave action. Most cities, marinas, and cottage developments are located in protected estuaries and embayments, which are also important habitats. Prime building spots are rare. Rocky bluffs sport rows of huge steel and wood stair complexes giving recreational homeowners the ability to reach the water. They construct piers of stone, rock and concrete to protect their boats from the lake. Homeowners tend to remove trees, shrubs, and vegetation to gain a better view of the lake.

Highways also hug many kilometers of Superior's shore, and new homes often are squeezed into the ribbon of land between the road and shore. Homes allowed too close to the shore areas of Lake Superior are exposed to flooding during high water or storm events, causing erosion, property damage, and shore edge destruction.

The increase in residential and cottage development, and the associated infrastructure, can dramatically impact sensitive shoreline habitats. These impacts include the construction of access roads that fragment wildlife travel corridors, removal of native shoreline vegetation, construction of harbours and marinas in sensitive estuaries, lake filling, and construction of erosion control structures or breakwalls that impair natural sediment transport processes. In some cases, residential developments permitted in areas of shallow soil or rocky headlands can also lead to temporary or long-term contamination of land and water resources through faulty septic systems.

Approximately five percent of the Lake Superior shoreline consists of artificial, made-made structures (Figure 63). Much of the artificial shorelines is concentrated near cities at the mouths of the larger rivers (Nipigon, Kaministiquia, St. Louis) and in many cases is probably replacing wetland habitat. Other areas with significant artificial shoreline are the Bayfield Peninsula (presumably associated with erodable red clays) and the Keweenaw Peninsula.

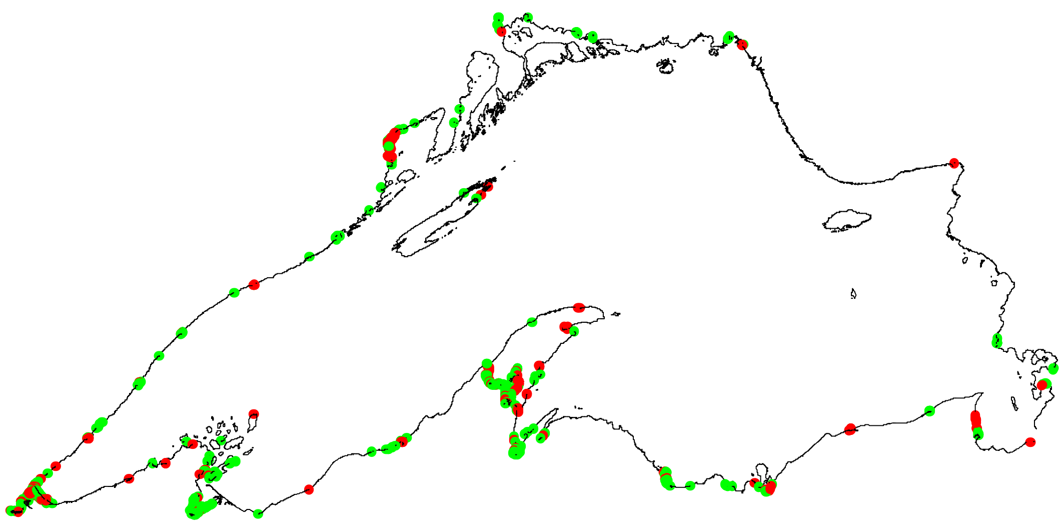


Figure 63. Artificial shorelines: red is retaining walls, harbour structure, and breakwater; green is rip-rap (Compiled from U.S. EPA 1994 and Environment Canada 1993).

The impact of shoreline development on Lake Superior habitat is a primary focus of many management forums. The binational State Of the Lakes Ecosystem Conferences (SOLEC) present papers that describe shoreline processes and explore stresses on these habitats. The intent is to report on the state of the Great Lakes ecosystem and the major factors impacting it and to provide a forum for exchange of this information among Great Lakes decision-makers.

Shoreline Regulation

Uncontrolled development takes many forms, including industrial, agricultural, commercial, and residential, and can lead to significant cumulative impacts for natural shoreline habitats. There is no comprehensive data on the extent, distribution, or trends in shoreline development on Lake Superior. Information of this type would need to be obtained from individual municipal offices, permit review agencies (i.e., OMNR and DFO) and other land use control sources.

From a regulatory perspective, the issue of land-use planning along Lake Superior's shoreline is complex. The responsibility for land-use decisions is fragmented among many government regulatory agencies. Often the decision-making authority rests with small local municipalities or county governments that are ill-equipped to handle thorough environmental assessments. In many cases, these local governments encourage shoreline development as a mechanism for increasing their tax base.

Overall, there does not appear to be a comprehensive mechanism in place to determine the impact of shoreline development approvals. Nor does there appear to be a process for the implementation of uniform development standards across the basin (i.e., set-back requirements) for new shoreline developments in the Lake Superior basin (Thorp and others 1997). Although some regions may be making individual efforts to compile statistics on the subdivision of shoreline properties, significant data gaps exist. There needs to be a better understanding of the cumulative consequences of local land-use decisions in relation to shoreline habitat impacts.

One positive trend has been the reclamation of former industrial lands in some urban communities. Recent shifts in markets, has in some waterfront cities, reduced the industrial demand for shoreline sites. As a result many urban centres have recently focused their attention on developing strategic waterfront plans that encourage the acquisition of former industrial lands in an effort to improve public waterfront access or to encourage the restoration of green space along the shore. This trend may continue in many centers within the Lake Superior basin.

Communities struggle with the issues of economy vs. environment but new solutions are being found. Responding to requests from the local officials concerned with the explosive growth, Wisconsin has spent $2 million in the past three years to help local governments develop a lake classification system. The idea is to guide development in sensitive lakeshore areas on inland lakes. Twenty-seven northern counties are developing stronger land use strategies and rules on their shorelines.

Specific basin-wide needs include:

- Inventorying current educational programs and materials regarding shoreland development.
- Reviewing current zoning and land use ordinances and their enforcement.
- Continuing research on the impacts of shoreline development.
- Working with and bringing together local communities, government units and concerned individuals to develop long-term solutions and visions for the Lake Superior shorelands.
- Discussing the possibility of developing a Lake Superior-wide set of building standards.

Lake Level Management

For over 150 years, the outflow of Lake Superior at Sault Ste. Marie has been modified to improve navigation and hydroelectric generation (Environment Canada 1993). Power canals and navigation channels increased the amount of water that could be discharged. The increased capacity required the construction of control works to compensate for the increased outflow capacity from Lake Superior.

The Lake Superior Board of Control was established to supervise the operation of all control works, canals, headgates, and bypasses and to formulate rules for them. The Board's goal is to regulate the level of Lake Superior in such a matter as not to interfere with navigation, protect the sport fishery in the rapids of the St. Mary’s River, and ensure adequate flow for hydroelectric generation. Flow regulations also help prevent ice jams in the St. Mary’s River.

Regulation of Lake Superior also depends on water levels in the lower Great Lakes. Regulating outflow from Lake Superior can compensate for extreme high or low water levels in Lakes Michigan and Huron.

One of the main objectives of the IJC’s 1914 order was to maintain Lake Superior levels within a more narrow range than was recorded through past monitoring history. However, this objective soon proved impossible when record high and low water levels occurred in later years. In the 1950s, the maximum water level as prescribed in the 1914 Order was exceeded. During the mid-1950s to the 1960s, water levels were also frequently below the minimum level.

In the mid-1960s, when water levels were extremely low on lakes Michigan and Huron, Lake Superior was used to help alleviate the situation on these lakes. Permission was granted to discharge outflows greater than the regulation plan. In the early 1970s, Lake Superior flows were reduced as part of an emergency action since water levels were critically high in the lower Great Lakes.

In the spring of 1985, Lake Superior’s outflows were again reduced because of high water levels in the lower Great Lakes. However after four months of flow reductions it became necessary to reverse procedure and increase outflows since large amounts of precipitation on the Superior basin had caused the Lake to climb to a record high level. Continued rains saw Lake Superior levels exceed the level of 186.86 m for a period of two months despite allowing the largest outflow on record.

The presence of Lake Superior compensating facilities does not mean that full control of Lake Superior’s water level is attainable or desirable. Lake Superior levels are greatly affected by natural conditions that cannot be controlled, such as evaporation, runoff, and over-lake precipitation. Since these factors cannot be accurately predicted, levels on Lake Superior remain largely a product of natural occurrences (IJC 1993, Tushingham 1992).

The effects of water level regulation on the lake ecosystem are not well understood. The reduced range of high and low water levels influences wetland and shoreline plant communities, but site-specific studies are needed to evaluate the effects of fluctuating water levels on the Great Lakes fishery. Wilcox and Whillans (1999) call for the restoration of natural lake level fluctuations on Lake Superior to restore wetland hydrological processes.

Water Diversion Projects

Waters from the Albany River basin, which formerly flowed into Hudson Bay, have been diverted from the Ogoki and Kenogami rivers and now flow into Lake Superior. The purpose of the diversions was to increase flows at hydroelectric dams and improve log drives.

The Long Lac diversion was established in 1939. It consists of a concrete overflow dam on the Kenogami River at Long Lac. The diverted water passes through a channel built across the watershed divide and into the Aguasabon River, which drains into Lake Superior. A concrete dam at the end of the channel regulates flows. Since 1940, an average of about 40 cubic meters per second (cms) has been diverted to Lake Superior (IJC 1976). Electricity is generated at a power plant near the mouth of the

Aguasabon River in Terrace Bay. This diversion was also used for the transport of pulpwood logs southward.

The Ogoki diversion was established in 1943. It redirects water from the Ogoki River into Lake Nipigon, which flows into Lake Superior via the Nipigon river system. The Waboose Dam on the Ogoki raises water levels so that most of the flow is redirected across the watershed divide, and then through a number of small lakes into the Jackfish River and into Lake Nipigon. The Summit Dam controls the amount of diverted water. The diversion discharges an average of 113 cubic meters per second (cms) (IJC 1976). Since 1943, the diversion has had closures and reduced flows on at least 25 occasions for a variety of reasons. A generating station at Pine Portage at the top of the Nipigon River controls the outflow. Pine Portage generating station is the first of three hydroelectric plants on the Nipigon River. A minimum flow of 227 cms is required to ensure appropriate water levels for the town of Nipigon's water supply system. Flows in excess of 566 cms would endanger the railway and highway bridges at Nipigon.

In 1951-53, the volume diverted from the Ogoki River was reduced during a period of high water. Diversion of water was stopped for a numbers of months in each of these high water years. Ontario Hydro reduced water diversions again during 1972-74. During this period the outflow through the Nipigon River was reduced to natural levels and diversion waters were stored in Lake Nipigon. Once Lake Nipigon reached peak levels, water diversion was completely halted and Ogoki flows were temporarily diverted north again.

The Long Lac and Ogoki diversions have had significant local environmental effects resulting from the initial construction and operation of the diversion structures, channels, and reservoirs. Greatly altered flow regimes and the accumulation of bark and other woody debris from log drives represent a continuing stress on the local environment and negatively impact upon fish spawning habitat. Lower reaches of the Little Jackfish River on the Ogoki Diversion experience severe erosion of unconsolidated glaciolacustrine sediments which has resulted in increased siltation and turbidity stresses of the Obamika Bay on Lake Nipigon. This has contributed to the decline of the walleye fishery and may also be responsible for the increase in sauger compared to walleye (Bridger and Day 1978).

The Long Lac and Ogoki diversions have also had significant hydrological effects on the Great Lakes. The mean water level of Lake Superior has increased by 6.4 cm, Lakes Migichan-Huron by 11.3 cm, Lake Erie by 7.6 cm, and Lake Ontario by 6.7 cm. The changes in water level attributed to the diversions result in an estimated annual loss of $4.8 million due to erosion and flooding. However, direct benefits to the pulp and paper industry (located on the Aguasabon River), navigation (higher water levels permit greater loads), and power generation are estimated to exceed the calculated losses by $57 million annually. The effects of water level increase on recreational boating and beach use have not been quantified for Lake Superior, but generally raising water levels benefits boating and harms beaches. No basin-wide negative environmental effects have been documented for these two diversions (IJC 1985). No introductions of aquatic species from the Arctic watershed have been reported.

Recreational Use

The waters and shoreline of Lake Superior have witnessed a significant growth in the volume and range of water and land based recreational activities. The impacts of leisure and recreational pursuits on water quality and shoreline habitat are largely unknown. This assessment of habitat stress related to recreational activities is drawn from anecdotal evidence from park and resource managers and members of the academic communities within the Lake Superior basin.

Commercial and private shoreline development has significantly changed the complexion and composition of natural habitats along extended sections of the Lake Superior shoreline. Developments, together with access roads and associated leisure facilities are the most visible consequences of leisure and recreational use of the lake.

The development of marinas (for example at Red Rock, Nipigon, and Michipocoten Harbour in Ontario and Silver Bay and others on the Minnesota shore in various stages of advanced planning) reflects increases or anticipated increases in motor and sailboat traffic. Marina facilities inevitably concentrate boating activity and may amplify the impacts of fuel spillage, jetsam, and unsanitary discharge of solid wastes. Conversely, if used as intended, marina facilities could help mitigate some of the impacts of increased boat traffic on the lake. Commercial cruise ships are a recent phenomenon on Lake Superior. Small boats onboard the ships allow guests to disembark and explore remote and secluded shorelines. This eventuality could see repetitive, large group use of offshore islands or otherwise secluded bays and coves.

Sea kayaking is one of the fastest growing recreational activities in Apostle Islands National Lakeshore, Pukaskwa National Park, and along the Rossport/ Nipigon island archipelago. Kayakers have the ability and a preference to visit and camp in secluded bays and inlets. Pictured Rocks National Lakeshore and other high-use kayak areas have expressed a concern regarding the concentration of debris and the unsanitary disposal of human waste in backcountry campgrounds. Monitoring plots have been located within the Pictured Rocks area; however, no long-term data are yet available.

Research regarding the effects of air emissions and gas and oil leaching from two cycle engines as found in snowmobiles and personal water craft has been conduced in some U.S. national parks; however, no data were located for the Lake Superior basin. Both sledding and personal watercraft are popular recreational activities on or near Lake Superior. The noise of these activities and the pattern of repetitive use of trails or nearshore waters may disrupt wildlife use of otherwise suitable habitats.

Off-road trucks and all-terrain vehicles have significantly impacted some shoreline habitats. Blowouts and denuded sandscapes in the Pic River dune complex and in the Michipicoten Bay area of Ontario are the scars of repetitive use by vehicular traffic. Similar impacts have been reported in areas within and adjacent to the Picture Rocks National Shoreline, Michigan.

Evaluated individually, recreational activities have small or localized impacts on the shoreline habitats of Lake Superior. However, the cumulative effects of recreational activities may degrade the integrity of natural patterns and processes. The subtleties and extended time frame of these changes make it impossible to link a recreational activity that is perceived to be beneficial or benign to a change or stress in the natural habitat.

5.2 Coastal Wetlands

The greatest threats to Lake Superior's wetlands (Figure 64) are water level regulation and site-specific stresses such as shoreline development (Chow-Fraser and Albert 1998). Other threats include invasive species and diminished water quality (Epstein and others 1997).

Loss of wetland habitat has been small in Cook (zero percent loss) and Lake (two percent loss) counties, Minnesota (MPCA 1997), but most of the St. Louis River estuary wetlands at Duluth / Superior have been lost since the early 1900s (Epstein and others 1997). The wetlands of the Apostle Islands, Bad River and Kakagon Slough are largely intact (Chow-Fraser and Albert 1998).

Wetland loss in Ontario has not been quantified, but is probably low (0 to 25 percent) for most of the basin, given the low intensity of land use (Detenbeck and others 1999). In local areas, however, wetland losses are substantial. Wetland area around the city of Thunder Bay has declined by over 30 percent since European settlement (NWWG 1988). Lake Superior shoreline wetlands are a particular concern in Ontario, given their scarcity and proximity to developed areas. Continued cottage development at Cloud Bay, Sturgeon Bay and Pine Bay threatens wetlands (Maynard and Wilcox 1997).

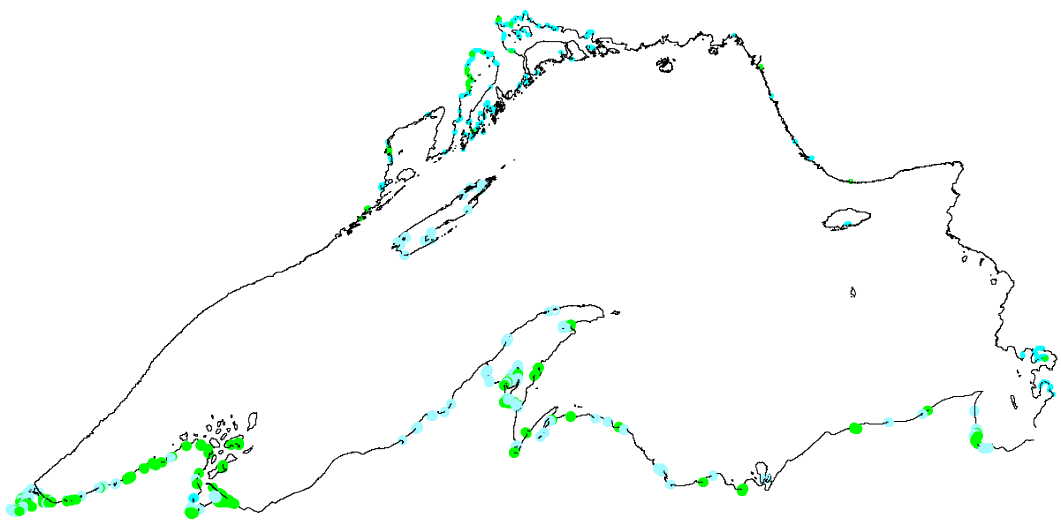


Figure 64. Lake Superior shoreline wetlands: extensive (green) and fringing (blue) (compiled from U.S. EPA 1994 and Environmental Canada 1993).

No estimate is available for the amount of coastal wetlands lost on Lake Superior. No large-scale losses have occurred along the north shore because the shoreline is remote and sparsely populated. However, considerable wetland area has been lost within the Areas of Concern at Thunder Bay, Nipigon Bay, Jackfish Bay, and Peninsula Harbour due to shoreline modification and urban encroachment (Wilcox and Maynard 1996). On the other Great Lakes, 11 to 100 percent of historical wetland area has been lost (LSBP 1995a). Nutrient enrichment and toxic contamination of waters and sediments and modified water level fluctuations are other potential threats to Lake Superior wetlands (Wilcox and Maynard 1996).

Water level regulation on Lake Superior has affected all coastal wetlands by restricting the natural flooding and drawdown cycle. In an unregulated wetland, periodic flooding kills back woody species along the fringe, allowing less competitive wetland plants to occupy the zone. Drawdown below the average water level allows the seed bank to germinate and promotes oxidation of substrates. Maintaining relatively constant water levels result in a smaller and less diverse wetland zone. On Lake Superior, although the flooding – drawdown cycle hasn't been altered substantially, the extreme low water levels are probably not frequent enough to maintain natural wetland conditions (Maynard and Wilcox 1997). No data on changes in wetland vegetation due to water level regulation are available. Similar effects occur on wetland on inland lakes and streams with altered water level regulation (Wilcox and Whillans 1999).

Shoreline alteration influences wetlands, both through direct loss of wetland area and disruption of hydrological and sedimentation processes. Wetlands enclosed by groynes, dykes, and breakwalls have reduced supplies of sediments that naturally nourish the shoreline and replace eroded sediments (Maynard and Wilcox 1997). By obstructing natural disturbances, such as storms and ice-scour, artificial structures cause shifts in plant species composition of enclosed wetlands.

Dredging

In Lake Superior, dredging has been taking place since the early 1900s. Dredging involves removal of lake bottom sediments to maintain shipping and recreational boating channels. In the period 1937 to 1972, 68.7 million m^3 were dredged from Lake Superior (Edsall and Charlton 1997).

Dredging can have harmful impacts on wetlands. In addition to loss of wetland area, dredging in shallow waters near wetlands can create new channels, altering water movements and changing nutrient regimes and plant communities (Maynard and Wilcox 1997). Dredging can also cause lower water tables and increased sediment loading in the rest of the marsh. Deepening the water adjacent to the marsh can prevent the natural migration of the marsh boundary during low water years.

Disposal of dredged material can also alter habitats. Dredge spoils are sometimes deposited in shorelines, filling wetlands or burying other shoreline communities (Thorp and others 1997). Depositing dredge spoils in nearshore habitats can bury spawning areas, but carefully planned open water disposal can have only temporary or minor impacts if spawning areas and other significant benthic habitats are avoided (Edsall and Charlton 1997). Most dredge spoils are now deposited in confined disposal facilities due to concerns about contaminants.

Dredging operations on Lake Superior regularly take place at the Thunder Bay harbour and the St. Louis River estuary at Duluth / Superior, with smaller operations at recreational marinas. The upper St. Marys River is also routinely dredged for channel maintenance and recent low water periods have resulted in calls for channel deepening and associated studies.

Sedimentation

Natural sedimentation processes of erosion, transport and deposition are essential for maintaining healthy coastal wetlands and sand dunes (Wilcox and Whillans 1999). Sediments can form barrier beaches and sand spits that protect wetlands. Some wetlands depend on sediment inputs to maintain vegetation. Active sand dunes are in a continuous state of flux as sand is deposited and eroded.

Artificial structures disrupt these processes. Breakwalls and revetments are structures placed parallel with the shoreline to enclose a harbour. Unintended side effects include scouring of sediments on the lakeside and increased erosion down wind as wave energy is transferred parallel with the wall. During high water levels, marshes inside the breakwall can be flooded out (Maynard and Wilcox 1997).

Groins are low walls constructed perpendicular to the shore. They are installed to protect beaches by intercepting longshore and beach drift. However, marshes and dunes that are eroded by storms may not be replenished if the supply of sediments is trapped by artificial structures (Maynard and Wilcox 1997). A breakwall near Grand Marais, Michigan may be interfering with longshore drift and altering habitat for Pitcher's Thistle (Loope 2003). Similarly, dams on tributary rivers trap sediment that previously nourished estuarine wetlands. Wilcox and Whillans (1999) recommend improved designs for breakwalls and other erosion protection structures that incorporate the principles of sedimentation processes.

Excessive sedimentation from upland sources can also impair aquatic habitats. Increased erosion from agriculture, lake-level changes, logging, and urban land use can increase sediment deposition in streams, smothering fish spawning substrate and causing excessive turbidity.

The extent and magnitude of these impacts on Lake Superior habitats are unknown, but they are probably greater on the south shore than the north.

Exotic Species

Purple Loosestrife

Purple loosestrife is a well-known invasive plant of wetlands. Native to Europe, it was first brought to North America in the early 1800s and is now found throughout much of the United States and Canada. Impacts of purple loosestrife can be severe. It has displaced up to 50 percent of the native plant biomass in some wetlands. Impacts on wildlife are not well understood, but some studies suggest serious declines in waterfowl and furbearer productivity in loosestrife-infested wetlands (Thompson and others 1987). Competition with rare plant species is also a concern.

In the Lake Superior basin, purple loosestrife is found around Thunder Bay, Duluth / Superior, Sault Ste. Marie and scattered other locations (Figure 65). It grows extensively along the Kaministiquia River and at number of other areas around Thunder Bay and north to Hurkett (David Ellingwood, LRCA, personal communication). Purple loosestrife is prevalent in the Sault Ste. Marie area and the St. Mary's River (S. Greenwood, OMNR, personal communication). In Wisconsin, purple loosestrife is widespread, but still at low density in most areas, occurring in only about five percent of the total wetland area statewide (WI DNR 1999).

At Thunder Bay, the Lakehead Region Conservation Authority has implemented control by digging plants and the introduction of beetles (*Galerucella* spp) that feed on loosestrife. The use of beetles has had mixed results (David Ellingwood, personal communication). Minnesota has a statewide control program using herbicides and biological control (Skinner and others 1994). In Wisconsin, there are limited control programs in place; Bad River Band of Lake Superior Indians use chemical control in the Kakagon Sloughs. The Apostle Islands Nationals Lakeshore (Gary Czypinski, personal communication) has used biological control since 1997.

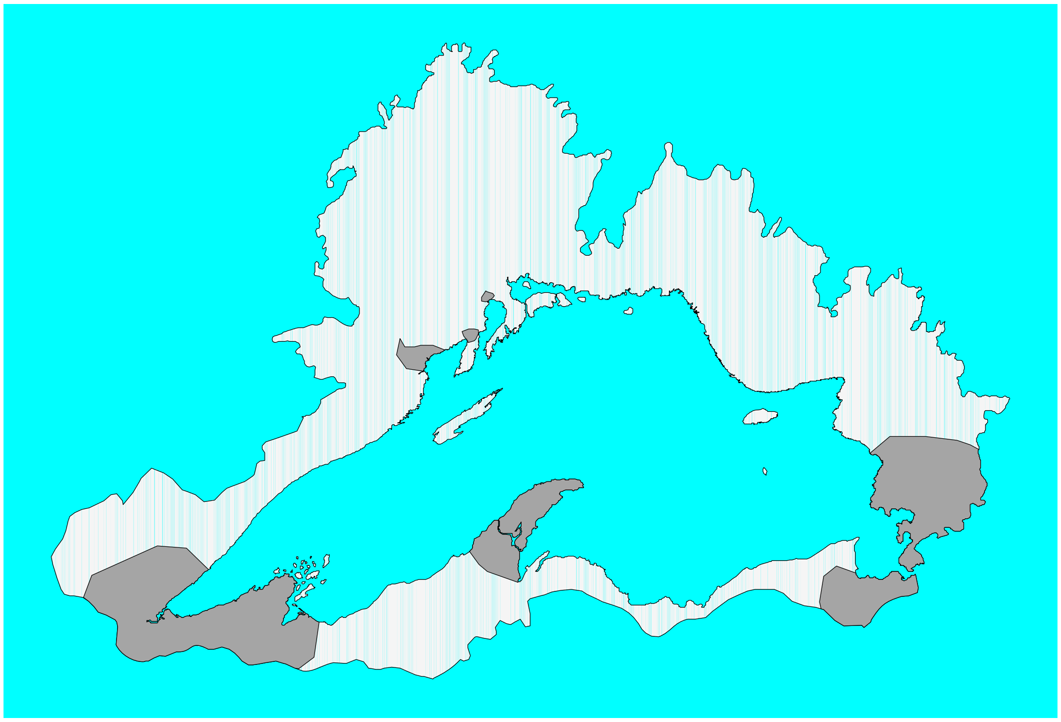


Figure 65. Approximate distribution of purple loosestrife in the Lake Superior basin. Local occurences exist outside the shaded zones (Skinner and others 1994, Voss 1985, White and others 1993, WI DNR 1999).

5.3 Species and Ecosystems of Concern

Wild Rice

To Chippewa tribes around the Lake Superior basin, wild rice (*manoomin*) is "the food that grows on water." It fulfilled a prophesy in the story of the Chippewa tribe's migration from the east – they would know that they had found their new home when they found the food growing on water. Wild rice has been a vital part of Chippewa culture and religion ever since. It was also significant in the lives of the Dakota and Menominee tribes, and provided food for early European explorers.

The "wild rice bowl" extends from Manitoba, through northwestern Ontario, Minnesota, and Wisconsin (Figure 66). Some populations in Ontario were probably introduced by native peoples many years ago (Aitken and others 1988). There have been more recent introductions to several locations in the eastern part of the basin.

Wild rice habitat is shallow water in slowly-moving streams and inlets and outlets of lakes. It does poorly in stagnant water and fast moving streams. Soft organic material is the preferred substrate.

Wild rice is important to the ecology of lakes, streams, and shallow water wetlands. It helps maintain water quality by binding loose soils, tying up nutrients, and slowing winds across shallow wetlands. Wild rice is an important habitat component for many species. It provides wildlife, particularly waterfowl, with food and cover.

Many of the historic wild rice stands have been lost. Although a number of factors can harm rice, it is particularly sensitive to water level changes (Vennum 1988). Many lakes and rivers have been dammed, and even small water level changes can destroy wild rice habitat. A number of interagency efforts are underway to try and reverse this decline in wild rice populations. These include abundance and harvest monitoring, restoration and enhancement, and research.

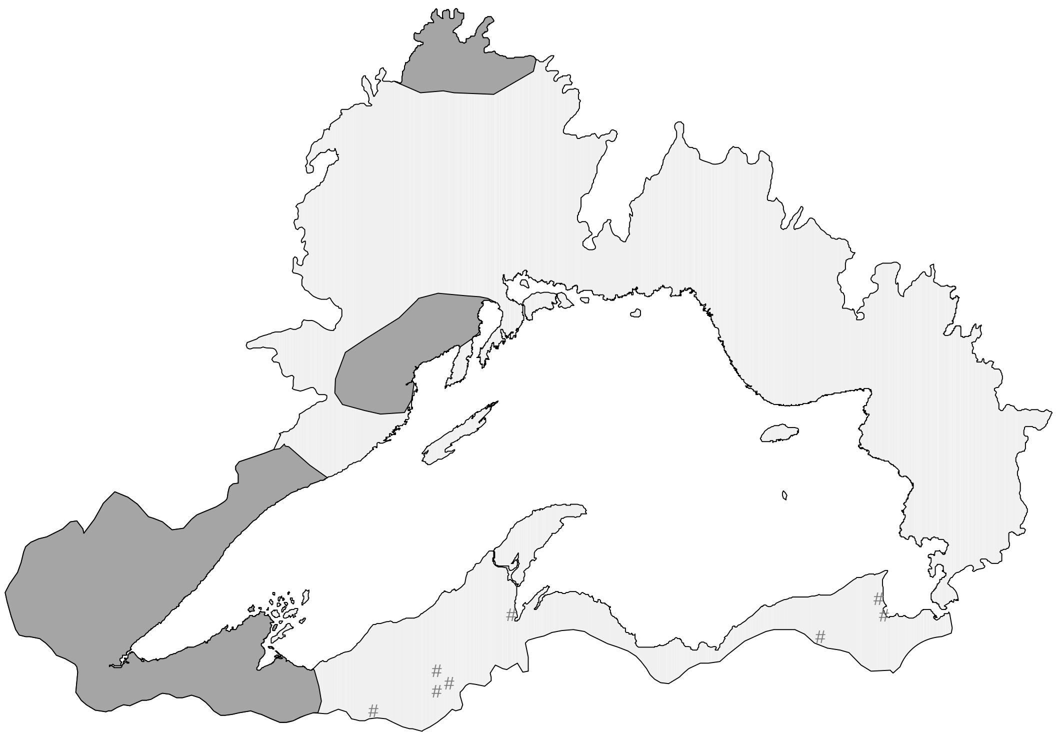


Figure 66. Distribution of wild rice in the Lake Superior basin (Based on Aitken and others 1988, Voss 1972).

Piping Plover

Piping plover is classified as Endangered in Michigan, Wisconsin, Minnesota and Ontario and federally in both Canada and the U.S. (Great Lakes Population).

In the Great Lakes area, these birds historically nested on sandy and gravel beaches and sparsely-vegetated shorelines with gravel or pebbly mud substrate. At Duluth, they nested on dredge-spoil islands (Coffin and Pfannmuller 1988). Beaches separated from the tree line by a wide dune system or slough offer the best habitat and wide beaches provide better habitat than narrow beaches (Lambert and Ratcliff 1979).

Since the 1960s, piping plover populations have declined precipitously. Threats to habitat include high water levels (mid-summer storms), recreational uses, and all-terrain vehicles on beaches. Additional threats to plovers include increased gull populations and free running dogs on beaches. The quantity and quality of beach habitat is dynamic and influenced by fall and winter storms that erode and deposit sand and set back vegetation succession.

Ontario
There have been no documented reports of piping plovers nesting along the Lake Superior shoreline, although there is potential habitat at Caribou Island (good), Agawa Bay (marginal) and Beaver Rock (marginal) (Heyens 1998). Also, the mouth of the Pic River should be considered as good habitat. There are no annual surveys for piping plovers on Lake Superior.

Minnesota
The Minnesota north shore has very limited Piping Plover habitat. Historically they nested at the Duluth Harbour on industrial lands; with six to eight pairs during the early 1970s and three pairs in 1985. However, development pressures, recreational use, increased ring-billed gull populations, and lack of management has limited this area for breeding (Coffin and Pfannmuller 1988). No plovers have nested here in the 1990s (Katie Haws, personal communication).

Wisconsin
Historically piping plovers nested in the 1950s at Barkers Island and Wisconsin Point in the Duluth - Superior Harbour. Piping Plovers did not nest along Lake Superior coastline for many years, but in 1998, one pair was successful in raising four young at Long Island/Chequamegon Point (Sumner Matteson, personal communication). In 1999, one nesting pair and four other adults were observed here. The pair laid four eggs, hatched two young, but a mammalian predator killed both young. Surveys have been conducted each year since 1974. The habitat at Long Island has expanded due to lower water levels and the area could support 15 to 20 pairs (Sumner Matteson, personal communication). Long Island and the Michigan Island sandspit of the Apostle Islands N. L. were designated as critical habitat for piping plovers in 2001.

Michigan
Michigan has most of the piping plover habitat on Lake Superior. There is excellent habitat in Luce, Alger and Chippewa Counties. Another site at Pictured Rocks National Seashore has marginal habitat.

The 1998 survey located seven nests at four sites: four nests at two sites near Grand Marais (Alger County), one nest at Vermillion (Luce County) and two nests at Weatherhogs Beach, (Chippewa County) (Hinshaw 1998). Two historical nesting areas were surveyed with no nests found : Twelve Mile Beach, Pictured Rocks National Lakeshore, Alger Co. and Lake Superior State Forest Campground beach, Luce Co. The number of pairs is similar to those found in a 1979 survey (Lambert and Ratcliff 1979) (Figure 67, Table 23).

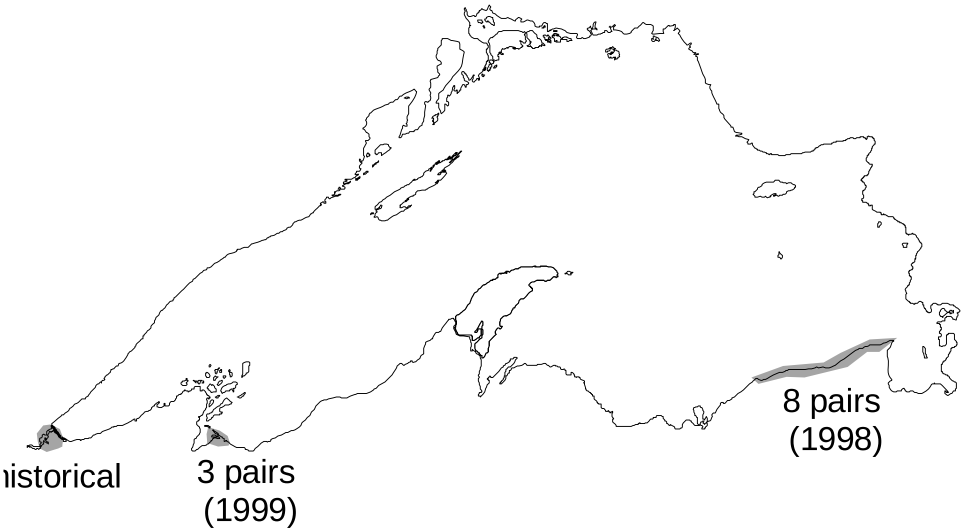


Figure 67. Piping plover habitat in the Lake Superior basin.

Table 23. Piping plover survey results, Michigan (Lambert and Ratcliff 1979, Hinshaw 1998).

Location	Number of sites		Nests	
	1979	1998	1979	1998
Luce County	5	1	4	1
Alger County	1	2	3	4
Chippewa Co.	5	1	3	2

Habitat for plovers in Michigan at Vermillion is shifting eastward as vegetation encroaches on more westerly areas. The eastern portions of the beach are becoming narrower and more vegetated as well, resulting in a shift toward less suitable nesting habitat at this site. East of the Vermillion site, Weatherhogs Beach is widening and use of this area by plovers is increasing. Human disturbance of plover nests at Weatherhogs is more difficult to restrict than at Vermillion where the Whitefish Point Bird Observatory staff can restrict access and more closely monitor use of the beach. Enhancing habitat at Vermillion may be needed to retain it as a nesting area.

Common Tern and Caspian Tern

Common terns are Endangered in Wisconsin, Threatened in Michigan, Special Concern in Minnesota, and unlisted in Ontario (Matteson 1988). Common terns nest at the St. Louis River estuary at the Duluth-Superior Harbor in Minnesota / Wisconsin. This colony declined 63 percent between 1977 to 1987 (Matteson 1988). In Wisconsin, there are 29 colony records on Lake Superior from the period between 1946 and 1987, most of these since the 1950s (Matteson 1988). In Michigan, common terns formerly nested along the Lake Superior coast in Chippewa County, but there are no recent nestings here (Hyde 1997). Common terns nest at several locations in the Ontario portion of the basin, but the north shore of Lake Superior constitutes a conspicuous distribution gap in the province (Blokpoel 1987). Low productivity of the lakes in the boreal shield in Ontario may be a limiting factor.

Caspian terns are Endangered in Wisconsin, Threatened in Michigan and Vulnerable in Canada. This species was probably never common on Lake Superior (Hyde 1996). They nest at several locations in the Wisconsin part of the basin (WI DNR 1999a), but apparently don't nest in Minnesota. In Michigan, Caspian terns nest in several of the counties bordering Lake Superior, but are not known to nest within the basin itself (Hyde 1996). They nested at two small Lake Superior islands in Ontario between 1997 and 2003 (Brian Ratcliff, pers. comm.), but are otherwise not known to nest in the Ontario basin (Austen and others 1994).

Chemical contamination, harvest for the millinery trade, and gull displacement contributed to the decline of these species. Important habitat includes small, sparsely vegetated islands or peninsulas for nesting. They will nest on artificial islands. Habitat related concerns include human disturbance at nesting sites, destruction of nesting habitat, and encroaching dense vegetation on nest sites. Rising water levels can flood nests and decrease available nesting habitat (Matteson 1988).

The objectives of the Wisconsin common tern recovery program are protecting nesting sites and establishing new colonies, population monitoring, evaluating chemical and habitat conditions, and enhancing awareness (Matteson 1988).

6. THE AQUATIC ENVIRONMENT

The principal stresses to the aquatic environment in Lake Superior include: atmospheric deposition and point discharge of contaminants, shoreline development in embayments and inland lakes, hydroelectric facilities, barrier dams, industrial effluents, mining waste, wetland draining and filling, agricultural practices, timber harvesting practices, exotic species, and discharges from Great Lakes vessels. Atmospheric deposition and exotic species are stresses to the aquatic community that have lakewide effects, whereas most of the other stresses have more localized effects.

All offshore and most nearshore habitat remains healthy and productive. As a result, all forms of lake trout are abundant. The majority of impairments to aquatic habitat and water quality are found in embayments and tributaries. These tributaries remain significantly degraded by such stressors as agriculture, mining, hydroelectric dams, industrial effluents and waste, wetland dredging and filling, nonpoint source pollution, shoreline development, and land use practices that lead to increased runoff and erosion. In particular, discharges of mine chemicals and tailings have degraded a few local areas of the nearshore habitat zone along the Minnesota and Michigan shorelines. Atmospheric deposition of contaminants lakewide has degraded all habitat zones to some degree.

The principal stresses to habitat found in each of the habitat types are as follows:

- **Offshore –** atmospheric deposition, discharges from Great Lakes vessels, and exotic species.
- **Nearshore –** atmospheric deposition, dumping or discharges from vessels, industrial effluents, exotic species, over-exploitation, and mining.
- **Embayment –** atmospheric deposition, industrial effluents, dumping or discharges from vessels, exotic species, over-exploitation, loss of wetlands, land-use practices, urban development, sedimentation, shoreline development, and petroleum emissions and spills.
- **Tributary –** hydroelectric facilities, barrier dams, water crossings, loss of wetlands, land-use practices, exotic species, timber harvesting, mining, agricultural practices, urban development, industrial effluents, and sedimentation.
- **Inland Lakes –** Shoreline development, timber harvest, agriculture, contamination through septic systems or runoff, mining, atmospheric deposition, urban development, sedimentation, industrial effluents, loss of wetlands, and hydroelectric dams.

Stresses to the physical habitat affect the structure, function, and composition of the biological community. In addition to the above stresses, over-exploitation has had a significant impact on Lake Superior fish communities. The effects of some stresses on the aquatic community are easy to recognize. Overfishing is partly responsible for the decline of deepwater ciscoes (Lawrie and Rahrer 1973), brook trout (Newman and Dubois 1997), lake sturgeon (Slade and Auer 1997), walleye (Hoff 1996), lake trout (Hansen and others 1995a), and lake herring populations (Selgeby 1982) in Lake Superior from the late-1800s to the mid-1900s. Also during the same time period hydroelectric development and artificial barriers on tributaries, sedimentation of tributaries due to poor logging and land use practices, and physical destruction of stream channels contributed to the decrease in brook trout, walleye, lake sturgeon, and lake trout numbers (Lawrie and Rahrer 1973, Slade and Auer 1997, Hoff 1996, Newman and Dubois 1997). Predation by exotic sea lampreys contributed to the collapse of lake trout and whitefish populations in Lake Superior from the 1940s through the 1960s (Jensen 1976, Pycha 1980, Smith and Tibbles 1980, Coble and others 1990, Hansen and others 1995a). Logging, road crossings, and beaver and artificial dams are currently causing loss of spawning and nursery habitat in tributaries due to sedimentation and unfavorable changes in the thermal habitat. Walleye populations in Lake Superior are affected by high mercury levels, paper mill effluent, and habitat loss (Schram and others 1991).

All of the stresses described above can and are being managed in some manner or another. The effectiveness and appropriateness of these management actions may be debateable. Inventory, monitoring, and pre- and post-assessment are required to adequately evaluate whether management actions are reducing these stresses (N. Ward 2004). Examples of how several stresses are being managed are described below.

Overfishing is currently being addressed through fishery management regulations developed separately or jointly by state, provincial, and tribal agencies (Legault and others 1978, Ebener 1997, Brown and others 1999). Overfishing is currently not a pervasive problem on Lake Superior and occurs only in isolated areas on a few fish species, such as lake trout in Whitefish Bay and eastern Ontario waters where effective regulatory mechanisms have yet to be negotiated for the native fishery.

During re-licensing of several hydroelectric facilities on U.S. tributaries through the Federal Energy Regulatory Commission (FERC) agencies have had some success changing water power management from peak operations to run-of-the-river flows which more closely mimic natural conditions and improve conditions for aquatic life and fish reproduction. Options and capabilities for such biota-friendly flow management are often not available or more difficult at older or outdated facilities. More stable flow regimes implemented on the Nipigon River in the 1990s have helped increase reproduction of brook trout. However, until recently, hydropower facilities in Canada were not bound by the same criteria as FERC and flow management occasionally did not take fishery or aquatic community considerations into account. A recent initiative, Water Management Planning, is intended to plan sustainable solutions for water resources. Feasibility studies for construction additional hydropower facilities on Ontario tributaries is currently underway.

Present day logging practices are regulated to protect aquatic life. Best management logging and forestry practices, if properly implemented and enforced, are much less stressful to aquatic life than historic methods. However, roads that cross streams often associated with logging operations may increase erosion and sedimentation if improperly constructed and maintained. Likewise, improperly placed or constructed culverts may impede fish passage permanently or seasonally. In the U.S., there are many poorly designed roads or improperly placed culverts that increase erosion and limit fish movement. In Canada, Crown land, which is the majority of the watershed, is strictly monitored for erosion and culvert placement.

Sea lamprey populations have been successfully suppressed throughout most of Lake Superior because of integrated control using chemicals, low head barrier dams, and traps. While the use of lampricides has contributed substantially to the restoration of lake trout and whitefish in Lake Superior, a few fish and aquatic organisms can be negatively affected by their use. Barriers, established to limit sea lamprey access to upstream spawning habitat limit movement of non-jumping fish that would otherwise have access to upstream reaches.

Other stresses to the aquatic community of Lake Superior are more difficult to recognize and manage. Chemical contaminants in fish flesh have apparently not limited the ability of Lake Superior fish to reproduce, although absence or lower concentrations of chemical contaminants could improve reproductive success. Some chemicals deposited in Lake Superior through atmospheric deposition originate outside of the basin (even outside North America), making it very difficult to address management of these chemicals. Chlordane originates entirely outside of the Lake Superior basin, yet the chemical is in sufficient quantity in siscowet trout from Lake Superior that consumption advisories have been issued by the state of Michigan. Michigan closed its state-licensed commercial fishery for siscowets in the early 1990s due to chlordane contamination.

6.1 Offshore Habitats

Offshore areas are less heavily impacted by habitat destruction than embayment, tributary stream, and inland lake habitat. The offshore habitat types of Lake Superior are probably in sufficient quantity and quality to allow achievement of fish community and environmental objectives.

6.2 Nearshore Habitats

Like offshore areas, nearshore areas are largely intact in terms of physical habitat. Introduced species have perhaps their greatest impacts on nearshore habitats. Over-fishing has been a problem in this area, and its effects are discussed in a subsequent section.

6.3 Embayments

While less extensive than in other Great Lakes, pollution and nutrient loading have severely degraded some embayments on Lake Superior.

Pollutants in Lake Superior originate from a variety of sources, including point sources, nonpoint sources, and tributary discharge. Point sources are those originating at an identifiable point, such as industrial effluent, waste dumping, and spills (Table 24). Nonpoint sources are more diffuse and may originate from outside the Lake Superior basin. Atmospheric deposition in the form of contaminated rain, snow or dust is a major source of some pollutants. Others include agricultural and urban surface runoff and release of pollutants from contaminated sediments. Tributary discharge refers to pollutants entering the lake through tributary streams transported from elsewhere in the watershed, although ultimately these pollutants originated from point or nonpoint sources.

Embayments historically used as log storage areas altered or destroyed fish habitat and have in recent years received a degree of interest for submerged log salvage. These operations cause concern for resuspension of contaminated sediments and further alteration of fish habitat structure. The latter may have positive or negative outcomes (N. Ward 2004).

Table 24. Point sources of pollutants in the Lake Superior watershed (LSBP 1995).

	Water Sources	Air Sources	Dumps
Ontario	20	27	190
Michigan	36	14	na
Minnesota	72	216	40
Wisconsin	40	5	105
Total	168	262	145

Nutrient loading is increased input of plant nutrients, such as phosphorus. While these nutrients are not harmful at normal levels, excessive levels can have negative effects. Agricultural and urban runoff, sewage treatment plants, and faulty septic systems are sources of nutrients.

Pollutants and nutrient loading can result in loss of habitat. In addition to toxic effects, water pollution can act as a barrier to migratory fish. Point sources also have local effects on aquatic life through thermal pollution, biochemical oxygen demand, turbidity, and bacterial contamination.

Nutrient loading can cause shifts in wetland vegetation. By encouraging species tolerant of high fertility (such as cattails), nutrient enrichment can cause reduced diversity of plant communities and loss of rare species (Maynard and Wilcox 1997). Enhanced growth of algae and submergent plants, can cause oxygen depletion as the plants die and decompose.

Loss of fish and wildlife habitat due to pollution and nutrient enrichment is a local problem on Lake Superior. Habitat loss due to contamination has been identified at six of the seven Areas of Concern (AOCs) in the lake basin. These sites are typically at bays and estuaries, among the richest and most diverse habitats on the lake, and the consequences extend throughout the lake. A substantial amount of habitat destruction has taken place in embayment habitat. Lake Superior AOCs in the embayment habitat are located in Nipigon Bay, Jackfish Bay, Thunder Bay, Peninsula Harbour, Torch Lake, and the St. Louis River.

Nipigon Bay is the most northerly area of Lake Superior and receives most of its drainage from a watershed underlain by the Canadian Shield. Environmental concerns in Nipigon Bay center around water quality issues, degraded fish populations, and impaired natural watercourses. In 1995, the Nipigon AOC completed remedial strategies for ecosystem restoration, most of which have been implemented. Actions taken include reducing water level fluctuations, completion of secondary treatment at a paper mill, and cleanup and rehabilitation of nearshore and tributary habitat.

The Jackfish Bay AOC is located on the north shore of Lake Superior, approximately 250 km northeast of Thunder Bay, ON. The AOC consists of a 14 km stretch of Blackbird Creek between the Kimberly-Clark pulp mill and Jackfish Bay including Lake ‘A’, Moberly Lake, and Jackfish Bay. The town of Terrace Bay is the closest community west of the AOC. Jackfish Bay and Blackbird Creek have been impacted by effluent from the pulp and paper industry, resulting in contaminated sediments and degradation of fish and wildlife habitat. Process changes and the installation of secondary treatment at the Kimberly-Clark mill have substantially improved effluent quality, resulting in environmental improvements. It is expected that previously deposited organic sediments will degrade over time and the Remedial Action Plan (RAP) recommends natural recovery as the preferred option in the 1998 Stage 2 report on remedial strategies for ecosystem restoration. Natural rehabilitation of aquatic communities will continue to be monitored in the Jackfish AOC. A reference on this AOC is the Jackfish Bay Remedial Action Plan, Stage 2: Remedial Strategies for Ecosystem Restoration (1998).

The Thunder Bay AOC fans out from the city of Thunder Bay, extending for about 28 km along the shoreline and up to 9 km offshore. The AOC occupies the southwest corner of Thunder Bay proper. The greatest impacts on the area have resulted from industrial and urban development along the Thunder Bay waterfront and adjoining tributaries. Dredging, waste disposal, channelization, and the release of a number of pollutants have eliminated a significant portion of quality habitat along the waterfront. The consequences have included a loss of species abundance and diversity, reduced recreational opportunities, and a decline in the aesthetic value of the area. Impacts resulting from the release of process effluent into the Kaministiquia River and Lake Superior have been significantly reduced in recent years because of improved effluent treatment and changes in industrial processes; however, the ecosystem remains impaired in a number of ways. Some areas support benthic communities reflective of organic enrichment, contaminated sediments, and habitat loss from dredging activities. Dredging restrictions are still in effect because of sediment contamination in the harbour, particularly health hazards for water based recreational activities.

Peninsula Harbour, located on the northeastern shore of Lake Superior approximately 290 km east of the city of Thunder Bay is the site of a pulp and paper mill. The AOC is roughly bounded by the watershed of the harbour and Pebble Beach, and extends outward approximately four kilometers from the Peninsula into Lake Superior. The area has problems associated with degraded fish and benthic communities and high levels of toxic contaminants in fish and bottom sediments from mill effluent. The preferred remediation option currently under consideration is to remove mercury contaminated sediments and isolate them in a confined disposal facility. Mercury levels in lake trout have stabilized at a mean value of 0.35 mg/kg from 1984 to 1996 and are not significantly different from lake trout sampled at other locations along the north shore of Lake Superior.

The St. Louis River, the largest U.S. tributary to Lake Superior, drains 9,412 km^2, entering the southwestern corner of the lake between Duluth, Minnesota and Superior, Wisconsin. As it approaches Duluth and Superior, the river takes on the characteristics of a nearly 4,900 ha freshwater estuary. The upper estuary has some wilderness-like areas, while the lower estuary is characterized by urban development, an industrial harbour, and a major port. The lower estuary includes St. Louis Bay, Superior Bay, Allouez Bay, Kimball's Bay, Pokegama Bay, Howards Bay, and the lower Nemadji River.

The AOC is located in the lower 63 km of river. The RAP process determined that nine of 14 identified beneficial uses were impaired. Some impairments were associated with the physical loss and degradation of habitat, with the estuary having lost an estimated 3,100 (of nearly 4,900) ha of wetland and open water habitat since settlement. Other problems were related more to pollution and toxicity. For years, the river smelled bad from industrial discharges. That changed in 1978, when the Western Lake Superior Sanitary District (WLSSD) wastewater treatment plant began operation. Nevertheless, pollution continues to come from sources such as contaminated sediments, abandoned hazardous waste sites, poorly designed or leaky landfills, airborne deposition, industrial discharges, chemical spills, improperly sewered wastes, and surface runoff. Both Minnesota and Wisconsin issue fish consumption advisories for the St. Louis River. These are based on mercury and polychlorinated biphenyls (PCBs).

The Torch Lake AOC is located on the Keweenaw Peninsula, which roughly divides Lake Superior's southern shore into its eastern and western halves. The AOC spans the lower portion of the peninsula, encompasing the Keweenaw Waterway (North Entry Harbor of Refuge, Portage Lake, and Torch Lake), its watershed, portions of two other adjacent watersheds (Trout River and the Eagle River Complex), and several kilometers of its western Lake Superior shoreline – a total of approximately 953 km^2 all contained within the northern half of Houghton County, Michigan. The AOC boundaries include all of the Superfund sites and associated watersheds.

The unifying problem shared by these areas is widely scattered deposits of copper mining waste materials accumulated over more than 100 years of mining, milling, smelting, and recovery activities. These wastes occur both on the uplands and in the lake and occur in four forms: poor rock piles, slag and slag enriched sediments, stamp sands, and abandoned mine slurry settling ponds. The associated contaminants include copper, mercury, arsenic, lead, chromium, and other heavy metals. The beneficial use impairments inferred from the 1987 RAP included restrictions on fish and wildlife consumption, fish tumors or other deformities, contaminated sediments, loss of fish and wildlife habitat, restrictions on drinking water consumption, restrictions on dredging and shipping activities, and degradation of benthos.

6.4 Tributary Streams

Tributary streams are the most vulnerable component of Lake Superior's aquatic ecosystem. Due to the connections between terrestrial and aquatic systems, impacts on streams may extend to the entire lake. Streams are critical habitat for migratory fish and other species and stream habitat quantity and quality are sensitive to changes at local and watershed scales.

Minnesota

The Minnesota Pollution Control Agency (MPCA) assesses selected streams for Aquatic Life Use Support, "to determine if waters are of a quality to support the aquatic life that would be found in the stream under the most natural conditions" (MPCA 1997). The assessment is based on water chemistry data, biological and habitat information and a survey of local resource managers.

Water quality in Lake Superior tributary streams is typically quite good (Table 25) (MPCA 1997). "Threatened" streams do not currently show signs of degradation, but are likely to show signs of degradation due to future changes in the watershed. Turbidity, metals, and habitat alteration are the most common indicators of impairment. Forest removal, construction, urban and rural development, and landfill leachate are suspected source of pollution (Figure 68).

Thirty-nine kilometers of the Nemadji River has been assessed as "not supporting" due to turbidity and habitat alteration from a hydroelectric dam. Twelve kilometers of the Cloquet River has been assessed as not supporting due to metals from nonpoint sources.

The lower St Louis River is polluted from industrial effluent, stormwater runoff, and other sources. This area, covered by a Remedial Action Plan, has shown improvements in water quality. Contaminated sediments, stormwater runoff and leaky landfills continue to pollute the river. In addition to water quality impairments, human activity has altered habitat in more than 58 percent of the St. Louis River Estuary through dredging, shoreline modification, and filling of wetlands.

Table 25. Minnesota stream assessments for aquatic life (MPCA 1996).

Watershed	Length Assessed (km)	Fully Supporting (%)	Threatened (%)	Partially Supporting (%)	Not Supporting (%)	Not Attainable (%)
Lake Superior – North	251	23%	77%	-	-	-
Lake Superior – South	182	3%	41%	23%	34%	-
St. Louis River	432	-	23%	3%	72%	3%
Cloquet River	12	-	-	-	100%	-
Nemadji River	39	-	-	-	100%	-

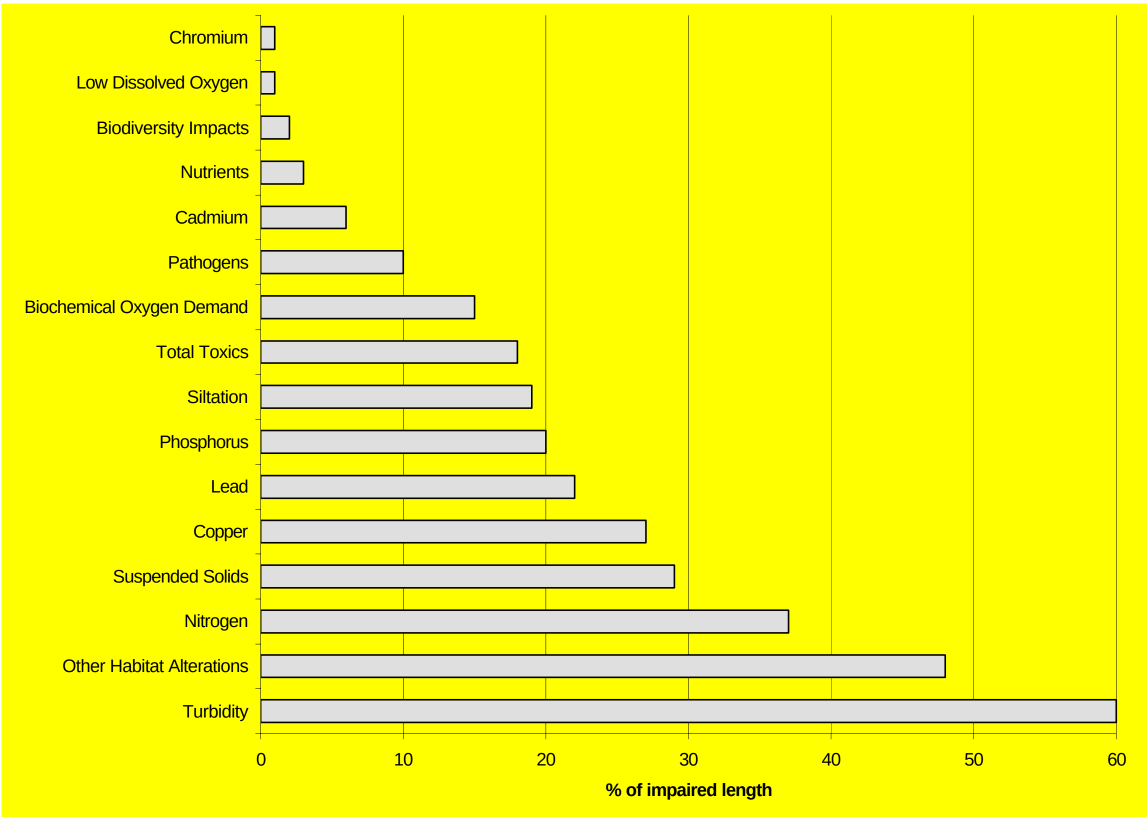


Figure 68. Causes of habitat impairment in Minnesota tributary streams.

The St. Louis River watershed has five hydroelectric dams, but the 1930 Shipstead-Nolan Act of Congress prohibits further construction of dams or other water-fluctuation structures in St. Louis, Lake, and Cook counties Minnesota (MPCA 1997). The small watersheds limit the feasibilty of hydroelectric dams on most streams.

Wisconsin

Most tributaries were impacted by a complete forest cut-over in the middle 1800s, extensive fires, and the cumulative watershed damage caused by human activities (e.g., agriculture). Resulting higher peak flood flows increased channel water velocities, which displaced the remaining woody cover, eroded stream banks, straightened channels, and ultimately sorted bottom substrates. Although watershed health has generally improved, altered runoff patterns, damage to channel structure, and redistribution of substrate components caused during this time period remain. Management actions include land acquisition, beaver control, stream habitat improvement in critical areas, watershed evaluations, wetland and riparian restoration projects, and fishery regulations.

Table 26 summarizes the habitat conditions of many of Wisconsin's Lake Superior tributaries by watershed. The relatively large amount of Threatened habitat is mostly due to potential impacts of exotic species or land use activities within the watershed, even where there are no observed effects.

Table 26. Wisconsin Lake Superior tributaries (from Turville-Heitz 1999). "Thr" = Threatened, "Unk" = Unknown.

	Watershed	**No. Streams**	**Total Stream Length (mi)**	Watershed Area **(mi^2)**	**Supporting Potential Use (%)**				
					Full	**Part**	**Not**	**Thr**	**Unk ***
LS01	St. Louis and Nemadji rivers	78	284	159	7	12	3	22	78
LS02	Black and Upper Nemadji rivers	52	180	126	12	-	-	45	88
LS03	Amnicon and Middle rivers	107	384	289	23	-	-	-	77
LS04	Bois Brule	72	165	195	27	2	-	49	71
LS05	Iron River	36	147	218	9	-	-	79	91
LS06	Bayfield Peninsula Northwest	56	172	236	1	-	-	52	99
LS07	Bayfield Peninsula Southeast	56	142	302	3	2	4	56	91
LS08	Fish Creek	35	115	157	9	23	3	36	66
LS09	Lower Bad River	18	129	124	-	-	-	95	100
LS10	White River	67	271	360	tr	tr	-	75	99
LS11	Potato River	46	160	140	2	-	-	47	98
LS12	Marengo River	85	261	218	-	-	-	47	100
LS13	Tyler Forks	46	124	79	-	-	-	35	100
LS14	Upper Bad River	62	194	135	-	-	-	28	100
LS15	Montreal River	80	264	226	19	-	-	62	81
LS16	Presque Isle River	53	91	108					
	Total	**949**	**3083**	**3072**					

** stream can be both "Threatened" and "Unknown" if potential impacts have been identified*

The St. Louis and Nemadji watersheds are discussed in the Minnesota section above. Tributaries within the Wisconsin part of the watershed with impaired water quality include Crawford Creek, an unnamed Drainage to Crawford Creek, and Newton Creek. Impairments are due to sediment contamination, point sources of pollution, aquatic toxicity, and other contaminants.

Habitat in the Fish Creek Watershed has been impacted by pathogens from sewage treatment plant and stormwater runoff from the City of Ashland. Other concerns are habitat loss, sedimentation and turbidity from unfenced pastureland, barnyard runoff, and logging (Turville-Heitz 1999).

Stream habitat in the Montreal River watershed has been altered by hydrologic modification. There are only six hydroelectric dams in the Wisconsin basin, three of which are in the Montreal River watershed (the others are in the White, Iron, and St. Louis watersheds). In general, Wisconsin's watersheds are small and provide inconsistent flows. Five dams have been removed or damaged and not replaced. They are the Upson Dam and Iron Lake Dam on Iron River, the Marengo Dam on the Marengo River, the Mellen Waterworks on Carrie Creek, and a dam at Red Granite Falls on the Bad River (Turville-Heitz 1999).

One of the major sources of turbidity and sedimentation in Wisconsin tributaries is related to the unstable red clay soils of the Lake Superior Clay Plain. (See text box below for a description of the Red Clay Plain.) For in-depth information on Wisconsin's Lake Superior Clay Plain, see the 1998 publication "Erosion and Sedimentation in the Nemadji River basin" (NRCS, 1998). Although there are some differences in the landscape character of the Nemadji River basin and part of the clay plain to the east, this publication's conclusions and strategies for management are very applicable. The Nemadji River basin study serves as an excellent template for remedial management of the hydrologic conditions in the clay plain in general. Any future work to improve hydrologic conditions in the clay plain should begin with a review of this document.

Changes in Pre-European Forest Cover Type on the Red Clay Plain and Stream Erosion

Between the late-1800s and early-1900s, the Lake Superior Clay Plain underwent substantial disturbance in association with European settlement. Effects of this disturbance still impact hydrologic processes in the clay plain today. Analyzing what disturbance forces took place, how they changed the forest landscape, and the impacts these had on forest hydrology can be helpful to planners who are applying management practices to improve stream habitat.

Although the disturbance period was initiated by timber harvest, primarily of white pine, fire and artificial drainage of upland surface water associated with agriculture and road development produced some of the greatest changes to the landscape.

Geologically speaking this landscape is relatively young. The last glacial deposit occurred between 9,500 to 11,000 years before present (BP), when receding glacial ice retreated into the Superior basin and then later advanced. The advance deposited a thin layer of clay till, Miller Creek Formation, over a deeper previously deposited coarser textured till, Copper Falls Formation (Clayton, 1984).

Young glacial landscapes generally have rapid erosion rates with geologic aging. Compounding this fact is the manner that the deposits occur. The clay till has fine clay texture and is strongly bonded. Beneath the clay lies coarse textured till, loosely bonded, and unconsolidated. Major streams have long ago cut through the clay till into the unconsolidated till. Water flowing in these streams, particularly during flooding, has been cutting away the loosely bonded till well before pre-European settlement. Streams eroding loosely aggregated channel sides are not uncommon, however the existence of the surface red clay cap has a two-punch effect in producing high erosion rates along these clay plain streams.

- Strongly bonded clay caps above a bend in a stream channel, where the loose material is being eroded, slow the stabilization process of the slope above the channel. This results in long, steep, mass-wasting slopes immediate to the stream channel.
- Water infiltration rates in uplands covered by red clay till are very slow. Runoff is very rapid during rainfall and snowmelt events, creating frequent flooding in streams. These floods produce high-energy water flows that frequently erode stream channels, compounding the problem of mass waste erosion on adjacent slopes.

Undoubtedly some of this rapid erosion occurred prior to European settlement, but there were factors in the forested landscape that buffered runoff and erosion in streams. After European settlement and the disturbance that came with it, much of this buffering was dismantled, resulting in increased erosion rates.

Forest Cover

Keeping in mind this characterization of the surficial geology and the effects it has on stream erosion processes, the following is a simplified description of what pre-European forest conditions were like in the clay plain. This description also includes changes that occurred in forest cover, what forest cover conditions are today, and the impacts these changes have had on forest hydrology in the clay plain.

Based on survey information (Finley 1976) the pre-European forest cover on the clay plain was predominantly coniferous. To the east of the Douglas/Bayfield county line and continuing to the eastern extent of the clay plain there was an increase of northern hardwood species associated with this coniferous forest. White pine was the predominant overstory species in number and stature. White spruce and balsam fir created a dense sub-overstory canopy beneath the white pine in the western clay plain. To the east sugar maple, yellow birch, and hemlock were mixed with the fir and spruce. White birch and aspen were common associates throughout the clay plain. Their presence was associated with natural disturbance in the forest.

At a smaller scale of forest cover, in ravines vs. uplands, there were some interesting differences in forest composition. More mature forest conditions, including a predominance of larger diameter white pine associated with dense spruce-fir and cedar trees, occurred in ravines. Uplands had a more even size class distribution of white pine. Also white birch and aspen were more common in the upland forest (Koch 1979). One conclusion to be drawn from this difference in cover type is that natural disturbance was more common in the uplands, and ravines provided protection from disturbance. Later succession forest conditions in ravines likely had well-developed vertical structure of live standing and dead downed woody debris.

Forest floors associated with these conifer forest cover types accumulated organic matter and a fairly thick duff surface soil layer existed. This duff layer along with large volumes of downed woody debris was capable of retaining large volumes of water that would otherwise runoff the clay textured surface soil.

Although natural disturbance information is not well documented for the pre-European clay plain forest, the primary disturbance forces were likely wind and fire. Wind storms could easily blow down areas of shallow rooted fir and spruce in the uplands. Ravines were somewhat protected from the wind. The downed conifer trees provided fuel for occasional fires, most likely started by lightning. These fires were seldom severe, and with fairly high moisture conditions in the standing forest, burned through the blow down and then were extinguished by the moist conditions in the adjacent standing forest. Again, ravines were very moist and resistant to fire disturbance.

When Europeans arrived they found a dense forest cover, particularly along waterways. Conditions within this dense forest cover inhibited human passage. To them, the forest was a hindrance to be overcome.

Initially harvesting the white pine was the focus. Because roads were few and poor at best, waterways were the thoroughfare to move logs to sawmills. Waterways were dammed and large volumes of logs were floated down stream to Lake Superior. The energy and force resulting from this activity drastically effected erosion along waterways. Also, log drives removed most of the large natural woody debris that had been deposited over hundreds of years. Removal of the woody debris deteriorated the structural features of the streams, reducing habitat for organisms and negatively impacting their hydrological character. Evidence of damage caused by log drives is still visible today.

Harvesting was soon followed by the desire to clear land for farming. The relatively stone-free clay soil offered great opportunity for farming. Remaining forest cover in areas to be farmed was removed. This land clearing usually involved burning of the unwanted forest debris.

While it is often thought that the harvesting of white pine is what left the clay plain landscape so barren, it was actually fire that so completely opened up the landscape. Most of these fires were man caused, likely associated with land clearing operations for agriculture. With already large volumes of conifer slash left on the forest from harvesting and land clearing, fires were much larger and more intense than natural fires that occurred during pre-European settlement times.

Where land was not farmed, burned over areas offered great opportunity for pioneer species like aspen and paper birch to become established. Conifers did remain on the landscape but due to their flammability much of the cover type was consumed by fire. Most of the remaining conifer cover was likely confined to the ravines.

Harvesting, land clearing for agriculture, and fire were the main three man-caused disturbances that removed almost all forest cover indicative of pre-European settlement. Of these disturbances, fire produced the greatest change. Log drives down streams scarred channels, initiating large erosion areas still evident today. Upland retention of rainfall and snowmelt water runoff was substantially reduced. Energy produced by increased runoff flowing through the badly scarred waterways produced high stream erosion rates.

Artificial Drainage

One additional man-caused disturbance that went beyond changing forest cover was changing the shape of the landscape surface itself. Artificial drainage associated with agricultural fields and road infrastructure moves rain and snow-melt water, already rapidly running off the exposed clay soil, at an even faster rate off the uplands. This expedited delivery to streams creates even greater energy available to erode stream banks and adjacent slopes. While impacts from disturbance to the pre-European forest and stabilization of stream riparian areas is slowly occurring with time through natural forest succession, artificial drainage is maintained, and likely has a great impact on modern day flooding of south shore streams.

Michigan

Table 27 lists the 12 streams in the Michigan portion of the Lake Superior basin that are not meeting designated uses.

Elevated copper concentrations from copper ore tailings are problems for a number of streams (i.e., Hammell Creek, Kearsarge Creek, Scales Creek, and Traprock River) in Houghton County. Habitat loss to sedimentation has also been a problem in this watershed. The west and east branches of the Eagle River also have high levels of copper.

Table 27. Michigan non-attainment streams in the Lake Superior basin (Michigan Dept. of Environmental Quality 1998).

Stream	Length (km)	Problem	Source
Adventure Creek	1	Macroinvertebrate community rated poor	Obstruction of stream channel resulted in severe erosion and sedimentation
Mineral River	1	Macroinvertebrate community rated poor; total dissolved solids	
Bluff Creek	21	Fish community rated poor	Sedimentation and bank erosion related to extreme flow fluctuations
Kearsarge Creek	6	Copper; macroinvertebrate community rated poor	Copper ore tailings
Scales Creek	418	Copper; macroinvertebrate community rated poor	Copper ore tailings
St. Louis Creek	1	CSO, bacterial slimes, pathogens	
Hammell Creek-Osceola Mine Discharge	1	Mercury and copper	Copper ore tailings
Trap Rock River	10	Copper	Copper ore tailings
Eagle River, E. Br.	10	Copper	
Eagle River, W. Br.	4	Copper; macroinvertebrate	

Table 27. Michigan non-attainment streams in the Lake Superior basin (Michigan Dept. of Environmental Quality 1998).

Stream	Length (km)	Problem	Source
		community rated poor	
Carp River	47	Mercury	
Whetstone Creek	3	Periodic fish kills	Urban stormwater runoff, severe sedimentation and discharges of suspected toxic substances
Carp Creek	18	Mercury	

A standardized stream assessment protocol has been developed by the Michigan Department of Natural Resources in order to evaluate and compare stream habitats and the status of fish populations in the streams. Using this method, efforts are ongoing to establish a database of baseline habitat and population information on Lake Superior tributary streams. The standardized assessment protocol will facilitate monitoring of the effects of management actions.

Ontario

Hydroelectric development has impacted a number of Lake Superior tributary watersheds including the Aguasabon, Kaministiquia, Michipicoten, Montreal, and Nipigon Rivers. Other major facilities are located on the Black River and Kagiano River. Many waterpower facilities in Ontario have Operational Plans in place with constraints on water levels and flows that voluntarily recognize the multiple uses of the river.

For example, a voluntary water management agreement was developed in the 1990s for the Nipigon watershed that balances the needs of all stakeholders on the Nipigon River and Lake Nipigon with the protection of fish habitat. This agreement was brought about in part after a landslide occurred on the Nipigon River, which was partly attributed to water level fluctuations caused by a hydroelectric dam. Heavy siltation caused by the slide damaged fish habitat and forced the Town of Nipigon to relocate its water intake (Atria Engineering Hydraulics Inc. 1993). Rapid draw down for hydroelectric generation contributed to the initial slide on the riverbank, which was followed by failure of the land behind the bank (Atria Engineering Hydraulics 1993). Other factors were the naturally susceptible soils, high soil moisture due to sudden thaw, natural erosion by river water, removal of tree cover by logging and disruption of drainage patterns by a pipeline right of way. Smaller slides are common on the river. Sudden draw downs by the power company on the Nipigon River have also resulted in the stranding of spawning salmon (R. Hartley, Nipigon District OMNR, personal communication).

Recent years however have seen a restructuring of Ontario's electricity market. The OMNR, in response to amendments to the Lakes and Rivers Improvement Act and its New Business Relationship with the Power Industry, has introduced Water Management Planning to Ontario. Water Management Planning is a consultative process that brings together the OMNR, waterpower producers such as Ontario Power Generation (OPG) and local stakeholders to plan sustainable solutions for water resources. The final Water Management Plan (WMP) for a river system will include an Operational Plan for each individual waterpower facility that addresses water levels and flows. These Operational Plans will be the enforceable components of the WMP in relation to the operation of each waterpower facility.

Ontario Hydro identified ten undeveloped major sites (>10 megawatt potential) within the basin, including the Pic, University and White rivers (Cheng 1987). An additional 28 sites with 2.0 to 10.0 average megawatt potential have been identified on the Agawa, Aguasabon, Black Sturgeon, Magpie, University, Pukaskwa, Pic, Steel, Namewaminikan, Kopka, Gull, Kaministiquia, Pigeon, and Ogoki rivers (Cheng 1987).

Accessible stream length has decreased due to construction of dams, lamprey barriers, and other artificial structures. Estimates of the decrease in available habitat are not available. Power dams are the lowest barrier on some significant tributaries, including the Black, Michipicoten and Montreal rivers, but the decrease in accessible stream is not easily determined because dams sometimes are constructed at natural barriers (falls or rapids) that may or may not have passed fish pre-construction.

Another potential impact of hydroelectric developments on the Lake Superior ecosystem is elevated levels of methylmercury associated with reservoirs.

Shoreline development has impacted fish habitat in tributaries in urban and rural areas such as Thunder Bay and Sault Ste. Marie, Ontario. More widespread stresses are associated with water crossings. Both the trans-Canada highway and railway are close to the north shore of Lake Superior and cross the majority of tributaries. Many of the crossings do not meet current standards and have resulted in barriers to migration of anadromous fish, habitat fragmentation, and severe erosion problems in some cases. Improvements to some of these crossings have been undertaken as opportunities have arisen. Tail-water controls have been used to improve fish passage at perched or inclined culverts. Flood conditions frequently cause washouts and replacement culverts are sized and installed to facilitate fish passage. Recently the OMNR and DFO have taken a proactive role in ensuring that natural channel design and ‘soft’ engineering approaches are used in the design of replacement water crossings. It is anticipated that this approach will reduce the frequency of washouts as well as facilitating fish passage.

The Ontario Ministry of the Environment (OME) monitors background levels of 37 streams to assess impacts of point source pollution. These sites include the mouths of some major tributaries. Seventeen Ontario streams have habitat impairments due to point source pollution, siltation, urban runoff and other causes (Table 28). Five of these streams (McVicar Creek, McIntyre River, Neebing River, Current River and Kaministiquia River) run through the City of Thunder Bay and receive urban runoff as well as industrial effluent. Four streams near the Hemlo gold fields are contaminated by mine waste (Cedar Creek, Fox Creek, Hayward Creek, Upper Black River). A 1992 report (OME 1992) noted some improvements in pulp mill effluent and urban sources, but there are continued problems, especially during low water levels. No current (post 1992) summary is available. A summary of selected stream parameters is presented in Addendum 6-E. OMNR has conducted surveys on 65 tributary streams (Addendum 6-C).

Fish habitat has also been degraded by historical logging practices, such as log drives, logging of banks and erosion from road crossings (Lawrie and Rahrer 1973). Logging, and associated road crossings, has taken place in all the major watersheds. In Ontario, application of habitat guidelines (OMNR 1988a, 1988b) has improved stream side logging practices, but landscape-level impacts of logging across the watershed are unknown. Ontario streams have a wide range of natural turbidity levels due to differences in soil types. This makes it difficult to distinguish the influence of natural erosion processes and artificial causes.

Table 28. Ontario streams with habitat impairments (OME 1992, OMNR unpublished data).

Stream	Impairment	Source of Impairment	Receiving water
Agawa River	Channelization	Bridge construction	Lake Superior
Blackbird Creek	BOD, pH, coliform bacteria	Pulp and paper mill effluent	Lake Superior
Cedar Creek	Phosphorus, nitrogen, fecal coliform bacteria	Diffuse source – extractive industrial land	Black River, Pic River
Current River	Fecal coliform bacteria	Rural and urban runoff	Lake Superior
Deadhorse Creek	Siltation		Lake Superior
East Davignon Creek	Siltation, pollution, low summer flow, BOD, high temperatures,	Urban runoff, industrial effluent	Lake Superior
Fox Creek	Sulphates, metals, pH	Diffuse source – extractive industrial land downstream from mine seepage	Black River, Pic River
Hayward Creek	Conductivity, chlorides, sulphates, metals, phosphorus, pH	Mine effluent	White River
Little Cypress R.	Erosion, low summer flows, High temps, barrier	Highway washout	Lake Superior
Little Pic River	Siltation		Lake Superior
Lower Kaministiquia River	BOD, suspended solids, phosphorus, nitrogen, metals, fecal coliform bacteria	Industrial point sources, pulp and paper mill effluent, sewage treatment plant	Lake Superior
McIntyre River	Chlorides, conductivity, metals	Rural and urban runoff	Lake Superior
McVicar Creek	Alkalinity, chlorides, conductivity	Urban runoff	Lake Superior
Michipicoten River	Water fluctuations	Power dam	Lake Superior
Neebing River	Alkalinity, phosphorus, organic nitrogen, fecal coliform bacteria	Rural and urban runoff	Lake Superior
Rudder Creek	Alkalinity, BOD, chlorides, conductivity, nutrients, suspended solids, sulphates, fecal coliform bacteria	Municipal sewage	Pic River
Upper Black River	Sulphates, conductivity, ammonia	Diffuse source – extractive industrial land and point source, mining	Pic River

A standardized stream assessment protocol for wadeable streams has been developed by the OMNR in order to evaluate and compare stream habitats and the status of fish populations in the streams. This methodology was developed for southern Ontario streams but is being used for Superior tributaries in the absence of a methodology specific for northern streams. Using this method, efforts are ongoing to establish a database of baseline habitat and population information on Lake Superior tributary streams to identify streams in need of harvest controls or habitat rehabilitation. Currently data are stored in the OMNR's Habprogs database (S. Greenwood, personal communication). In addition, the standardized assessment protocol will facilitate monitoring of the effects of such management actions.

6.5 Inland Lakes

The status of habitat in inland lakes in the Lake Superior basin is generally very good. Gross habitat impairment from point sources has occurred in only a few lakes. More subtle changes in lake habitat, such as eutrophication, sedimentation, and warming due to land use changes, are more difficult to detect and measure, as are the impacts of nonpoint source pollutants.

Shoreline development on inland lakes typically results in the loss of aquatic vegetation, which is important to the survival and reproduction of some fish species, such as yellow perch and northern pike. However, the direct, measurable effects of shoreline development are not as recognizable. Land use practices and urban development alter drainage patterns and increase surface water runoff, but the effects on the aquatic community are difficult to assess and understand.

Minnesota

Most of Minnesota's inland lakes are in very good condition. High quality pristine areas in the watershed include portions of the Boundary Waters Canoe Area, natural heritage lake trout lakes that are supported only by wild populations, state parks, and state and federal forests.

The Minnesota watershed, however, is in general experiencing increased stress from a variety of sources. The major stresses include logging, iron ore mining, increased construction of roadways, increased development of both riparian stream and lake shoreline areas, and increased exploitation on the fisheries resource. There are ongoing discussions with the timber industry on implementation of best management practices, specifically requiring increased protection of the riparian zone along streams, lakes, and wetlands. The Minnesota Division of Forestry is presently working on a new policy for timber harvest in the Lake Superior watershed. Iron ore mining is an important industry in northeast Minnesota and in general the industry has made efforts to improve water quality near mining sites, but there are still areas that need attention. With the renewed interest in experiencing "wilderness" and the changing demographics of our society there is a major development boom in Minnesota's portion of the Lake Superior watershed that includes expansion of roads, businesses, cabins/homes, and general shoreline development.

Lake trout, in the natural heritage lakes, and other native species are especially affected by the above stresses because of their need for undisturbed shoreline and native aquatic vegetation for natural reproduction.

There are five major hydroelectric dams on the St. Louis River system creating two of the largest impoundments in the basin: Island Reservoir and Whiteface Reservoir (MPCA 1996). These are headwater reservoirs that store water during the spring run off and release it to augment low flows at other times of the year. Other impoundments (Two Rivers Reservoir and Whitewater Reservoir) are used for mine processing water and recreation.

Water quality monitoring in Minnesota lakes is done by the Minnesota Pollution Control Agency. Emphasis has recently shifted away from point-source influenced lakes to volunteer monitoring (approximately 30 lakes in the basin – secchi depth, recreational suitability) and reference lake monitoring (water quality, land use in the watershed) (MPCA 1997).

Water quality is generally quite good (MPCA 1996). Thompson and Fond du Lac reservoirs have significantly contaminated sediments (MPCA 1996). Ninety-four percent of inland lakes tested (137/146) have fish consumption advisories due to mercury from atmospheric deposition (n = 133), PCB levels (n = 1) or both (n = 3) (MPCA 1996).

Minnesota, Michigan, and Wisconsin have volunteer lake monitoring programs (Lake Superior Binational Program 1998).

Lake trout, in the natural heritage lakes, and other native species are especially affected by the stressors cited above because of their need for undisturbed shoreline and native aquatic vegetation for natural reproduction. Many of the other stressorss in the watershed are being addressed through a variety of policy and regulatory changes. The Binational Program will provide an important tool to assist in implementing the required changes.

Wisconsin

Most lakes in the Wisconsin basin have basic, descriptive data. A document summarizing the status of inland lakes in the Lake Superior basin is in preparation (Turville-Heitz 1999). The soft water seepage lakes are most commonly found in the Wisconsin Lake Superior basin. These lakes are typically clear, slightly acid, and relatively infertile. The principal fishery resources pursued by anglers in the Wisconsin basin include muskellunge, northern pike, walleye, largemouth and smallmouth bass, and panfish.

Lakes within the Wisconsin Lake Superior basin are continually being stressed as an increasing number of people purchase shoreline properties. Shoreline development has resulted in a reduction of aquatic habitat and in some cases a reduction in water quality. Management actions to improve water quality include acquisition of remaining undeveloped shoreline near fish spawning areas and wildlife marshes, and improvement in sewage treatment facilities.

Twenty six lakes in Wisconsin are listed as having "Impaired Waters" (Turville-Heitz 1999), all related to mercury levels in fish (Table 29). Five Wisconsin lakes in the basin were identified as priority sites from a biodiversity perspective (Epstein and others 1997). These are Anodanta Lake, Bad River Slough, Hoodoo Lake, Rush Lake, and Smith Lake. Most of these lakes have rich invertebrate communities or support rare invertebrate species.

Table 29. Wisconsin lakes in the Lake Superior basin with impaired waters (Turville-Heitz 1999).

Lake	Impairment
Amnicon Lake	Mercury/fish advisory/atmospheric deposition
Annabelle Lake	Mercury/fish advisory/atmospheric deposition
Bear Lake	Mercury/fish advisory/atmospheric deposition
Bladder Lake	Mercury/fish advisory/atmospheric deposition
Cisco Lake	Mercury/fish advisory/atmospheric deposition
Diamond Lake	Mercury/fish advisory/atmospheric deposition
English Lake	Mercury/fish advisory/atmospheric deposition
Forest Lake	Mercury/fish advisory/atmospheric deposition
Galilee Lake	Mercury/fish advisory/atmospheric deposition

Table 29. Wisconsin lakes in the Lake Superior basin with impaired waters (Turville-Heitz 1999).

Lake	Impairment
Gile Flowage	Mercury/fish advisory/atmospheric deposition
Island Lake	Mercury/fish advisory/atmospheric deposition
Long Lake	Mercury/fish advisory/atmospheric deposition
Long Lake	Mercury/fish advisory/atmospheric deposition
Lynx Lake	Mercury/fish advisory/atmospheric deposition
Mineral Lake	Mercury/fish advisory/atmospheric deposition
Oxbow Lake	Mercury/fish advisory/atmospheric deposition
Palmer Lake	Mercury/fish advisory/atmospheric deposition
Perch Lake	Mercury/fish advisory/atmospheric deposition
Pike Chain of Lakes	Mercury/fish advisory/atmospheric deposition
Potter Lake	Mercury/fish advisory/atmospheric deposition
Siskiwit Lake	Mercury/fish advisory/atmospheric deposition
Spider Lake	Mercury/fish advisory/atmospheric deposition
Spillerberg Lake	Mercury/fish advisory/atmospheric deposition
Tahkodah Lake	Mercury/fish advisory/atmospheric deposition
Three Lake	Mercury/fish advisory/atmospheric deposition
West Twin Lake	Mercury/fish advisory/atmospheric deposition

Michigan

In general, Michigan inland lakes within the Lake Superior basin receive minimal fishing pressure because of the sparse human population in their region and their remote locations. A few lakes are storage reservoirs used for hydroelectric power; associated lake level fluctuations negatively impact those fisheries. These lakes include: Gogebic, Prickett, Bond Falls, Victoria, Silver, McClure, and Autrain.

The Michigan Department of Environmental Quality and the Great Lakes Indian Fish and Wildlife Commission have instituted a general mercury advisory for fish existing within all lakes, stipulating that smaller and leaner fish should be eaten. Specific advisories exist for the following lakes: Siskiwit, Gogebic, Bond Falls Flowage, Perch, Langford, Clearwater, Lindsley, Marion, Torch, Portage, Parent, Lake Independence, Cisco Chain, Deer, and Autrain. All of the above lakes have fish advisories for mercury, while Portage, Siskiwit, and Torch lakes also have advisories related to PCB contamination.

Ten lakes in the basin are listed as "non-attainment," mostly due to fish consumption advisories for mercury (Table 30). Currently, there are two AOCs identified by the International Joint Commission within Michigan's Lake Superior basin: Torch Lake in Houghton County and Deer Lake in Marquette County. Torch Lake was the receiving water for copper ore tailings and other contaminants. Sediments have high levels of arsenic, copper, and other metals and benthic invertebrate communities are impaired (MDEQ 1998). In the Torch Lake AOC, the impaired beneficial uses identified include restrictions on fish and wildlife consumption, fish tumors or other deformities, and degradation of benthos. The 2003 fish consumption advisory includes the larger sizes of northern pike, smallmouth bass, and walleye for mercury and PCBs. However, sauger, the fish species most heavily afflicted with tumors and anomalous growths, is no longer present within the AOC and consequently is not listed in the Advisory. Deer Lake environmental concerns include elevated mercury levels in fish. The Michigan Department of

Environmental Quality has been working to address and remediate these concerns for several years. Their efforts have been supported by the Deer Lake PAC since 1997. The AOC includes the Carp River watershed, Deer Lake, and the Carp River downstream about 32 km to Lake Superior in Marquette.

Table 30. Michigan non-attainment lakes in the Lake Superior basin (Michigan Dept. of Environmental Quality 1998).

Lake	Impairment
Chaney Lake	FCA – mercury
Marion Lake	Mercury Lake
Langford Lake	FCA – mercury
Six Mile Lake	Mercury Lake
Torch Lake	Macroinvertebrate community rated poor; water quality standard exceedances for copper
Perch Lake	Mercury Lake
Lake Independence	Mercury Lake
Deer Lake	FCA-mercury
Nawakwa Lake	Mercury Lake
Pike Lake	Mercury Lake

Ontario

Some of Ontario's inland lakes, particularly in the Thunder Bay and Sault Ste. Marie areas, are experiencing stress due to the effects of shoreline development. However, the majority of the lakes are undeveloped and the shorelines are managed as public lands. Current Ontario government policy prohibits development on lake trout lakes where all of the shoreline is public land, and limits development on patent lands with lake trout lakes based on the late summer hypolimnetic dissolved oxygen level.

More widespread stresses to Ontario inland lakes are associated with logging activity and exploitation. Most inland lakes in Ontario are within forest management units where logging takes place. Potential impacts of logging and associated road construction include increased sedimentation, increased water temperatures, changes in water yield and availability of woody debris (OMNR 1988). Ontario's Timber Management Guidelines for the Protection of Fish Habitat have been used since 1988 to minimize the effects of crown land logging operations on inland lakes and streams. A large, ongoing research project was initiated in 1990 to experimentally evaluate the effects of logging on boreal forest lakes and streams. In 2001, a second long term research study, funded by Ontario's Living Legacy Trust, was undertaken to determine the effects of two partial harvesting methods in riparian reserves. The results of these projects will help in the development of more scientifically-based guidelines to ensure the protection of fish habitat. With regard to exploitation on Ontario's inland lakes, standardized rapid assessment protocols have been developed in order to identify stressed populations which may require management intervention and to facilitate the development of management support models. These protocols include the spring littoral index netting, fall walleye index netting, and nearshore community index netting. A modified version of the trap net, based nearshore community index netting, has recently been used to assess walleye populations in the Georgian Bay area of Lake Huron and may prove to be a valuable assessment tool for the assessment of sensitive populations in embayments on Lake Superior.

Lake Nipigon is the largest inland lake in Ontario's portion of the Lake Superior watershed; with a surface area of 448,060 ha, it is approximately one quarter the size of Lake Ontario. Lake Nipigon supports trophy sports fisheries for brook trout and lake trout, as well as commercial fisheries for whitefish, lake trout, walleye, and more recently rainbow smelt. Stresses acting on the fish community of Lake Nipigon include exploitation, water level fluctuations, and the introduction of the non-indigenous rainbow smelt. Declines in Lake Nipigon walleye stocks in the early 1980s, attributed primarily to over-fishing, have led to angling closures and reduced commercial walleye quotas. Recovery of the walleye stocks in Ombabika Bay is being monitored on an ongoing basis. Rainbow smelt were first discovered in Lake Nipigon in the early 1980s and smelt numbers have increased dramatically since. It is unknown, however, what the long-term impacts of smelt will be on the Lake Nipigon fish community.

The level of Lake Nipigon is controlled by hydroelectric dams on the Nipigon River and by the diversion of water from the Ogoki River into Ombabika Bay. Winter draw-downs have impacted brook trout reproduction by de-watering brook trout spawning shoals. The draw-down impact on other fall spawning species is unknown. A water level agreement signed in 1994 for the Nipigon system has reduced water level impacts on Lake Nipigon as well as on the Nipigon River. This agreement is presently under review for renewal by the parties involved including OMNR (M. Chase, personal communication).

The Lake Nipigon Fisheries Assessment Unit (LNFAU) was established by the OMNR around 1980 to collect long-term data sets on the Lake Nipigon fish community. Current LNFAU projects include fish community index netting, fall walleye index netting, commercial catch sampling, smelt index netting, and lake trout index netting. The Anishinabek/Ontario Fisheries resource Centre has partnered with Lake Nipigon First Nations and the OMNR to conduct a number of projects since 1995. Studies included walleye, whitefish, and pike tagging and index netting programs for lake trout and whitefish.

Ontario lake survey data are available from 1,251 lakes within the basin, but there are thousands of unsurveyed lakes. Surveyed lakes tend to be large, accessible and support sport fishes. Many of the lake survey data are over 20 years old.

Two lakes in the basin, Lim and Mose lakes, are severely degraded by mine effluent (OME 1992). Numerous other lakes have fish consumption advisories, primarily due to mercury levels. Ontario does not have an on-going lake water quality program.

Dams have altered water level regimes on many of the larger inland lakes. Dams were built to improve navigation or for historical log drives and many of these dams persist today. Increased water levels resulted in flooding the original shoreline and disruption of the natural flooding-drawdown cycle.

6.6 Species and Ecosystems of Concern

6.6.1 Fish Populations

The fish community of Lake Superior is generally good and remains relatively intact compared to the other Great Lakes (Figure 69). Through rehabilitation, lake trout and lake whitefish stocks have increased substantially and may be approaching ancestral states. Some stocking still occurs in selected regions, but indigenous species are naturally reproducing throughout the lake and in numbers sufficient to sustain themselves. Diporeia populations appear stable. Lake herring have recovered but under sporadic recruitment. Natural reproduction supports most salmonid populations. Some nearshore fish populations, especially lake sturgeon, walleye, and brook trout, remain below historical levels.

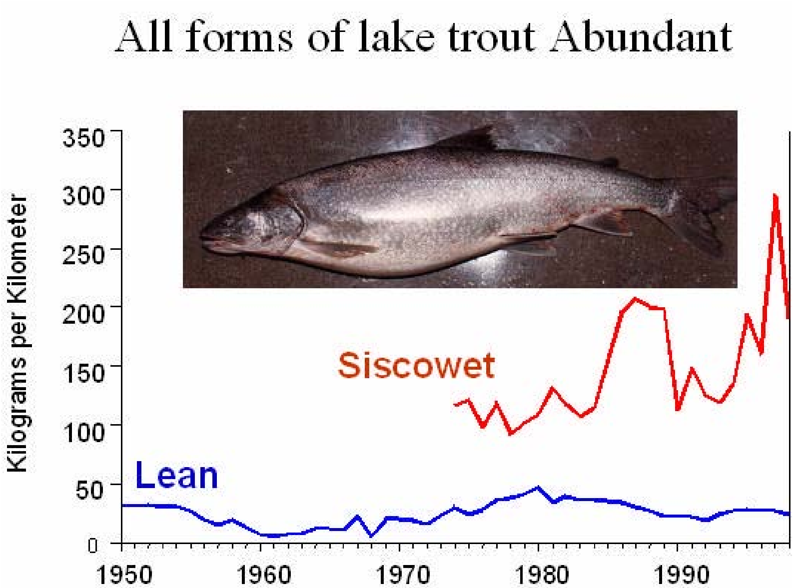


Figure 69: All Forms of Lake Trout are Abundant

Non-native species continue to be introduced to Lake Superior, although the fish community appears to contain enough buffering capacity to withstand and minimize the current levels of non-native species. Sea lampreys still kill thousands of lake trout each year. Ruffe and round gobies have colonized some areas and have the ability to negatively impact the nearshore cool-water fish community.

Lake Superior fish communities can be separated into two groups based on habitat preferences. The deeper water fish community made up of fish occupying the nearshore and offshore habitats are not currently habitat limited. While the shallower water fish community comprised of fish inhabiting embayments, estuaries, and tributaries are habitat limited. Habitat limits can be thermal, spatial, and artificially imposed by man due to some form of degradation or manipulation to the habitat. Species that are not limited by habitat and for which there is a sufficient amount of habitat to sustain and achieve both fish community and environmental objectives include:

- All lake trout forms, lake herring, lake whitefish, chubs, and round whitefish that spawn in Lake Superior itself;

- Salmonines other than lake trout that live in the offshore, nearshore, and embayment habitat; and
- Prey species like sculpins, trout-perch, ninespine stickleback, and pigmy whitefish.

In comparison, the following fish species are limited due to habitat loss and degradation in the Lake Superior basin, and achievement of fish community or environmental objectives may not be possible under current habitat conditions.

- Lake trout stocks that spawn in rivers found in eastern Ontario waters of the lake. The Montreal and Michipicoten River spawning populations of lake trout may be limited by habitat due to fluctuating water levels caused by a hydroelectric facility.
- The lake whitefish stock that historically spawned in the St. Louis estuary. This stock of whitefish was extirpated over 100 years ago because of habitat destruction.
- Walleyes, lake sturgeon, Pacific salmon, brown trout, brook trout, and other fish that live in Lake Superior but spawn in the tributaries, as well as tributary resident species such as brook trout, brown trout, sculpins, and cyprinids. Logging, road crossings, beaver and artificial dams are causing (1) loss of spawning and nursery habitat (due to sedimentation) and/or preventing access for upstream migrants, and (2) unfavorable changes in the thermal habitat.
- Yellow perch, northern pike, muskellunge, and smallmouth bass. Habitat loss and degradation in embayments and large tributaries has reduced the limited distribution and abundance of these species in the basin. These species are naturally limited thermally and by depth in Lake Superior.

The following are discussions of some of the fish populations impacted by overfishing, habitat loss and other stresses. These include walleye, coaster brook trout, lake trout, lake whitefish, deepwater ciscoes, and lake sturgeon.

Walleye

Historically, walleye was an important member of shallow-water (<3 m) fish communities in large embayments, estuaries and tributaries of Lake Superior (Hoff 1999). Walleye have been caught in at least 73 Lake Superior tributaries since 1950, and spawning has been documented at 33 areas. During the late 1800s and the first half of this century, walleye populations declined due to habitat degradation and overharvest (Hoff 1996). Walleye habitats in Lake Superior have been impaired by:

- Reduction or elimination of fish passage in spawning tributaries,
- Reduction in water quality caused by sedimentation and discharge of contaminants into the lake, and
- Degradation of spawning and nursery habitats in six areas.

Most walleye in the Minnesota waters of Lake Superior spawn within the 35 km stretch of the St. Louis River below the hydroelectric dam near the village of Fond du Lac (Hoff 1996). Spawning and nursery habitats in the St. Louis River have been degraded since the turn of the century by water pollution from the upstream discharge of untreated domestic and industrial waste. In particular, chlorophenolics and chloro-organics from pulp and paper mills caused oxygen deficiencies and reduced the palatability of walleye (Schram and others 1999). Improvements in waste treatment initiated by the Western Lake Superior Sanitary District in 1978 have curtailed obvious widespread habitat degradation caused by inadequately treated organic compounds and biochemical oxygen demand. It also dramatically improved walleye palatability and, consequently, angling pressure. Persistent toxic contaminants in walleye remain a problem in the St. Louis River, and further water quality improvements in the St. Louis

River basin have been recommended to enhance walleye populations (Hoff 1996). Key spawning areas in the St. Louis River are strongly influenced by manipulated water levels caused by hydroelectric dam operations. Fish kills and stranding of spawning walleye have been caused by bypassing water from the natural river channels to hydroelectric plants or from shutting down flows to recharge reservoirs. Recent licenses for dam operations have stipulated more favorable flow regimes, thereby increasing available walleye habitat.

The protection and enhancement of shallow nursery habitats within the St Louis River estuary has been aided by the purchase of waterfront property adjacent to the main spawning area by the Wisconsin DNR (Schram and others 1991).

In Wisconsin, there were historically three separate spawning populations:

- Western Lake Superior stocks that spawned primarily in the St. Louis River,
- Chequamegon Bay stocks that primarily spawn in the Kakagon River, and
- Bad River spawning population (Schram and others 1999).

Poor forestry and agricultural practices (e.g., management of livestock and associated wastes) in the Bad River watershed have degraded riparian habitats, increased sedimentation at some locations, and contributed to increased flooding and reduced water quality. Contaminants may also have negatively affected spawning walleye populations in the Bad River (Schram and others 1999) and consumption advisories remain for both the Kakagon and Bad Rivers.

Habitat for four of the five major walleye populations in Michigan waters of Lake Superior has been damaged. The Victoria Dam and Bond Falls Dam have impeded upstream migration to traditional spawning areas in the Ontonagon River. Peak flows from hydroelectric facilities at those dams have also caused bank erosion. Development, poor land use practices (e.g., logging), and poorly constructed road crossings have increased bank erosion and sedimentation and likely affected spawning habitats and wetlands throughout the Ontonagon River, the Huron Bay Watershed (Silver, Ravine, and Slate rivers), and the lower Tahquamenon River. Habitat loss from past logging-related shipping has also occurred in Sherman Park, Izaak Walton Bay, Cedar Point and Waishkey Bay (Hoff and others 1998). Habitat degradation does not appear to be significantly impacting the other major Michigan populations.

Black Bay and Nipigon Bay in Ontario historically had the largest population of walleye in Lake Superior. Thunder Bay and Whitefish Bay also supported large fisheries (Ryder 1968; Schneider and Leach 1977; Kelso and others 1996). The Black Bay population declined due to commercial fishing in the 1960s. Impaired water quality from paper mill effluent downstream of spawning areas on the Nipigon River has been identified as a major cause in the decline of the Nipigon Bay population in the 1960s (Ryder 1968), although overfishing also probably contributed (MacCallum and Selgeby 1987). Electrical barriers operated by the Sea Lamprey Control Centre during the 1950s and 1960s caused direct mortality of walleye in Lake Superior tributaries (including the Jackfish River) and prevented upstream migration to spawning grounds (Schram and others 1999). The Goulais Bay and Goulais River of the Whitefish Bay area supported a commercial walleye fishery until the mid 1960s. Current use of TFB-Bayer 73 lampricide treatments and low alkalinities in spawning areas are probably reducing survival of walleye eggs and larvae (Rose and Kruppert 1984). Hydroelectric dams on the Michipocoten River have restricted access to upstream spawning grounds. Habitat loss along the shoreline within the city of Thunder Bay may be limiting walleye stocks (Schram and others 1991). Concentrations of persistent toxic chemicals in walleyes from Goulais, Batchawana, and Nipigon bays remain above consumption advisories so further rehabilitation of water and sediment quality in walleye habitats is needed.

The Walleye Subcommittee of the Lake Superior Technical Committee has reported on the status of walleye populations (Hoff 1996) and drafted a rehabilitation plan (Hoff 1999). They recommend that:

> *The Lake Superior fish community will be managed to maintain, enhance, and rehabilitate habitat for, and self-sustaining populations of, walleye in areas where the species historically maintained populations.*

Objectives for rehabilitation of walleye habitats included (Hoff 1999):

- Creating or maintaining spawning and nursery habitats (St. Mary's River, Ontonagon River, Huron Bay Watershed, Bad River);
- Enhancing fish passage past a dam in the Ontonagon River;
- Reducing sedimentation by 50 percent in the St Mary's River, Tahquamenon River, and the Huron Bay Watershed;
- Eliminating point source discharges of persistent toxic chemicals into the lake to reduce contaminant concentrations in walleyes; and
- Improving land and water use practices in the St Mary's River, Ontonagon River, Huron Bay Watershed, and the Bad River.

Brook Trout

Brook trout are common in Lake Superior cold water tributaries. The large form of brook trout that exhibits a migratory or lake dwelling life history was historically common and widespread in the nearshore waters of Lake Superior and was often referred to as "coasters" or "rock trout" because of their preference for rocky, shallow coastal areas. Coaster brook trout typically spawn in tributaries in the fall before returning to the lake; fry remain in-stream during early development before descending to the lake. Shoal spawning coasters may spend their entire life cycle in Lake Superior, whereas others make many movements between stream and lake habitats during the year (Newman et. al. 2003).

There is little information on Lake Superior brook trout before 1900 because early catch records did not distinguish brook trout from lake trout. In the early 1800s, lake-dwelling brook trout were found in most Lake Superior waters within about 15 m from shore, or about islets and shoals close to shore (Shiras 1935). They were less common along sandy beaches and steep, wave-washed cliffs. Coasters historically spawned in at least 106 Lake Superior tributaries, including 61 in Ontario, 25 in Michigan, 12 in Wisconsin, and nine in Minnesota. They were probably present below the first barrier in all streams along Lake Superior's north shore (Waters 1983) and most coldwater streams along the south shore.

Overfishing, particularly by anglers, is considered the primary cause for the abrupt decline of coaster brook trout populations after the 1860s. Brook trout are very vulnerable to angling, and coasters particularly so because they inhabit shallow shoreline areas and congregate at stream mouths for feeding and spawning. Incidental catch of brook trout in nearshore gill nets increased as fishing effort for lake trout and whitefish expanded in the early 1900s. In some areas, spawning fish were netted at stream mouths, which led to extirpation of local populations (Newman and Dubois 1997). During the late

1800s and early 1900s, anglers from across North America fished for large brook trout in Lake Superior's waters and tributaries, particularly the Nipigon, St. Mary's, Bois Brule and Salmon Trout rivers (Newman and Dubois 1997). By the early to mid 1900s, coaster brook trout were reduced to the small, scattered populations which have persisted in less accessible areas.

Habitat loss contributed to the decline in coaster populations and may be responsible for suppressing the recovery of stocks. Most destruction of habitat resulted from logging in the Lake Superior watershed, which accelerated in the late-1800s. Critical spawning areas were degraded by sedimentation from increased erosion and deposition of bark debris from log drives. Coarse, woody material essential for fish habitat was removed from stream banks and bottoms during log drives. Elimination of riparian cover, clear-cutting of watersheds and resulting wildfires may have increased water temperatures and changed groundwater movement. Finally, dam construction blocked migration routes and altered natural stream flow, sometimes resulting in exposure of eggs during drawdown for hydroelectric production (Newman and Dubois 1997). At about the same time, introduction of non-native salmonids such as the rainbow trout, brown trout, coho salmon, and chinook salmon may have represented an additional stress.

Assessment of the current distribution and abundance of coaster brook trout is difficult due to the presence of introduced hatchery fish and non-migratory stream fish. Interbreeding with domestic strains of brook trout may also have altered the genetic composition of native brook trout and reduced their migratory tendency (Newman and Dubois 1997). Coaster brook trout now persist as scattered remnant populations and have been eliminated from many areas, especially along the south shore of the lake. They persist where there is suitable habitat and some measure of protection from overexploitation by angling.

In Ontario, small numbers of coaster brook trout are caught at numerous locations in the lake and in many tributaries. The most important remaining spawning location is the Nipigon River (Newman and Dubois 1997), which may offer some degree of protection from over harvest due to its large water volume and flow. The Cypress, Gravel, and Little Gravel rivers also support consistent spawning runs. A shoal-spawning coaster brook trout population is present at Isle Royale, and stream spawning stocks are likely present in Washington and Grace Creeks and the Big and Little Siskiwit rivers. Coaster brook trout numbers are occasionally reported at numerous locations along the south shore of Lake Superior, but abundance is considered very low. In mainland Michigan, only the Salmon Trout River still has a spawning run of coaster brook trout, and that population may be imperiled. In Minnesota, the Little Marais River may have spawning coaster brook trout, and reintroduced coaster brook trout appear to be spawning in two tributary streams on the Grand Portage Indian Reservation. No reproducing coaster populations are known from Wisconsin.

Recovery efforts for Lake Superior coaster populations have focused on identifying, protecting, and rehabilitating historical spawning streams. Efforts involve angling regulation (seasons, bag limits, and size restrictions) and water level regulation (Newman et. al. 2003). Stocking brook trout in U.S. waters of Lake Superior has taken place since the late 1800s, but return rates have been low and little or no natural reproduction has been recorded. In Ontario, brook trout were stocked in Lake Superior tributaries from 1921 to 1987. Stocking records indicate that approximately 4.8 million brook trout were planted along the north shore between 1921 and 1940, with 1.9 million of these fish being placed in the Nipigon River. Brook trout fingerlings were stocked annually on lakeshore springs and upwelling areas in western Lake Superior from 1994-1997.

The use of strains that originated outside of the Lake Superior basin may have contributed to poor stocking success. Currently there are three brood stocks from the basin that are available for stocking. The U.S. Fish and Wildlife Service maintains two strains of brook trout from Isle Royale and the OMNR and the Red Cliff Band each rear Lake Nipigon strain fish.

A binational effort is underway between federal and provincial/state agencies, universities, and two non-governmental organizations (Trout Unlimited and Trout Unlimited Canada) in order to coordinate work toward rehabilitating coaster brook trout in Lake Superior.

Lake Trout

Lake trout were historically the dominant predator in Lake Superior until the 1950s, when they declined rapidly due to commercial fishing pressure and sea lamprey predation (Hansen 1994). Lake trout numbers are dependent on a complex combination of fishing pressure, prey abundance, competition with introduced salmonids and other species, stocking, and predation, especially by sea lamprey. Despite stocking efforts, lake trout populations have not recovered to historical levels. With a few exceptions, habitat loss and degradation is not considered to have been a major factor in lake trout decline, nor as a limiting factor for their recovery. While consumption of alewife and smelt, two species with high concentrations of thiaminase, may be a factor hindering recovery of lake trout in other Great Lakes, there is no evidence that this was the case in Lake Superior.

Lake trout are well adapted to cold, clear, oligotrophic conditions, and most offshore and nearshore areas of Lake Superior comprise important habitat for lake trout at some life stage. Lake trout historically spawned at 337 sites in the main basin of Lake Superior, of which 210 were along the mainland and 127 offshore or along island shorelines (Table 32).

Approximately one-half of the spawning sites were in Canadian waters, with a greater proportion of the offshore sites. Lake trout typically spawn over coarse substrates (e.g., boulder and cobble) with little or no fine material on offshore reefs and shoals or on points extending into deep water (Marsden and others 1995). In Minnesota, shallow water habitats (<20 m) had a greater proportion of good spawning habitat with coarse substrate than deeper habitats that tended to have more fine materials (Richards and others 1999).

Lake Superior lake trout consist of a number of reproductively isolated stocks distinguished from each other by differences in the shape of the snout, body shape, coloration, fat content, size of the eye, and thickness of the abdominal wall. Although up to 12 variants have been identified, three main forms are recognised: leans, siscowets, and humpers (Goodier 1981).

Lean lake trout typically inhabit nearshore waters less than 80 m deep, shallow offshore reefs, and the nearshore waters around the islands in Lake Superior. Lean lake trout spawning grounds are found in both nearshore and offshore areas in <80 m of water. Approximately 23 percent or 1.9 million ha of Lake Superior is less than about 80 m deep, but in U.S. waters only 12 percent of the area <73 m deep should be considered as lean lake trout spawning habitat (Ebener 1998). A similar proportion may be suitable in Canadian waters. Lean lake trout spawn offshore at the Gull Islands, Superior Shoal, Stannard Rock, Caribou Island, Michipicoten Bay, and the area north of Whitefish Bay.

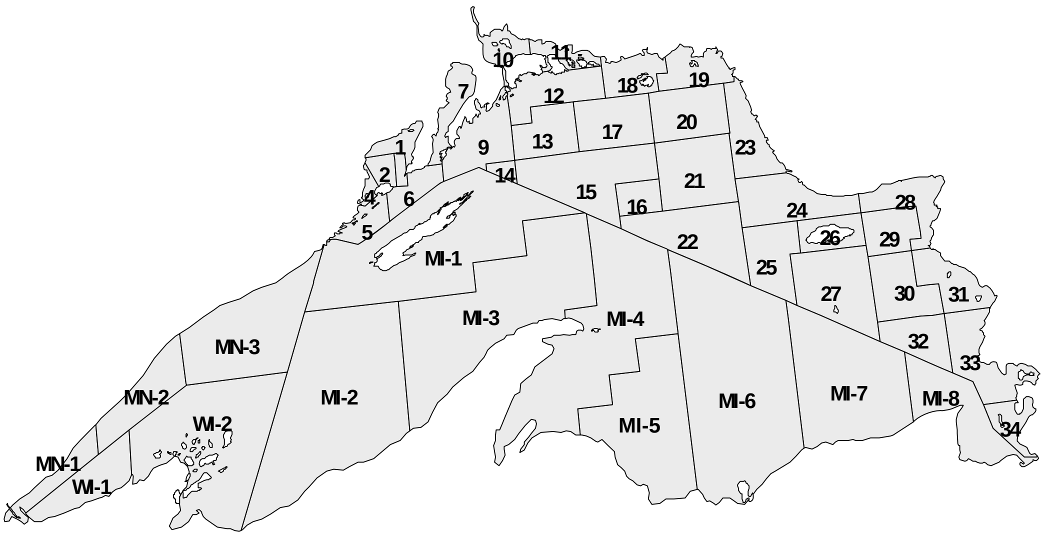


Figure 70. Commercial fisheries zones.

Nearshore spawning habitats in most of the lake are associated with the mainland shoreline, with the exception of Wisconsin where almost all lean lake trout spawning habitat in the nearshore zone is located along the outer periphery of the Apostle Islands, since most of the mainland shore is sand or clay (MacCallum and Selgeby 1987). The Gull-Michigan Island Reef, approximately 30 km offshore, is the main site of wild reproduction in Wisconsin, although limited natural reproduction occurs at numerous other locations in Wisconsin (Swanson and Swedberg 1980).

Lean lake trout spawning habitat in embayments is found in Keweenaw, Whitefish, Thunder, and Nipigon bays. Lean lake trout historically spawned in nine tributaries in eastern Lake Superior (Goodier 1981; Ebener 1998) from the Steel to Montreal rivers. Wild lean lake trout have been recently found in spawning condition inside the mouths of the Montreal and Dog rivers, but spawning has not been confirmed (Ebener 1998). Lake trout also use these rivers during the non-spawning season.

Siscowets usually are found in deep (50 to 150 m), offshore waters, but they are also abundant in nearshore waters. All water <90 m, and much that is deeper, is considered spawning habitat for siscowets. They spawn in deep water around offshore reefs. Siscowets appear to be more abundant in nearshore areas relative to lean lake trout than was observed in the past.

Humpers are less common and live predominantly on isolated shoals surrounded by deep waters around Isle Royale and in eastern waters of the lake around Caribou Island (Hansen 1996). They spawn at most of the same offshore sites as leans, with the potential exception of Stannard Rock.

Table 31 summarizes critical and important habitats for leans, siscowets and humpers (Ebener 1998). Most of the identified important habitat is in offshore areas such as Superior Shoal, Caribou Island, Isle

Royale, and Stannard Rock where remnant stocks of native lake trout persisted. Offshore habitats were critical since abundance, especially of mature wild fish, never fell as low as it did in the inshore region (MacCallum and Selgeby 1987). Stocks of lean lake trout occupying many offshore reefs or shoals are probably genetically distinct (Ebener 1998). In addition, they are less vulnerable to impacts from human activities than nearshore areas. Although much of the focus has been on spawning sites, optimal habitat for other life history stages of lake trout is also essential. However, the distribution of larval lake trout in Lake Superior is too poorly known to accurately quantify nursery habitat. About 40 percent of the waters less than 90 m is suitable nursery habitat for lean lake trout.

Table 31. Critical and important habitat in Lake Superior for lake trout.

STRAIN	LIFE STAGE	IMPORTANT HABITAT	CRITICAL HABITAT
Offshore(>80 m)			
Lean	juvenile	all water <91 m	Stannard Rk., Superior Sh., Caribou I., Gull Island Sh., Isle Royale
	non-spawning adult	all water <146 m	Stannard Rk., Superior Sh., Caribou I., Gull Island Sh., Isle Royale
Siscowet	egg	all water >110 m	unknown
	juvenile	all water 80 to 128 m	none
	non-spawning adult	all water >110 m	none
	spawning adult	all water >110 m	unknown
Humper	egg	rock substrate <60 m in offshore areas	Caribou I., Isle Royale, Superior Sh.
	juvenile	Unknown	none
	non-spawning adult	Unknown	none
	spawning adult	rock substrate <60 m in offshore areas	Caribou I., Isle Royale, Superior Sh.
Nearshore (<80 m)			
Lean	egg	rock substrates 0.5 to 30 m	rock substrates 0.5 to 30 m, DO>6mg/l
	juvenile	all water 35 to 80 m	None
	non-spawning adult	all water 35 to 80 m	None
	spawning adult	rock areas 0.5 to 30 m	rock substrates 0.5 to 30 m
Siscowet	egg	Unknown	Unknown
	juvenile	all water <80 m	None
	non-spawning adult	water 36 to 80 m	None
	spawning adult	unknown, probably very little	Unknown
Humper	egg	rock substrate <60 m	water <60 m Caribou I., Isle Royale, Superior Sh.
	juvenile	offshore banks Isle Royale, Caribou Is.	none
	non-spawning adult	offshore banks Isle Royale, Caribou Is.	none
	spawning adult	rock substrate <60 m	water <60 m Caribou I., Isle Royale, Superior Sh.
Tributaries			
Lean	egg	eastern Lake Superior tributaries	Montreal & Dog (University) rivers
	juvenile	eastern Lake Superior tributaries	Montreal & Dog (University) rivers

Lake trout habitat can be adversely affected by toxic pollutants, poor water quality, watershed misuse, sedimentation, eutrophication, and residential and commercial development (Hansen 1996). Industrial pollution in the form of low-level contamination by organic pollutants and metals may have had effects on the health and reproduction of lake trout (especially fatty siscowets) (Busiahn 1990); however, the effects have not been thoroughly evaluated in Lake Superior fishes. Relatively shallow water directly adjacent to the shore is important as potential spawning areas for lake trout but such areas are frequently impacted by upland land uses (Richards and others 1999). For example, lake trout spawning habitat in Terrace Bay has been destroyed through the historic deposition of orgainc materials and chemical contamination of sediments. Mine tailing at the north and south entry to the Keweenaw Bay Waterway have degraded lake trout habitat (Donifrio 2003). In eastern Lake Superior, the Montreal River population of lake trout may currently be limited by habitat due to fluctuating water levels caused by a hydroelectric facility (Ebener 1998).

The Lake Trout Restoration Plan for Lake Superior (Hansen 1996) recommended that an atlas of lake trout spawning grounds be developed. General locations of lake trout spawning habitats were mapped by Cobery and Horrall (1980), Goodier (1981), and Goodyear and others (1981) but need to be ground-truthed. Habitat that is essential for lake trout reproduction and survival should be identified, mapped and protected (Busiahn 1990). Progress has been made in Minnesota, where lake trout spawning habitat along 65 km^2 of waters less than 30 m deep on Minnesota's North Shore has been surveyed using remote hydro-acoustic techniques coupled with a GPS and GIS (Richards and others 1999).

Table 32. Estimated quantity of total, spawning, and nursery habitat, and biological parameters for lake trout in each management unit in Lake Superior. Number of spawning sites taken from Cobery and Horrall (1980), Goodyear and others (1981) and Goodier (1981) and includes present day as well as historically important areas. Spawning habitat is considered to be <9 m deep. Average CPUE, wild fish, and mortality for U. S. and Canadian waters adjusted for area <73 m and <91 m deep, respectively.

Mgt Unit	Total habitat (ha)		No. spawning sites		Spawning habitat		Nursery habitat		Biological parameters			
									Years	Survey CPUE[3]	Wild fish[4] (%)	Annual Mortality * (%)
	total	<73 m[1]	onshore	offshore	(ha)	% area[2]	(ha)	% area[2]				
MI-1	573,003	49,645	18	2	13,600	27	1,200	2	1993-95	16	98	29
MI-2	636,599	87,786	7	0	4800	5	1,200	1	1996	34	87	45
MI-3	620,654	64,674	10	0	4625	7	1,200	2	1996	7	91	41
MI-4	622,657	132,146	15	7	15,213	12	2,300	2	1996	14	88	51
MI-5	367,935	76,385	13	0	4,290	6	14,500	19	1996	32	83	42
MI-6	761,196	74,934	7	3	36,600	49	71,500	95	1996	45	90	58
MI-7	411,881	81,697	1	5	31,300	38	42,800	52	1996	18	94	54
MI-8	179,626	176,868	2	1	14,300	8	40,100	23	1996	10	17	68
WI-1	107,408	48,513	1	0	12	0	0	0	1995 & 97	20	42	36
WI-2	400,703	231,797	12	23	7,773	3	266,131	115	1995 & 97	18	71	37
MN-1	107,723	57,185	8	0	5,700	10	1,190	2	1996	34	45	45
MN-2	173,567	7,955	9	0	400	5	430	5	1996	7	20	40
MN-3	358,789	14,899	21	0	1,200	8	4,500	30	1996	26	70	45

Table 32. Estimated quantity of total, spawning, and nursery habitat, and biological parameters for lake trout in each management unit in Lake Superior. Number of spawning sites taken from Cobery and Horrall (1980), Goodyear and others (1981) and Goodier (1981) and includes present day as well as historically important areas. Spawning habitat is considered to be <9 m deep. Average CPUE, wild fish, and mortality for U. S. and Canadian waters adjusted for area <73 m and <91 m deep, respectively.

Mgt Unit	Total habitat (ha)		No. spawning sites		Spawning habitat		Nursery habitat		Biological parameters			
									Years	Survey CPUE[3]	Wild fish[4] (%)	Annual Mortality * (%)
	total	<73 m[1]	onshore	offshore	(ha)	% area[2]	(ha)	% area[2]				
Subtot.	5,321,741	1,104,485	124	41	139,813	13	447,051	40	1993-97	21	69	48
1	33,366	33,046	4	2					1992-96	90		<45
2	22,451	22,440	0	4					1992-96	47		<45
3	10,922	9,765	1	1					1992-96	100		<45
4	13,871	13,871	3	3					1992-96	44		
5	41,614	25,361	5	1						22		
6	46,285	5,875	3	2					1992-96	46		
7	60,139	60,139	2	0					1992-96	16		
8	4,431	3,409										
9	101,191	28,759	11	3					1992-96	37		
10	39,818	39,818	3	6								
11	35,627	31,229	1	6					1992-96	34		
12	105,284	14,218	0	10					1992-96	36		
13	91,264	0										
14	27,415	2,784	0	3					1992-96	185		
15	209,058	0										
16	45632	2,192	0	4					1992-96	318		
17	119784	919										
18	67,572	17,485	9	8						110		
19	72,227	26,510	9	0					1992-96	27		
20	119,784	13,209										
21	159,712	23										
22	204,436	0										
23	99,844	10,240	8	0					1992-96	68		<45
24	137,912	26,158	5	0					1992-96	51		<45
25	109,766	6,347										
26	49,287	15,657	0	15						291		
27	182,150	57,232	0	3					1992-96	270		
28	88,909	43,661	10	0					1992-96	52		23
29	79,856	10,681	0	0						280		
30	114,080	0	0	0					1992-96	229		<45
31	90,303	51,997	2	11					1987-92	11	45	42
32	77,099	2,552	0	0					1992-96	273		<45
33	131,729	90,707	4	3					1987-92	8	35	69
34	47,452	44,409	6	1					1987-92	7	2	63
Subtot	2,840,270	710,693	86	86	0	0	0	0	1992-96	61		<45
Total	**8,162,011**	**1,815,178**	**210**	**127**	**139,813**	**0**	**447,051**	**0**				

[1] *Canadian waters is <91 m deep.*
[2] *Percent of areas <73 m deep in U. S. waters.*
[3] *CPUE is fish per 305 m of survey gill net in U. S. waters and in Canada CPUE is based on commercial catches and expressed as kg/km.*
[4] *In MN-1, MN-2, and MN-2 is percent of fish ≤635 mm total length.*
[5] *Mortality rates are for ages 5-9 in 1996-97 for MI-8, whereas ages 9-12 MI-3 through MI-7.*

Lake Whitefish

Lake whitefish are not generally limited by habitat in Lake Superior. Lake whitefish spawn on sand, gravel, and rock substrates in 2 to 23 m (usually <5m) of water from late October to early December at water temperatures of 0.5 to 5.5°C (Ebener 1998). Upon hatching in the spring, the pelagic larvae float with the currents and often accumulate in embayments (Reckahn 1970). During the first summer, young lake whitefish (age-0) are believed to be associated with the 17° C isotherm in bays and estuaries until they switch from a planktivorous to a benthic diet and move to colder and deeper water in the fall. Juvenile and adult lake whitefish feed primarily on benthic invertebrates over soft bottom areas (primarily sand and silt) from the nearshore to offshore waters <73 m deep. Adults often return to shallower waters in the spring to feed on emerging mayflies (Goodier 1982). Most adult whitefish remain within 40 km of natal spawning grounds, which has led to the differentiation of semi-discrete stocks (Lawrie and Rahrer 1973).

The general locations of lake whitefish spawning grounds in Lake Superior are summarized by Cobery and Horrall (1980), Goodier (1981) and Goodyear and others (1981). These areas are considered critical spawning habitat and are generally restricted to nearshore and embayment habitats. Current whitefish spawning grounds are located in the Apostle Islands, along the Keweenaw Peninsula, and in Whitefish Bay (Table 33). Lake whitefish spawn off Isle Royale but there is very little whitefish spawning habitat in western Wisconsin waters, Minnesota waters and along the northeastern Canadian shoreline.

Approximately 123,000 ha or 11 percent of the water <73 m deep is considered lake whitefish spawning habitat. As much as 300,000 ha of suitable lake whitefish nursery habitat may be available in Lake Superior, but this estimate is very rough (Ebener 1998). Lake whitefish historically spawned at 106 sites, 60 of which were in nearshore areas and the remainder on the outside of islands. Ten sites were located in embayment habitats. Most sites (90) were in U.S. waters. Lake whitefish historically spawned in the St. Louis estuary, the Michipicoten, White, University (Dog) and Kaminstiquia rivers, and St. Mary's River above the rapids (Lawrie and Rahrere 1972, Goodier 1982). Spawning populations are still known from the Anna River near Munising (Ebener 1998).

Nearshore habitat bordered by beaches and sandy bays are critical both as spawning habitat and food sources for adults. These areas require protection from dredging, shoreline development, contaminants, and localized increase in nutrients. Past illegal dredging for aggregate on whitefish spawning grounds in Whitefish Bay reduced habitat (S. Greenwood 2004, personal communication). Mine tailing from the north and south entry, to the Keweenaw Peninsula Waterway negatively impact lake whitefish populations. Lake whitefish have been reported to contain a wide variety of organic and metallic contaminants, such as PCBs from Peninsula Harbour near Marathon (ULRG 1977). Deposition of woody debris in rivers, embayments and nearshore areas has degraded other habitat. The lake whitefish stock that historically spawned in the St. Louis River estuary was extirpated in the late 1800s because of habitat destruction. Dredging and dumping of grain screenings degraded spawning grounds in the Kaministiquia River (Goodier 1982).

Fish community objectives for Lake Superior include restoring the presence of lake whitefish to historic spawning sites in the lake and historic spawning tributaries (Ebener 1998).

Table 33. Estimated quantity of total, spawning, and nursery habitat, and biological parameters for lake whitefish in each management of Lake Superior. Number of spawning sites taken from Cobery and Horrall (1980), Goodyear and others (1981) and includes present day as well as historically important areas. Spawning habitat is considered to be <9 m deep. Average catch per unit effort (CPUE) and mortality in U. S. and Canadian waters adjusted for area <73 m and <91 m deep, respectively.

Mgt unit	Total habitat (ha)		No. spawning sites		Spawning habitat		Nursery habitat		Biological parameters		
									Years	CPUE[1]	Annual mortality
	Total	<73 m[1]	on shore	off shore	(ha)	% area[2]	(ha)	% area[2]			
MI-1	573,003	49,645	9	0	628	1			1978-81		55
MI-2	636,599	87,786	0	0	300	0	700	1	1996	160	45
MI-3	620,654	64,674	7	0	400	1	600	1	1996	130	78
MI-4	622,657	132,146	14	2	500	0	800	1	1996	72	73
MI-5	367,935	76,385	2	1	18,600	24	4,700	6	1994-96	71	30
MI-6	761,196	74,934	9	0	52,500	70	37,000	49	1996	57	50
MI-7	411,881	81,697	1	0	13,000	16	20,000	24	1996	156	53
MI-8	179,626	176,868	6	0	25,500	14	39,500	22	1996	93	57
WI-1	107,408	48,513	2	0	162	0	0	0		20	
WI-2	400,703	231,797	4	35	8,500	4	187,023	81	1996	126	73
MN-1	107,723	57,185	0	0	0	0	0	0			
MN-2	173,567	7,955	5	0	0	0	7,955	100			
MN-3	358,789	14,899	2	0	3,000	20	0	0			
Subtot.	5,321,741	1,104,485	61	38	123,090	11	298,278	27		104	63
1	33,366	33,046	1	0					1992-96	427	<45
2	22,451	22,440	1	0					1992-96	184	
3	10,922	9,765							1992-96	102	
4	13,871	13,871							1992-96	132	
5	41,614	25,361							1992-96	129	
6	46,285	5,875							1992-96	88	
7	60,139	60,139							1992-96	88	<45
8	4,431	3,409									
9	101,191	28,759							1992-96	140	
10	39,818	39,818									
11	35,627	31,229							1992-96	74	
12	105,284	14,218							1992-96	200	
13	91,264	0									
14	27,415	2,784							1992-96	5	

Table 33. Estimated quantity of total, spawning, and nursery habitat, and biological parameters for lake whitefish in each management of Lake Superior. Number of spawning sites taken from Cobery and Horrall (1980), Goodyear and others (1981) and includes present day as well as historically important areas. Spawning habitat is considered to be <9 m deep. Average catch per unit effort (CPUE) and mortality in U. S. and Canadian waters adjusted for area <73 m and <91 m deep, respectively.

Mgt unit	Total habitat (ha)		No. spawning sites		Spawning habitat		Nursery habitat		Biological parameters		
									Years	CPUE[1]	Annual mortality
	Total	<73 m[1]	on shore	off shore	(ha)	% area[2]	(ha)	% area[2]			
15	209,058	0									
16	45,632	2,192							1992-96	0	
17	119,784	919									
18	67,572	17,485							1992-96	59	
19	72,227	26,510							1992-96	79	
20	119,784	13,209									
21	159,712	23									
22	204,436	0									
23	99,844	10,240							1992-96	143	<45
24	137,912	26,158							1992-96	76	<45
25	109,766	6,347									
26	49,287	15,657							1992-96	109	
27	182,150	57,232									
28	88,909	43,661							1992-96	152	<45
29	79,856	10,681									
30	114,080	0									
31	90,303	51,997							1992-96	108	68
32	77,099	2,552									
33	131,729	90,707	2	1					1992-96	99	39
34	47,452	44,409	1	1					1992-96	151	36
Subtot.	2,840,270	710,693	5	2					1992-96	131	<45
Total	8,162,011	1,815,178	66	40	123,090	0	298,278	0		114	

[1]*Canadian waters is <91 m deep.*
[2]*Percent of areas <73 m deep in U. S. waters*
[3]*Catch Per Unit Effort is expressed as kg/km of gill net.*

Lake Sturgeon

A commercial sturgeon fishery had started by the early-1800s and the lake sturgeon population probably began to decline in the mid-1800s. By the late-1800s, the stock had declined dramatically. Low reproductive rate and slow growth made sturgeon vulnerable to over-fishing. Despite harvest restrictions implemented in the 1920s, sturgeon were commercially extinct in Lake Superior by 1940 (Waters 1987). Sturgeon populations have not recovered to historical levels (Hansen 1994).

Lake sturgeon prefer nearshore waters, 4 to 9 m deep, but are occasionally found at depths up to 43 m (Harkness and Dymond 1961). Shoals and embayments where benthic organisms are most abundant are the preferred foraging areas (Table 35). Offshore waters (>80 m) are not used. Spawning occurs in rapids in streams or in lakes over shallow rocky ledges and shoals where wave action keeps the eggs oxygenated (Scott and Crossman 1973). Larval fish drift downstream after hatching and typically remain in the stream or shallow waters for the first two years. Juvenile habitat requirements are poorly understood. Yearlings are sometimes found over flat sandy areas.

Ten Lake Superior tributaries currently have self-sustaining sturgeon populations (Table 34, Figure 70) (Auer 2003). Populations in all tributaries are reduced from historical levels. Another ten tributaries were historically used for spawning but are not presently used.

The decline of sturgeon on Lake Superior was largely due to over-fishing, but habitat loss also contributed. Dams on spawning rivers created barriers for spawning migration and altered natural stream flow regimes during the spawning period. Unnaturally low water levels can kill embryos by exposing them to air. High flows can dislodge eggs or embryos from the substrate (Kempinger 1988). Adults are sometimes trapped by falling water levels (Mike Friday, personal communication). Deposition of bark and other debris from log drives buried spawning beds (Harkness and Dymond 1961) and changes in land use along streams may have increased sedimentation and degraded water quality.

Dredging shipping channels in nearshore waters and harbor construction and shipping at river mouths contributed to decline in benthic organisms. Bioassays showed that young lake sturgeons (<100 mm) are sensitive to the lampricide 3-trifluoromethyl-4-nitrophenol (TFM) at concentrations that were applied to streams to kill sea lamprey larvae (Johnson et al. 1999). Lampricide treatments are scheduled to avoid vulnerable life stages and lampricide is applied concentrations that minimize risk to larval and juvenile lake sturgeon.

A rehabilitation plan for lake sturgeon in Lake Superior (Auer 2003) recommends several habitat-related measures, including (1) protecting existing habitat, (2) restoring natural stream flow regimes through re-licensing criteria for hydroelectric dams, (3) providing passage past barriers and dams, and (4) minimizing the impact of sea lamprey control activities. Eight “critical management areas,” with suitable habitat and existing spawning stocks, are priorities for rehabilitation and protection (Figure 71). Other recommendations involve harvest, stocking and contaminants.

Information needs include (1) basic life history and abundance data, (2) descriptions and of nursery, juvenile, and adults habitats, and (3) quantification and mapping of habitat.

Figure 71. Critical management areas for lake sturgeon. Numbers indicate self-sustaining spawning tributaries (Table 34) (Auer 2003).

Table 34. Tributaries with current or historical lake sturgeon populations (Auer 2003). Numbers refer to stream locations on Figure 71.

Tributary	Status	Stressors
Pigeon River, MN/ON	Historical	
St. Louis River, MN/WI	Historical	Exotic species, loss of wetlands
Bad River, WI (8)	Current	Sedimentation, harvest
*Ontonagon River, MI	Historical	Erosion, loss of wetlands, regulated flow, dredging in lower river
Sturgeon River, MI (9)	Current	Dam, sediment loads, regulated flow
Tahquamenon River, MI	Historical	Sedimentation, past logging practices, little spawning habitat
Batchewana River, ON	Current**	Harvest**
Pic River, ON (5)	Current	Dam, regulated flow, historical and current logging,
*Black Sturgeon River, ON (2)	Current	Dam, historical logging
Goulais River, ON (7)	Current	
Gravel River, ON (4)	Current	
Chippewa River, ON	Historical	
Kaministiquia River, ON (1)	Current	Dam, regulated flow, power plant entrainment
*Michipicoten River, ON (6)	Current	Dam, poaching, regulated flow
Montreal River, ON	Historical	Regulated flow
Montreal River, MI/WI	Historical	Dam, regulated flow
Nipigon River, ON (3)	Current	Dam, regulated flow
White River, ON	Historical	

White River, WI	Historical	Dam, regulated flow
*Wolf River, ON	Historical	Dam, lamprey barrier

* *priorities for habitat restoration*
** S. *Greenwood, personal communication 2003*

Table 35. Embayments important to lake sturgeon in Lake Superior (Auer 2003).

Harbor/ Bay	Most Recent Observation	Stressors
Grand Portage Bay, MN	2003	
St. Louis, MN/WI	2003	
Chequamegon, MI	2003	
Bete Gris, MI	1993	Fishing
Huron, MI	1995	Siltation from poor stream crossings, logging practices, fishing
Keweenaw Bay, MI	2003	Treated waste management, treated paper mill effluent, fishing
Misery, MI	1995	Fishing
Munising Bay, MI	1991	Fishing
Whitefish Bay, MI	2003	Dredging for ship channel, contaminants, fishing
Batchewana Bay, ON	1997	Habitat loss, harvest
Black Bay, ON	1996	
Clark's Bay, ON	1997	
Goulais Bay, ON	1997	By-catch of juveniles and adults
Michipicoten , ON	1997	
Nipigon Bay, ON	1997	
Thunder Bay, ON	1997	Shoreline development
Wawanagon Bay, ON	1997	

Deepwater Ciscoes

Deepwater ciscoes consist of seven species, five of which inhabited Lake Superior: blackfin cisco (*Coregonus nigripinnis),* shortjaw cisco (*C. zenithicus),* bloater *(C. hoyi),* shortnose cisco *(C reighardi),* and kiyi (*C. kiyi).* Two other species, deepwater cisco *(C. johannae)* and longjaw cisco *(C. alpenae)* were found only in the lower Great Lakes, and longjaw cisco is now probably extinct. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) reports as of 2003 that shortjaw cisco is in decline in Lake Superior. It is still present in Lake Nipigon and numerous smaller lakes where its status is not well known. Blackfin cisco is now probably extirpated from Lake Superior, although it is still found in Lake Nipigon and other inland lakes. All but blackfin cisco and shortjaw cisco were endemic to the Great Lakes (Scott and Crossman 1973). Five of these seven are listed by COSEWIC: the deepwater cisco is Extinct; shortnose cisco, shortjaw cisco, and blackfin cisco are Threatened; and the kiyi is considered of Special Concern.

The *Species at Risk Act* (SARA), proclaimed in June 2003, is one part of a national three part Government of Canada strategy for the protection of wildlife species at risk. Section 28 of SARA allows any person who considers that there is an imminent threat to the survival of a wildlife species to apply to COSEWIC for an assessment of that threat and to have the species listed as endangered on an emergency basis. COSEWIC has not reported on any new assessments for ciscoes or other fish species in the Lake Superior basin in their November 2003 report (COSEWIC 2003).

Deepwater ciscoes formerly supported a substantial fishery in the Great Lakes. Fish were caught in deep-water gill nets, smoked, and sold in the U.S. Fishermen targeted the larger, fatter species (blackfin, deepwater, and longjaw) until these stocks collapsed and then moved on to smaller species. The commercial cisco fishery declined through the 1940s and 1950s and collapsed by about 1960. Cisco populations increased through the early 1960s apparently in response to the decline of lake trout, an important predator (MacCallum and Selgeby 1987). Deepwater cisco populations declined again between the mid-1960s through the mid-1990s, possibly as a result of expanding lake trout population (Selgeby and others 1994, MacCallum and Selgeby 1987). Throughout this period, social factors, such as operating costs, demand, and prices caused some variability in catch. The bloater is the only species left in large numbers today (Hansen 1994).

Competition for food with introduced smelt and alewife may also have been a factor in their decline. Sea lamprey preyed on the larger cisco species (Lawrie and Rahrer 1972), but lamprey-caused mortality was offset by declines in their major predator, lake trout. Hybridization between closely related species may have hastened the decline of rarer species (Scott and Crossman 1973). Oxygen depletion resulting from eutrophication contributed to the decline in the lower Great Lakes, but was probably not a factor in Lake Superior (McAllister and others 1985, ROM 1999, Scott and Crossman 1973).

The present status of deepwater ciscoes is clouded by uncertain taxonomic status of the species and difficulty in monitoring. Hybridization between species and with the ubiquitous lake herring apparently took place as stocks began to decline, resulting in populations with characteristics intermediate between their parent species. Their deepwater habitat also makes it difficult to determine population levels (Parker 1989).

Chemical and physical habitat changes do not appear to have had an adverse impact on these species. Deepwater ciscoes are protected indirectly in the Great Lakes through Canadian and U.S. commercial harvest quotas for all deepwater ciscoes as a group. In Canada, they have the general protection given by the habitat sections of the Fisheries Act (ROM 1998). No recovery plans have been developed by U.S. or Canadian governments.

Kiyi

The kiyi is still relatively common in Lake Superior, but is extirpated from the other Great Lakes (McAllister and others 1985). COSEWIC lists the kiyi as a species of Special Concern in Ontario (COSEWIC, 2003). It is one of the smaller deepwater ciscoes, but otherwise very similar to the shortjaw cisco and the bloater (a common deepwater cisco). It occurs at depths of 35 to 200 m but usually at more than 100 m (ROM 1998). Changes in chemical habitat features, likely responsible for the extirpation of this species in the other Great Lakes, have apparently not resulted in significant habitat degradation for kiyi in Lake Superior.

Shortjaw Cisco

Shortjaw cisco lives in deep waters (50 to 150 m depth) where it can grow to a length of up to 35 cm. It is found in Lake Superior, Lake Nipigon, and in scattered inland lakes from northern Ontario west to the Northwest Territories. It is extirpated from lakes Michigan and Huron (Houston 1988, ROM 1998). The USGS Ashland Biological Station is attempting to relocate the shortjaw cisco at known historical sites (Bob Kavetsky, personal communication). COSEWIC classifies shortjaw cisco as a Threatened species in Canada.

Shortnose Cisco
Shortnose cisco is one of the smaller deepwater ciscoes and it inhabits shallower water than the other species (depths of 25 to 100 m). It is the only deepwater cisco that spawns in the spring rather than fall and winter, although recently spawning has occurred in the fall in Lake Michigan (McAllister and others 1985, Parker 1988c, Webb and Todd 1995). It is listed by COSEWIC as Threatened in Canada.

The historical status of shortnose cisco in Lake Superior is uncertain. Populations formerly reported from lakes Nipigon and Superior are now considered by some authorities to be shortjaw cisco. Shortnose cisco was known only from Lakes Huron, Michigan and Ontario, but may now be extinct (Bob Kavetsky, personal communication, McAllister and others 1985, ROM 1998, Scott and Crossman 1973). As with the other deepwater ciscoes, overharvest and sea lamprey predation, rather than habitat degradation, are probably responsible for its decline.

Rare Species

Ten rare fish species are known from the Lake Superior basin. Of these, lake sturgeon, and deepwater ciscoes have been discussed the preceding pages of this report.

Northern Brook Lamprey
Northern brook lamprey is a native, non-parasitic relative of the sea lamprey. Its range includes parts of the Mississippi, Hudson Bay, and Great Lakes drainages. In the Lake Superior basin, it is known from a number of small streams in Ontario, Michigan and Wisconsin (Scott and Crossman 1973).

This species apparently does not move out to Lake Superior, but completes its life cycle in streams. Larval lampreys live in streambeds and feed on diatoms and protozoans. When the larvae hatch they make burrows in soft mud and spend six years growing. Following metamorphosis into an immature adult stage, they overwinter in the mud and emerge to spawn. Adults never feed and live for about a year before dying.

Northern brook lamprey is classified as of Special Concern at the federal level in Canada (COSEWIC 2003). It is primarily a warm water species and may never have been common here. Larvae are subject to mortality by lowering water levels and increased siltation from erosion. Habitat may be limited by lampricide intended to control sea lampreys (Scott and Crossman 1973). Seventy-nine (45 United States, 34 Canada) Lake Superior tributaries have been treated with lampricide at least once during 1987-96. Of these, 53 (30 United States, 23 Canada) tributaries are treated on a regular (3 to 5 year) cycle (Klar and others 1996). Northern brook lamprey persists in untreated streams and above barriers and in backwater areas that are not affected by the treatments (Lanteigne 1991, Royal Ontario Museum 1999).

Arctic Grayling
Arctic grayling formerly inhabited the Otter River and Little Carp River in the Lake Superior watershed of the Michigan Upper Peninsula, as well as several streams in the Lower Peninsula (Hubbs and Lagler 1958). Relict populations of this arctic species were found in Montana and Michigan following deglaciation. Michigan populations disappeared by about 1936.

The extirpation of grayling from Michigan was caused by overfishing and habitat modification caused by logging (Eddy and Underhill 1974). Grayling spawn in the shallow water of small streams on sand and gravel substrate. This habitat is vulnerable to sedimentation, warming water, and pollution.

Suitable habitat to support this species may no longer be present in the basin. The state of Michigan stocked grayling into several lakes and streams between 1987 and 1991 (Nuhfer 1992). Most stream populations disappeared within six months as fish dispersed downstream. Dams and warm water impoundments hampered survival and dispersal upstream. Some lake populations persisted where competition and predation by other fish species was low. Hooking mortality, illegal harvest, diseases, and episodes of low pH were significant mortality factors (Nuhfer 1992). No reproduction has been detected. Introduction attempts in Minnesota (Musquash Lake and Twin Lake) and Ontario (Blue Lake) in the 1950s had similar results (Eddy and Underhill 1974, Scott and Crossman 1973).

Other Species

Silver lamprey and American brook lamprey live in similar habitats as northern brook lamprey and are subject to similar stresses.

Deepwater sculpin inhabits deep lakes from Quebec to the Northwest Territories. Populations in Lake Superior and Lake Huron appear healthy, but the species is extirpated in Lake Erie and was only recently rediscovered in Lake Ontario. The Great Lakes populations are therefore classified as Threatened in Canada (Parker 1988a). The decline of deepwater sculpin in the lower Great Lakes may be related to exposure to contaminants in lake sediments. Predation on larva by introduced fishes may have also played a role (Parker 1988a).

Paddlefish is known from a single record in the Lake Superior basin, a specimen from the Nipigon River in Ontario (McAllister and others 1985). Paddlefish is now extirpated in Ontario.

Three species of herring from the Lake Superior basin: Lake Ives cisco, known from Lake Ives in the Huron Mountains of Michigan; Siskiwit Lake cisco from Siskiwit Lake on Isle Royale; and Nipigon Tullibee from Lake Nipigon and Black Sturgeon Lake have been described as full species (Hubbs and Lagler 1958), but are now generally regarded as members of the lake herring “complex” (Scott and Crossman 1973).

6.6.2 Aquatic Nuisance Species

An increasing concern for natural resource managers and environmental policy makers in the Great Lakes region is the invasion of aquatic habitats by exotic or non-native species. These are nonindigenous species that do not naturally exist in an environment and have been introduced by human activity, either intentionally or unintentionally. Exotic species that are deemed by management agencies and society to be detrimental or harmful are considered aquatic nuisance species. Aquatic nuisance species have seriously altered and disrupted Great Lakes ecosystems due to a lack of co-evolved parasites and predators to keep their populations under control. Exotic species have the ability to out-compete native species for food and habitat and, in the most severe cases, to displace native species entirely. Although there are hundreds of exotic species in the basin, only a few are invasive enough to threaten natural habitats, native species abundance, and community structure and function.

Since the 1800s, more than 139 nonindigenous aquatic organisms have become established in the Great Lakes, including 25 species of fish (Mills and others 1993). Of the 94 fish species known to inhabit Lake Superior and its tributaries, 18 are nonindigenous (U.S. Fish and Wildlife Service [USFWS] 1995). Approximately 10 percent of the nonindigenous species introduced into the Great Lakes can be classified as nuisance species; all have had significant impacts, both economic and ecological. Unintentional introductions of these species into the Great Lakes have occurred primarily through the transport of ballast water carried in ships engaging in international trade, but other practices, such as the building of canal systems within the Great Lakes basin, fish stocking practices, angling, recreational boating, and aquarium releases have also contributed to the problem. The rate of introductions has increased; nearly a third of the nonindigenous organisms found in the Great Lakes have been introduced since the opening of the St. Lawrence Seaway in 1959. Once introduced to the Great Lakes, nonindigenous species spread inland, frequently by way of barges, recreational watercraft, bait buckets, fish stocking, and other human-assisted transport mechanisms. Natural barriers such as the open ocean, different salinity levels, and the inability of organisms to reach hospitable ecosystems on their own usually hamper the spread of species between ecosystems. However, shipping allows many organisms to bypass these natural barriers through the transportation in the ballast water of seagoing vessels involved in international trade. In summary, shipping disrupts the customary checks and balances in place to prevent introductions of nonindigenous species and the subsequent degradation of ecosystems (U.S. Coast Guard [USCG] 1999).

Some intentionally introduced species also may disrupt the Lake Superior and inland lake ecosystems. Smelt have become established in inland lakes following the original introduction into Lake Superior. Pacific salmon provide valuable sport and limited commercial fisheries on Lake Superior, but they may also negatively interact with indigenous brook trout in some tributaries (Newman et. al. 2003). Implementing changes in the stocking rates of hatchery-reared Pacific salmon typically causes substantial political problems for fishery agencies, and since most Pacific salmon now living in Lake Superior are the product of natural reproduction, there are few options available for managing their populations.

One of the impacts of an established nonindigenous species is the promotion of instability and unpredictability in stable ecosystems and the loss of diversity in biotic communities (Mills and others 1993). Aquatic nuisance species can also be responsible for extinctions of native species and ecological degradation of the Great Lakes basin.

Aquatic nuisance species have had and continue to have significant economic effects on the commercial fishing industry, agriculture, tourism, sport fishing, recreation, utilities, and other industries. The U.S. Office of Technology Assessment (OTA) delivered a 1993 Report to Congress entitled *Harmful Non-Indigenous Species in the United States*, which attempted to measure the economic impact of nonindigenous plants, animals and microbes on aquatic environments. The report assessed over 4,500 nonindigenous nuisance species, including 2,000 plants, 2,000 insects, 142 terrestrial invertebrates, 91 molluscs and 70 species of fish. Economic costs are hard to accurately estimate since no federal agency comprehensively compiles such statistics. Ecological damage and other nonmarket impacts were not assessed; the report stated, however, that even when such losses were estimated, cost assessments of losses tended to be underestimated (OTA 1993).

Another estimate of economic losses due to nonindigenous species documented over 50,000 nonindigenous species in the U.S. with an estimated annual economic cost of $138 billion (Pimental and others 1999). Included among the cost estimates were control costs, property value damage, health costs and various other expenses. If monetary values could be assigned for ecological losses, the economic cost would be much higher than the $138 billion estimated. Given the high ecological and economic costs to the Great Lakes, heightened vigilance is necessary for the prevention and control of aquatic nuisance species.

The risk of introducing exotics to Lake Superior continues to be high. Increased ship traffic represents an enormous risk for the introduction of exotics. Trans-Atlantic ships are increasingly fast, improving the likelihood that exotic organisms picked up in foreign ballast water will survive the passage. With improving water quality in Lake Superior harbors, recently arrived exotics are more likely to survive and reproduce. Currently, Canada and the United States only have voluntary guidelines in place regulating ballast water discharge. Effective legislation and compliance monitoring is required to regulate discharge of tanker ballast water. In addition, public education programs are essential to minimize further spread of introduced exotics. Most introduced species are impossible to eradicate, so prevention is the best measure.

Various federal programs have been implemented in an attempt to check the negative impact that nonindigenous species are having on the Great Lakes. Foremost is the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA), which provides federal legislative support for programs aimed at aquatic nuisance species prevention and control. Under the NANPCA, the Great Lakes became the first area where ballast water regulations were imposed. A variety of other programs to help prevent and control the spread of aquatic nuisance species have been established under the authority of the NANPCA, including the Aquatic Nuisance Species Task Force, Comprehensive State Management Plans and the Great Lakes Panel on Aquatic Nuisance Species. In 1996, the NANPCA was reauthorized through the National Invasive Species Act (NISA). President Clinton reinforced the need to stop the further introduction of nonindigenous species when he signed the Invasive Species Executive Order on Feb. 3, 1999.

Other programs implemented to help stem the invasion by nonindigenous species include Ruffe Control Program, Great Lakes Action Plan for the Prevention and Control of Aquatic Nuisance Species, model guidance, The Great Lakes Ballast Water Technology Demonstration Project (GLBTDP), U.S. Coast Guard programs, Canadian Coast Guard programs, tribal programs, and Canadian programs. In an effort to have ballast water more stringently regulated by the U.S. government, the Pacific Environmental Advocacy Center (PEAC) filed a petition with EPA requesting that EPA repeal its exemption of ballast water from National Pollutant Discharge Elimination System (NPDES) regulation under the Clean Water Act (CWA).

The management activities of aquatic nuisance species have four distinct components: educational outreach, detection and monitoring efforts, prevention activities and control activities. Within each of these components are a variety of measures that can and/or should be taken. Of particular concern is the need to design and implement effective ballast management programs and resolution of the “no ballast on board” (NOBOB) issue.

Experts disagree about the relative importance of prevention and control. Effective control in aquatic systems is often impossible, but the impacts of aquatic nuisance species merit an attempt. At least partial success has been achieved in control programs with the sea lamprey, ruffe, and purple loosestrife. Preventing an invasion is most effective, because once a species invades a new habitat, it is virtually impossible to eradicate it. Restricting and regulating ballast water discharges are key to stopping further introductions of aquatic nuisance species.

Finally, additional efforts need to be explored and implemented to stop further introduction and spread of nonindigenous species. Examples of such efforts are suggested in the policy recommendations and needed actions section and include the need for better identification of possible future invaders, the need to encourage interjurisdictional cooperation and information sharing, the necessity to devise new technology to deal with the threat of aquatic nuisance species, and the need to improve ballast water management.

The aquatic nuisance species discussed below are listed in alphabetical order and are not prioritized in terms of potential or known impacts.

Eurasian Water Milfoil

Eurasian water milfoil is an extremely aggressive submergent plant native to Eurasia and Africa. By the 1980s, it spread to inland lakes in the Wisconsin basin and was present in shallow bays of Lake Superior by 1993 (WI DNR 1999). In 1999 it was discovered in Lake Superior at Thunder Bay, but is suspected of being present for a number of years (P. Lee, personal communication). It is not known elsewhere in the Ontario basin.

Its preferred habitat is fertile, mineral sediments in eutrophic, nutrient-rich lakes. It is an opportunistic species that prefers highly disturbed lakebeds, lakes receiving nitrogen and phosphorous-laden runoff (WI DNR 1999).

Dense stands of Eurasian water milfoil can alter nutrient cycling from the sediments to the water column and may lead to low oxygen levels and algae blooms. It forms masses of vegetation in nutrient-rich lakes, crowding out native aquatic vegetation and interfering with water recreation (WI DNR 1999).

Eurasian milfoil is unlikely to become widespread in Lake Superior due to its oligotrophic nature and fast water of most of its tributaries, but warmer, nutrient-rich bays and inland waters are vulnerable.

It reproduces from vegetative fragments and can be inadvertently transported between water bodies by boats. Control measures have focused on increasing public awareness of the necessity to remove weed fragments at boat landings. Mechanical and biological controls are being attempted in Wisconsin (WI DNR 1999).

Rainbow Smelt

Rainbow smelt, native to the Atlantic coast, entered Lake Superior around 1930. Rainbow smelt populations grew rapidly during the 1950s and 1960s and became the dominant prey species for lake trout in Lake Superior (Dryer and others 1965, Conner and others 1993). Rainbow smelt became the principal forage fish for lake trout and other top predators and have been implicated as a competitor for the native lake herring, whose populations collapsed during the buildup of the smelt population. The rainbow smelt population continued to grow until the late 1970s and then declined greatly due to heavy predation by trout and salmon, reaching all-time low levels of abundance in the early 1980s. Rainbow smelt prey upon the larvae of native fish and eat a diet that broadly overlaps that of other native cisco species although there has been no direct measure of the effect of smelt on these fish species in Lake Superior (Selgeby and others 1994a). Smelt are the preferred food for predator fish, and have profoundly changed the flow of energy through the Lake Superior fish community. Rainbow smelt also contain thiaminase (about half as much as alewives) and therefore reduce the survival rate of newly-hatched salmonine larvae. Fishery management agencies in the Lake Superior basin have agreed that rainbow smelt is an undesirable species that should not be protected from fishing.

Round Goby

The round goby is a small, bottom-dwelling, soft-bodied fish. It is native to the Black and Caspian Seas, was first detected in the St. Clair River in 1990, and by 1995 had spread to four of the five Great Lakes. The round goby was discovered in Lake Superior in the St. Louis River Estuary in 1995. It is believed that round gobies were introduced to the Great Lakes through ballast water transfer. The goby is currently poised to enter almost half the United States through connected waterways unless its progress can be halted. The round goby is currently found 71 km downstream in the Illinois Waterway, which connects to the Mississippi River.

Round gobies are particularly threatening because they are aggressive, territorial, competitive for food, spawning, and shelter areas, highly tolerant of a variety of environmental conditions, feed on eggs and fry of native fish, and have a large body size compared to similar bottom-dwelling fish species. On the beneficial side, gobies eat large quantities of small zebra mussels, up to 78 mussels per day in laboratory settings. Because gobies eat zebra mussels and in turn are eaten by many piscivorous fishes, they provide a conduit from mussel tissue to fish tissue that was previously less available in a goby-free environment. Contaminant transfer from zebra mussels to highly-valued fish species is an issue. Research is underway to investigate the severity of this problem.

Ruffe

The ruffe, a small perch-like Eurasian fish, was first detected in the estuary of the St. Louis River in western Lake Superior in 1986 and became very abundant in the favorable habitat of the nearshore waters, raising concerns about competition with native species (Ruffe Task Force 1992, Bronte and others 1998). It was probably transported there in the ballast water of seagoing vessels, as Duluth is a major port on Lake Superior. It also occurs in the Kaministiquia River at Thunder Bay. By 1991, the ruffe was the most abundant species in the St. Louis River estuary. The ruffe is also now found in Lake Huron at Alpena Harbor, Michigan, very likely the result of transport in ballast water of interlake shipping. A negative effect of the Eurasian ruffe on the Lake Superior fish community has not currently been found, although ruffe have become the most abundant fish species in the estuaries of some tributaries to western U.S. waters of Lake Superior (Hoff and others 1998). The Great Lakes Fishery Commission estimates the European ruffe could cause losses of $105 million annually if it is not controlled. A control program for ruffe was approved in 1995 and has been successful in delaying the spread of ruffe in the Great Lakes and inland waters.

Rusty Crayfish

Rusty crayfish is native to the southern Great Lakes states, but has spread to lakes and streams in the Lake Superior basin, probably by anglers using them as bait (Gunderson 1995). Control efforts have included angler education to reduce the spread of crayfish to uninfested lakes and streams. Rusty crayfish alter habitat by reducing the abundance and diversity of aquatic plants, with consequent results on the fish, invertebrates and other species that depend on submergent vegetation for food and cover. They also feed on aquatic invertebrates and can displace native crayfish species (Gunderson 1995).

Rusty crayfish were discovered in 1985 in Pounsford Lake, Ontario and have since been found in the Neebing-McIntyre, Kaministiquia, Pigeon, and Little Pine rivers. They have invaded Pigeon Bay on Lake Superior, and are probably now in Black Bay (Momot 1995, W. Momot, personal communication). They are present in the Duluth/ Superior Harbor and other inland sites in Michigan and Wisconsin (G. Czypinski, personal communication).

Sea Lamprey

The sea lamprey is an eel-like, jawless fish that attaches itself to the body of a fish and sucks blood and tissue from the wound. The lamprey is native to coastal regions on both sides of the Atlantic and was first noticed in Lake Ontario in the 1830s. Originally, Niagara Falls served as a natural barrier to keep sea lampreys out of the upper Great Lakes. However, when the Welland Canal was constructed in 1829 for the shipping industry, a new route for sea lampreys was opened and the invasion of the upper Great Lakes began.

In 1921 the lamprey was discovered in Lake Erie, in 1936 in Lake Michigan, in 1937 in Lake Huron and finally in Lake Superior in 1938. The sea lamprey is considered the most devastating of all aquatic nuisance species to have infested the Great Lakes. A subsequent explosion in the sea lamprey population caused serious declines in lake trout in all the Great Lakes but Lake Superior. It is only through control and restocking activities that lake trout populations have recovered. Even today, sea lamprey continue to kill a substantial number of lake trout in Lake Superior every year (Hansen and others 1994, Weeks 1997). An international control program under the Great Lakes Fishery Commission has successfully suppressed sea lamprey populations since about 1960. The use of chemicals and barrier dams to control sea lamprey, although good at protecting lake trout and whitefish, present a difficult balancing act to managers because these control tools also have potential negative effects on lake sturgeon migration up tributaries and survival of recently hatched lake sturgeon in tributaries. This control program is the oldest control program in existence in the U.S., and yet all efforts have still been unable to eradicate the species from the Great Lakes ecosystem.

Spiny Waterflea

Spiny waterflea is an exotic zooplankton (*Bythotrephes* sp.) that is very abundant in early summer in Lake Superior. It was apparently introduced in ballast water. Larger fish regularly eat *Bythotrephes* but the large size of this zooplankter may prevent its consumption by fish during the critical early life stages when zooplankton are a principal component of the diet. Its effects on the aquatic community are unknown.

Experiments with alternative prey demonstrate how (*Bythotrephes longimanus*) co-exists with lake trout (*Salvelinus namacycush*) in Lake Superior. *Bythotrpehes'* caudal spine protects the animal from small fish predation and, at intermediate densities, disrupts foraging behavior of young-of-the-year fish (Barhisel and Kerfoot, 2004). Lake trout response to *Bythotrephes* depends on spine length and fish size. Aversion to *Bythotrephes* occurs after a certain threshold of encounters and foraging efficiency on the alternate prey (*Daphnia*) improves because *Bythotrephes* becomes recognized and ignored (Barnhisel and Kerfoot, 2004).

Zebra Mussel

Zebra mussels were introduced into the Great Lakes in the mid 1980s through ballast water discharge from transoceanic ships (Minnesota Sea Grant 1998). This species is native to the Caspian Sea region and quickly spread throughout Europe before the Industrial Revolution. By 1989, zebra mussels were found in all of the Great Lakes, as well as many inland lakes. Under the right conditions, zebra mussels reproduce quickly, are very prolific, and are very tolerant to a wide range of environmental conditions. They can become established over a wide range of depth, light intensity, and temperatures, but are rare in wave-washed zones, except for sheltered nooks and crevices.

Zebra mussels alter habitat by filtering particulate matter, including phytoplankton and some small forms of zooplankton from the water column. This reduces the food base for many small fish, increases water clarity and alters the nutrient flow of the lake. They also densely cover any hard substrate, including the shells of native mollusks to the extent that they kill their host by encrusting their shell so heavily that the native species cannot open to feed or breathe. Zebra mussels contribute to the cycling of some contaminants. Beyond their ecological effects, zebra mussels also create serious financial costs for facilities that draw water from the Great Lakes by clogging water intake systems. Although various methods are being explored, no effective means of control in natural aquatic systems has yet been found for zebra mussels in the Great Lakes. Currently, industry treats their intake water with chlorine in order to limit zebra mussel infestations.

Zebra mussels are confirmed at only a few sites on Lake Superior, including Duluth/Superior Harbor, Chequamegon Bay and most recently Whitefish Bay (Gary Czypinski, personal communication). They are apparently not yet established on the Ontario side of Lake Superior, but have been observed attached to ships and navigational buoys at the Thunder Bay Port and at Mamainse (Jeff Black, personal communication; S. Greenwood, personal communication). They have also established small colonies in the St. Marys River in association with the navigation locks.

The spread of zebra mussels in Lake Superior might be limited by low calcium availability and low summer water temperatures (below 12 degrees Celsius) although mild weather in recent years has apparently allowed reproduction to occur in the St. Louis Estuary. As with other exotic aquatic species, increased public awareness should help controlling the spread.

Other Species

Several other species of concern have colonized Lake Superior and its tributaries. A summary of these species has been compiled for this chapter by Douglas A. Jensen, Exotic Species Information Center

Coordinator at the University of Minnesota Sea Grant Program, Duluth and is listed in Addendum 10-A at the end of this chapter. For completeness, the previously mentioned species have also been included in the table.

IV. MOST SIGNIFICANT NEEDS AND STRATEGIES

Introduction

Five key action areas: Information Gathering, Monitoring, Communication, Planning, and Stewardship are identified in this section. For each action area, a broad statement of need is followed by a list of specific needs and some suggested strategies to address them. By implementing these strategies, we will move toward achieving a sustainable Lake Superior ecosystem which is a global model for resource management.[2]

Active and continuous *information gathering* is required to help us understand and piece together the intricacies of the complex relationship between living organisms and their physical environment. *Monitoring* may take many forms and is ultimately designed to direct management activities and policy development. Monitoring of population trends (change, stability), or research oriented monitoring to gain an understanding of the cause and effect of specific actions on species or habitats, or why a project was a success or failure, will provide sign posts to improve future management within the lake basin. Together these actions will provide insight and knowledge that can be communicated to governments, policy makers, planners, managers, and citizens of the basin. This will enable informed and effective *communication* about the links between land and resource use and ecosystem health with industry, business, landowners, and the public.

Moving toward actively *planning* at a basin-wide scale will assist in addressing the gaps in, and impediments to, sustainable resource management of land and water resources, help speak to the needs of today, and prepare us for future challenges.

Finally, addressing *stewardship* needs will help foster the development of a healthy basin ecosystem that is resilient to perturbations from human activities and provides a broad range of sustainable benefits to its citizens.

Note that these strategies represent a long term approach to identifying management needs. As opposed to representing specific committed actions, they represent work that needs to be initiated and continued over many years or decades. Projects will be accomplished not only by agencies, but by industry, non-governmental organizations (NGOs), and individuals.

Information Gathering

Broad Statement: Broad-scale data collection and analysis are needed to support natural resource management and protection through informed decision-making. More specifically, resource managers need:

- **Accessible and up to date data bases containing comprehensive information related to terrestrial and aquatic ecosystems, native and exotic species, and habitat in the basin.**

---

[2] Lake Superior Lakewide Management Plan LaMP: 2002 Progress Report

Strategies to meet this need include:

Expand the existing, shared GIS habitat database to include information about past and present research and resource management activities and knowledge gaps for habitats, communities, and biota.

Develop comprehensive and detailed inventories of habitats for the creation of a habitat data base.

In the medium term, develop and maintain a complete, comprehensive database of important habitat information including storage in a GIS format to ensure basin wide access to data.

In the short term, begin the process of developing agreements among jurisdictions and agencies including engaged NGOs for data sharing.

Continue to provide information for an aquatic data layer in the Lake Superior Decision Support GIS database and ensure a linkage to the GLFC Aquatic GIS database under development.

Develop and support standardized quantitative protocols for the collection of physical habitat data by professionals and engaged NGOs.

- **Quantitative information about predator/prey relationships and impacts to productivity at all scales.**

Strategies to meet this need include:

Encourage academic institutions and others to conduct research into both aquatic and terrestrial predatory-prey relationships and productivity.

Encourage research into the impacts of varying prey (small mammal) abundance on wide-ranging predators (e.g., lynx, fisher, marten).

Improve the knowledge of the pelagic fish community through development of acoustic survey techniques and predictive models.

Conduct bottom trawling to waters greater than 90 m deep in Lake Superior to increase knowledge about the deep water fish community.

Improve the bioenergetics knowledge of predators and their prey in aquatic systems.

Update the knowledge of plankton communities in Lake Superior via analysis of existing collections and new collections.

Determine the distribution and abundance of benthic organisms in Lake Superior and inland lakes and their role and importance in sustaining the fish communities.

Understand the impact spring flow fluctuations on tributaries with hydroelectric facilities have on recruitment of brook trout, walleye, and lake sturgeon.

- **Analysis and insight into species interactions between native and non-native species as well as between native species in an altered or manipulated environment.**

Strategies to meet this need include:

Determine the distribution and abundance of benthic organisms in Lake Superior and inland lakes and their role and importance in sustaining the fish communities.

Describe and measure the competitive relationships between coaster brook trout and naturalized anadromous salmonines in all shared habitats.

Describe the interaction of siscowet, humper, and lean forms of lake trout related to habitat use and forage availability.

Describe and measure the interactions between non-native species (e.g., round gobie, Eurasian ruffe) with native species in all habitats where non-native species have become established in Lake Superior.

- **Knowledge of the role and influence of disease and contaminants in species demography and basin ecosystems**.

Strategies to meet this need include:

Determine present contaminant load status of “best bet” wildlife species.

Determine which species have the highest contaminant loads or are otherwise most affected by contaminants.

Establish a mechanism for reporting, tracking, and responding to diseases in wild populations.

- **An understanding of meta-population dynamics in the sustainability of species’ populations, including the influence of “overabundant” species (e.g., herbivory) on ecosystem functioning.**

Strategies to meet this need include:

Identify population issues for threatened and endangered species.

Identify and conduct studies on impacts of overabundant native species.

Develop education materials which inform the public and agency managers of problems.

- **An understanding of the risk of invasion by new exotic species from outside the Lake Superior basin including an annual forecast of imminent threats.**

  Strategies to meet this need include:

  Inventory the distribution and abundance of exotic invasive species to support strategies for monitoring, determining introduction pathways, preventing range expansion, and control or eradication.

- **Descriptive information about historic and current habitat conditions and important habitat sites in the basin.**

  Strategies to meet this need include:

  Identify and quantify critical aquatic habitat for key fish species that are both indicators of ecosystem health and fish community stability and illustrate that habitat on GIS maps.

  Complete comprehensive substrate mapping for nearshore waters, harbors, bays, and estuaries of Lake Superior to identify important fish habitat.

  Complete comprehensive habitat assessment and aquatic community surveys to identify important habitat sites in tributary streams and inland lakes of the watershed.

  Create digital, basin-wide coverage of original land cover in GIS format.

  Develop an approach to quantifying land use (or habitat) change using GIS.

  Identify sites that meet the criteria for important habitat. This includes integrating co-operative, long term habitat inventory and assessment efforts.

  Inventory and assess impacts to habitat at a basin wide scale from current and historic sources of degradation.

  Complete comprehensive, systematic Natural Heritage Inventory/biological surveys in the watershed to identify remaining high-quality natural communities and locations of rare plants and animals.

  Facilitate development of decision-making tools, natural resource information, and expertise originating from an actively supported and funded Lake Superior basin research community.

Monitoring

Broad Statement: Support for and maintenance of long-term biota and habitat monitoring programs is needed to protect and restore the Lake Superior basin ecosystem. More specifically, resource managers need:

- **Biological, community-based monitoring programs on which to base species status and trends reports.**

  Strategies to meet this need include:

  Hold an annual workshop over a three year period to tackle one of the identified "Best Bet" wildlife indicators and develop a basin-wide monitoring protocol.

  Field test the proposed monitoring protocols developed above and make revisions as required.

  Solicit buy-in from basin resource agencies to conduct monitoring activities and set an implementation schedule.

  Develop a basin-wide database to track results of monitoring efforts temporally and spatially within the basin.

  Explore the development of an inventory, monitoring, assessment and reporting protocol for the Lake Superior basin and how it might be implemented.

  Inventory all levels of the biotic community, with particular attention to little known species and key species to allow assessment of species and community needs.

  Support and encourage literature reviews, which summarize the current knowledge base and provide direction on where future monitoring and research should be focused.

  Determine what monitoring programs exist and where further development of monitoring is needed.

  Continue established monitoring programs of the Great Lakes Fishery Commission's Lake Superior Technical Committee including spring lake trout assessment and siscowet surveys.

- **Information concerning control efforts and annual range extensions of existing and new exotic species in the Lake Superior basin.**

  Strategies to meet this need include:

  Prepare an annual report on control efforts and dispersal of existing and new exotic species in the Lake Superior basin.

Continue to provide on the internet the annual summary report addressing ruffe surveillance in the Great Lakes.

- **Annual tracking of development activities at the land water interface that alter ecosystem form and function at a variety of scales.**

  Strategies to meet this need include:

  Develop a GIS layer to track development activities at the land-water interface that may alter ecosystem form and function.

  Develop a mechanism to track existing and planned development activities and keep the GIS layer current.

- **Monitor projects in the basin annually in order to track multi agency rehabilitation effort successes and failures through time and space.**

  Strategies to meet this need include:

  Develop a basin database, or modify existing basin databases, to have the ability to track multi-agency rehabilitation efforts through space and time.

  Convey to project proponents and funding agencies, the concept that long term monitoring is an essential part of any restoration project and must be integral to the projects (funded and implemented).

Communications
Broad Statement: Work with local, regional and national governments and their departments to encourage policy, planning, and action that preserves and protects the Lake Superior ecosystem. Find ways to facilitate a common understanding with industry, business, landowners, and the public about the links between land use and ecosystem health.

- **Become more involved with efforts to communicate with basin citizens about the importance and value of living things and our dependence upon their well being.**

  Strategies to meet this need include:

  Become more engaged with Sea Grant and University Extension offices to bring a binational, basin-wide focus to outreach efforts.

  Pursue the development of informational programming related to the Lake Superior basin through existing contacts.

  Influence ongoing television and radio programming to reflect a binational, basin-wide approach to the restoration and protection of the Lake Superior basin.

Develop a position for a Binational Program educator to present material to local governments and decision makers highlighting the linkages between land use and ecosystem health.

- **Develop communication tools to present information, issues, and solutions related to the Lake Superior basin ecosystem**.

  Strategies to meet this need include:

  Develop tools to inform citizens and governments about ecosystem restoration and protection strategies, both those that are successful and those that are unsuccessful.

  Develop a guidance document for vegetation restoration projects in the basin.

  Provide information to local governments and landowners about the linkages between land use and ecosystem health.

  Develop and distribute a GIS map of known coastal wetland hectares, types, condition and areas where restoration is required.

  Support the Lake Superior Decision Support System's (LSDSS) efforts to develop methods to present user friendly information about the impact of various management/development scenarios on local and basin ecosystems.

  Ensure that a linkage between the LSDSS and GLFC Aquatic database is available to planning, development, and natural resource managers.

  Educate citizens in the Lake Superior basin about the importance and appropriate use of local native plants in restoration and landscaping projects.

  Promote the development of an IMAX film about Lake Superior.

  Develop an information focused web site for use by the Binational Program.

- **Engage governments at all levels in resource management and resource use by promoting and facilitating intergovernmental and interagency partnerships**.

  Strategies to meet this need include:

  Contact all agencies within each jurisdiction to ensure that they are aware of intergovernmental partnerships related to resources within their control.

  Establish a committee of technical/field experts to address terrestrial issues modeled after the Lake Superior Technical Committee of the Great Lakes Fishery Commission.

Advocate that existing intergovernmental partnerships become aware of issues related to full intergovernmental participation and encourage them to reach out to unrepresented or under- represented agencies.

Advance efforts to provide funding to agencies that need it in order to be able to participate in inter-jurisdictional efforts.

Develop materials and media to educate government planning personnel and development agencies (Department of Transportation, highway and road departments, etc.) and improve access to information related to threatened, endangered, and extirpated species.

Planning
Broad Statement: Discover and pursue means to achieve common understandings and consensual agreements for needed actions related to the goals of this chapter and their integration into planning at all levels within the basin.

The following two strategies are common to each of the first five specific needs identified:

Identify priority research needs and research gaps, and develop appropriate projects to address those needs and gaps.

Encourage funding entities to revise criteria upon which grant applications are assessed to support the needs identified in this chapter.

- **Determine the future mix of biological communities and landscape mosaics desired within the basin and integrate the principles of natural resource management to develop guidelines for long-term ecological direction to achieve that desired condition.**

Strategies to meet this need include:

See above.

Utilize existing planning documents such as Fish Community Objectives for Lake Superior and ensure that these documents are regularly revisited and updated as necessary.

Evaluate restoration projects and restoration ecology research that addresses native species in order to link successes to specific restoration features to allow planning for future needs.

- **Plan for sustainable land, shoreline and water development.**

Strategies to meet this need include:

See above.

Develop a mechanism to make the GIS layer that monitors and tracks development activities at the land-water interface available to resource/land-use/municipal managers throughout the basin for use in planning.

Identify priority research needs and research gaps, and develop appropriate projects to address those needs and gaps.

Encourage funding entities to revise criteria upon which grant applications are assessed to support the needs identified in this chapter.

Hire two staff each in the U.S. and Canada to directly assist local governments with development or amendment of community growth plans.

Promote and elevate status of protection as a mitigation tool.

Integrate into the planning process the minimization of impacts and mitigate for loss of habitat integrity and function as well as biotic community structure from existing development.

- **Determine protection levels for important habitat areas.**

  Strategies to meet this need include:

  See above.

  Identify priority areas of important habitat throughout the basin and enter them into the LSDSS GIS database.

  Develop a process by which the LSDSS GIS database is fully developed and regularly updated (twice/yr).

  Develop a mechanism to integrate information contained in the LSDSS into activities of local planning agencies and organizations.

- **Address preventative measures related to aquatic species transport in ballast water in Lake Superior.**

  Strategies to meet this need include:

  See above.

  Encourage funding entities to revise criteria upon which grant applications are assessed to support the needs identified in this section.

Ensure that all ships navigating in Lake Superior follow best management practices (BMPs) for ballast water.

Support research into ballast water treatment methods.

Develop a list of organisms that are likely to be transported through ballast water and identify their potential for ecological, economic, and social impacts.

Enact legislation that prevents the sale and transport of live non-native plants and animals into the jurisdictions of the basin.

Complete an inventory and control plan for priority existing exotic species at the scale of the Lake Superior basin and begin implementation.

- **Develop a mechanism to deal with new invasive species and diseases not transported by ballast water.**

Strategies to meet this need include:

See above.

Work with state and provincial Aquatic Nuisance Species coordinators to implement rapid response plans for new invasive species and diseases in the Lake Superior basin.

Develop a coordinated, basin-wide exotic species control and monitoring program that has the support and the participation of all municipal, state/provincial and federal jurisdictions in the Lake Superior basin.

- **Obtain greater involvement by local land, roadway, rail way and water managers in Lakewide Management Planning.**

Strategies to meet this need include:

Get representation from regional planning entities on Binational Program committees.

Educate local land and water managers and the public about the LaMP through varied outreach outlets (newsletters, presentations, web sites, newspapers, video productions, hunting/fishing expos, lawn, and garden shows, etc.).

Distribute CDs of the integrated LaMP ecosystem chapters to all Lake Superior basin governmental and NGO land and water managers and individual landowners with 40 ha or more of land.

Continue periodic contact through public meetings, workshops, local planning commission meetings, etc. to further understanding and involvement in the LaMP process.

Invite and secure participation and exchange of planning initiatives with local land and water conservation departments, soil and water conservation agencies, municipal organizations, regional planning organizations, and townships in Lake Superior Work Group meetings.

- **Over the long term, develop ecologically based integrated watershed management plans for all watersheds within the Lake Superior basin.**

Strategies to meet this need include:

Determine which watersheds have existing plans and develop a list of watersheds that need a new or revised plan.

Prioritize the watershed list.

Develop watershed plans for the highest priority watersheds in need of a new or revised plan.

Active Stewardship

Broad Statement: Foster a healthy basin ecosystem that is resilient to perturbations from human activities and non-native species and provides a broad range of sustainable benefits to its citizens.

- **Promote a common understanding of how the Lake Superior ecosystem functions**.

Strategies to meet this need include:

Develop educational/outreach materials and information kiosks throughout the basin to deliver common message to the public.

Involve local and regional environmental oriented organizations in restoration projects and research studies.

- **Identify mechanisms to increase awareness of natural resource issues and enhance a stewardship conscience among the basin residents.**

Strategies to meet this need include:

Encourage the use of native species for all projects requiring vegetation restoration.

Encourage land use planning efforts that are targeted at protecting and restoring wildlife while also maintaining economic viability of local communities.

Educate nurseries, gardeners, florists, boaters, anglers, commercial fishers, aquaculture facilities, aquarium hobbyists, the general public, and the shipping industry to help prevent the introduction of new non-native species, and reduce the spread and control or eliminate already established non-native species.

- **Achieve no net loss of the productive capacity of habitat supporting Lake Superior basin plants and animals.**

  Strategies to meet this need include:

  Implement conservation actions to maintain and restore habitat function and structure at sites that meet the criteria for important habitat sites, including the application of special designations.

  Design and implement projects to address lost ecosystem functions at degraded sites.

  Restore degraded wetland hectares in the Lake Superior basin.

  Implement actions to reduce stressors and eliminate sources of stress to important terrestrial and aquatic habitat sites.

  Restore and protect conifer forests in appropriate upland and stream corridors.

  Restore or protect riparian conifer forests.

  Implement recommendations contained in the North American Waterfowl Management Plan.

  Encourage land use planning efforts that are targeted at protecting and restoring wildlife while also maintaining economic viability of local communities.

  Implement conservation actions recommended in watershed plans, reservation integrated resource management plans, lake management plans, and eco-regional conservation plans.

- **Reduce human induced contaminants so that traditionally consumed fish and wildlife are safe to eat by all individuals.**

  Strategies to meet this need include:

  Succeed in the zero discharge goal for nine persistent toxic chemicals for the Lake Superior basin.

- **Rehabilitate populations of indigenous species.**

  Strategies to meet this need include:

  Restore and protect habitat for native species of economic and cultural importance, including lake sturgeon, lake trout, lake whitefish, wild rice, ginseng, and others where appropriate.

  Encourage the use of native plant species for all projects requiring vegetation restoration.

  Agencies individually and cooperatively continue to carry out aspects of Rehabilitation Plans for walleye, lake sturgeon, and brook trout.

  Implement conservation actions recommended in watershed plans, reservation integrated resource management plans, lake management plans, and eco-regional conservation plans.

  Hold workshops and conferences to establish research needs and agency coordination for brook trout and lake sturgeon rehabilitation efforts on Lake Superior.

- **Reduce the impact of existing hydroelectric facilities and prevent future impacts.**

  Strategies to meet this need include:

  Ensure that agency personnel participate in hydropower re-licensing projects and that projects implement practices that ensure passage for all desired fish species, and maintain a natural hydrograph, thermal regime, and adequate flow rates to allow native aquatic species to thrive.

  Remove artificial impediments to fish passage or develop by-pass systems in tributaries where appropriate.

  Identify all FERC (U.S.) and Water Management Plans (Canada) projects within the basin and list those for which review or renegotiations will occur within the next five years. Ensure that agency biologists participate in the project review process.

- **Reduce or eliminate atmospheric deposition of contaminants in Lake Superior and contaminant loads in basin-dwelling fish and wildlife species in concert with efforts to de-list Areas of Concern.**

  Strategies to meet this need include:

  Achieve and maintain water and air quality standards by enforcing existing legislation.

Develop new legislation, and/or incentive programs to meet standards that extend to those areas outside the basin that contribute to impairments within the basin.

- **Foster healthy basin communities of native species that are resistant to non-native species invasions.**

  Strategies to meet this need include:

  Implement habitat recommendations of the Great Lakes Panel on Aquatic Nuisance Species.

  Implement the recommendations contained in federal threatened and endangered species recovery plans. Restore and protect habitat for state, tribal, and provincially listed species.

  Identify recovery actions for threatened and endangered species.

  Protect, enhance, and restore species of concern such as caribou, moose, colonial water birds, boreal owl, northern goshawk, white pine, and hemlock.

  Implement conservation actions recommended in watershed plans, reservation integrated resource management plans, lake management plans and eco-regional conservation plans.

  Encourage the appropriate use of native species for all projects requiring vegetation restoration.

- **Promote management actions that maintain genetic diversity in fish and aquatic organisms.**

  Strategies to meet this need include:

  Hold workshops and conferences to establish research needs and agency coordination for brook trout and lake sturgeon rehabilitation efforts on Lake Superior.

  Ensure species reintroduction minimizes genetic distance from the original local species population rather than use a common source for reintroduction throughout the basin.

- **Control existing populations of exotic invasive species and implement actions to deal with new invasive species and diseases.**

  Strategies to meet this need include:

  As appropriate, develop legislation, regulations, or establish guidelines to prevent the sale and/or transfer of live plants and animals outside of their native range.

  Educate plant nurseries, boaters, anglers, commercial fishers, aquaculture facilities, aquarium hobbyists, general public, and the shipping industry to help prevent the introduction of new non-native species, and reduce the spread and control or eliminate already established non-native species.

Establish and implement Best Management Practices for a human transport vectors of non-native species (forest industry, recreation and tourism, intra-lake shipping, horticultural and agriculture practices, etc.) to prevent the introduction and spread of exotics.

Develop sources of native plants and seeds in an ecologically appropriate manner throughout the Lake Superior basin for use in vegetation restoration.

Establish standards of native species propagation and use as well as definitions of seed zones.

Develop a list of native species that are regionally/habitat specific and ecologically appropriate for propagation.

Complete an inventory and control plan for priority existing exotic species at the scale of the lake superior basin and begin implementation.

Accomplishments and Next Steps

Since its completion, the LaMP 2000 has served as a guide and provided impetus for state/provincial, tribal, and federal management and regulatory agencies to achieve their vision for Lake Superior. In addition, it has been used by local decision-makers to assist with land and water use projects and priorities. As a result, many significant accomplishments have been realized that address a mission of the Lake Superior Binational Program. That mission is, to support intact, diverse, healthy and sustainable ecosystems and the native plant and animal communities that depend on them. As we make progress toward the mission and goals of LaMP 2000, some existing issues remain or evolve, and new issues emerge that influence the future direction of natural resource use and management.

In addition to the LaMP 2000, updates on progress being made and recommendations for future direction are developed on a semi annual basis. To learn more about the LaMP 2000 visit the Environmental Protection Agency web site at http://www.epa.gov/glnpo/lakesuperior/lamp2000/. The LaMP 2002 and 2004 Progress Reports can be viewed by visiting www.epa.gov/glnpo/lakesuperior/.

V. REFERENCES

Aitken, S.G. P.F.Lee, D.Punter, and J.M.Stewart. 1988. Wild Rice in Canada. Agriculture Canada Publication 1830. NC Press Ltd. Toronto.

Albert, D. A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: a working map and classification. Gen. Tech. Rep. NC-178.St. Paul, MN: U.S. Department of Agriculture, Forest Service, NorthCentral Forest Experiment Station. Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov /resource /1998/rlandscp/rlandscp.htm (Version 03JUN98).

Argus, G.W., K.M. Pryer, D.J. White, and C.J. Keddy. 1982-1987. Atlas of the rare vascular plants of Ontario. National Museum of Natural Sciences. Ottawa (looseleaf).

Argus, G.W. and D.J. White. 1984. Ginseng. In: Argus, G.W., K.M. Pryer, D.J. White, and C.J. Keddy. Atlas of the rare vascular plants of Ontario. National Museum of Natural Sciences. Ottawa (looseleaf).

Armantrout, N.B., compiler. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, Maryland.

Armstrong, Ted. 1999. OMNR. Personal communication.

Armstrong, E.R. 1998. Integration of woodland caribou habitat management and forest management in northern Ontario – current status and issues. Rangifer, Special Issue 10: 221–230.

Atria Engineering Hydraulic Inc. 1993. Nipigon River: Development of a water management plan: Draft Options Report. Prepared for Nipigon River Management Committee.

Aubry, K.B. G.M. Koehler, and J.R. Squires. 1999. Ecology of Canada lynx in southern boreal forests. USDA Forest Service Gen. Tech. Rep. RMRS GTR-30.

Auer, N.A. [ed.]. 2003. A lake sturgeon rehabilitation plan for Lake Superior. Great Lakes Fish. Comm. Misc. Publ. 2003-02.

Auer, M.T. and L.A. Bub. 2004. Selected features of the distribution of chlorophyll along the southern shore of Lake Superior. Journal of Great Lakes Research. In Press.

Auer, N.A. and J.E. Kahn. 2004. Abundance and distribution of benthic invertebrates, with emphasis on Diporeia, along the Keweenaw Peninsula, Lake Superior. Journal of Great Lakes Research. In Press.

Austen, M.J.W., M.D.Cadman, and R.D.James. 1994. Ontario Birds at Risk Status and Conservation Needs. Federation of Ontario Naturalists. Don Mills.

Balgooyen, C. P., and D. M. Waller. 1995. The use of *Clintonia borealis* and other indicators to gauge impacts of white-tailed deer on plant communities in northern Wisconsin, USA. Nat. Area J. 15: 308–318.

Bakowsky, W.D. 1996. Rare communities of Ontario: Glaciere talus. Natural Heritage Information Centre 3(2): 2–4.

Bakowsky, W.D. 1997. Rare communities of Ontario: Freshwater coastal dunes. Natural Heritage Information Centre 4(1): 5–8.

Bakowsky, W.D. 1998. Rare communities of Ontario: Great Lakes arctic-alpine basic shoreline. Natural Heritage Information Centre 4(2): 10–12.

Barbiero, R.P. and M.L. Tuchman. 2000. Results from the Program Office's Biological Open Water Surveillance Program of the Laurentian Great Lakes for 1998. U.S. EPA Great Lakes National Program Office. Chicago.

Barbiero, R.P, and M.L. Tuchman. 2001. Results from the U.S. EPA's biological open water surveillance program of the Laurentian Great Lakes: I. Introduction and phytoplankton results. J. Great Lakes Res. 27(2):134–154.

Barbiero, R.P., R.E. Little, and M.L. Tuchman. 2001. Results from the U.S. EPA's biological open water surveillance program of the Laurentian Great Lakes: III. Crustacean Zooplankton. J. Great Lakes Res. 27(2):167–184.

Barbiero, R.P. and M.L. Tuchman. 2004. The Deep Chlorophyll Maximum in Lake Superior. J. Great Lakes Res. 30 (sup1): 256-268.

Barnhisel, D.R. and W.C. Kerfoot. 2004. Fitting into food webs: Behavioral and functional response of young lake trout (Salvelinus namacycush) to an introduced prey, the spiny cladoceran (Bythotrephes cederstroemi). Journal of Great Lakes Research. In Press.

Barton. D. R. and H. B. N. Hynes 1976. The distribution of Amphipoda and Isopoda on the exposed shores of the Great Lakes. J. Great Lakes Res. 2(2):207–214.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison.

Bennet, E.B. 1978. Characteristics of the thermal regime of Lake Superior, J. Great. Lakes Res., (3–4):310–319.

Bertram, P. and N. Stadler-Salt. 1998. Selection of indicators for Great Lakes basin ecosystem health. Draft for discussion at SOLEC 98. State of the Lakes Ecosystem Conference 1998.

Bishop, C. A., D. V. Weseloh, N. M. Burgess, J. Struger, R. J. Norstrom, R. Turle, and K. A. Logan. 1992a. An atlas of contaminants in eggs of fish-eating colonial birds of the Great Lakes (1970-1988). Vol. I, Accounts by species and location. Can. Wildl. Serv. Tech. Rep. 152. 313 pp.

Bishop, C. A., D. V. Weseloh, N. M. Burgess, J. Struger, R. J. Norstrom, R. Turle, and K. A. Logan. 1992b. An atlas of contaminants in eggs of fish-eating colonial birds of the Great Lakes (1970-1988). Vol. II, Accounts by Chemical. Can. Wildl. Serv. Tech. Rep. 153. 300 pp.

Best, D. 2000. USFWS. Personal communication.

Black, J. 1999. OMNR. Personal communication

Blais, J.R. 1983. Trends in the frequency, extent and severity of spruce budworm outbreaks in eastern Canada. Can. J. For. Res. 13:539–547.

Blais, J.R. 1985. The ecology of the eastern spruce budworm: a review and discussion. *In* Recent advances in spruce budworm research. [*Ed.*] CJ. Sanders, R.W. Stark, E.J. Mullins, and J. Murphy. Can. For. Serv., Ottawa, Ont. pp. 49–59.

Blaustein, A. R., D. G. Hokit, R. K. O'Hara, and R. A. Holt. 1994. Pathogenic fungus contributes to amphibian losses in the Pacific Northwest. Biol. Conserv. 67:251–254.

Blaustein, A. R., and D. B. Wake. 1995. The puzzle of declining amphibian populations. Sci. Am. 272:52–57.

Blaustein, A. R., B. Edmond, J. M. Kiesecker, J. J. Beatty, and D. G. Hokit. 1995. Ambient ultraviolet radiation causes mortality in salamander eggs. Ecol. Appl. 5:740–743.

Blaustein, A. R., J. M. Kiesecker, D. P. Chivers, and R. G. Anthony. 1997. Ambient UV-B causes deformities in amphibian embryos. Proc. Nat. Acad. Sci. 94:13735–13737.

Blokpoel, H. 1987. Common Tern. pp. 188–189. In Cadman, M.D., P.F.J. Eagles and F.M. Helleiner (eds). Atlas of the Breeding Birds of Ontario. Federation of Ontario Naturalists and the Long Point Bird Observatory, University of Waterloo Press.

Blokpoel, H., and W. C. Scharf. 1999. The importance of the islands of the Great Lakes as nesting habitat for colonial waterbirds. Pages 32–42 in K.E. Vigmostad, [ed.] Proceedings from the 1996 U.S.-Canada Great Lakes islands workshop. Mich. State Univ., East Lansing, MI.

Blymyer, J. F., and B. S. McGinnes. 1977. Observations on possible detrimental effects of clearcutting on terrestrial amphibians. Bull. of the Maryland Herpetol. Soc. 13:79–83.

Bodaly, R.A. 1986. Biology, exploitation and culture of coregonid fishes in Canada. Arch. Hydrobiol. Beih. Ergebbn. Limnol. Vol. 22:1–30.

Bowerman, B. 2000. Clemson University. Personal communication.

Bowerman,W.W. 1993. Regulation of bald eagle (*Haliaeetus leucocephalus*) productivity in the Great Lakes Basin: An ecological and toxicological approach. Ph.D. Thesis. Michigan State University.

Bowling, C. and G. Niznowski. 1996. White pine in northwestern Ontario: Distribution, silviculture history and prospects. Ont. Min. Natur. Res. NWST Tech. Rep. TR-94.

Bridger, K.C., and J.C. Day. 1978. The Ogoki River Diversion Reservoir, Downstream, Diversion Channel, and Receiving Water-Body Effects. 2001 Environment and Resources Consulting Ltd., Waterloo, Ont.

Bronte, C. R., J. H. Selgeby, J. H. Saylor, G. S. Miller, and N. R. Foster. 1998. Hatching, dispersal, and bathymetric distribution of age-0 wild lake trout at the Gull Island Shoal Complex, Lake Superior. Journal of Great Lakes Research 21 (Supplement 1): 233–245.

Brooks, R.J., D.A. Galbraith, E.G. Nancekivell, and C.A. Bishop. 1988. Developing management guidelines for snapping turtles. Pages 174 0 179 in R.C. Szaro, K.D. Severson, D.R. Patton, eds. Management of amphibians, reptiles and small mammals in North America. U.S. For. Serv. Tech. Rep. RM-166. Fort Collins, CO.

Brown, R. W., M. Ebener, and T. Gorenflo. 1999. Great Lakes commercial fisheries: historical overview and prognosis for the future, pp. 307–354. *In* Great Lakes fisheries policy and management: a binational perspective. Michigan State University Press, East Lansing, Michigan. 551 p.

Bruland, K.W., M. Koide, C. Bowser, L.J. Maher, and E.D. Goldsberg. 1975. Lead-210 and pollen geochronologies on Lake Superior sediments. Quat. Res. 5:89–98.

Bryan, S. 1994. Survey of the breeding birds of Lake Nipigon, Thunder Bay District, Ontario (Part II). Nature Northwest: Newsletter of the Thunder Bay Field Naturalists. 48 (1): 6–8.

Burt, W.H. 1975. Mammals of the Great Lakes Region. University of Michigan Press, Ann Arbor.

Busiahn, T.R. [ed.] 1990. Fish community objectives for Lake Superior. Great Lake Fishery Commission Special Publication 90–1.

Buss, M. and M. de Almeida. 1997. A review of wolf and coyote status and policy in Ontario. OMNR, Fish & Wildlife Branch, Peterborough ON.

Cadman, M. D., H. J. Dewar, and D. A. Welsh. 1998. The Ontario Forest Bird Monitoring Program (1987-1997): goals, methods and species trends observed. Can. Wildl. Serv. Tech. Rep. Ser. No. 325.

Cadman, M.D., P.F.J. Eagles and F.M. Helleiner (eds). 1987. Atlas of the Breeding Birds of Ontario. Federation of Ontario Naturalists and the Long Point Bird Observatory, University of Waterloo Press.

Candau, J. N., R.A. Fleming, and A. Hopkin. 1998. Spatiotemporal patterns of large-scale defoliation caused by the spruce budworm in Ontario since 1941. Can. J. For. Res. 28:1733–1741.

Canham, C.D. and O.L. Loucks. 1984. Catastrophic windthrow in the presettlement forests of Wisconsin. Ecology 65:803–809.

Carleton, T.J. 2000. Vegetation responses to the managed forest landscape of central and northern Ontario. pp. 178 – 197. *In*: A.H. Perera, D.L. Euler, and I.D. Thompson (eds). Ecology of a Managed Terrestrial Landscape. Patterns and Processes of Forested Landscapes in Ontario. UBC Press. Vancouver.

Carleton, T.J. and R.W. Arnup. 1993. Vegetation ecology of eastern white pine and red pine forests in Ontario. Ont. Min. Natur. Res., Forest Fragmentation and Biodiversity Project Report No. 11.

Casper, G. S. 1998. Review of the status of Wisconsin amphibians. Pages 199–205 *in* Lannoo, M. J., [ed.] Status and conservation of midwestern amphibians. Univ. of Iowa Press, Iowa City, IA. 507 pp.

Casper, G. S. 2002. A review of the amphibians and reptiles of the Lake Superior watershed. Tech. Rept. To the Terrestrial Wildlife Community Committee, Lake Superior Binational Program. 96 pp.

Cheng, P.N. 1987. Hydroelectric power resources of the Province of Ontario. Ontario Hydro. Geotechnical and Hydraulic Engineering Department. Report No. 87360.

Chow-Fraser, P. and D.A. Albert. 1998. Biodiversity investment areas: Coastal wetland ecosystems. Draft for discussion at State of the Lakes Ecosystem Conference 1998. Environment Canada and U.S. Environmental Protection Agency.

Chase, M. 2003. OMNR. Personal communication.

Cieminski, K. 1999. Minnesota Department of Natural Resources. Personal communication.

Clayton, L., 1984. Pleistocene Geology of the Superior Region, Wisconsin. Wisconsin Geological and Natural History Survey Information Circular Number 46.

Cobery, C.E. and R.M. Horrall. 1980. Fish spawning grounds in Wisconsin waters of the Great Lakes. Marine Studies Center, University of Wisconsin – Madison. Published by the University of Wisconsin Sea Grant Institute. 42 p.

Coble, D. W., R. E. Bruesewitz, T. W. Fratt, and J. W. Scheirer. 1990. Lake trout, sea lampreys, and overfishing in the upper Great Lakes: a review and reanalysis. Transactions of the American Fisheries Society 119: 985–995.

Coffin, B. and L. Pfannmuller. 1988. Minnesota's Endangered Flora and Fauna. Univ. of Minnesota Press. Minneapolis.

Colby, P.J. and S.J. Nepszy. 1981. Variation among stocks of walleye (*Stizostedion vitreum vitreum*): management implications. Can. J. Fish. Aquat. Sci. 38: 1814 – 1831.

Conant, R. and J.T. Collins. 1991. Reptiles and Amphibians: Eastern/Central North America. Houghton Mifflin Company, Boston.

Conner, D. J., C. R. Bronte, J. H. Selgeby, and H. L. Collins. 1993. Food of salmonine predators in Lake Superior, 1981-1987. Great Lakes Fish Commission Technical Report 59. 20 p.

Cook, D.G. 1975. A preliminary report on the benthic macroinvertebrates of Lake Superior. J. Fish. Res. Board Can. Tech. Rep. 572.

Cook, F.R. 1984. Introduction to Canadian amphibians and reptiles. National Museums of Canada, Ottawa.

Cooper, J. 1999. OMNR, Wawa District. Personal communication.

COSEWIC. 2002. Assessment and Update Status Report on the Woodland Caribou *Rangifer tarandus caribou* Boreal Population in Canada. Committee on the Status of Endangered Wildlife in Canada, 109 pp.

COSEWIC. 2003. Canadian Species at Risk. November 2003. Committee on the Status of Endangered Wildlife in Canada, 44 pp.

Crum, H. 1988. A Focus on Peatlands and Peat Mosses. University of Michigan Press. Ann Arbor.

Curtis, J.T. 1959. The Vegetation of Wisonsin. Univ. Wisc. Press, Madison.

Cuthbert, F. J., and J. McKearnan. 1999. U.S. Great Lakes gull survey: 1998 progress report. Univ. of Minn., St. Paul MN. Rep. to U.S. Fish and Wildl. Serv., Ft. Snelling, MN.

Cuthrell, D.L. 1999a. Special animal abstract for *Euxoa aurulenta* (dune cutworm). Michigan Natural Features Inventory,Lansing, MI. 2 pp.

Cuthrell, D.L. 1999b. Special animal abstract for *Somatochlora incurvata* (incurvate emerald dragonfly). Michigan Natural Features Inventory, Lansing, MI. 2 pp.

Czypinski, G. MN DNR Personal communication.

Darby, W.R., H.R. Timmermann, J.B. Snider, K.F. Abraham, R.A. Stefanski, and C.A Johnson. 1989. Woodland caribou in Ontario. Background to a policy. Ontario Ministry of Natural Resources. Toronto. 38 pp.

Daulton, T., M. W. Meyer, and P. W. Rasmussen. 1997. The 1995 status of the common loon in Wisconsin. Passenger Pigeon 59:195–205.

Dawson, Neil. 2000. OMNR. Personal communication.

Dawson, N. 2000. Report on the status of wolverine (Gulo gulo) in Ontario. OMNR. Unpublished report.

DeCalesta, D. S. 1994. Effect of white-tailed deer on songbirds within managed forests in Pennsylvania. J. Wildl. Manage. 58:711–717.

Dell, C.I., 1973. A quantitative mineralogical examinination of the clay-size fraction of Lake Superior sediments. In Proc. 16th Conf. Great Lakes Res., Internat. Assoc. Great Lakes Res., pp. 413–420.

Dell, C.I. 1974. The stratigraphy of northern Lake Superior late-glacial and postglacial sediments. In proc. 17th Conf. Great Lakes Res., Internat. Assoc. Great Lakes Res., pp. 179–192.

Dermott, R. 1978. Benthic diversity and substrate-fauna associations in Lake Superior. J. Great Lakes Res. 4(3–4):505–512.

Desrochers, A., and S. J. Hannon. 1997. Gap crossing decisions by forest songbirds during the post-fledging period. Conserv. Biol. 11:1204–1210.

Detenbeck, N.E., S.M. Galatowitsch, J. Atkinson, and H.Ball. 1999. Evaluating perturbations and developing restoration strategies for inland wetlands in the Great Lakes Basin. Wetlands 19: 789 – 820.

de Vos, A. 1952. Ecology and management of fisher and marten in Ontario. Ont. Dept. Lands and Forests Tech. Bull. 90 pp.

Diana, S. G., and V. R. Beasley. 1998. Amphibian toxicology. Pages 266–277 in Lannoo, M. J., [ed.] Status and conservation of midwestern amphibians. Univ. of Iowa Press, Iowa City, IA. 507 pp.

Diehl, S., W. Maanau, T. Jordan, and M. Sydor. 1977. Transports in Lake Superior. J. Geophys. Res. 82:977–978.

Dobbyn, J. 1994. Atlas of the Mammals of Ontario. Federation of Ontario Naturalists, Don Mills.

Dobson, H.F. 1972. Nutrients in Lake Superior. Unpublished manuscript. CCIW.

Dodge, D. and R. Kavetsky 1995. Aquatic habitat and wetlands of the Great Lake. . Environment Canada and U.S. EPA. State of the Great Lakes Ecosystem Conference. Background Paper. 71 pp.

Doepker, R. V., D. E. Beyer, Jr., and M. Donovan. 1996. Deer population trends in Michigan's Upper Peninsula. Mich. Dept. of Nat. Resour., Wildl. Div. Rep. 3254.

DonCarlos, Mike. 1999. MN DNR Personal communication.

DonCarlos, M.W. 1994. Factsheet: Management of the lynx (*Felis lynx*) in Minnesota. Unublished Report.

Donifrio,M. 2003. Keweenaw Bay Natural Resources Department. Personal communication.

Dorn, Kevin. 1999. USFS. Personal communication

Dredge, L.A. and Cowan, W.R. 1989. Quaternary geology of the southwestern Canadian Shield; in Quaternary Geology of Canada and Greenland, R.J. Fulton [ed.], Geological Survey of Canada, Geology of Canada No.1, pp.214–249. ISBN 0-660-13114-5.

Dryer, W. R., L. F. Erkkila, and C. L. Tetzloff. 1965. Food of lake trout in Lake Superior. Trans. Am. Fish. Soc. 94: 169-176.

Duffy, W.G., T.R. Baterson, and C.D. McNabb. 1987. The St. Marys River, Michigan: an ecological profile. U.S. Fish Wild. Ser., Biol. Rep. 85(7.10). 138 p.

Dyksta, C.H., M.W. Meyer, D.K. Warnke, W.H. Karasov, D.E. Andersen, W.W. Bowerman IV, and J.P. Giesy. 1998. Low reproductive rates of Lake Superior Bald Eagles: Low food delivery rates or environmental contaminants? J. Great Lakes Res. 24(1): 32–44.

Ebener, M.P. [ed.]. 1998. Discussion paper on development of fish community objectives for Lake Superior. Unpublished draft. manuscript. 52 pp.

Ebener, M. P. 1997. Recovery of lake whitefish populations in the Great Lakes: a story of successful management and just plain luck. Fisheries 22 (7): 18–20.

Eddy, S. and J.C. Underhill. 1974. Northern Fishes. 3rd Ed. University of Minnesota Press. Minneapolis. 414 pp.

Edsall, T.A. 1998. Great Lakes. In: Mac, M.J., P.A. Opler, C.E. Puckett Haecker, and P.D. Doran. 1998. Status and trends of the nation's biological resources. 2 vols. U.S. Department of the Interior, U.S. Geological Survey, Reston, Va. 964 pp.

Edsall, T.A., R.H. Brock, R.P. Bukata, J.J. Dawson, and F.J. Horvath. 1992. State-of-the-art techniques for inventory of Great Lakes aquatic habitats and resources, p. 179–190. *In* W

Edsall, T.A., E.F. Stoermer and J.P. Kociolek. 1991. Periphyton accumulation at remote reefs and shoals in Lake Superior. J. Great Lakes Res. 17(3): 412–418.

Edsall, T.A. and M.N. Charlton 1997. Nearshore waters of the Great Lakes. Environment Canada and U.S. EPA. State of the Great Lakes Ecosystem Conference. Background Paper. 143 pp.

Eisenreich, S. J., B. B. Looney, and J. D. Thornton. 1981. Airborne organic contaminants in the Great Lakes ecosystem. Environ. Sci. Technol. 15:30–38.

Elkie, P.C., R.S. Rempel, and A.P. Carr. 1999. Patch analyst user's manual. A tool for quantifying landscape structure. Ont. Min. Natur. Resour. Northwest Sci. and Technol. Thunder Bay, Ont. Technical Manual TM-002. 16 pp + append.

Ellingwood, D. 1999. Lakehead Region Conservation Authority, Personal communication

Ensor, K. L., W. C. Pitt, and D. D. Helwig. 1993. Contaminants in Minnesota wildlife 1989-1991. Minn. Pollut. Control Agency, St. Paul, MN. 75 pp.

Environment Canada. 2000. The Importance of Nature to Canadians: The Economic Significance of Nature-Related Activities. Prepared by the Federal-Provincial-Territorial Task Force on the Importance of Nature to Canadians. 50pp. http://www.ec.gc.ca/nature/survey.htm

Environment Canada. 1993a. Environmental Sensitivity Atlas for Lake Superior's Canadian Shoreline. Conservation and Protection Branch.

Environment Canada. 1993b. The Great Lakes-St. Lawrence River Regulation: What it Means and How it Works.

Environment Canada and U.S. EPA. 1995. The Great Lakes: An Environmental Atlas and Resource Book. 3rd ed. www.epa.gov/glnpo/atlas

Epstein, Eric. 2000. WI DNR. Personal communication.

Epstein, E.J., E.J. Judziewicz, and W.A. Smith. 1997. Wisconsin's Lake Superior coastal wetlands evaluation. Wisconsin Natural Heritage Inventory Program. Bureau of Endangered Resouces. Dept. of Natural Resources. Madison. 330 pp.

Escott, N.G. 1991. Survey of the breeding birds of Lake Nipigon, Thunder Bay District, Ontario. Nature Northwest. Newsletter of the Thunder Bay Field Naturalists. 45 (4): 5 – 11.

Eshenroder, R. L., James W. Peck. and Charles H. Olver. 1999. Research priorities for lake trout rehabilitation in the Great Lakes: A 15 year retrospective. Great Lakes Fish Comm. Tech. Report. 64. 40 p.

Evers, D. C., J. D. Kaplan, M. W. Meyer, P. S. Reaman, W. E. Braselton, A. Major, N. Burgess, and A. M. Scheuhammer. 1998. Geographic trend in mercury measured in common loon feathers and blood. Environ. Toxicol. and Chem. 17: 173–183.

Faeh, S. A., D. K. Nichols, and V. R. Beasley. 1998. Infectious diseases of amphibians. Pages 260–265 in Lannoo, M. J., [ed.] Status and conservation of midwestern amphibians. Univ. of Iowa Press, Iowa City, IA. 507 pp.

Fee, E.J. 1971. A numerical model for the estimation of photosynthetic production, integrated over time and depth in natural waters. Contribution 22, Centre for Great Lakes Studies, University of Wisconsin-Milwaukee.

Filion, F. L., E. DuWors, P. Boxall, P. Bouchard, R. Reid, P. A. Gray, A. Bath, A. Jacquemot, and G. Legare. 1993. The importance of wildlife to Canadians: highlights of the 1991 survey. Can. Wildl. Serv., Environ. Can., Ottawa. 60 pp.

Finley, R. W., 1976, Original Vegetation of Wisconsin: Wisconsin Geological and Natural History Survey Map, 1:500,000-scale, 1 sheet.

Foster, D.R. 1988. Disturbance history, community organization and vegetation dynamics of the old-growth Pisgah forest, south-western New Hampshire, USA. J. Ecol. 76:105–134.

Foster, R.F., A.G. Harris, J. Holenstein and B. Ratcliff. 1999. Current trends and future impacts on the Lake Superior ecosystem. Unpublished report.

Fox, G. A., S. Trudeau, H. Won, and K. A. Grasman. 1998. Monitoring the elimination of persistent toxic substances from the Great Lakes: chemical and physiological evidence from adult herring gulls. Environ. Monit. and Assess. 53:147–168.

Freitag, R., P. Fung, J.S. Mothersill, and G.K. Prouty. 1976. Distribution of benthic macroinvertebrates in Canadian waters of northern Lake Superior. J. Great Lakes Res. 2:177–192.

Frelich, L.E. 1995. Old forest in the Lake States today and before European settlement. Natural Areas Journal 15:157–167.

Frelich, L. E., P. F. J. Eagles, and R. J. Mackay. 1995. Effects of residential development on forest-dwelling neotropical migrant songbirds. Conserv. Biol. 9:1408–1414.

Frelich, L.E. and C.G. Lorimer. 1985. Current and predicted long-term effects of deer browsing in hemlock forests of Michigan, USA. Biol. Cons. 34:99–120.

Frelich, L.E. and C.G. Lorimer 1991. A simulation of landscape level stand dynamics in the northern hardwood region. J. Ecol. 79:223–233.

Friday, Mike. Personal communication. Ontario Ministry of Natural Resources, Upper Great Lakes Management Unit – Lake Superior. 435 James Street South, Suite 221e. Thunder Bay, Ontario P7E 6S8. Phone: 807-475-1231; FAX: 807-473-3024; email: mike.friday@mnr.gov.on.ca .

Friesen, L., P.F.J. Eagles, and R.J. Mackay. 1995. Effects of residential development on forest-dwelling neotropical migrant songbirds. Conservation Biology 9:1408-1414.

Galbraith, D.A., and R.J. Brooks. 1987. Survivorship of adult females in a northern population of snapping turtles (Chelydra serpentina). Can. J. Zool. 65: 1581–1586.

Geddes, R.S., Kristjansson, F.J. and Teller, J.T. 1987. Quaternary features and scenery along the north shore of Lake Superior; XIIth International Union for Quaternary Research (INQUA) Congress Field Excursion Guidebook, 62p. ISBN 0-660-12313-4.

Gerstenberger, S. L., J. H. Gilbert, and J. A. Dellinger. 1996. Environmental contaminants and cholinesterase activity in the brain of fisher (Martes pennanti) harvested in northern Wisconsin. Bull. Environ. Contam. Toxicol. 56:866–872

Gilbert, J. H., J. L. Wright, D. J. Lauten, and J. R. Probst. 1997. Den and rest site characteristics of American marten and fisher in northern Wisconsin. Pages 135–145 in G. Proulx, H. Bryant, and P. M. Woodard, eds. Martes: taxonomy, ecology, techniques, and management. Proc. of the Second Int. Martes Symp. Prov. Mus. of Alberta, Edmonton. 474 pp.

Gilbertson, M. 1974. Pollutants in breeding herring gulls in the lower Great Lakes. Can. Field-Nat. 88:273–280.

Gillum, S. S., A. R. Lindsay, and M. W. Meyer. 1998. Quantifying the impact of lake shore housing development on breeding bird populations in northern Wisconsin. Bur. of Integrated Sci. Serv., Wisc. Dept. of Nat. Resour. Rep. to U.S. Fish and Wildl. Serv., Ft. Snelling, MN.

Glooschenko, V., and N. Burgess. 1987. Moose and deer cadmium program 1985-86. Ont. Minist. of Nat. Resour. Internal Rep., Toronto, ON.

Givens, D.R. and J.H. Soper. 1981. The arctic-alpine element of the vascular flora at Lake Superior. National Museums of Canada. Publications in Botany No. 10.

Goodier, J.L. 1981. Native lake trout stocks in the Canadian waters of Lake Superior, prior to 1955. Can. J. Fish. Aquat. Sci. 28:1724–1737.

Goodyear, C.D., T.A. Edsall, D.M. Ormsby Dempsey, G.D. Moss, and P.E. Polanski. 1981. Atlas of the spawning and nursery areas of Great Lakes Fishes, Vol. I. Lake Superiro. Great Lakes Fishery Laboratory, Ann Arbour, Michigan 109 pp.

Green, J. C. 1995. Birds and forests: a management and conservation guide. Minn. Dept. of Nat. Resour., St. Paul, MN. 182 pp.

Greenwood, S. 1999. OMNR. Personal communication.

Greenwood, S. 2003. OMNR. Personal communication.

Gunderson, J. 1995. Rusty crayfish: a nasty invader biology, identification and impacts of the rusty crayfish. Minnesota Sea Grant Program. (http://www.d.umn.edu/ seagr/areas/aqua/rusty.html).

Hamady, M. 2000. MN DNR. Personal communication

Hansen, M.J. [ed.] 1994. The state of Lake Superior in 1992. Great Lakes Fish. Comm. Spec. Pub. 94–1. 110 pp.

Hansen, M.J. [ed.] 1996. A lake trout restoration plan for Lake Superior. Great Lakes Fish. Comm. 34 pp.

Hansen, M. J., M. P. Ebener, J. D. Shively, and B. L. Swanson. 1994. Lake trout, pp. 13–34. In M. J. Hansen [ed.] The state of Lake Superior in 1992. Great Lakes Fishery Commission Special Publication 94-1. 110 p.

Hansen, M. J., J. W. Peck, R. G. Schorfhaar, J. H. Selgeby, D. R. Schreiner, S. T. Schram, B. L. Swanson, W. R. MacCallum, M. K. Burnham-Curtis, J. W. Heinrich, and R. J. Young. 1995a. Lake trout (Salvelinus namaycush) populations in Lake Superior and their restoration in 1959-1993. Journal of Great Lakes Research 21 (Supplement 1): 152–175.

Hansen, M. J., R. G. Schorfhaar, J. W. Peck, J. H. Selgeby, and W. W. Taylor. 1995b. Abundance indices for determining the status of lake trout restoration in Michigan waters of Lake Superior. North American Journal of Fisheries Management 15: 830–837.

Harding, J. H. 1997. Amphibians and reptiles of the Great Lakes region. The Univ. of Michigan Press, Ann Arbor, MI. 361 pp.

Harkness, Mary. 2000. The Nature Conservancy. Personal communication.

Harkness, W.J. and J.R. Dymont. 1961. The lake sturgeon. Ontario Department of Lands & Forests, Fisheries & Wildlife Branch Toronto. 121 pp.

Harrington, B. A. 1995. Shorebirds: East of the 105th Meridian. Pages 57–60 in E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, eds. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals and ecosystems. U.S. Dept. of Int., Natl. Biol. Serv., Washington, D.C. 530 pp.

Harrington, M.W. 1985. Surface currents of the Great Lakes. U.S. Department of Agriculture, Weather Bureau Bulletin.

Harris, A.G. 1999. Report on the status of woodland caribou in Ontario. Draft. OMNR. Unpublished report.

Harris, L.D. 1984. The Fragmented Forest. Island Geographic Theory and the Preservation of Biotic Diversity. Univ. of Chicago Press. Chicago.

Hartley, R. 1999. OMNR. Personal communication.

Haws, K. 1999. MN DNR. Personal communication.

Hazard, E.B. 1982. The Mammals of Minnesota. University of Minnesota Press. Minneapolis.

Heaton, S. N., S. J. Bursian, J. P. Giesy, D. E. Tillitt, J. A. Render, P. D. Jones, D. A. Verbrugge, T. J. Kubiak, and R. J. Aulerich. 1992. Effects of polychlorinated biphenyls on mink. Arch. Environ. Contam. Toxicol. 28:334–343.

Hebert, C. E., R. J. Norstrom, and D. V. Weseloh. 1999. A quarter century of environmental surveillance: The Canadian Wildlife Service's Great Lakes Herring Gull Monitoring Program. Environ. Rev.

Heinselman, M.L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quat. Res. 3:329–82.

Heinselman, M.L. 1981. Fire and succession n the conifer forests of northern North America. Pp. 374 – 405 in D.C. West, H.H. Shugart, and D.B. Botkin, eds. Forest succession concepts and application. Springer-Verlag. New York.

Heinselman, M.L. 1996. The Boundary Waters Wilderness Ecosystem. Univ. of Minnesota Press. Minneapolis.

Heyens, L.E. 1998. The 1996 piping plover census in Ontario. Ontario Birds 16 (1): 26 – 31.

Higgins, J.V. and M.dePhilip. 1999. The Nature Conservancy. Personal communication.

Higman, P.J. and M.R. Penskar. No date. Special plant abstract for Cirsium hillii (Hill's thistle). Michigan Natural Features Inventory, Lansing, MI. 2 pp.

Hills,G.A. 1959. A ready reference to the description of the land of Ontario and its productivity. Ontario Department of Lands and Forests. Maple, Ontario.

Hinshaw, A.L. 1998. Piping Plover Breeding Success and Management in Michigan's Eastern Upper Peninsula: 1998 Final Report. Submitted to: Endangered Species Office, Michigan Department of Natural Resources, Lansing, Michigan.

Hoff, M.H. [ed.]. 1996. Status of walleye in Lake Superior and its tributaries. Lake Superior Committee Annual Meeting minutes. Great Lakes Fishery Commission. 60 p.

Hoff, M.H. 1999. [ed.] A rehabilitation plan for walleye populations and habitats in Lake Superior. Walleye Subcomm., Lake Superior Tech. Comm., Great Lakes Fish. Comm. 16 p.

Hoff, M. H., and C. R. Bronte. 1998. Population status and trends for economically and ecologically important fishes in Lake Superior, 1978-1997. Minutes of the Lake Superior Committee Meeting, March 17-18, 1998, Thunder Bay, Ontario.

Hoff, M. H., and C. R. Bronte. 1999. Structure and stability of the fish communities of Chequamegon Bay, Lake Superior during 1973-1996. Transactions of the American Fisheries Society: 128:362–373.

Hoff, M. H., J. Link, and C. Haskell. 1997. Piscivory by Lake Superior lake herring (Coregonus artedi) on rainbow smelt (Osmerus mordax) in winter, 1993-1995. Journal of Great Lakes Research 23: 210–211.

Hoff, M. H., L. M. Evrard, A. J. Edwards, and C. R. Bronte. 1998. Ruffe population investigations in Lake Superior tributaries. Final Report. U. S. Geological Survey, Biological Resources Division Great Lakes Science Center, Lake Superior Biological Station, 2800 Lake Shore Drive East, Ashland, Wisconsin, 54806. 44 p.

Hoopes, J.A., R.A.Ragotzkie, S.L. Line, and N.P. Smith. 1973. Circulation patterns in Lake Superior. Tech. Rep. WIS WRC 73-04., Water Resources Center, Univ. of Wisconsin., Madison, Wisconsin.

Houston, J. J. P. 1988. Status of the shortjaw cisco, Coregonus zenithicus, in Canada. Can. Field-Nat. 102: 97–102.

Howe, R. W., G. Niemi, and J. R. Probst. 1995. Management of western Great Lakes forests for the conservation of neotropical migratory birds. Pages 144–167 in F.R. Thompson III, [ed.] Management of midwestern landscapes for the conservation of neotropical migratory birds. U.S. For. Serv. Gen. Tech. Rep. NC-187. St. Paul, MN.

Howe, R. W., S. A. Temple and M. J. Mossman. 1992. Forest management and birds in northern Wisconsin. Passenger Pigeon 54:297–305.

Howe, R. W., and M. Mossman. 1995. The significance of hemlock for breeding birds in the western Great Lakes region. Pages 125–139 in Mroz, G., and J. Martin, eds. Proceedings of a regional conference on ecology and management of eastern hemlock. Univ. of Wisc., Madison, WI.

Hubbs,C.L. and K.F. Lagler. 1958. Fishes of the Great Lakes Region. Cranbrook Institute of Science. Bulletin No. 26. Bloomfield Hills. 213 pp.

Hyde, D.A. 1996. Special animal abstract for Sterna caspia (Caspian tern). Michigan Natural Features Inventory, Lansing, MI. 3 pp.

Hyde, D.A. 1997. Special animal abstract for Sterna hirundo (common tern). Michigan Natural Features Inventory, Lansing, MI. 3 pp.

International Joint Commission (IJC). 1977. Upper Lakes Reference Group. The waters of Lake Huron and Lake Superior, Vols 1–3.

International Joint Commission (IJC). 1976. Further Regulation of the Great Lakes. An IJC Report to the Governments of Canada and the United States. Unpublished Report.

International Joint Commission (IJC). 1985. Great Lakes diversions and consumptive uses.

International Joint Commission (IJC). 1993. Methods of alleviating the adverse consequences of fluctuating water levels in the Great Lakes-St. Lawrence River Basin.

Irbe, G.J. 1991. Great Lakes Surface Water Temperature Climatology. Environment Canada. Climatological Studies No. 43. 215 pp.

Jensen, A. L. 1976. Assessment of the United States lake whitefish (Coregonus clupeaformis) fisheries of Lake Superior, Lake Michigan, and Lake Huron. Transactions of the American Fisheries Society 33: 747–759.

Johnson, T.B., Hoff, M.H., Trebitz, A.S., Bronte, C.R., Corry, T.D., Kitchell, J.F., Lozano, S.T., Mason, D.M., Scharold, J.V., Schram, S.T. and D.R. Schreiner. 2004. Spatial patterns in assemblage structures of pelagic forage fish and zooplankton in western Lake Superior. Journal of Great Lakes Research. In Press.

Jones, Scott. 1999. OMNR . Personal communication.

Jonsson, B.G. and M. Dynesius. 1993. Uprooting in boreal forests: Long-term variation in disturbance rate. Can. J. For. Res. 23:2383–2388.

Judziewicz E.J. 1997. Vegetation and flora of Passage Island, Isle Royale National Park, Michigan. Michigan Botanist 36: 35–62.

Kavetsky, B. 1999. USFWS. Personal communication.

Kelso, J.R.M., W.M. Gardner, and S. Greenwood. 1996. Status in Ontario waters of Lake Superior, p. 38–44. In M.H. Hoff [ed.] Status of walleye in Lake Superior and its tributaries. Walleye Subcomm., Lake Superior Tech. Comm., Great Lakes Fish. Comm. 60 p.

Kemp, A.L.W., C.I. Dell and N.S. Harper. 1978. Sedimentation rates and a sediment budget for Lake Superior. J. Great Lakes Res. 4(3–4):276–287.

Kempinger, J.J. 1988. Spawning and early life history of lake sturgeon in the Lake Winnebago system, Wisconsin. American Fisheries Society Symposium 5:110-122.

Kenkel, N.C. and P.R. Watson, and P. Uhlig. 1998. Modelling landscape-level vegetation dynamics in the boreal forests of northwestern Ontario. Ontario Ministry of Natural Resources Forest Research Report No. 148.

Kershner, B. 1999. Survey finds last U.S. Great Lakes ancient forest. Great Lakes United. Fall 1999: 3–6.

Klar, G.T., L.P. Schleen and R.J. Young. 1996. Integrated management of sea lampreys in the Great Lakes. 1996. Annual Report to the Great Lakes Fishery Commission. Web site: http://www.glfc.org slar961.htm.

Kling,G.W., K.Hayhoe, L.B.Johnson, J.J.Magnuson, S.Polasky, S.K.Robinson, B.J.Shuter, M.M.Wander, D.J.Wuebbles, D.R.Zak, R.L.Lindroth, S.C.Moser, and M.L.Wilson. 2003. Confronting Climate Change in the Great Lakes Region:Impacts on our Communities and Ecosystems.Union of Concerned Scientists, Cambridge, Massachusetts, and Ecological Society of America, Washington,D.C.

Koch, R.G., Stackler, S. H., Koch, L. M., and Kapustka, L., 1979, Vegetation Cover Analysis – Presettlement Vegetation of the Namadji River Basin. In: Andrews, Christensen, Wilson, eds., Impact of Nonpoint Pollution Control on Western Lake Superior; Red Clay Project Final Part II, EPA 905/9-79-002-B. pp. 276–297.

Koehler, G.M. and K.B. Aubrey. 1994. Lynx. In: L.F. Ruggiero et al.. (eds). The Scientific Basis for Conserving Forest Carnivores. American Marten, Fisher, Lynx and Wolverine. USDA Forest Service General Technical Report RM-254.

Koonce, J.F. C.K. Minns, and H.A. Morrison. 1998. Biodiversity investment areas: Aquatic ecosystems. Aquatic biodiversity investment areas in the Great Lakes Basin: Indentification and Validation. Environment Canada and U.S. EPA. State of the Great Lakes Ecosystem Conference. Background Paper. 44 pp.

Krizan, P. 1997. The Effects of Human Development, Landscape Features, and Prey Density on the Spatial Use of Wolves (*Canis lupus*) on the North Shore of Lake Superior. M. S. Thesis. Center for Wildlife and Conservation Biology, Acadia University, 109pp.

Kronberg, B. I., and V. Glooschenko. 1994. Investigating cadmium bioavailability in northwestern Ontario using boreal forest plants. Alces 30:71–80.

Kubiak, T. J., and D. A. Best. 1991. Wildlife risks associated with passage of contaminated, anadromous fish at Federal Energy Regulatory Commission licensed dams in Michigan. U.S. Fish and Wildl. Serv. Internal Rep., East Lansing, MI.

LaBerge, G.L. 1994. Geology of the Lake Superior region; Geoscience Press, Inc. 313p.

Lake Superior Binational Program. 1995. Ecosystems principles and objectives, indicators and targets for Lake Superior. Discussion Papers. Lake Superior Work Group of the Lake Superior Binational Program.

Lake Superior Binational Program. 1998. Ecosystems principles and objectives, indicators and targets for Lake Superior (revision date). Lake Superior Working Group of the Lake Superior Binational Program, Thunder Bay, Ontario. 110 pp.

Lake Superior Technical Committee. 1999. Lake Superior fish community objectives. Draft report.

Lam, D.C. 1978. Simulation of water circulations and chloride transports in Lake Superior for Summer 1973. J. Great Lakes Res. 4(3-4): 343–349

Lambert, A., and B. Ratcliff. 1979. A survey of piping plovers in Michigan, 1979. Report submitted to Michigan Department of Natural Resources, Lansing, Michigan.

Lambert, A. and B. Ratcliff. 1981. Present status of the piping plover in Michigan. The Jack Pine Warbler 59: 44–52.

Lannoo, M. J. 1998. Amphibian conservation and wetland management in the Upper Midwest: a catch-22 for the cricket frog? Pages 330–339 in Lannoo, M. J., [ed.] Status and conservation of midwestern amphibians. Univ. of Iowa Press, Iowa City, IA. 507pp.

Lanteigne, J. 1991. Status report on the Northern Brook Lamprey, Ichthyomyzon fossor. COSEWIC. 24 pp.

Lawrie, A.H. 1978. The fish community of Lake Superior. International Association for Great Lakes Research 43: 513 – 549.

Lawrie, A.H. and J.R. Rahrer. 1972. Lake Superior: effects of exploitation and introductions on the salmonid community. J. Fish. Res. Bd. Canada. 29: 765 – 776.

Lawrie, A.H. and J.F. Rahrer. 1973. Lake Superior: a case history of the lake and its fisheries. Great Lakes Fish. Comm. Tech. Report 19. Ann Arbor, Michigan. 53 p.

Leach J.H. and R.C. Herron 1996. A review of lake habitat classification. In: W.D.N. Busch and P.G. Sly (eds). The Development of an Aquatic Habitat Classification System for Lakes. CRC Press. Ann Arbor.

Lee, H. D., and F. C. Southham. 1974. Effect and implications of differential iostatic rebound on Lake Superior's regulation limits. Journal of Great Lakes Research 20(2): 407–415.

Lee, Peter. 2000. Lakehead University. Personal communication.

Lee, Y. 1999. Special animal abstract for Clemmys insculpta (wood turtle). Michigan Natural Features Inventory, Lansing, MI. 3 pp.

Legault, J., and T. Kuchenberg, and M. E. Sisulak. 1978. Reflections in a tarnished mirror: the use and abuse of the Great Lakes. Golden Glow Publishing, Sturgeon Bay, Wisconsin. 224 p.

Lenter, J.D. 2004 Trends in the Lake Superior water budget since 1948: A weakening seasonal cycle. Journal of Great Lakes Research. In Press.

Leskevich, G.A. 1975. Lake Superior bathythermograph data. Contribution No. 32, Great Lakes Environmental Research Laboratory. Ann Arbour, Michigan.

Loftus, D.H., C.H. Olver, E.H. Brown, P.J. Colby, W.L. Hartman, and D.H. Schupp. 1987. Partitioning potential fish yields from the Great Lakes. Can. J. Fish. Aquat. Sci. 44 (Supp. 2): 417–424.

Loope,W.L. 2003 Monitoring natural and anthropogenic change in the Grand Sable Dunes, Pictured Rocks National Lakeshore. Western Great Lakes Research Conference and Chequamegon Bay Natural Resource Conference.

Loope, W.L. and A.K. McEachern. 1998. Habitat change in a perched dune system along Lake Superior. In: Mac, M.J., P.A. Opler, C.E. Puckett Haecker, and P.D. Doran. 1998. Status and trends of the nation’s biological resources. 2 vols. U.S. Department of the Interior, U.S. Geological Survey, Reston, Va. 964 pp.

Ludwig, J. P. 1986. A short report on the Michigan marten re-introduction program in 1985-86: comparison to trapping success with the Algonquin Park efforts of 1980-81. Unpublished report, Ecological Research Services, Inc., Boyne City, MI. 24 pp.

MacCallum, W.R. and J.H. Selgeby. 1987. Lake Superior revisited 1984. Can. J. Fish. Aquat. Sci. 44 (Suppl. 2): 23–36.

Mallik, A.U. 2002. Soil invertebrates and mycorrhizal fungi as indicators of ecosystem health in the Lake Superior basin: A literature review. Tech. Rept. to the Terrestrial Wildlife Community Committee, Lake Superior Binational Program. 28 pp.

Marsden, J.E., D.L. Perkins, and CC. Krueger. 1995. Lake trout spawning habitat in the Great Lakes – a review of current knowledge. J. Great Lake. Res. 21: 487–497.

Marshall, E.W. 1968. Lake Superior ice characteristics. In Proc. 10th Conf. Great Lakes Res., Internat. Assoc. Great Lakes Res. pp. 214–220.

Marshall, S. 1999. Tiger Beetles Of Ontario http://www.uoguelph.ca/~samarsha/photos.htm

Matheson, D.H. and M. Munawar. 1978. Lake Superior basin and its development. J. Great Lakes Res. 4(3-4):249–263.

Matteson, S. 2000. . Wisconsin DNR. Personal communication.

Matteson, S.W. 1988. Wisconsin common tern recovery plan. Wisconsin Endangered Resources Report 41. Wisconsin Dept. of Natural Resources. 74 pp.

Matthiae, P.E. and F. Stearns. 1981. Mammals in forest islands in southeastern Wisconsin. In: Forest island dynamics in man-dominated landscapes. R.L. Burgess and D.M. Sharpe (eds). Springer-Verlag. New York. Pp. 59–66.

Maynard, L. and D. Wilcox.1997. Coastal wetlands of the Great Lakes. State of the Lakes Ecosystem Conference 1996. Environment Canada and U.S. Environmental Protection Agency.

McAllister, D.E., B.J. Parker, and P.M. McKee. 1985. Rare, endangered and extinct fishes in Canada. National Museums of Natural Science. Syllogeus 54. Ottawa. 192 pp.

McCaffery, K. R., J. Tranetzki, and J. Piechura. 1974. Summer foods of deer in northern Wisconsin. J. Wildl. Manage. 38:215–219.

McCaffery, K. R. 1995. History of deer populations in northern Wisconsin. Pages 109–113 in Mroz, G., and J. Martin, eds. Proceedings of a regional conference on ecology and management of eastern hemlock. Univ. of Wisc., Madison, WI.

McCammon Soltis, A. 1999. Personal communication.

McGarigal, K. and B. Marks 1993. FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure: USDA Forest Service, Pacific Northwest Research Station. Gen. Tech. Rep. PNW-GTR-351. Portland, OR. 122 pp.

McKelvey, K.S., K.B. Aubry, G.M. Koehler, and Y.K. Ortega. 1999. History and distribution of lynx in the contiguous United States. USDA Forest Service Gen. Tech. Rep. RMRS GTR-30.

McNab, W.H. and P.E. Avers (compilers). 1994. Ecological Subregions of the United States. WO-WSA-5. U.S. Forest Service. (http://www.fs.fed.us/land/pubs /ecoregions/index.html)

Meating, J. 1999. BioForest Technologies. Personal communication.

Mech, L.D. 1980. Age, sex, reproduction and spatial organization of lynxes colonizing northeast Minnesota. J.of Mammology. 61: 261 – 267.

Merrill, S. B., F. J. Cuthbert, and G. Oehlert. 1998. Residual patches and their contribution to forest-bird diversity on northern Minnesota aspen clearcuts. Conserv. Biol. 12:190–199.

Meyer, M.W. 1992. Factors controlling Great Lakes bald eagle productivity: 1992 annual progress report. Unpubl. Rep. to Great Lakes Protection Fund, Wisconsin DNR, Madison, Wisconsin.

Meyer, M. 1999. Wisconsin DNR. Personal communication.

Michigan Dept. of Environmental Quality 1998. Clean Water Act Section 303 9d. List Michigan Submittal for 1998. Unpublished Report.

Michigan Gray Wolf Recovery Team. 1997. Michigan Gray Wolf Recovery and Management Plan. Website: http://www.dnr.state.mi.us/Wildlife/Publications/Mammals/Wolf/ mgmtplan /default.htm

Michigan Loon Recovery Program. 1992. A plan for recovery of the common loon in Michigan. Rep. submitted to Mich. Dept. of Nat. Resour. 66 pp.

Michigan Natural Features Inventory. 1996. Special plant abstract for Panax quinquefolius (ginseng). Lansing, MI. 3 pp.

Michigan Natural Features Inventory. 1999a. Natural community abstract for open dunes. Lansing, MI. 5 pp. Compiler: D.A. Albert.

Michigan Natural Features Inventory. 1999b. Natural community abstract for wooded dune and swale complex. Lansing, MI. 6 pp. Compilers: D.A. Albert and P.J. Comer.

Miller, S. G., S. P. Bratton, and J. Hadidian. 1992. Impacts of white-tailed deer on endangered plants. Nat. Areas J. 12:67–74.

Mills, E.L., J. H. Leach, J. T. Carlton, and C. L. Secor. 1993. Exotic species in the Great Lakes: a history of biotic crises and anthropogenic introductions. Journal of Great Lakes Research 19(1): 1-54.

Mineau, P., G. A. Fox, R. J. Norstrom, D. V. Weseloh, D. J. Hallett, and J. A. Ellenton. 1984. Using the herring gull to monitor levels and effects of organochlorine contamination in the Canadian Great Lakes. Pages 426–437 in Nriagu, J. O., and M. S. Simmons, eds. Toxic contaminants in the Great Lakes. John Wiley and Sons, Inc.

Minnesota Pollution Control Agency. 1997. Lake Superior Basin Information Document. Minnesota Pollution Control Agency. 125 pp. + appendices.

Minnesota Sea Grant. 1998. Zebra mussels threaten inland waters. (http://www.d.umn.edu/seagr/areas/exotic/)

Mladenoff, D.J., T.A. Sickley, R.G. Haight, and A.P. Wydeven. 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the Northern Great Lakes region. Conserv. Biology 9:279–294.

Mladenoff, D. J., and F. Stearns. 1993. Eastern hemlock regeneration and deer browsing in the northern Great Lakes region: a re-examination and model simulation. Conserv. Biol., 7:889–900.

Momot, W.T. 1995. History of the range expansion of Orconectes rusticus into northwestern Ontario and Lake Superior. Freshwater Crayfish 16: 61–72

Momot, W., 1999. Lakehead University. Personal communication.

Moore, H. H., and R. A. Braem. 1965. Distribution of fishes in U.S. streams tributary to Lake Superior. United States Fish and Wildlife Service, Special Scientific Report, Fisheries No. 516. 61 p.

Moriarty, J. J. 1998. Status of Amphibians in Minnesota. Pages 166–168 in Lannoo, M. J., [ed.] Status and conservation of midwestern amphibians. Univ. of Iowa Press, Iowa City, IA. 507 pp.

Mossman, M. J., L. M. Hartman, R. Hay, J. R. Sauer, and B. J. Dhuey. 1998. Monitoring long-term trends in Wisconsin frog and toad populations. Pages 169–198 in Lannoo, M. J., [ed.] Status and conservation of midwestern amphibians. Univ. of Iowa Press, Iowa City, IA. 507 pp.

Munawar, M. and I.F. Munawar. 1978. Phytoplankton of Lake Superior 1973. J. Great Lakes. Res., 4(3-4): 415–442.

Munawar, M., I.F. Munawar, L.R. Culp, and G. Dupuis. 1978. Relative importance of nannoplankton in Lake Superior phytoplankton biomass and community metabolism. J. Great Lakes Res., 4(3-4):462–480.

Mysz, A., R.Reid and K. Rodriguez. 1998. Biodiversity Investment Areas – Nearshore Terrestrial Ecosystems. Background Paper – State of the Lakes Ecosystem Conference.

National Wetlands Working Group 1988. Wetlands of Canada. Ecological Land Classification Series No. 24. Sustainable Development Branch. Environment Canada, Ottawa. Polyscience Publications Inc. Montreal. 452 pp.

National Wildlife Federation. 1993. Saving all the pieces: protecting biodiversity in the Lake Superior region. A report on phase one of the Lake Superior Biodiversity Project. Natl. Wildl. Fed., Ann Arbor, MI.

Natural Resources Conservation Service (NRCS) USDA Forest Service, 1998, Erosion and Sedimentation in the Nemadji River Basin.

Niemi, G., A. Lima, A. Hanowski, and L. Pfannmuller. 1995. Recent trends of breeding birds in Minnesota and Minnesota forested regions, 1966-1993. The Loon 67:191–201.

Nelson, Sharron, MN DNR, Natural Heritage and Nongame Research Program, Personal communication.

Newman, L. E., and R. B. Dubois. 1997. Status of brook trout in Lake Superior. A report prepared for the Lake Superior Technical Committee by the Brook Trout Subcommittee. 33 p.

Newman, L. E., J. T. Johnson, R. G. Johnson, R. J. Novitsky. 1999. Defining habitat use and movement patterns of a reintroduced coaster brook trout population in Lake Superior. U.S. Fish and Wildlife Service, Ashland Fishery Resource Office and Grand Portage Natural Resources Department, P. O. Box 428, Grand Portage, Minnesota, 55605. 10 pp.

Newman, L.E. , R.B. DuBois, and T.N. Halpern [eds.] 2003. A brook trout rehabilitation plan for Lake Superior. Great Lakes Fish. Commission. Misc. Publ. 2003-03.

Novak, M. 1987. Wild furbearer management in Ontario. Pages 1049 to 1061 in M. Novak, J. A. Baker, M. E. Obbard & B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trapper's Assoc., North Bay.

Nuhfer, A.J. 1992. Evaluation of the reintroduction of the arctic grayling into Michigan lakes and streams. Michigan Dept. of Natural Resources. Fisheries Research Report No. 1985.

Oldham, M.J. 1998. Natural heritage resources of Ontario: rare vascular plants. Natural Heritage Information Centre, Ontario Ministry of Natural Resources, Peterborough, Ontario. 53 pp.

Oldfield, B., and J. J. Moriarty. 1994. Amphibians and reptiles native to Minnesota. Univ. of Minn. Press, Minneapolis, MN. 237 pp.

Ontario Ministry of the Environment. 1992. The provincial water quality monitoring network in Northwestern Ontario: Data summary 1968 to 1990. Queen's Printer for Ontario.

Ontario Geological Survey. 1991. Geology of Ontario, Ontario Geological Survey, Special Volume 4, Parts 1 and 2, 1525 pp.

Ontario Ministry of Natural Resources (OMNR). 1999. A management framework for woodland caribou conservation in northwestern Ontario. Northwest Region Caribou Task Team.

Ontario Ministry of Natural Resources (OMNR). 1986. The forest resources of Ontario, 1986. Ont. Min. Natur. Res., Forest Resources Group. 91 p.

Ontario Ministry of Natural Resources (OMNR). 1988a. Timber management guidelines for the protection of fish habitat. Queen's Printer for Ontario. Toronto.

Ontario Ministry of Natural Resources (OMNR). 1988b. Environmental guidelines for access roads and water crossings. Toronto. 64 pp.

Ontario Ministry of Natural Resources (OMNR). Old Growth Policy for Ontario's Crown Forests. Queen 's Printer for Ontario

Ontario Ministry of Natural Resources (OMNR). 2003. Natural Resources Values Information System database.

Orr, B. 1997. Land use change on Michigan's Lake Superior shoreline: integrating land tenure and land cover type data. J. Great Lakes Res. 23 (3): 328–338.

Paloheimo, J.E. and H.A. Regier 1982. Ecological approaches to stressed multispecies fisheries resources, pp. 127–132. In: M.C. Mercer [ed.]. Multispecies approaches to fisheries management advice. Can. Spec. Publ. Fish. Aquat. Sci. 59.

Parker, B. J. 1988a. Status of the deepwater sculpin, Myoxocephalus thompsoni, in Canada. Can. Field Nat. 102: 126–131.

Parker, B. J. 1988b. Status report on the blackfin cisco, Coregonus nigripinnis. COSEWIC. 19 pp.

Parker, B. J. 1988c. Status of the shortnose cisco, Coregonus reighardi, in Canada. Can. Field Nat. 102: 92–96.

Parker, B. J. 1989. Status of the kiyi, Coregonus kiyi, in Canada. Can. Field Nat. 103:171–174.

Pascoe, D.A. and R.E. Hicks. 2004. Genetic structure and community DNA similarity of picoplankton communities from the Laurentian Great Lakes. Journal of Great Lakes Research. In Press.

Patalas, K. 1972. Crusteacean zooplankton and eutrophication of the St. Lawrence Great Lakes. J. Fish Res. Board Can. 29:1451–1462.

Pekarik, C., D. V. Weseloh, G. C. Barrett, M. Simon, C. A. Bishop, and K. E. Pettit. 1998a. An atlas of contaminants in the eggs of fish-eating colonial birds of the Great Lakes (1993-1997). Vol. I, Accounts by location. Can. Wildl. Serv. Tech. Rep. 321. 245 pp.

Pekarik, C., D. V. Weseloh, G. C. Barrett, M. Simon, C. A. Bishop, K. E. Pettit. 1998b. An atlas of contaminants in the eggs of fish-eating colonial birds of the Great Lakes (1993-1997). Vol. II, Accounts by chemical. Can. Wildl. Serv. Tech. Rep. 322. 214 pp.

Pekarik, C., and D. V. Weseloh. 1998. Organochlorine contaminants in herring gull eggs from the Great Lakes, 1974-1995: change point regression analysis and short-term regression. Environ. Monitor. and Assess. 53:77–115.

Penskar, M.R. and P.J. Higman. 1996. Special plant abstract for Asplenium scolopendrium (Hart's-tongue fern). Michigan Natural Features Inventory, Lansing, MI. 3 pp.

Perera, A.H. and D.J.B. Baldwin. 2000. Spatial patterns in the managed forest landscape of Ontario. pp. 74–99. In: A.H. Perera, D.L. Euler, and I.D. Thompson (eds). Ecology of a Managed Terrestrial Landscape. Patterns and Processes of Forested Landscapes in Ontario. UBC Press. Vancouver.

Perera, A.H. and D.J.B. Baldwin. 1993. Spatial characteristics of eastern white pine and red pine forests in Ontario. Ont. Min. Natur. Res., Forest Fragmentation and biodiversity Project Report No. 9.

Peterjohn B. G., and J. R. Sauer. 1994. Population trends of woodland birds from the North American Breeding Bird Survey. Wildl. Soc. Bull. 22:156–164.

Pettit, K. E., C. A. Bishop, D. V. Weseloh, and R. J. Norstrom. 1994a. An atlas of contaminants in the eggs of fish-eating colonial birds of the Great Lakes (1989-1992). Vol. I, Accounts by location. Can. Wildl. Serv. Tech. Rep. 193. 319 pp.

Pettit, K. E., C. A. Bishop, D. V. Weseloh, and R. J. Norstrom. 1994b. An atlas of contaminants in the eggs of fish-eating colonial birds of the Great Lakes (1989-1992). Vol. II, Accounts by chemical. Can. Wildl. Serv. Tech. Rep. 194. 300 pp.

Pimental, D., L. Lach, R. Zuniga, D. Morrison. 1999. Environmental and Economic Costs Associated with Non-Indigenous Species in the United States. College of Agricultural and Life Sciences, Cornell University, Ithaca, N.Y.

Policy Advisory Committee 1994. Interim report on conserving old growth red and white pine. Ontario Ministry of Natural Resources. 35 pp.

Potter, Brian. 2000. OMNR. Personal communication.

Promaine, A. 1999. Threatened species monitoring: Results of a 17-year survey of Pitcher's thistle, Cirsium pitcheri, in Pukaskwa National Park, Ontario. Can. Field Nat. 113 (2): 296–298.

Pycha, R. L. 1980. Changes in mortality of lake trout (Salvelinus namaycush) in Michigan waters of Lake Superior in relation to sea lamprey (Petromyzon marinus) predation, 1968-78. Canadian Journal of Fisheries and Aquatic Sciences 37: 2063–2073.

Pye, E.G. 1997. Roadside geology of Ontario: North shore of Lake Superior; Ontario GEOservices Centre, ROCK ON Series 2, 164 pp.

Rabe, M.L. 1999. Special animal abstract for Trimerotropis huroniana (Lake Huron locust). Michigan Natural Features Inventory, Lansing, MI. 3 pp.

Racey, G.D., A.G. Harris, E.R. Armstrong, L. Gerrish, R. Schott, and J. McNicol. 1999. Landscape planning for the conservation of forest-dwelling woodland caribou. Northwestern Ontario. Ontario Ministry of Natural Resources.

Racey, G., and B. Hessey. 1989a. Fisher (Martes pennanti) and timber management in Northern Ontario, a literature review. Ont. Minist. of Nat. Resour., Northwest. Ont. For. Technol. Dev. Unit Tech. Rep. No. 15.

Racey, G., and B. Hessey. 1989b. Marten and Fisher response to cutover: a summary of the literature and recommendations for management. Ont. Minist. of Nat. Resour., Northwest Sci. and Technol. Tech. Note TN-04. Thunder Bay, ON.

Ragotzkie 1974. Vertical motions along the north shore of Lake Superior. In Proc. 17th Conf. Great Lakes Res., Internat. Assoc. Great Lakes Res. pp. 456–461.

Rao, S.S. 1978. Seasonal surface distribution of aerobic heterotrophs and their relationships to temperature and nutrients in Lake Superior during 1973. J. Great Lakes. Res. 4(3-4):408–414.

Ratcliff, B. 1997-2003. Project Peregrine annual reports. Thunder Bay Field Naturalists. Unpublished reports.

Reckahn, J.A. 1970. Ecology of young lake whitefish (Coregonus clupeaformis) in South Bay, Manitoulin Island, Lake Huron. pp. 437 – 460. In C.C. Lindsey and C.S.Woods (eds). Biology of Coregonid Fishes. University of Manitoba Press, Winnipeg.

Reid, R. and K. Holland. 1997. The Land by the Lakes – Nearshore Terrestrial Ecosystems. Environment Canada background paper – State of the Lakes Ecosystem Conference.

Regier, H.A. and K.H. Loftus 1972. Effects of fisheries exploitation on salmonid communities in oligotrophic lakes. J. Fish. Res. Board Can. 29: 959 – 968.

Richards, C. J. Bonde, D. Schreiner, J. Selgeby, G. Cholwek, and K. Win. 1999. Mapping lake trout spawning habitat along Minnesota’s North Shore. Natural Resources Research Institute, University of Minnesota, Duluth. NRRI Technical Report No. 99–01.

Robbins, C.S., D.K Dawson, and B.A. Dowell. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic states. Wildlife Monog. No. 103.

Rogers, Joe. 1999. Shepherd, MI.. Personal communication.

Rondy, D.R. 1971. Great Lakes ice atlas. National Oceanic and Atmospheric Administration Tech. Memo. Detroit, Michigan NOS LSCR 1. 33 pp.

Rose, G.A., and G. Kruppert. 1984. An assessment of the walleye fishery and migration patterns of other species, Goulais River, spring of 1984. Ont . Min. Nat. Res., Sault Ste. Marie. 18 pp.

Royal Ontario Museum (ROM). 1999. Ontario's Species at Risk. Website (http://www.rom.on.ca).

Ruffe Task Force. 1992. Ruffe in the Great Lakes: a threat to North American fisheries. Great Lakes Fishery Commission, Ann Arbor, MI.

Russell, E.B. 1983. Indian-set fires in the forests of the northeastern United States. Ecology. 64:78–88.

Rustem,Ray. 2000. MI, DNR. Personal communication.

Ryder, R.A. 1968. Dynamics and exploitation of mature walleyes, Stizostedion vitreum vitreum, in the Nipigon Bay region of Lake Superior. J. Fish. Res. Board Can. 25:1347–1376.

Ryckman, D. P., D. V. Weseloh, and C. A. Bishop. 1997. Contaminants in herring gull eggs from the Great Lakes: 25 years of monitoring levels and effects. Fact sheet. Can. Wildl. Serv., Environ. Can., Burlington, ON.

Ryckman, D. P., D. V. Weseloh, P. Hamr, G. A. Fox, B. Collins, P. J. Ewins, and R. J. Norstrom. 1998. Spatial and temporal trends in organochlorine contamination and bill deformities in double-crested cormorants (*Phalacrocorax auritus*) from the Canadian Great Lakes. Environ. Monit. and Assess. 53:169–195.

Saulesleja, A. 1986. Great Lakes Climatological Atlas. Atmospheric Environment Service, Environment Canada.

Saunders, J. 1999. OMNR Sault Ste. Marie. Personal communication.

Sauer, J. R., J. E. Hines, G. Gough, I. Thomas, and B. G. Peterjohn. 1997. The North American breeding bird survey results and analysis. Version 96.3. Patuxent Wildl. Res. Center, Laurel, MD.

Scarf, W.C., M.L. Chamberlin, T.C. Erdman and G.W. Shugart. 1979. Nesting and migration of birds of the U.S. Great Lakes. Washington, D.C., U.S. Fish and Wildlife Service Biological Report. No. 77 (2).

Scharold, J.V., Lozano, S.J., and T.D. Corry. 2004. Status of the amphipod *Diporeia* spp. in Lake Superior, 1994-2000. Journal of Great Lakes Research. In Press.

Schertzer, W.M., F.C. Elder, and J. Jerome. 1978. Water transparency of Lake Superior in 1973. J. Great Lakes Res. 4(3-4):350–358.

Schmidt, K. A., and C. J. Whelan. 1999. The relative impacts of nest predation and brood parasitism on seasonal fecundity in songbirds. Conserv. Biol. 13:46–57.

Schneider, J.C. and J.H. Leach. 1977. Walleye (Stizostedion vitreum vitreum) fluctuations in the Great Lakes and possible causes, 1800-1975. J. Fish. Res. Board Can. 34:1878–1889.

Scholten S. 1999. OMNR Thunder Bay District. Personal communication.

Schram, S.T., J.R. Atkinson, and D.L. Pereira. 1991. Lake Superior walleye stocks: status and management, p. 1–22. In P.J. Colby, C.A. Lewis, and R.L. Eshenroder [eds.] Status of walleye in the Great Lakes: case studies prepared for the 1989 workshop. Great Lakes Fish Comm. Spec. Pub. 91-1.

Schram, S. T., J. Lindgren, and L. M. Evrard. 1999. Reintroduction of lake sturgeon in the St. Louis River, western Lake Superior. North American Journal of Fisheries Management 19: 815–823.

Scott, W.B. and E.J. Crossman 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada. Bulletin 184. Ottawa.

Seburn, D. C., and C. N. L. Seburn. 1997. Northern leopard frog survey of northern Ontario: report on a declining amphibian. Report to Ont. Minist. of Nat. Resour., Wildl. Assess. Unit. Seburn Ecological Services, Oxford Mills, ON.

Selgeby, J. H. 1982. Decline of lake herring (Coregonus artedii) in Lake Superior: an analysis of the Wisconsin herring fishery, 1936-78. Canadian Journal of Fisheries and Aquatic Sciences 39: 554–563.

Selgeby, J. H., W. R. MacCallum, and M. H. Hoff. 1994a. Rainbow smelt-larval lake herring interactions: competition of casual acquaintances? National Biological Survey, Technical Report Series, Biological Report 25. 9p.

Selgeby, J. H., C. R. Bronte, and J. W. Slade. 1994b. Forage species. pp. 53–62. In M. J. Hansen [ed.] The state of Lake Superior in 1992. Great Lakes Fishery Commission Special Publication 94-1.

Seyler, J., J.Evers, S.McKinley, R.R.Evans, G.Prevost, R.Carson and D.Phoenix. 1996. Mattagami River lake sturgeon entrainment: Little Long Generating Station Facilities. NEST Tech. Report TR-031.

Semple, J.C. and G. S.Ringius. 1983. Solidago houghtoniana. In: Argus, G.W., K.M. Pryer, D.J. White, and C.J. Keddy. Atlas of the rare vascular plants of Ontario. National Museum of Natural Sciences. Ottawa (looseleaf).

Shiras, G. 1935. Fishes of Lake Superior, the Huron Mountains District. National Geographic Society. Vol. 1 pp. 377 – 396. Washington.

Shirose, L., C. Bishop, and A. Gendron. 1996. Amphibians and reptiles in Great Lakes wetlands: threats and conservation. Great Lakes Fact Sheet, Environ. Can., Ottawa, ON.

Simpson, E. 1996. Old growth red and white pine forests: Northwest Region report on protection. Ont. Min. Natur. Res. NWST Tech. Rep. TR-98.

Skinner, L.C. W.J. Rendall and Ellen L. Fuge. 1994. Minnesota's purple loosestrife program: history, findings and management recommendations. Minnesota Dept. of Natural Resources Special Publictrion No. 145.

Slade, J. W., and N. A. Auer [ed.]. 1997. Status of lake sturgeon in Lake Superior. A report prepared for the Lake Superior Technical Committee by the Lake Sturgeon Subcommittee.

Smith, B. R., and J. J. Tibbles. 1980. Sea lamprey (Petromyzon marinus) in Lakes Huron, Michigan, and Superior: history of invasion and control, 1936-78. Canadian Journal of Fisheries and Aquatic Sciences 37: 1780–1801.

Snider, B. 1989. The Slate Islands. In: Theberge, John B. [ed.] Legacy: The Natural Heritage of Ontario, pp. 339–340. McClelland & Stewart, Toronto.

Snyder, L. L. 1938. A faunal investigation of western Rainy River district Ontario. Trans. Roy. Can. Inst. Vol. 14, Part 1:157–181, Toronto.

Soper J.H. C.E. Garton, and D.R.Given. 1989. Flora of the North Shore of Lake Superior (Vascular plants of the Ontario portion of the Lake Superior drainage basin). National Museum of Natural Sciences. Syllogeus 63.

Soule, J.D. 1993a. Preliminary identification of critical habitat in the Lake Superior watershed in Michigan. Unpublished Report. Michigan Department of Natural Resources.

Soule, J.D. 1993b. Biodiversity of Michigan's Great Lakes Islands: Knowledge, Threats and Protection. Lansing, MI: Michigan Department of Natural Resources.

Southam, C. and G. Larsen 1990. Great Lakes levels and flows under natural and current conditions. pp. 181 – 191 in: J.E. FitzGibbon. Ed. Proceedings of the Symposium on International and Transboundary Water Resource Issues. American Water Resources Association.

Stearns, F. W. 1995. History of the lake states forests: natural and human impacts. Lakes States Regional Forest Resources Assessment, Lake States Forestry Alliance.

Stebbins R. C., and N. W. Cohen. 1995. A natural history of amphibians. Princeton Univ. Press, Princeton, NJ.

Steedman, R.J. 1992. Centres of ecosystem function in the Lake Superior coastal zone. Making a Great Lake Superior. Lakehead University. Pp. 66 – 89.

Stephenson, S.A. 1999. Status of lake sturgeon (Acipenser fulvescens) in three Canadian Lake Superior tributaries. Lake Superior Management Unit Technical Report 99-21.

Stoeckeler, J. H., R. O. Strothmann, and L W. Krefting. 1957. Effect of deer browsing on reproduction in the northern hardwood-hemlock type in northeastern Wisconsin. J. Wildl. Manag. 21:75–80.

Storz, K., R. Clapper, and M. Sydor. 1976. Turbidity sources in Lake Superior. J. Great Lakes. Res. 2(2):393–401.

Strong, P., and R. Baker. 1991. An estimate of Minnesota's summer population of adult common loons. Minn. Dept. of Nat. Resour. Biol. Rep. 37. 30 pp.

Suarez, A.V., K. S. Pfennig, and S. K. Robinson. 1997. Nesting success of a disturbance-dependent songbird on different kinds of edges. Conserv. Biol. 11:928–935.

Sutherland, D. 1999. OMNR Natural Hertitage Information Centre. Personal communication.

Swanson, B.L. and D.V. Swedberg. 1980. Decline and recovery of the Lake Superior Gull Island Reef lake trout (Salvelinus namayscush) population and the role of sea lamprey (Petromyzon marinus) predation. Can. J. Fish. Aquat. Sci. 37: 2074–2080.

Terborgh, J. 1989. Where Have all the Birds Gone? Princeton University Press, Princeton.

Tesky, L. 1999 Wisconsin DNR. Personal communication.

The Nature Conservancy. 1994. The conservation of biological diversity in the Great Lakes ecosystem: issues and opportunities. The Nature Conservancy Program, Chicago, IL. 118 pp.

The White Pine Society. 2001. http://www.whitepines.org/index.htm

Thomas, R.L. and C.I. Dell. 1978. Sediments of Lake Superior. J.Great Lakes Res. 4(3-4):264–275

Thomson, F.R., S.J Lewis, J. Green, and D. Ewert. 1992. Status of neotropical migrant landbirds in the Midwest: Identifying species of management concern. pp. 145–158 In D.M. Finch, and P.W. Stangel (eds). Status and management of neotropical migratory birds. USDA, For. Ser. Rocky Mtn. For. & Range Expt. Station Gen. Tech. Rep. RM-229

Thompson, D.Q. R.L. Stuckey, and E.B. Thompson. 1987. Spread, impact and control of purple loosestrife (Lythrum salicaria) in North American wetlands. United States Depertent of the Interior. Fish and Wildlife Research #2. 56 pp.

Thompson, I.D. 2000. Forest vegetation of Ontario. pp. 30 – 53. In: A.H. Perera, D.L. Euler, and I.D. Thompson (eds). Ecology of a Managed Terrestrial Landscape. Patterns and Processes of Forested Landscapes in Ontario. UBC Press. Vancouver.

Thorp, S., R. Rivers, and V. Pebbles. 1997. Impacts of changing land use. State of the Lakes Ecosystem Conference 1996. Background Paper. Environment Canada and U.S. Environmental Protection Agency.

Thunder Bay Field Naturalists. 1998. Checklist of vascular plants of Thunder Bay District (revised). Published by the Thunder Bay Field Naturalists. 52 pp.

Timmermann, H. R., and M. E. Buss. 1997. The status and management of moose in northern American in the early 1990s. Ont. Minist. of Nat. Resour., Northwest Sci. and Technology Tech. Rep. TR-109. Thunder Bay, ON.

Tordoff, B. 1999. University of Minnesota. Personal communication.

Tordoff, H. B., J. A. Goggin and J. S. Castrale. 2003. Midwest Peregrine Falcon restoration, 2003 report. Unpublished report, Bell Museum of Natural History, St. Paul, MN. 36 pp.

Turville-Heitz, M. 1999. Lake Superior basin water quality management plan. Wisconsin Dept. of Natural Resources PUBL-WT-278-99-REV. 300 pp.

Tushingham, A.M. 1992. Postglacial uplift predictions and historical water levels of the Great Lakes. J. Great Lakes Res. 18(3):440–455.

ULRG. 1977. The waters of Lake Huron and Lake Superior Vol. 3, Parts A and B, Report to the International Joint Commission by the Upper Lakes Reference Group.

Urban, N.R., Lu, X., Chai, Y. and D. Apul. 2004. Sediment trap studies in Lake Superior: Insights into resuspension, cross-margin transport and carbon cycling. Journal of Great Lakes Research. In Press.

U.S. Coast Guard [USCG] 1999).

U.S. Congress, Office of Technology Assessment. September 1993. Harmful Non-Indigenous Species in the United States, OTA-F-565 (Washington, DC: U.S. Government Printing Office).

U.S. Department of the Interior Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census. 1993. 1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. U.S. Gov. Printing Off., Washington, DC.

U.S. Department of the Interior Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census. 1998. 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. U.S. Gov. Printing Off., Washington, DC.

USDA. 1998. Gypsy moth in North America. Forest Service Northeastern Research Station website. (http://www.fsl.wvu.edu/gmoth/)

USEPA. 1994. Inland Spill Response Mapping Project. Digital database.

USFWS. 2002. Pitcher's Thistle (Cirsium pitcheri) Recovery Plan. Fort Snelling, Minnesota. vii + 92 pp.

USFWS 2000a. Dwarf Lake Isis Factsheet. U.S. F&WS Region 3 website: http://www.fws.gov.r3pao/

USFWS 2000b. American Hart's-Tongue Fern Factsheet. U.S. F&WS Region 3 website: http://www.fws.gov.r3pao/

USFWS 2000c. American Burying Beetle Factsheet. U.S. F&WS Region 3 website: http://www.fws.gov.r3pao/

USFWS 2000d. Kirtland Warbler Factsheet. U.S. F&WS Region 3 website: http://www.fws.gov.r3pao/

USFWS. 1999a. Houghton's Goldenrod Factsheet. U.S. F&WS Region 3 website : http://www.fws.gov/r3pao/).

USFWS. 1999b. Pitcher's Thistle Factsheet. U.S. F&WS Region 3 website : http://www.fws.gov/r3pao/).

USFWS. 1998. Waterfowl Population Status, 1998. Off. Migr. Bird Manage., Washington, DC.

USFWS. 1995. Great Lakes Fishery Resources Restoration Study. Report to Congress pursuant to the Great Lakes Fish and Wildlife Restoration Act, P.L. 101-537. 198 pp.

Utych, R. 1999. Whitefish Point Bird Observatory. Personal communication.

Van Stappen, J. 1999. Apostle Islands National Lakeshore. Personal communication.

Van Wagner, C.E. 1978. Age-class distribution and the forest fire cycle. Can. J. For. Res. 8(2):220–227.

Vennum, T. 1988. Wild Rice and the Ojibway People. Minnesota Historical Society Press. St. Paul.

Vigmostad, K. E., editor. 1999. Proceedings from the 1996 U.S.-Canada Great Lakes islands workshop. Mich. State Univ., East Lansing, MI.

Vigmostad, K. 1996. U.S. – Canada Great Lakes Islands Project: Project Summary. Michigan State University.

Voss, E.G. 1985. Michigan Flora. Part 2. Cranbrook Institute of Science. Bulletin 59. Ann Arbour.

Voss, E.G. 1996. Michigan Flora. Part 3. Cranbrook Institute of Science. Bulletin 61. Ann Arbour.

Wagner, W.H. and F.S.Wagner. 1993. Ophioglossaceae. In: Flora of North America Editorial Committee. Flora of North America Vol. 3. Oxford University Press.

Waller, D. M., and W. S. Alverson. 1997. The white-tailed deer: a keystone herbivore. Wildl. Soc. Bull. 25:217–226.

Ward, N. 2003. Fisheries and Oceans Canada Personal communication.

Ward, P.C. and A.G. Tithecott. 1993. The impact of fire management on the boreal landscape of Ontario. Aviation, Flood and Fire Management Branch Publication No. 305, Ont. Min. Natur. Res. 12 p.

Waters, T.F. 1983. The Streams and Rivers of Minnesota. University of Minnesota Press. Minneapolis. 361 pp.

Waters, T.F. 1987. The Superior North Shore. University of Minnesota Press. Minneapolis. 361 pp.

Watson, H.F. 1974. Zooplankton of the St. Lawrence Great Lakes – species composition, distribution, and abundance. J. Fish. Res. Board Can. 31:783–794.

Watson, H.F. and J.B. Wilson. 1978. Crustacean zooplankton of Lake Superior. J. Great Lakes. Res. 4(3-4):481–496.

Webb, S. A., and T. N. Todd. 1995. Biology and status of the shortnose cisco (Coregonus reighardi Koelz) in the Laurentian Great Lakes. Arch. Hydrobiol. Spec. Issues Advanc. Limnol. 46: 71–77.

Webb, W.L., D.F. Behrend and B. Saisorn. 1977. Effect of logging on songbird populations in a northern hardwood forest. Wildlife Monog. No. 55.

Weeber, R. C. 1999. The Canadian lakes loon survey: temporal patterns in breeding success of Ontario common loons (1981-1997) and representation of Ontario lakes. Prog. Rep. to Wildl. Assess. Program, Ont. Minist. of Nat. Resour., North Bay, ON.

Weeks, C. T. 1997. Dynamics of lake trout (Salvelinus namaycush) size and age structure in Michigan waters of Lake Superior, 1971-1995. MS Thesis, Dept. of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan.

Weiler, R.R. 1978. Chemistry of Lake Superior. J. Great Lakes Res. 4(3-4):370–385

Wetzel, R.G. 1975. Limnology. Saunders. Philadelphia.

Weseloh, D. V., P. J. Ewins, J. Struger, P. Mineau, C. A. Bishop, S. Postupalsky, and J. R. Ludwig. 1995. Double-crested cormorants of the Great Lakes: changes in population size, breeding distribution and reproductive output between 1913 and 1991. Colonial Waterbirds 18:48–59.

Weseloh, D. V., and B. Collier. 1995. The rise of the double-crested cormorant on the Great Lakes. Fact sheet. Can. Wildl. Serv., Environ. Can.

Weseloh, D. V. C., C. Pekarik, and H. Blokpoel. 1999. Breeding populations of cormorants, gulls and terns on the Canadian Great Lakes in 1997/98. Bird Trends: a report on results of national ornithological surveys in Canada. Can. Wildl. Serv., Env. Can.

Whitcomb, R.F., C.S. Robbins, J.F. Lynch, B.L. Whitcomb, M.K. Klimkiewicz and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pp. 125 – 205 In: R.L. Burgess and D.M. Sharpe (eds). Forest Island Dynamics in Man-Dominated Landscapes. Springer-Verlag. New York.

White, B., P. Wilson, A. Johnson, S. Grewal and K. Shami. 2001. Status of the eastern wolf (Canis lycaon). Natural Resources DNA Profiling and Forensic Centre, Trent University, Peterborough, ON. Unpublished Rept., 14 pp.

White, D.J., R.V. Mahler and C.J. Keddy. 1983. Cirsium pitcheri. In: Argus, G.W., K.M. Pryer, D.J. White, and C.J. Keddy. Atlas of the rare vascular plants of Ontario. National Museum of Natural Sciences. Ottawa (looseleaf).

White, D.J., E. Haber, and C. Keddy. 1993. Invasive plants of natural habitats in Canada. Canadian Wildlife Service and Canadian Museum of Nature.121 pp.

Wickware, G.M. and C.D.A. Rubec. 1989. Ecoregions of Ontario. Ecological Land Classification Series, No. 26. Sustainable Development Branch, Environment Canada. Ottawa, Ontario. 37 pp.

Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66: 1211 – 1214.

Wilcox, D. A. 1990. Water-level fluctuations and Great Lakes wetlands. Great Lakes Wetlands 1(2):1–3.

Wilcox, D. and L. Maynard. 1996. Great Lakes coastal wetlands. SOLEC Working Paper presented at State of the Great Lakes Ecosystem Conference. EPA 905-R-95-014. Chicago, Ill.: U.S. Environmental Protection Agency.

Wilcox, D.A. and T.H. Whillans. 1999. Techniques for restoration of disturbed coastal wetlands of the Great Lakes. Wetlands 19: 835 – 841.

Wild Rice Ecology, Harvest, Management, GLIFWC, DNR, MNR, USFWS & NA Waterfowl Management Plan (no date).

Wisconsin Department of Natural Resources. 1999. State Comprehensive Outdoor Recreation Plan, 2000-2005, Draft 2.0. Madison, WI. Web page: www.dnr.wi.us/org/land/parks/scorp/2000/index.html.

Wisconsin Dept. of Natural Resources. 1999a. Endangered species factsheets. Website: Website: http://www.dnr.state.wi.us

Wisconsin Dept. of Natural Resources. 1999b. Exotic species factsheets. (http://www.dnr.state.wi.us/org/land/er/invasive/factsheets/)

Wisconsin Department of Natural Resources. 1995. Wisconsin's biodiversity as a management issue. Wisc. Dept. of Nat. Resourc., Madison, WI. 240 pp.

Wisconsin Wolf Advisory Committee 1999. Wisconsin Wolf Management Plan (Draft). Website: http://www.dnr.state.wi.us

Woods, G.T. and R.J. Day. 1977. A summary of the fire ecology study of Quetico Provincial Park. Ont. Min. Natur. Res. Report no. 8. Fire Ecology Study, Atikokan District. 39 p.

World Wildlife Fund. 1997. Terrestrial and aquatic protected areas representation analysis: Lake Superior basin. Draft report. 26 pp.

World Wildlife Fund. 1999. Terrestrial and aquatic protected areas gap analysis: Lake Superior basin. 34 pp. + maps and appendices.

Wright, H.E. B.A. Coffin and N.E. Aaseng (eds). 1992. The Patterned Peatlands of Minnesota. Univ. of Minnesota Press. Minneapolis.

Wydeven, A. 1999. WI DNR. Personal communication

Wydeven, A.P., R.N. Schultz, and J.E. Wiedenhoeft. 1999. Lynx and wolf track surveys in Wisconsin in winter 1998 – 1999. USFWS. Region 3, Endangered Species Grant Program. Section 6.

Wydeven, A.P. 1999. Status of the timber wolf in Wisconsin – performance report. July 1997 through June 1998. Wisconsin Endangered Resources Report #117. www.dnr.state.wi.us/org/land/er/publications/reports/report117/

Yeske, L.A., T. Green, F.L. Scarpace, and R.E. Terrell. 1973. Measurements of currents in Lake Superior by photogrammetry. Presented at the 16th Conf. Great Lakes Res., Internat. Assoc. Great Lakes Res., Huron, Ohio.

Zimmerman, J. W. 1968. Water quality of streams tributary to Lakes Superior and Michigan. U.S. Fish and Wildlife Service, Special Scientific Report, Fisheries No. 559. 41p.

VI. LIST OF ADDENDA

Addendum 6-A: Rare plant and animal species in the basin

Addendum 6-B: Rare community associations in the basin

Addendum 6-C: Habitat data for 65 Lake Superior tributaries in Ontario

Addendum 6-D: Important habitat areas of the Lake Superior basin.

Addendum 6-E: Selected stream monitoring data for Ontario tributaries

Addendum 6-F: Presence of fish species observed during 1953-1996

Addendum 6-G: Fish species names

Addendum 6-H: Lake Superior habitat map

Addendum 7-A: Ecosystem conservation example – Woodland Caribou

Addendum 7-B: Ecosystem conservation example – White-Tailed Deer

Addendum 7-C: Scientific names of non-fish species included in text

Addendum 8-A: Habitat requirements for lake trout, whitefish, lake herring, and walleye

Addendum 10-A: Documented exotic species aquatic species in Lake Superior

The addenda can be found in the LaMP 2000, Chapter 6, which is available at http://www.epa.gov/glnpo/lakesuperior/lamp2000/chap6.html.

Chapter 7

Developing Sustainability in the Lake Superior Basin: 2006 Progress Report

Ashland, Wisconsin, contaminated sediment sign.
Photo Credit: John Marsden, Environment Canada.

Lake Superior Lakewide Management Plan
2006

Chapter 7 Contents

Chapter 7
Developing Sustainability in the Lake Superior Basin: 2006 Progress Report

7.0 ABOUT THIS CHAPTER

Accomplishments. Since we last updated Chapter 9 of the LaMP in 2004, the Developing Sustainability Committee (DSC) has focused on a variety of projects aimed at meeting the sustainability objectives of the Lake Superior Binational Program. In addition to providing assistance and information to various environmental and civic organizations in the watershed, members of the committee also worked with the Forum to integrate sustainability education into the Lake Superior Leadership program and provided guidance to workgroups dealing with the Presidential Executive Order on the Great Lakes (i.e., the Great Lakes Regional Collaboration). As detailed below, the committee also coordinated the completion of two major projects forecast in the previous LaMP for Lake Superior (i.e., the first phase of our community-based survey of and education regarding sustainability and a riparian conservation easement demonstration project).

Challenges. Since the inception of the Lake Superior Binational Program, one of our greatest challenges has been to promote awareness of the need for sustainability throughout the basin. Given the rise in local and regional efforts to advance the cause of sustainability in recent years, we believe citizens in the watershed have slowly begun to consider more than immediate social and economic interests when planning for the future. Although much work still needs to be done, we can celebrate the progress that is occurring.

Next Steps. Limited resources hinder the DSC's ability to pursue a number of additional projects. For example, we are now at the point to collect and analyze a second set of data relevant to our "Baseline Sustainability Indicators" project, thus allowing more of a longitudinal measure of changes in the economic and social conditions that move basin residents toward or away from sustainable lifestyles. The "Baseline Sustainability Indicators" project was completed in 2000 to determine the status of basinwide sustainability. This project examined a wide range of existing databases to also determine the extent to which sustainability trends could be observed without creating new indexes or gathering additional information.

We would like to enter the second phase of our "Community Awareness Review and Development" initiative (see below). And the committee still plans to investigate and facilitate sustainability education in the region by working with K-12 educators as well as hosting a First Nations conference on indigenous systems of knowledge that would serve to inform community leaders throughout the basin.

7.1 SELECTED ACTIVITIES

A sample of the kinds of activities recently pursued by the DSC, as well as independent community-based initiatives that complement our efforts regarding regional sustainability, is provided on the following pages.

7.1.1 Community Awareness Review and Development Project

In 2005, Phase I of the Community Awareness Review and Development (CARD) project sponsored by the DSC was completed. The overall intent of the CARD is to increase knowledge and awareness of issues relevant to the Lake Superior Binational Program and the LaMP in order to foster improved decision-making within the basin. Our objective in Phase I was to better understand the attitudes and awareness of residents regarding sustainability and environmental issues that mattered in local communities so as to specifically tailor outreach campaigns germane to the goals of the Binational Program.

All committees of the Binational Program cooperated in developing the Phase I CARD survey, and surveys previously used in the basin were examined to determine the extent to which the areas of interest had already been assessed. Analysis of more than a dozen other instruments (drawn from interest-group, agency-based, and academic research conducted over 15 years) revealed little if any direct overlap with the CARD focus. To that end, we hoped to produce a survey that could meet a number of objectives: providing a demographic profile for the sample, allowing respondents free-choice in qualitatively describing their most important concerns of local and regional interest, isolating quantitative reactions to various LaMP related issues, and assessing differences between knowledge of and concerns over a range of environmental concerns. After several versions of the survey were considered, pilot testing of the final instrument in Ontario and the U.S. confirmed that respondents could complete the survey in 10 to 15 minutes. Subsequently, in the U.S., we surveyed intact community organizations such as service/community, business/economic development, tourism/recreation, environmental, local government, education, youth, and church groups from nine basin communities (i.e., Iron Range, Duluth, Two Harbors, Grand Marais, Newberry, Marquette, Houghton, Ironwood, Ashland and Superior). We distributed 955 surveys with a 29 percent response rate. In Canada, a mass-mailing was sent to more than 3,000 residents in four communities (i.e., Thunder Bay, Wawa, Marathon and Sault Ste. Marie), resulting in a 25 percent response rate, and a similar project is currently being conducted for the First Nations in the basin.

Once all data had been collected, U.S. and Canadian contractors coded the qualitative responses using an inductive coding scheme which, along with the original quantitative responses, were input into a spreadsheet for statistical analysis. Additional procedures were then used to determine the extent to which dominant themes clustered together or were related to one another in systematic ways. Thus, the coding process resulted in our being able to generate a more useful understanding of how respondents differ from one another as well as what they consider to be the most salient aspects of their lives in their respective communities. In the end, various analyses were conducted to reveal patterns of awareness and concern.

When asked to identify the most pressing issues facing their particular community, respondents in the basin identified a wide range of general and specific issues associated with economic, environmental, and social conditions. Most of those surveyed cited economic concerns (e.g., employment) as most pressing, even though (especially in Canada) environmental concerns were quite often listed as well. When our respondents identified environmental issues, several types of concerns were elicited (i.e., natural resources, overall pollution, contaminated sites, mercury pollution, toxins in food, pesticides/herbicides, noise pollution, light pollution, invasive species, exotic species, agriculture, forestry, mining/drilling, planning and development, shoreline development, open space loss, habitat loss or fragmentation, wetlands, erosion/watershed management, septic/sewer systems, storm water, water quality, drinking water, water quantity, water privatization, air quality, global warming, energy conservation, pest problems, fish and wildlife, recycling, and hazardous waste). Of these, the largest percentage of responses in the U.S. indicated that people were mostly concerned with watershed-related concerns (and, to a lesser extent, land-use practices) at a personal, community, state, and Lake Superior basinwide level. In Canada, air and energy issues were top concerns when the focus was on the province as a whole, water issues when the focus was on the Lake Superior basin, and water and garbage issues when the focus was on the community and the household.

The CARD survey also focused on a number of specific areas of particular interest to different work group committees. Roughly half of the respondents indicated that their water (most often associated with a municipal system) had been tested in the last four years. Most reported that they generally conserve oil, gas, or electrical energy, though less than half reported a discerned effort to conserve water. Most respondents were using municipal waste disposal systems, yet 5 percent (Canada) to 19 percent (U.S.) continue the practice of open burning of garbage (and significant numbers of those sampled perceive that the practice is quite common in their communities). Although most were aware of the need and opportunity to safely dispose of hazardous waste in their communities, at most only 25 percent reported "always" using the program if it is available. Less than half of either the Canadian or U.S. samples were aware of local watershed management programs, and 72 percent reported an awareness of local land trusts and conservancies in the U.S. (50 percent in Canada). While many U.S. respondents knew of local fish consumption advisories, two-thirds of those in Canada were unaware (41 percent) or unsure (24 percent). Nonetheless, of those who knew of fish consumption advisories in Canada, 32 percent indicated they ate less fish because of the information; in the U.S., even fewer reported substantial changes in their consumption patterns. Finally, most respondents cited "inconvenience" or a perceived lack of self-efficacy when describing why some citizens persist in conducting themselves in an environmentally unsustainable manner.

Respondents were asked to rate both their level of knowledge and level of personal concern regarding issues in four general areas – water pollution, air pollution, land use, and health issues. In general, they indicated modest levels of knowledge and higher scores for personal concern across the range of issues associated those areas. No more than one third reported that they knew a great deal about, or were similarly concerned over, any given issue. Furthermore, correlations between knowledge and concern were, by and large, modest at best.

The findings of the Phase I CARD survey suggest four general conclusions that may be of use to the Lake Superior Binational Program. First, our respondents were significantly more concerned about economic issues than they were about the environment. Second, when they were asked to specifically focus on environmental issues linked to the basin or their communities, those sampled cited issues associated with water and land-use more than any others. Third, there remains only a modest association between personal concerns over environmental issues and changes in lifestyles or behavior. Finally, the modest correlations between beliefs and values may be used to design effective advocacy and educational campaigns at the local level.

In light of this study, we can assume that future community-based social marketing approaches to educate and persuade citizens in the Lake Superior basin may be modestly successful. At that time, we will want to (a) focus on the areas of water, land use, and economics; (b) tailor campaigns to particular community interests; (c) demonstrate how threats may be averted and economic opportunities capitalized upon in a way that is convenient, efficacious, and economical; and (d) primarily rely upon electronic and newspaper venues for delivering information (since our respondents clearly preferred such means of communication over workshops or other avenues).

In light of the Phase I CARD study, we can assume that specific community-based social marketing approaches to inform citizens in the Lake Superior basin may be modestly successful, given available resources. Such specific marketing approaches might also be warranted at this time for at least two related reasons:

1. Data from our project reveals that those in the Lake Superior basin have not generally recognized the importance of LaMP related issues, let alone the existence of the Binational Program per se. Even in those communities where local initiatives have focused on increasing citizens' awareness of issues such as water quality, habitat protection, or sustainable lifestyles (e.g., Thunder Bay, Marquette), many seem to believe that most threats to ecosystem integrity have been mitigated, are irrelevant to their daily lives, or are not being addressed by broad scale initiatives such as the zero discharge demonstration focus of the LaMP. In short, we not only need to increase the awareness or "branding" of the Lake Superior Binational Program and LaMP, but more importantly, we need to significantly increase local knowledge regarding pivotal issues and options that pertain to those initiatives.

2. In addition to the sundry other programs currently promoted by natural resource and environmental protection agencies at the federal, provincial, and state level (e.g., Forest Service's L.U.C.I.D. initiative, US EPA's Energy Star program, various NRCS activities), the Lake Superior Binational Program directly or indirectly deals with at least four major concerns: (a) its own load reduction schedules for persistent bioaccumulative substances, (b) a broader program of ecosystem remediation and management in the region, (c) a substantial role in Great Lakes-wide initiatives such as the Binational Toxics Strategy and SOLEC, and (d) an emerging focus on watershed-based analysis and delivery of environmental programming. To greater or lesser degrees, the success of our efforts to address each of these areas of concern depends on having those in the Lake Superior watershed understand the extent to which they complement one another, as well as how much local conditions and opportunities can be better dealt with by working in concert with the separate programs.

As a specific case in point, consider the pattern of responses represented by the Two Harbors (MN) respondents. Unlike other communities in Minnesota that cited watershed management issues as the most important issue facing their respective localities, Two Harbors identified land use practices most often, with air quality coming in second (though 71 percent believed that water quality and the like was the most pressing issue to the basin as a whole). Of this sample, 17 percent indicated that they burned at least some of their garbage (and estimated that 8 percent of their entire community did as well). Consequently, the Two Harbors area could be targeted for increased burn barrel outreach and projects (e.g., a barrel-for-a-barrel swap), especially when you consider their concern about air pollution. However, any outreach campaign dealing with the open burning of garbage issue (or any other as well) would necessarily have to stress the convenience of any personal pollution control or land-use option; 100 percent of the respondents in Two Harbors reported “being too busy” as the primary reason for citizens continuing environmentally destructive behavior.

For an alternative illustration, consider the example of Ironwood (MI). Ironwood is a relatively compact community that has experienced a good deal of economic downturn in recent decades. As a consequence, 67 percent of those surveyed in CARD Phase I cited economic issues as their primary concern (as opposed to, say, Marquette (MI) where only 27 percent focused on the economy), and no respondent identified the environment as most pressing (cf. 29 percent for Marquette). Thus, a tailored media campaign and set of discussions with community planners in Ironwood would significantly focus upon economic development vis a vis promoting LaMP issues. Furthermore, insofar as fully half of those surveyed focused on water-related issues when specifically asked about the natural environment, watershed management issues would likely be grounded in the outreach activities, especially since 50 percent of the sample reported being unaware of current watershed management plans. It’s not that other issues would be ignored; rather, those areas might be highlighted along with other more watershed-relevant issues such as the existence of local land trusts and forest fragmentation, in terms of their economic relationship to broad-based water quality concerns.

7.1.2 Lake Superior Land Trust Partnership

Since 2002, land trusts and conservancies working in the Lake Superior basin have been partnering to discuss common concerns and needs, develop regional strategies, and promote a wide range of issues relevant to the LaMP. The Lake Superior Land Trust Partnership (LSLTP) has been coordinated and supported through the efforts of the Land Trust Alliance, and the Lake Superior Binational Program has taken an active role in providing information and drawing links between the work of the partnership and the broader ecosystem goals of the program. In particular, the watershed approach and critical habitat mapping projects reviewed in the integrated ecosystem chapter of the LaMP, as well as the tripartite focus on social and economic factors along with environmental integrity that buttresses the work of the Developing Sustainability Committee, have assisted the LSLTP through ongoing and active participation by work group members in partnership meetings.

The goal of the LSLTP—and what makes this partnership unique—is to focus on the advancement of private land conservation through private nonprofit organizations that collectively span the three states and province included within the Lake Superior basin. Figure 7-1 illustrates the LSLTP service areas. The organization also clearly recognizes the importance of engaging public agencies at the federal, state, provincial and local levels since such partnerships are one key strategy for protecting resources within the basin.

At present, the LSLTP includes each of the land trusts and conservancies located within the Lake Superior basin. These partners represent groups with a wide variety of organizational capacity and scope of service, plus national organizations that are active within the watershed. With support from the Charles Stewart Mott Foundation, the LSLTP has convened three 2-day meetings for each of the past three years. At these meetings the participants share ideas, as well as conduct joint problem solving and training sessions on topics of common interest (e.g., understanding the opportunities and challenges to cross-border projects, conservation easement monitoring, and working forest conservation easements).

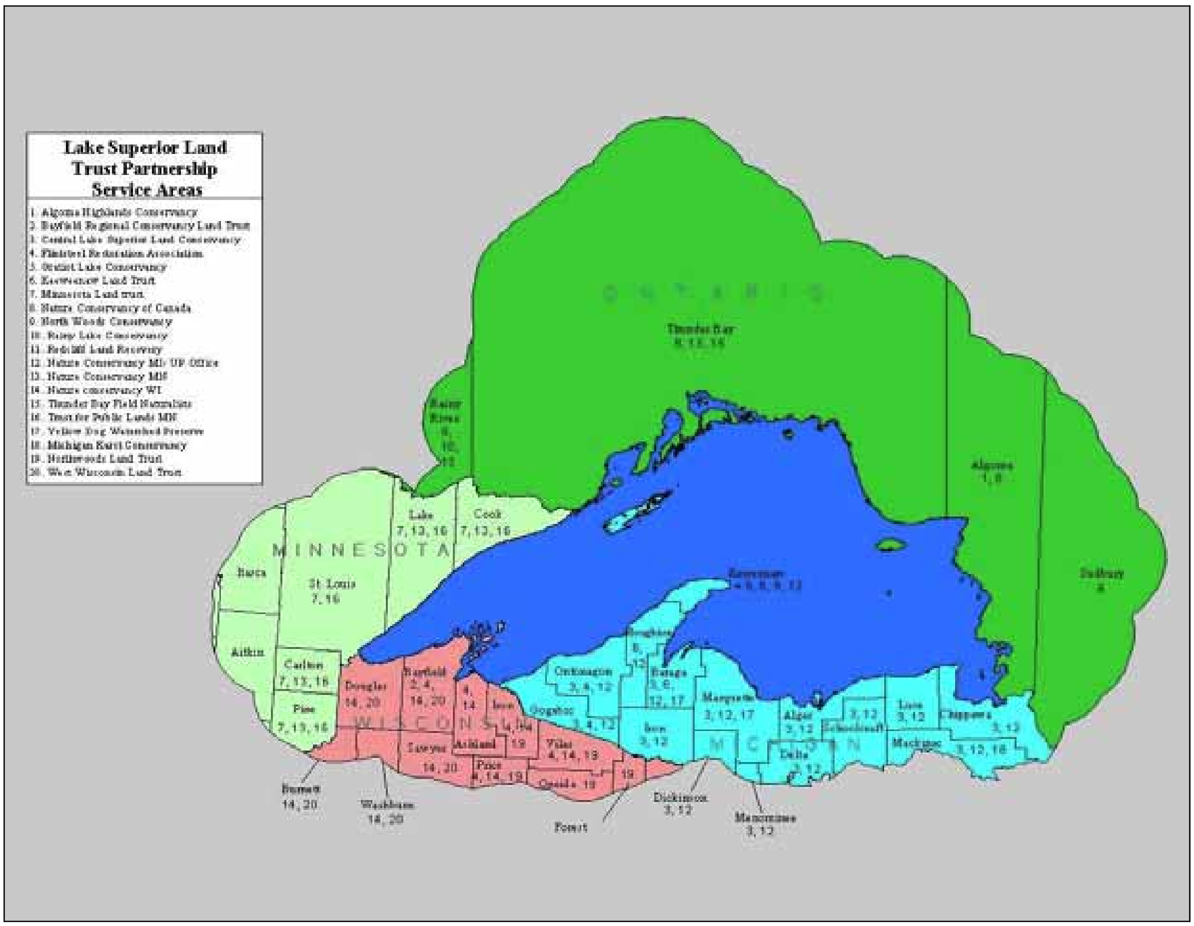


Figure 7-1. Lake Superior Land Trust Partnership Service Areas.

In addition to private foundation support, the LSLTP is assisted by a variety of other organizations. For example:

- The Land Trust Alliance has awarded nine Lake Superior Strategic Conservation Grants to various partner organizations. This initiative is intended to help land trusts implement common standards and practices, assist with the implementation of the Lake Superior Land Trust Partnership goals, and protect freshwater ecosystems of significance to the Lake Superior basin (especially those identified in the LaMP as comprising critical habitats).

- The Great Lakes Advancement Grants Program helped expand the capacity of two partners, the Keweenaw Land Trust (MI) and the Bayfield Regional Conservancy (WI). Great Lakes Advancement Grants are intended to assist land trusts in building their organizational capacity and expertise with the goal of becoming healthier, more vital organizations capable of protecting significant freshwater ecosystems in perpetuity.

- The Nature Conservancy has funded a series of site conservation planning exercises around the basin so as to help develop effective strategies for conserving functional, working landscapes. The sites addressed by this initiative included the watershed area and estuary of the Pigeon River on the border of Minnesota and Ontario, the Rainy Lake complex situated at the western edge of the basin, the Presque Isle/Ontonagon River watershed extending from north central Wisconsin across the western Upper Peninsula of Michigan, and the Upper Peninsula's Michigamme Highlands that contain the most rugged and remote wilderness areas in the state. This highly participatory process provided local project teams a rich opportunity to give and receive critical inquiry from a variety of conservation professionals, share ideas regarding the role land trusts and conservancies play in promoting regional sustainability, and develop specific strategies for conserving resources critical to selected priority conservation areas in the watershed.

Aside from the cooperative projects sponsored by the LSLTP, the partnering conservancies and land trusts that constitute the organization also draw upon its collective expertise and the resources of the Lake Superior Binational Program to pursue their own, individual initiatives. A prime example of how such local projects contribute to the LaMP and regional sustainability can be seen in the Central Lake Superior Land Conservancy's (CLSLC) recently completed "Riparian Remediation Buffer" project funded by US EPA through its Great Lakes National Program Office (GLNPO).

Historically, the central portion of Michigan's Upper Peninsula was well known for the quality of its lakes and streams. In the past century, however, increasing urbanization has resulted in greater concentrations of non-point pollution, the loss of native riparian habitat, and more sedimentation. It is well understood that a healthy and thriving riparian environment requires an abundance of vegetation—preferably species adapted to its particular eco-region—and the use of planned buffer strips between developments and waterways has proven valuable in filtering contaminants, preventing sedimentation, and improving both aquatic and terrestrial habitat conditions. Nonetheless, property owners typically remain unaware of or ambivalent toward the protection of lakeside or streamside habitat. People also find it difficult to envision how riparian habitat repatriation works, the extent to which it can improve upon aesthetics, and the cost savings that can accrue from its institutionalization on the land. And, given the cynicism that often follows history, there also exists a widespread suspicion that what we do today in the name of conservation can easily by undone by future landowners who bring with them a different set of values. To address this situation, the CLSLC applied for and received a GLNPO grant to demonstrate the value and sustainability of using native plants and binding conservation easement agreements (CEAs) to remediate five riparian sites in the Lake Superior basin.

The first stage of the remediation demonstration project involved identifying a range of private landholdings containing riparian habitats that have experienced either substantial human modification of streamside or lakeside vegetation (e.g., management of non-native turf grass all the way to the water's edge) or significant erosion caused by human activity (e.g., access to private boat landings or leisure sites). In the end, the Conservancy identified five geographically distributed parcels divided between various types of riparian landscapes and ownership land-use patterns (i.e., a large lot on a relatively developed lake with an existing home, a residential lot on an urban stream, and a recreational or vacation home on a major river, a residence on a stream in an area currently experiencing pressures for further development, and conference center on a popular lake surrounded by both seasonal and year-round residences). The owners of each of the five demonstration parcels consented to placing a CEA on a portion of their property, including specific provisions for the permanence of restored riparian habitat.

Once landowners had agreed to preserve in perpetuity the riparian areas they possessed, an in-depth assessment of what was required for the remediation of each demonstration site was conducted. Native plant specialists associated with the Marquette County Conservation District and technicians from the Natural Resource Conservation Service were used to identify cost effective options commensurate with the goals of the project and provisions in the newly contracted CEAs. In turn, appropriate flora was ordered from sources at the Conservation District or identified for gathering at local native plant locations. Contracted workers and/or volunteers (e.g., college student interns, Student Conservation Association members) were used to rehabilitate the riparian areas at each demonstration site, and construction materials (e.g., timbers, rock riprap) were purchased from or donated by local organizations.

As each demonstration site was rehabilitated, local media were used to promote the goals of the project and report on the successes of the initiative. Through collaborative efforts with the other partners on this project (e.g., The Nature Conservancy—Upper Peninsula Office, Central Lake Superior Watershed Partnership, Marquette County Conservation District, USDA—Forest Service, and JZ Environmental Consultants), the Riparian Remediation Buffer Project was discussed in a workshop designed to assist landowners, foresters, and other natural resource professionals on the elements of conservation easements. Additionally, other landholders in the basin were sent information on the project along with an offer of assistance if they wish to voluntarily rehabilitate the habitat on their property or place a CEA on their own holdings. Long-term monitoring of project outcomes (e.g., continued regeneration of native plant growth, permanent reductions in human impacts) will occur through periodic inspections by the CLSLC to ensure CEA compliance.

The Riparian Remediation Buffer Project is typical of the types of activities undertaken by conservancies and land trusts in the Lake Superior basin. By coordinating efforts and learning from one another's experiences through meetings of the LSLTP, such organizations can better meet the key objective of developing sustainable lifestyles in the watershed and help the Lake Superior Binational Program achieve its overall goals.

7.1.3 The Great Lakes Cities Initiative

The Great Lakes Cities Initiative was established in 2003 by Richard M. Daley, Mayor of Chicago, to provide a forum for cities to be involved in Great Lakes decision-making with federal, state, and provincial governments. Mayor Daley and Toronto Mayor David Miller currently co-chair the group's 15-member steering committee. Through this initiative, cities in the Lake Superior basin participate actively with international organizations, the federal governments of Canada and the United States, state and provincial governments, Great Lakes organizations, and environmental groups on environmental projects. For example, in Canada, mayors in a number of cities have charted a course for the care of the world's largest freshwater system. This work focuses on issues with environmental and economic implications for municipalities, including: water quality, waste water and storm water treatment, beach closures, algal blooms, water diversion, invasive species, shoreline restoration, water levels, and waterfront redevelopment.

Throughout the Great Lakes region, local governments have assumed a leadership role to work in partnership with federal, provincial, and state agencies to restore and protect the watershed. They are committed to educating the public, the business community, and others on the challenges and opportunities of maintaining a sustainable society. To do so, elected officials encourage other local, regional, and national governments, conservation authorities, and First Nations groups, as well as business, agricultural, and environmental organizations, to build on existing regional and binational networks. The aim is to share best practices and policies for preservation and remediation of the Great Lakes and the St. Lawrence River ecosystem.

7.1.4 EarthWise Thunder Bay

EarthWise Thunder Bay is a community-based group that was formed in May 2004 when the concept of developing a "Community Environmental Action Plan" was proposed to the City Council of the City of Thunder Bay. The action plan was proposed by a delegation from the Zero Waste Action Team (ZWAT). ZWAT is a local group with membership from the commercial, industrial, and institutional sector that have come together to promote programs to reduce waste going into the municipal landfill site. City Council unanimously endorsed the proposal, and an EarthWise Steering Committee was established with representatives from City Council, industry, the business community, the University and College, and established environmental groups.

With funding from the City, a coordinator was hired for an initial two-year period. A funding proposal was developed and submitted to the Federation of Canadian Municipalities (FCM). FCM applications for funding are based on the potential for greenhouse gas reductions that will result from the proposal. Recently, EarthWise was informed that they have been successful in this application, and they are awaiting the written notification. This grant will be used to develop a community energy map identifying where energy is used in the community and the type of energy (electricity, natural gas, fuel, etc.) that supplies those needs. This study will be used as a baseline to measure success (reductions in energy used) going forward.

EarthWise has developed an "Environmental Policy" for the City of Thunder Bay that was adopted by City Council in December 2005. This policy requires municipal departments to report annually on how each department has complied with the policy each year.

EarthWise does not want to replace existing groups in the community that are already doing a good job of promoting sustainable projects, such as Trees Thunder Bay, which promotes tree planting on municipal and private property, and Thunder Bay Trails Association, which promotes walking and bicycling trail development throughout the City, and so on. EarthWise exists to assist those groups in achieving their goals. This may be done by accessing funding that is otherwise not available to them (e.g., funding that requires a private/municipal partnership), or by bringing groups with similar interests together to develop coordinated plans that will better advance everyone's interests.

The goals of the EarthWise Thunder Bay Environmental Action Plan are as follows:

- Produce a Community Environmental Action Plan that identifies specific actions for solving problems, measuring the results, and promoting the vision of the community.
- Consider a 20 percent reduction of Green House Gases (GHG) for the City (organization) and 6 percent reduction of GHG for the community (residential, institutional, commercial, and industrial) from 1994 baseline levels, by the year 2013 as an interim measure, subject to a review of a finalized emissions inventory and the development of Community Environmental Action Plan, to ensure that the target is realistic for the both City and the community.
- Improve community health and quality of life and ensure long-term sustainability by implementing cost-effective action strategies.
- Promote public awareness of and responsibility for environmental issues and to increase public support for action strategies and investments.
- Strengthen the capacity to manage and implement programs, and the ability to obtain financing from provincial and national institutions and sponsors.
- Promote partnerships between The City of Thunder Bay, citizens, First Nations, businesses, industry, non-profit agencies, educational institutions, rural communities and Northern Ontario towns and cities.
- Work together in solving community and regional problems.
- Identify, assess and set environmental priorities for action based on community values and scientific data.

Working groups have been formed with representatives from existing groups with similar interests to develop suggestions that they collectively believe will be critical to ensure the sustainability of the community. To date, the following subcommittees have been established:

- "Greening Committee" – tree planting, trails development, green spaces, residential development, and reducing liter, anti-idling etc.;
- "Energy Committee" – promoting green energy development, reducing energy used in residential, commercial, and industrial settings, and developing an energy footprint for the City of Thunder Bay;
- "Green Building Committee" – promoting more energy efficient buildings in residential, municipal, and commercial settings, and retrofitting existing buildings;
- "Food Security Committee" – promoting community gardens, increasing food availability, organic gardens, and the market for locally grown produce.

When each of these committees has developed a list of critical projects, the EarthWise Steering Committee will compile a master list and organize an open community meeting. Citizens will hear a short description by a champion for each project and then have an opportunity to ask questions regarding the project before voting on the top five projects they feel will do the most for the community to ensure sustainability.

The EarthWise Steering Committee will then work with the Thunder Bay City Council and appropriate existing community groups to find ways to get those projects completed. This process will be repeated as new priorities arise.

7.1.5 Sustainable Chequamegon

In 2005, a grass roots effort called the Sustainable Chequamegon Initiative commenced along the southern shores of Lake Superior. The Initiative is based on principles outlined in the Swedish Natural Step framework, which has been used by over 60 communities in Sweden to guide them toward sustainable planning and development. The first step for the Sustainable Chequamegon Initiative was an eco-municipality workshop sponsored by the Alliance for Sustainability, a local non-profit organization. Sarah James, member of the American Planning Association, and Torbjörn Lahti, project director of Sustainable Robertsfors, both co-authors of *The Natural Step for Communities* (2004), presented ideas and proven methods for applying the Natural Step framework to community planning. This workshop addressed four sustainability guidelines in the Natural Step framework. The guidelines are to: 1) reduce dependence upon fossil fuels, underground metals, and minerals: 2) reduce dependence on synthetic chemicals; 3) reduce encroachment upon nature (land, water, wildlife, etc.); and 4) meet human needs fairly and efficiently (basic needs first). The 65 workshop participants developed a list of recommended actions to meet these guidelines. The recommended actions were placed in one of the following categories: Tourism, Food/Agriculture, Education, Housing, Transportation, Waste, Business/Economic Development, and Energy.

In Summer 2005, the City Councils of Ashland and Washburn, Wisconsin, located on Chequamegon Bay, Lake Superior, passed eco-municipality resolutions that "endorse the principles of sustainable community development" described in the Natural Step framework. These resolutions commit city employees and elected officials to implement practices of sustainable community development whenever possible in their "planning, policy making, and municipal practices". These communities are among the first in the nation to adopt the Natural Step framework as part of their community planning.

Interest in and support for the Sustainable Chequamegon Initiative continues to grow. The Alliance for Sustainability organized Study Circles in Bayfield, LaPointe, Ashland, and Washburn during Fall 2005. About 70 citizens participated in the Study Circles, which met weekly over an 8-week period to review and discuss the book, *The Natural Step for Communities: How Cities and Towns Can Change to Sustainable Practices*. Ideas and projects identified by these groups were presented at a January 2006 community celebration of the first year of the initiative. Further efforts are underway in 2006 to continue community involvement and development of sustainability in the Chequamegon Bay region. This and other related information is available on the web pages of the Alliance for Sustainability at www.allianceforsustainability.org/.

Chapter 8

Collaborative Efforts

Photo of Shovel Point, Minnesota.
Photo Credit: Carri Lohse-Hanson, MPCA.

Lake Superior Lakewide Management Plan
2006

Chapter 8 Contents

Chapter 8
Collaborative Efforts

8.0 INTRODUCTION

Section 1.3 in Chapter 1 describes the relationship of the LaMP to other initiatives and efforts, in particular the Areas of Concern (AOC)/Remedial Action Plan (RAP) program (and its funding) and the Great Lakes Binational Toxics Strategy.

In this chapter, a number of other important Great Lakes programs are described that either have ongoing collaborative efforts, or anticipate collaborative efforts in the near future.

8.1 THE GREAT LAKES CHARTER

The Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement

On December 13, 2005, the Ontario, Quebec, Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin governments signed an historic agreement to strengthen protection of the Great Lakes.

The Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement:

- Bans diversions, with rare, strictly regulated exceptions such as for communities that straddle the Great Lakes-St. Lawrence River Basin boundary and the boundaries between Great Lake watersheds;
- Strengthens water conservation through programs in each state and province;
- Establishes a stronger new environmental standard for regulating water uses across all Great Lakes-St. Lawrence River Basin states and provinces;
- Builds the information and science needed to support sound decision-making;
- Formally recognizes the authority of the federal governments and the International Joint Commission under the Boundary Waters Treaty, which remains unchanged;
- Builds regional collaboration, for example in the review of water management and conservation programs;
- Is founded on the principles of ecosystem protection, a precautionary approach, recognition of cumulative impacts, and climate change uncertainties.

8.2 CONNECTING THE COASTS

Connecting-the-Coasts (CTC) Web-based Curriculum

Recognizing youth as the future leaders within their communities, the Lake Superior Binational Program (LSBP) has identified high school students within the Lake Superior Basin as a primary target audience group to receive educational outreach on LSBP issues. The goal is to bring this message to every high school student within the Basin and empower them to take action to help resolve these issues.

Using an EPA grant, the University of Wisconsin-Extension will create a web-based interactive curriculum that expands LSBP research based knowledge on identified critical issues into opportunities for student initiated and applied personal and community change. The CTC uses a "service learning" educational model delivered through an interactive curriculum that can be effectively outreached around Lake Superior's coast, supported by educator training and strategic partnerships to encourage the use of this model.

The issues to be addressed as curriculum elements focus on those identified in the LaMP, including: 1) building a sustainable Lake Superior environment; 2) reducing critical Lake Superior pollutants; 3) restoring critical habitats and native species, both aquatic and terrestrial, and controlling invasives; and 4) understanding the relationship of the Lake Superior ecosystem and human health.

The website information is currently complete and ready for upload to the Northland College website, where it will be ready for testing, critique, and many modifications to improve its connectivity. The Northland College IT staff is working to get the website uploaded. The CTC site information will be taken to area high schools, and it will be an important component in the Pathfinders curriculum (See Chapter 2, Section 2.2.3 for a description of the Pathfinders Program).

8.3 COASTAL AMERICA

The Corporate Wetlands Restoration Partnership (CWRP) is an innovative private-public initiative that brings together businesses, government agencies, conservation organizations, community groups, and academia to protect, enhance, and restore critically-important wetlands, coasts, and waterways in the U.S. Corporations can voluntarily help restore critical habitats across the U.S. by contributing money and in-kind services, such as engineering, legal, and environmental support. The Lake Superior LaMP is encouraging corporations and businesses in the Lake Superior Basin to participate in this innovative initiative. Additional information may be found at www.cwrp.org, or cwrp@coastalamericafoundation.org.

8.4 GREAT LAKES REGIONAL COLLABORATION

In May 2004, President Bush signed Executive Order 13340 to create a cabinet-level interagency task force and to call for a "regional collaboration of national significance." After extensive discussions, the federal Great Lakes Interagency Task Force, the Council of Great Lakes Governors, the Great Lakes Cities Initiative, Great Lakes tribes, and the Great Lakes Congressional Task Force moved to convene a group now known as the Great Lakes Regional Collaboration (GLRC).

The Collaboration brought together the US EPA-led federal agency task force, the Great Lakes states, local communities, tribes, non-governmental organizations, and other interests in the Great Lakes region. The initial "Conveners" meeting was held on December 3, 2004. Following the Conveners meeting, the issue area strategy teams began their work. These eight teams were organized using priorities identified by the Council of Great Lakes Governors. The priorities are: Aquatic invasive species, Habitat conservation and species management, Near-shore waters and coastal areas, Areas of Concern, Non-point sources, Toxic pollutants, Sound information base and representative indicators, and Sustainability.

The teams were made up of subject-matter experts from many diverse backgrounds. Lake Superior Work Group members participated on nearly all of the issue teams. There were more than 1,500 people from all levels of government, and non-governmental organizations, working on the specific issues identified as crucial to the health of the Great Lakes ecosystem. Resulting from this effort was the Great Lakes Strategy, which was released by the Collaboration through a Declaration on December 12, 2005.

Strategy Team recommendations focus on those high-priority actions that can be taken over the next five years and that will achieve the greatest results. The Great Lakes Strategy recommendations include:

Aquatic invasive species (AIS)

1. prevention of AIS introductions by ships through ballast water and other means;
2. stopping invasions of species through canals and waterways;
3. restricting trade in live organisms;
4. passage of comprehensive federal AIS legislation;
5. establishing a program for rapid response and management; and
6. education and outreach on AIS introduction and prevention.

Habitat conservation and species management

1. native fish communities in open waters and near shore habitats;
2. wetlands;
3. riparian (streams) habitats in tributaries to the Great Lakes; and
4. Coastal shore and upland habitats.

The near shore waters and the coastal areas

1. major improvements in wet weather discharge controls from combined and sanitary sewers;
2. identify and control releases from indirect sources of contamination;
3. implement a "risk-based approach" to manage recreational water;
4. protect sources of drinking water; and
5. improve the drinking water infrastructure and support source water protection.

Figure 1. Lake Superior winter shoreline.
Photo Credit: Chris Zadak, MPCA.

Areas of Concern (AOC)

1. amend the U.S. *Great Lakes Legacy Act* to increase funding and streamline the process;
2. improve federal, state, and local capacity to manage the AOC cleanups;
3. create a federal-state AOC coordinating committee to work with local and tribal interests to speed cleanups; and
4. Promote clean treatment and disposal technologies as well as better beneficial use and disposal options.

Non point sources

1. wetland restoration;
2. restoration of buffer strips;
3. improvement of cropland soil management;
4. implementation of comprehensive nutrient and manure management plans for livestock
5. operations; and
6. improvements to the hydrology in watersheds.

Toxic pollutants

1. reduce and virtually eliminate the discharge of mercury, PCBs, dioxins, pesticides, and other toxic substances to the Great Lakes;
2. prevent new toxic substances from entering the Great Lakes;
3. institute a comprehensive research, surveillance, and forecasting capability;
4. create consistent, accessible basinwide messages on fish consumption and toxic reduction methods and choices; and
5. support efforts to reduce continental and global sources of toxics to the Great Lakes.

A sound information base and representative indicators

1. better coordinate the collection of critical information regarding the Great Lakes ecosystem and support the U.S. Integrated Earth Observation System (IEOS) and the Integrated Ocean Observing System (IOOS) as key components of the Global Earth Observation System of Systems (GEOSS);
2. promote the continued development of science-based indicators, including those developed through the SOLEC process;
3. double funding for Great Lakes research over the next five years;
4. establish a regional information management infrastructure; and
5. create a Great Lakes communications workgroup to manage scientific and technical information.

Sustainability

1. adapt and maintain programs that promote sustainability across all sectors;
2. align governance to enhance sustainable planning and management of resources;
3. build outreach that brands the Great Lakes as an exceptional and competitive place to live, work, invest, and play; and
4. provide leadership for sustainable development through implementation of the Strategy recommendations.

The Lake Superior LaMP will consider the recommendations of the Great Lakes Regional Collaboration and will incorporate, as much as possible, the highest priority actions in LaMP workplans.

8.5 THE U.S. – CANADA GREAT LAKES BINATIONAL TOXICS STRATEGY

Signed between the U.S. and Canada in 1997, the Great Lakes Binational Toxics Strategy (GLBTS) helps provide an overall coordinating effort across the lakes to reduce and virtually eliminate persistent toxic substances in the Great Lakes Basin. The GLBTS provides a framework for actions to reduce or eliminate persistent toxic substances (PTS) and establishes reduction challenges in the time frame 1997 to 2006 for twelve Level 1 (highest priority) persistent toxic substances, including mercury and PCBs.

This effort is critical to the toxic reduction efforts of the Lake Superior LaMP for several reasons. First, the GLBTS can work in the national and international arenas to address out-of-basin air deposition sources of toxic substances, an increasingly important source of inputs to the Lake. Second, it can help coordinate ongoing toxic reduction efforts across the basin, disseminating critical information on these successful projects. Also, because the GLBTS effort is closely coordinated with the U.S. national Persistent, Bioaccumulative and Toxic Chemical Initiative at US EPA headquarters, the GLBTS can disseminate the most current national and international scientific information on the Lake Superior critical pollutants. Finally, the ambitious reduction time frames and schedules for virtual elimination of critical pollutants at the basinwide and national levels can help support similar reduction efforts in Lake Superior.

The GLBTS sets forth 17 interim reduction goals for 12 Level 1 PTS over a 10 year time frame which ends in 2006. In anticipation of this important milestone, in 2004, the Parties (US EPA and EC), working with many stakeholders from industry, non-governmental organizations, Provinces, States, Tribes, cities, and academia, commenced an overall program review of each of the Level 1 substances.[1] The purpose of the Level 1 reviews was to review progress made to date in reducing these substances and to explore future directions for the continued management of these substances. The following provides a concise summary of each substance review. This report also addresses two non-substance-specific goals in the GLBTS: 1) to assess atmospheric inputs of Level 1 substances from worldwide sources, and 2) to complete or be well advanced in remediation of priority sites with contaminated bottom sediments in the Great Lakes Basin by 2006.

The substance reviews include two major parts: 1) an overall environmental assessment of Level 1 substances in the Great Lakes environment, including a review of current levels in Great Lakes media and biota, an evaluation of these levels against available health based/risk based criteria, historical trends and projected trends looking forward; and 2) a source reduction assessment that looks at use and emission reductions accomplished to date under the GLBTS against the original targets, as well as an analysis of the remaining source sectors, and further opportunities for the GLBTS and others to continue to effect reductions toward our ultimate goals of virtual elimination. Finally, these reviews provide recommendations to the Parties for the future management of each Level 1 substance.

General Outcomes

With regard to source reductions, much progress has been made to date. Of 17 reduction goals, 10 have been met, three more will be met by 2006, and the remaining four will be well advanced toward their respective targets. Notwithstanding these accomplishments, much remains to be done to achieve the ultimate goal of virtual elimination in the Great Lakes.

Overall, the environmental analyses show many of the Level 1 substances remain in the Great Lakes environment at levels which exceed health based criteria, particularly mercury, PCBs, and the cancelled pesticides. These substances continue to impair the Great Lakes, and limit fish consumption, particularly among sensitive populations such as pregnant women and children, and among subsistence fishers.

The Level 1 analyses suggest that source reduction opportunities remain for the "active substances" (i.e., substances for which there are ongoing GLBTS workgroup activities). These include mercury, PCBs, dioxins and furans, HCB, and B(a)P. With respect to the "inactive" (i.e., no ongoing workgroup activity) Level 1 substances, which include the cancelled pesticides, alkyl lead, and OCS, the Parties have decided to suspend GLBTS workgroup activities indefinitely, pending periodic review, and to leverage other programs, as appropriate. However, these substances will continue to be tracked and monitored in the Great Lakes. Finally, the GLBTS will continue to monitor and report on progress of sediment remediation activities in Areas of

[1] Mercury, PCBs, dioxins and furans, hexachlorobenzene (HCB), benzo(a)pyrene (B(a)P), octachlorostyrene (OCS), alkyl lead, mirex, aldrin/dieldrin, toxaphene, DDT, chlordane

Concern in the Great Lakes Basin, and will continue to study issues associated with long-range transport of toxic substances from worldwide sources, in order to better inform GLBTS priorities and identify necessary action steps to move forward.

Specific Recommendations

Table 8-1 provides a brief summary of GLBTS management recommendations and future opportunities by substance/challenge.

Table 8-1. Summary of GLBTS Management Recommendations and Future Opportunities by Substance/Challenge

Substance	Recommendation	Future Opportunities
Mercury	Continue Active Level 1 Status	Source reduction opportunities remain for the GLBTS Mercury Workgroup in the auto scrap, appliance, industrial equipment, and dental sectors. In addition, the GLBTS will continue to encourage and track efforts to reduce mercury releases in sectors with regulatory systems in place or under implementation (e.g., mercury cell chlor-alkali plants and coal-fired power plants).
PCBs	Continue Active Level 1 Status	Source reduction opportunities remain for the GLBTS PCB Workgroup to continue to encourage decommissioning of in-service PCB equipment. Other significant future Workgroup opportunities include updating the current inventories, which will help in identifying additional intervention steps; mandatory dates for PCB phase out in Canada through voluntary activities (via the anticipated Canadian PCB phase out proposal scheduled for publication next year) and proposed regulatory amendments to existing Canadian PCB regulations; and incentives and recognition for PCB phase out and outreach programs.
Dioxins/ Furans	Continue Active Level 1 Status	Source reduction opportunities remain for the GLBTS Dioxin Workgroup to address the use of burn barrels. Other significant future Workgroup opportunities include characterization of sources such as uncontrolled burning, and exploring pathway interventions to mitigate exposure to dioxins and furans.
HCB	Continue Active Level 1 Status	Future Workgroup opportunities include continuing to update and improve the emissions inventories, identifying long-range transport contributions of HCB to the Great Lakes, and cooperating with the Dioxin Workgroup on similar source sectors to take advantage of the HCB reduction co-benefits that may also be achieved. The Workgroup should determine the co-benefits of reducing specified chlorobenzene compounds as a result of actions that reduce HCB.

Substance	Recommendation	Future Opportunities
B(a)P	Continue Active Level 1 Status	Source reduction opportunities remain for the GLBTS HCB/B(a)P Workgroup in residential wood combustion and scrap tire pile mitigation. Other significant future Workgroup opportunities may be identified through continued updating and improvement of emissions inventories. The Workgroup should determine the co-benefits of reducing Level 2 PAHs (Anthracene, Benzo(a)anthracene, Benzo(g,h,i)perylene, Perylene, Phenanthrene) resulting from activities that reduce B(a)P emissions.
Alkyl Lead	Suspend GLBTS Workgroup Activities	The Parties will refer to the National Programs to continue to work with National Association of Stock Car Auto Racing (NASCAR) to reduce the use of leaded fuel in race cars, and with the Federal Aviation Administration and aviation industry to find alternatives to leaded gasoline in aviation fuel.
Pesticides (aldrin/ dieldrin, chlordane, DDT, mirex, toxaphene)	Suspend GLBTS Workgroup Activities	The Parties will refer to National, Provincial, State, Tribal and local Clean Sweep programs to continue to address the stockpile of cancelled pesticides in the Great Lakes Basin, and to various remediation programs that address pesticide contamination. The Parties will participate in international fora that address pesticide phase-outs and disposal, worldwide.
OCS	Suspend GLBTS Workgroup Activities	The Parties will continue to monitor OCS in the Great Lakes environment, and study OCS via long-range transport.
Sediments	Continue Remediation Activities	The Parties will continue to report annually on progress made in the Areas of Concern to remediate sediments contaminated with Level 1 Substances
LRT	Continue Study of Long-Range Transport of Level 1 and 2 Substances	The Parties will continue to study the long-range transport of Level 1 and 2 substances to the Great Lakes, evaluate the relative contributions from worldwide sources, and work within international fora such as UNEP to reduce releases.

GLBTS Conclusions

The GLBTS presents a unique model of how international cooperation and collaborative problem solving of issues that are beyond the reach of existing regulations can lead to real results in environmental protection. There may be an important ongoing role for the GLBTS, not only with respect to the current Level 1 substances, but also for newer chemicals of emerging concern. New innovative reduction strategies could be applied to the sources of current Level 1 PTS that can be eliminated from products and production processes as well as to additional chemicals that may fall under the scope of the GLBTS. The Parties intend to focus on next steps for the GLBTS in 2006. Protecting the chemical integrity of the Great Lakes, advancing the goals of the Great Lakes Water Quality Agreement, and virtually eliminating PTS from the Great Lakes Basin are of paramount importance. The GLBTS is one important tool to move us toward these goals. For more information, see http://www.binational.net.

8.6 STATE OF THE LAKES ECOSYSTEM CONFERENCE

The State of the Lakes Ecosystem Conference (SOLEC) is hosted biennially by the US EPA's Great Lakes National Program Office (GLNPO) and Environment Canada. The conferences are intended to provide a forum for exchange of information on the ecological condition of the Great Lakes and surrounding lands. A major goal is to bring together a large audience of government, corporate, and non-profit environmental managers to discuss the current problems that affect the lakes. The next SOLEC is scheduled for November 2006 in Milwaukee, Wisconsin; the theme of this conference will be "Chemical Integrity". The SOLEC 2004 Lake Superior Report may be found in the Executive Summary of this document. Further information may be found at http://www.epa.gov/solec/index.html and http://cfpub.binational.net/solec/intro_e.cfm.

Figure 2. Duluth lift bridge early in the morning. Photo Credit: Cindi Kahrmann, MPCA.

GLOSSARY

This glossary is a modified version of the Minnesota Sea Grant's "Glossary of the Great Lakes" (http//www.d.umn.edu/seagr/pubs/ggl.html).

2,3,7,8, tetrachlorodibenzo-p-dioxin TCDD
See Dioxin.

33 CFR 320-330
Federal regulations which identify Army Corps of Engineers (ACOE) general policies to implement Section 404 of the Clean Water Act. Part 320 outlines the ACOE's general policies; Part 321 -- permit regulations for dams and dikes; Part 322 -- permit regulations for structures; Part 323 -- permit regulations for dredged materials; Part 324 -- permit regulations for ocean dumping; Part 325 -- permit regulations for discharges to navigable waters and wetlands; Part 326 -- enforcement policies; Part 327 -- public hearings; Part 328 -- definition on navigable waters regulations; and Part 330 -- nationwide permit program regulations.

40 CFR
Federal regulations for air, waste, and water-related programs. Water-related regulations include the National Pollutant Discharge Elimination System (NPDES), water quality standards, discharges to navigable waters, other discharges, and test procedures. *See also* Code of Federal Regulations.

Abatement
A reduction in the degree or amount of pollution.

Accumulation
The build-up of a substance in a plant or animal due to repeated exposure to and uptake of that substance from the environment. *See also* bioaccumulation.

Acid Deposition
The total amount of pollutants that make up what is commonly referred to as acid rain. This includes both the wet deposition and dry deposition components that settle out of the atmosphere. *See* acid rain.

Acid Rain
Occurs when sulfur dioxide and nitrogen oxide emissions are transformed in the atmosphere and return to the earth in rain, fog, or snow. Acid rain can damage lakes, forests, and buildings, contribute to reduced visibility, and may harm human health. Regulations have been implemented at the federal and state (MN) level to reduce acid rain. Related programs: Clean Air Act, MN Rule Chapter 7009.

Acute Test
A comparative study in which organisms are subjected to different treatments and observed for a short period, usually not constituting a substantial portion of the organism's life span.

Acute Toxicity
Adverse effects to a plant or animal that result from an acute exposure to a stimulant, such as a

pollutant. The exposure usually does not constitute a substantial portion of the life span of the organism. In standard laboratory toxicity tests with aquatic organisms, an effect observed in 96 hours or less is typically considered acute. Also described as a stimulus severe enough to induce an effect.

Aerobic
A term that describes organisms or processes that require the presence of molecular oxygen.

Air Pollution Control Rules-Minnesota
MN state rules regulating air pollution and implementing requirements of the 1990 Clean Air Act Amendments (1990 CAAA). *See* Minnesota Rules Chapters 7007, 7009, and 7021. Related programs: Clean Air Act.

Air Toxics
Substances that cause or contribute to air pollution and which can cause serious health and environmental hazards, such as cancer or other illnesses. *See also* Hazardous Air Pollutants. Related programs: Clean Air Act, Minnesota Air Toxics Strategy.

Air Toxics Strategy
See Minnesota Air Toxics Strategy.

Algae
Simple plants found in water and elsewhere that have no roots, flowers, or seeds. These are usually microscopic plants and are the primary producers in lakes. *See also* phytoplankton and periphyton.

Ambient Toxicity
A measurement made using a standard toxicity test to determine how toxic a natural water body is. In some cases a water body may already possess some degree of toxicity before a known pollutant is discharged into it.

Anaerobic
A term that describes processes that occur in the absence of molecular oxygen. *See also* anoxia.

Anoxia
The absence of oxygen or a deficiency of oxygen that is harmful to living organisms. Anoxic conditions can develop in a lake bottom when oxygen is depleted by decomposition processes. This often happens in eutrophic lakes and can result in fish kills. *See also* anaerobic.

Anthropogenic
Anything that is human-caused or derived.

Anti-Backsliding
A federal policy to ensure that water bodies that have been improved are kept at that higher quality. Point source dischargers are required by governments to meet effluent limits, but if discharges become cleaner, or fall below the limit, they are not allowed to go up again. Relaxation of National Pollutant Discharge Elimination System permit limits are not allowed except in certain, limited circumstances.

Anti-Degradation
A federal policy to protect water quality. The policy states that the existing high quality of a particular water resource cannot get worse unless justified by economic and social development considerations. Contained in the U.S. Water Quality Guidance for the Great Lakes System. Related programs: Clean Water Act.

Aquatic Life Criteria
Water quality criteria designed to protect aquatic organisms, including fish, plants, and invertebrates. Related programs: Great Lakes Initiative, Clean Water Act.

Aquatic Nuisance Species (ANS)
Water-borne plants or animals that pose a threat to humans, agriculture, fisheries, and/or wildlife resources. *See also* non-indigenous species, zebra mussel, Bythotrephes, Eurasian ruffe, Eurasian watermilfoil.

Aquatic Nuisance Species Great Lakes Panel
A federal organization formed in 1991 by the Great Lakes Commission to advance exotic species research, monitoring, and control activities. The activities conducted are based on federal legislative and budgetary needs and research and management requirements. Activities include Great Lakes-wide education.

Aquatic Nuisance Species Task Force
An international organization that develops and implements programs to prevent the introduction and distribution of aquatic nuisance species. Their goal is to monitor, control, and study these species, and to disseminate technical and educational information. Made up of 19 provincial, state, and federal organizations.

Area of Concern (AOC)
Areas of the Great Lakes identified by the International Joint Commission as having serious water pollution problems requiring remedial action and the development of a Remedial Action Plan. AOCs are defined in the Great Lakes Water Quality Agreement as: “a geographic area that fails to meet the general or specific objectives of the Great Lakes Water Quality Agreement, or where such failure has caused or is likely to cause impairment of beneficial use or of the areas ability to support aquatic life.” Initially, there were 43 AOCs in the Great Lakes Basin. The 8 AOCs in Lake Superior are: Deer and Torch Lakes in Michigan; St. Louis River in Minnesota and Wisconsin; Jackfish Bay, Nipigon Bay, Thunder Bay, and Peninsula Harbour in Ontario; and St. Mary’s River in Michigan and Ontario. Related programs: Great Lakes Water Quality Agreement, Remedial Action Plans.

Army Corps of Engineers (ACOE)
The federal agency that administers the Section 404 permit program on dredging or filling navigable waters, including wetlands.

Arrowhead Regional Development Commission (ARDC)
One of several regional development commissions located throughout Minnesota, this one serves seven counties in northeastern Minnesota. Through its mission to provide local leadership it is involved in many issues related to the environment in the Lake Superior basin.

Atmospheric Deposition
Pollution that travels through the air and falls on land and water. Related programs: Clean Air Act, Great Lakes Toxic Reduction Effort.

Basin
The land area that drains into a lake or river. This area is defined and bounded by topographic high points around the water body. *See also* watershed.

Bayfield Institute
A Canadian federal organization that conducts fisheries research, habitat management, hydrographic surveys and chart production, fisheries and recreational harbor management, and ship support. Together with the work of the Freshwater Institute in Winnipeg, it provides the federal Fisheries and Oceans Program for Central and Arctic Canada.

Beneficial Use
The role that the government decides a water body will fulfill. Examples of these uses include healthy fish and wildlife populations, fish consumption, aesthetic value, safe drinking water sources, and healthy phytoplankton and zooplankton communities. Restoring beneficial uses is the primary goal of the Remedial Action Plans for the Areas of Concern and of the Great Lakes. Related programs: Great Lakes Water Quality Agreement, Lakewide Management Plans, Remedial Action Plans.

Beneficial Use Impairment
A negative change in the health of a water body making it unusable for a beneficial use that has been assigned to it. Examples of these use impairments, as designated in the Great Lakes Water Quality Agreement, include: restrictions on fish and wildlife consumption, beach closings, degradation to aesthetics, loss of fish and wildlife habitat, and restrictions on drinking water consumption. Related programs: Great Lakes Water Quality Agreement, Lakewide Management Plans, Remedial Action Plans.

Benthic
A term that describes both organisms and processes that occur in, on, or near a lake's bottom sediments. *See also* benthos.

Benthic Invertebrate
Refers to animals with no backbone or internal skeleton that live on the bottom of lakes, ponds, wetlands, rivers, and streams, and among aquatic plants. Benthic invertebrates provide an essential source of food for young and adult fish, wildlife, and other animals. Examples include caddisflies, midge larvae, scuds, waterfleas, crayfish, sponges, snails, worms, leeches, and nymphs of mayflies, dragonflies, and damselflies. The benthic invertebrate *Diaporeia*, is an ecosystem indicator.

Benthos
A term applied to organisms that live on or in a river or lake's bottom and/or bottom sediments. *See also* benthic.

Best Available Control Technology (BACT)
Technology required to reduce emissions of air pollutant. Defined in the Great Lakes Permitting

Agreement as: "emission limits, operating stipulations, and/or technology requirements based on the maximum degree of reduction which each Great Lakes State determines is achievable through application of processes or available methods, systems, and techniques for the control of listed pollutants, taking into account energy, environmental, and economic impacts, and other costs."

Best Available Technology (BAT)
The most effective, economically-achievable, and state-of-the-art technology currently in use for controlling pollution, as determined by the U.S. EPA.

Best Management Practice (BMP)
Methods used to control nonpoint source pollution by modifying existing management practices. BMPs include the best structural and non-structural controls and operation and maintenance procedures available. BMPs can be applied before, during, and after pollution-producing activities, to reduce or eliminate the introduction of pollutants into receiving waters. Related programs: Clean Water Act, Wetlands Conservation Act, Coastal Zone Management, Section 319.

Binational Policy Task Force
An international organization that provides overall policy coordination for the Binational Program. Representation includes federal, provincial, and state government agencies. Related Programs:Binational Program.

Binational Program
The commonly-used name for the Lake Superior Binational Program to Restore and Protect the Lake Superior basin. An international program developed by the governments of Canada, the U.S., Minnesota, Michigan, Wisconsin, and Ontario to protect the high quality waters of the Lake Superior basin and to restore those areas that have been degraded. These goals are to be met through pollution prevention, enhanced regulation, and special designations. One specific goal of the program is to achieve zero discharge and zero emission of designated persistent and bioaccumulative toxic substances from point sources in the basin. Related programs: Great Lakes Water Quality Agreement, International Joint Commission, the Broader Program.

Bioaccumulation
The net accumulation of a substance by an organism as a result of uptake from all environmental sources. As an organism ages it can accumulate more of these substances, either from its food or directly from the environment. Bioaccumulation of a toxic substance has the potential to cause harm to organisms, particularly to those at the top of the food chain. The pesticide DDT is an example of a chemical that bioaccumlates in fish and then in humans, birds, and other animals eating those fish. *See also* accumulation and biomagnification.

Bioaccumulation Factor (BAF)
The ratio of a substance's concentration in an organism's tissue to its concentration in the water where the organism lives. BAFs measure a chemical's potential to accumulate in tissue through exposure to both food and water. *See also* bioconcentration factor. Related programs: Great Lakes Initiative.

Bioaccumulative Chemicals of Concern (BCCs)
Any chemical which, upon entering surface waters, bioccumulates in aquatic organisms by a bioaccumulation factor greater than 1000. This formula takes into account metabolism and other factors that might affect bioaccumulation. Related programs: Great Lakes Initiative.

Bioassay
A test used to evaluate the relative potency of a chemical or mixture of chemicals by comparing its effect on a living organism with the effect of a standard preparation on the same organism. Bioassays are frequently used in the pharmaceutical industry to evaluate the potency of vitamins and drugs.

Bioavailability
A measure of how available a toxic pollutant is to the biological processes of an organism. The less the bioavailability of a toxic substance, the less its toxic effect on an organism.

Bioconcentration Factor (BCF)
The ratio of a substance's concentration in tissue versus its concentration in water in situations where the organism is exposed through water only. BCF measures a chemical's potential to accumulate in an organism's tissue through direct uptake from water (excludes uptake from food). *See also* bioaccumulation factor.

Biocriteria
See biological criteria.

Bioindicator
An organism and/or biological process whose change in numbers, structure, or function points to changes in the integrity or quality of the environment.

Biological Control
A method of controlling a disease-causing organism or pathogen or an exotic species. A biochemical product or bioengineered or naturally-occurring organism is used to cause death, inhibit growth, or inhibit the reproduction of an unwanted organism. One example is the import and use of the European beetle that feeds exclusively on Purple Loosestrife.

Biological Criteria
Biological measures of the health of an environment, such as the incidence of cancer in benthic fish species. Biological criteria can consist of narrative statements (in the simplest case) or of numeric statements.

Biological Oxygen Demand (BOD)
This is a measurement of the oxygen depletion in a water sample incubated under controlled conditions over a period of time. The aerobic decomposition of organic matter by bacteria in the sample requires oxygen. BOD is an important measurement of the impact that sewage discharge may have upon a water body because a certain amount of oxygen will be used in the breakdown of the wastewater.

Biomagnification
The process by which the concentration of a substance increases in different organisms at higher

levels in the food chain. For example, if an organism is eaten by another organism, these substances move up the food chain and become more concentrated at each step. *See also* bioaccumulation and accumulation.

Biomonitoring
The process of assessing the well-being of living organisms. Often used in water quality studies to indicate compliance with water quality standards or effluent limits and to document water quality trends.

Biosphere
A term that includes all of the ecosystems on the planet along with their interactions. The sphere of all air, water, and land in which all life is found. The Lake Superior Biosphere includes all ecosystems within the basin. Related programs: Lake Superior Biosphere Preserve.

Board of Water and Soil Resources (BWSR)
A Minnesota state agency that oversees a number of state programs designed to protect the state's soil and water. These programs include: the Soil and Water Conservation Districts, Comprehensive Local Water Management Plans, Conservation Reserve Program, Shoreland Block Grants, Reinvest in Minnesota, among others. BWSR is responsible for the Wetland Conservation Act and associated rules.

Boundary Waters
See Interstate Waters.

Boundary Waters Treaty
The international treaty between the United States and Great Britain signed on January 11, 1909, regarding the waters joining the two nations and relating to questions arising between the United States and Canada. It gave rise to the International Joint Commission. Related programs: Binational Program, International Joint Commission.

Broader Program
The portion of the Lake Superior Binational Program containing the Lakewide Management Plan and ecosystem approach pursuant to the Great Lakes Water Quality Agreement.

Bythotrephes BC
Also called the spiny water flea, this non-indigenous species has spread to all of the Great Lakes and some inland lakes. The impact that this new predator will have on the Great Lakes has yet to be determined, though it may compete for food with some fish.

Canada/Ontario Agreement (COA)
A federal/provincial agreement under which Canada's obligations to the Canada/U.S. Great Lakes Water Quality Agreement are coordinated and implemented. This 1994 agreement lists and defines 50 commitments specific to the restoration, protection, and conservation of the Great Lakes. Related programs: Great Lakes Water Quality Agreement.

Canadian Environmental Protection Act (CEPA)
A 1988 federal act designed to protect the people and environment of Canada from the effects of toxic substances.

Carcinogen
A substance that is known or suspected to cause cancer.

Center for Lake Superior Environmental Studies (CLSES)
The original name for the Lake Superior Research Institute. Related programs: University of Wisconsin-Superior.

Center for Water and the Environment (CWE)
One of three centers within the University of Minnesota's Natural Resources Research Institute. CWE provides basic environmental information essential to safe and sustainable natural resource development. Related programs: Natural Resources Research Institute.

Chlordane
A critical pollutant that was used as a pesticide until banned by the U.S. in 1983 (except for use in controlling underground termites). Chlordane bioaccumulates in the food chain. Concentrations are highest in fat and liver tissue of predatory species. It has been detected in lake trout and other wildlife. Related programs: Binational Program.

Chlorinated Organic Compounds
Organic chemicals that contain PCBs, DDT, chlorinated dioxins and furans, dieldrin, and hexachlorobenzene. Also called organochlorines or chlorinated organics.

Chlorination
The addition of chlorine to water for disinfection. Used in drinking water purification and sewage treatment prior to discharge.

Chlorine
A common, naturally-occurring element. One form of chlorine is a highly poisonous gas that is typically used for water disinfection, sewage treatment, and the manufacture of bleach and other chemicals.

Chronic Test
A comparative study in which organisms are subjected to different treatments and observed for a long period or a substantial portion of their life span.

Chronic Toxicity
A harmful and delayed response (such as death, unusual growth, reduced reproduction, or disorientation) to a chemical that causes adverse effects over a long period of time relative to an organism's natural life span. In standard laboratory tests an effect observed in 96 hours or more is considered a chronic effect. *See also* toxicity test.

Clean Air Act (CAA)
Federal law originally passed in 1970 for the purpose of protecting and enhancing the quality of the nation's air resources. *See also* Clean Air Act Amendments of 1990.

Clean Air Act Amendments of 1990 (CAAA)
Federal legislation passed in 1990 that amended the Clean Air Act. It resulted in major changes further limiting the generation of air pollution in the United States. Significant sections of the 1990 CAAA include:

- Title I - National Ambient Air Quality Standards;
- Title II - Mobile Sources (e.g. automobiles);
- Title III - Air Toxics;
- Title IV - Acid Rain;
- Title V - Permit Program; and
- Title VI - Ozone-depleting Chemicals.

Related programs: Clean Air Act.

Clean Water Act (CWA)
A federal law that identifies national requirements to protect the nation's waters. Originally known as the Federal Water Pollution Control Act. The CWA is divided into six subchapters:

- Subchapter I - Research and Related Programs;
- Subchapter II - Grants for Construction of Treatment Works;
- Subchapter III - Standards and Enforcement;
- Subchapter IV - Permits and Licenses;
- Subchapter V - General Provisions; and
- Subchapter VI - State Water Pollution Control Revolving Fund.

The law provides for pretreatment standards, plans involving point and nonpoint source pollution, and effluent limitations that satisfy the act's intent.

Clean Water Act Reauthorization (CWAR)
The name for a federal legislative process to amend the Clean Water Act. It is anticipated that the CWA will be reauthorized in the mid- to late-1990s.

Coastal
Waters in the Great Lakes basin, coastal waters are defined in the Coastal Zone Management Act as the waters within the territorial jurisdiction of the United States, consisting of the Great Lakes, their connecting waters, harbors, roadsteads, and estuary-type areas such as bays, shallows, and marshes. Related programs: Coastal Zone Management Act.

Coastal Zone Act Reauthorization Amendments of 1990 (CZARA)
Federal legislation reauthorized by Congress in 1990, resulting in states being asked to combat the problems of coastal water quality, specifically nonpoint source pollution. CZARA also encourages states to tackle issues such as wetland loss, cumulative and secondary impacts of growth, increased threats to life and property from coastal hazards, and dwindling opportunities for public access to the shoreline. Related programs: National Oceanic and Atmospheric Administration, U.S. EPA.

Coastal Zone Management Act (CZMA)
A federal law enacted in 1972 to deal with increasing stresses on the nation's coastal areas, including the Great Lakes. Administered by National Oceanic and Atmospheric Administration (NOAA), the CZMA provides money, technical help, and policy guidance to states for balancing conservation and development of coastal resources. Under CZMA, states voluntarily develop their own Coastal Zone Management programs. Related programs: National Oceanic and Atmospheric Administration.

Code of Federal Regulations (CFR)
Federal regulations on how to implement federal law.

Combined Sewer Overflow (CSO)
Occurs when heavy rainfall or thaw conditions overload a sewer system designed to carry both waste and stormwater. Often the result is the discharge of untreated sewage into receiving waters. Also refers to the outfall structures themselves.

Comparative Risk Analysis
A procedure for ranking environmental problems by their seriousness (relative risk) for the purpose of assigning program priorities. Typically, teams of experts put together a list of problems, sort the problems by types of risk, then rank them by measuring them against standards, such as the severity of effects, the likelihood of the problem occurring among those exposed, the number of people exposed, and the like. Relative risk is then used to set priorities. *See also* risk assessment, risk management, ecological risk assessment.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Superfund
A federal law, better known as Superfund, enacted in 1980 to give the EPA authority and money to take corrective measures and clean up hazardous waste sites. The 1986 Superfund Amendment Reauthorization Act (SARA) outlined preferred cleanup methods, including permanent on-site treatment.

Comprehensive Local Water Management Plan
See County Water Plan.

Confined Disposal Facility (CDF)
A facility providing a contained disposal area for contaminated sediments removed during dredging operations. Related programs: County Water Plan.

Cost-Benefit Analysis
The determination of how much it will cost to achieve a benefit, for example from pollution control, and the comparison of this amount to the cost of obtaining a higher or lower level of the benefit, or the cost of using some other alternative method.

Council of Great Lakes Governors (CGLG)
An organization comprised of the governors of the eight Great Lakes States who declared their shared intention to manage and protect the water resources of the Great Lakes basin through the Great Lakes Charter and the Great Lakes Toxic Substances Control Agreement.

Council of Great Lakes Industries (CGLI)
An organization that represents businesses with significant investments, facilities, products, and/or services in the Great Lakes basin, including manufacturing, utilities, telecommunications, transportation, financial, and trade. CGLI provides a focal point for offering industry's views and resources. It strengthens regional efforts to integrate social, economic, and environmental issues as a way to build a more vital Great Lakes basin.

Council of Great Lakes Research Managers
A binational advisory group to the International Joint Commission to evaluate the status of Great Lakes research.

County Water Plan
Also called Comprehensive Water Management Plans. These plans are developed by Minnesota counties to identify water resource problems and provide sound planning to prevent future problems. A bill was passed by the Minnesota State Legislature in 1985 encouraging counties to develop and implement County Water Plans. Related programs: Board of Water and Soil Resources, Clean Water Act.

Criteria
See water quality criteria.

Criteria Pollutants
A group of air and water pollutants regulated by the EPA under the Clean Air Act and Clean Water Act on the basis of criteria that includes information on health and environmental effects. Criteria pollutants include particulates, some metals, organic compounds, and other substances attributable to discharges.

Critical Pollutant
Chemicals that persist at levels that are causing or could cause impairment of beneficial uses lakewide. Other critical pollutants will be added to the list, but the Lake Superior Lakewide Management Program will first focus on the same nine critical pollutants identified in the zero discharge demonstration program (TCDD, OCS, HCB, chlordane, DDT, dieldrin, toxaphene, PCBs, and mercury). *See also* Great Lakes Critical Pollutants. Related programs: Lakewide Management Program, Binational Program, Zero Discharge Demonstration Program.

Decomposition
The breakdown of complex organic substances into more simple organic chemicals or substances. The ultimate product of decomposition in an aerobic environment is carbon dioxide.

Designated Scientific and Natural Areas (SNA)
See Scientific and Natural Areas.

Designated Uses
The role that a water body is slated to fulfill, such as a drinking water source. Uses are specified in water quality standards for each water body or segment, whether or not the current water quality is high enough to allow the designated use. Other typical uses of a water body include propagation of fish and wildlife, recreation, agriculture, industry, and navigation.

Dichlorodiphenyltrichloro-ethane, DDT
DDT, one of the nine critical pollutants, was commonly used as an insecticide after World War II and is now banned in the U.S. and Canada. DDT and its metabolites are toxic pollutants with long-term persistence in soil and water. They concentrate in the fat of wildlife and humans and may disrupt the human body's chemical system of hormones and enzymes. DDT caused eggshell thinning in a number of fish-eating birds and is associated with the mortality of embryos and sterility in wildlife, especially birds. DDT still enters the Great Lakes, probably from a number

of sources including airborne transport from other countries, leakage from dumps, and the illegal use of old stocks. Related program: Binational Program.

Dieldrin
Dieldrin, a critical pollutant, was used as a pesticide for veterinary uses and to control soil insects. In the U.S. and Canada, its use is now restricted to termite control. Dieldrin has a long half-life in shallow waters compared to most chlorinated organic compounds. It is acutely toxic and poses a potential carcinogenic threat to humans. This chemical enters the Great Lakes System from the air or contaminated sediments and has been detected in fish and wildlife in all of the Great Lakes. Related program: Binational Program.

Dioxin
A critical pollutant considered to be highly toxic, 2,3,7,8 tetrachlorodibenzo-p-dioxin, or TCDD, is a variant in a family of 75 chlorinated organic compounds referred to as dioxins. An unwanted chemical byproduct of incineration and some industrial processes that use chlorine, dioxin tends to accumulate in the fatty tissue of fish. Dioxin is a suspected human carcinogen. Related program: Binational Program.

Discharge
Any release or unloading of a substance or materials from a pipe, or other emission source. The addition of any pollutant to the waters of the state or to any disposal system from a point source. Related programs: 40 CFR.

Discharge of Dredged or Fill Material
Any addition of dredged or fill material into navigable waters or into the waters of the United States. This includes the driving of pilings and the addition of any material that changes the bottom elevation or configuration of a water body or material that might destroy or degrade any navigable water. Related programs: Section 404, 33 CFR.

Dry Deposition
The deposition of pollutants from the atmosphere (such as dust and particulate matter) that occurs during dry weather periods. Dry deposition rates are often drastically different than wet deposition rates.

Duluth-Superior Port Plan
A local program where the MN DNR is required to establish a port plan before it can authorize the filling of protected waters for port development. The plan includes provisions to protect designated natural resources areas, and to adopt a policy of no net loss for wetlands, fish habitat, and aquatic communities in the St. Louis River and Estuary.

Ecological Risk Assessment
An organized procedure to evaluate the likelihood that adverse ecological effects will occur as a result of exposure to stressors related to human activities, such as the draining of wetlands or release of chemicals.

Ecosystem
A biological community and its environment working together as a functional system, including transferring and circulating energy and matter.

Ecosystem Charter for the Great Lakes Basin
Initiated by the Great Lakes Commission, this is a binational statement of goals, objectives, principles, and action items for the Great Lakes with a plan for achieving it. This non-binding agreement supports a philosophy of "ecosystem management that recognizes natural resources as part of a dynamic and complete matrix that pays no heed to political boundaries or jurisdictions. Related programs: Great Lakes Commission.

Ecosystem Indicator
An organism or community of organisms that is used to assess the health of an ecosystem as a whole. For example, the Binational Program has selected the lake trout and *Diaporeia* (a benthic invertebrate) to be indicator species for Lake Superior. Related programs: Binational Program.

Ecosystem Principles and Objectives for Lake Superior
A binational program described in Volume IV of the Lake Superior Lakewide Management Program. The report lists specific ecosystem principles and objectives for the Lake Superior basin, provides a set of benchmarks, and helps guide decisions pertaining to land and water management in the Lake Superior ecosystem. Related programs: Binational Program.

Effluent
Liquid wastes that are discharged into the environment as a by-product of human-oriented processes, such as waste material, liquid industrial refuse, or sewage.

Effluent Limitation
Any restriction placed on quantities, discharge rates, and concentrations of pollutants that are discharged from point sources into waters of the United States or the ocean. Related programs: 40 CFR, Clean Water Act.

Endangered Species Act (ESA)
Federal statutes passed in 1973 that protect endangered and threatened species. The act has 16 sections.

Endangered Species Act Reauthorization (ESAR)
The name for the federal legislative process to amend the Endangered Species Act. It is anticipated that reauthorization will occur in the mid- to late-1990s.

Environment Canada (EC)
The lead federal agency responsible for implementing Great Lakes 2000 and the 1994 Canada-Ontario Agreement respecting the Great Lakes Basin ecosystem. Together, Great Lakes 2000 and the Canada-Ontario Agreement represent the Canadian response to the Great Lakes Water Quality Agreement.

Environmental Impact Assessment (EIA)
A decision-making process mandated under the National Environmental Policy Act (NEPA) which may require a detailed environmental impact statement analyzing the potential significant environmental impacts and alternatives to the action before the action is permitted. A public comment period takes place on each EIA.

Environmental Impact Statement (EIS)
A statement detailing the environmental impacts of and the alternatives to an action. *See* Environmental Impact Assessment.

Environmental Monitoring and Assessment Program (EMAP)
A federal program initiated by the EPA in 1988 to provide improved information on the current status and long-term trends in the condition of the nation's ecological resources. Seven resource categories are defined: near coastal waters, the Great Lakes, inland surface waters, wetlands, forests, arid lands, and agroecosystems. Related programs: Environmental Protection Agency.

Environmental Protection Agency (EPA)
A federal agency whose primary goal is to prevent or mitigate the adverse impacts of pollution on human health and the environment.

Environmental Research Laboratory (ERL) Duluth
See Mid-Continent Ecology Division.

Erosion
The wearing away of the land surface by running waters, glaciers, winds, and waves. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices related to farming, residential or industrial development, road building, or timber cutting.

Estuary (Freshwater)
Areas of interaction between rivers and nearshore lake waters, where seiche activity and river flow create a mixing of lake and river water. These areas may include bays, mouths of rivers, marshes, and lagoons. These ecosystems shelter and feed fish, birds, and wildlife. Most importantly, Great Lakes estuaries provide habitat for wildlife and for young-of-the-year and juvenile fish.

Eurasian Ruffe
A non-indigenous species now found in Lake Superior and Lake Huron. This relatively new invader is a member of the perch family. It is usually less than 6 inches long, has a perch-like body shape, and is very slimy when handled. This fish may be competing with native perch and other fish for food. There is a great deal of concern over the potential for this fish to expand its range into other North American waters. It has also been called the European ruffe and river ruffe. *See also* aquatic nuisance species.

Eurasian Watermilfoil
An exotic aquatic macrophyte that forms thick underwater stands of tangled stems and vast mats of vegetation on the surface of inland lakes. In many shallow areas this plant can crowd out native plants and interfere with water recreation such as boating, fishing, and swimming. The plant can spread from lake to lake by stem fragments that cling to boats and trailers. Public education campaigns aimed at preventing unintentional transport of the plant by boaters have successfully slowed its spread in some states. *See also* aquatic nuisance species.

Eutrophic
A term used to classify those lakes of high primary productivity as indicated by high algal concentrations or high nutrient levels. *See also* eutrophication.

Eutrophication
The process of physical, biological, and chemical changes that occurs in a lake when enriched by nutrients, organic matter, and/or silt and sediments. The process can occur naturally, but if accelerated by human activities such as agriculture, urbanization, and industrial discharge, it is called cultural eutrophication.

Exotic Species
See non-indigenous species.

Exposure
Contact with a chemical or physical agent.

Exposure Assessment
Estimates the amount of a substance something is exposed to.

Fecal Coliform
Bacteria that come from the intestines of humans and other large animals. A high coliform count in a water body indicates human or animal sewage is leaking or being dumped into the lake.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
Originally adopted in 1947 and currently enforced by EPA, this law regulates the marketing of pesticides.

Federal Register
The official document of the U.S. government that announces proposed federal rules and regulations. It signals the beginning of a period of time for public review and comment.

Federal Water Pollution Control Act (FWPCA)
A federal law that identifies national requirements to protect the nation's waters. Commonly referred to as the Clean Water Act (CWA). Related programs: Clean Water Act.

Fill Material
Material used to convert a water body into dry land or change its configuration or bottom elevation. Related programs: Section 404, 33 CFR, Wetlands Conservation Act, Wetlands Conservation Act Rules.

Fish Consumption Advisory (FCA)
An advisory issued by a government agency recommending that the public limit their consumption of fish. Advisories are issued to limit exposure to toxic substances in the fish that have the potential to impact human health. A fish consumption advisory is prepared annually by the Minnesota Department of Health. Fish caught from selected lakes and streams are tested for toxic substances (mercury, sometimes PCBs and dioxins). Many of the lakes tested have restrictions on fish consumption due to high mercury levels. PCBs and dioxin levels in fish have also resulted in suggested restrictions on fish consumption in some lakes and streams. Other states and the federal government also issue advisories.

Five-Year Strategy
See Great Lakes Five-Year Strategy.

Flushing Time
See residence time.

General Permit
An Army Corps of Engineers (ACOE) authorization that is issued on a nationwide or regional basis for categories of human activities within navigable waters of the U.S. General permits are issued when: (1) these activities are substantially similar in nature and cause only minimal individual and cumulative environmental impacts; or (2) the general permit would result in avoiding unnecessary duplication of the regulatory control exercised by another federal, state, or local agency provided it has been determined that the environmental consequences of the action are individually and cumulatively minimal. There are three types of general permits: regional permits, nationwide permits, and programmative permits. Related programs: Section 404, 33 CFR.

Glossary of the Great Lakes (GGL)
You are reading it!

Great Lakes
Lake Ontario, Lake Erie, Lake Huron (including Lake St. Clair), Lake Michigan, and Lake Superior, and the connecting channels (St. Mary's River, St. Clair River, Detroit River, Niagara River, and St. Lawrence River to the Canadian border).

Great Lakes 2000 (GL2000)
Led and implemented by Environment Canada, GL2000 is based on a vision of sustainable development in the Great Lakes Basin, with specific objectives of restoring degraded ecosystems, preventing and controlling pollutant impacts, and conserving human and ecosystem health. Other participating federal agencies include the Department of Fisheries and Oceans, Health Canada, Agriculture and Agri-food Canada, Transport Canada, Canadian Heritage, and Public Works and Government Service Canada.

Great Lakes Atmospheric Deposition Network
See Integrated Great Lakes Atmospheric Deposition Network.

Great Lakes Basin
See Great Lakes System.

Great Lakes Charter
An international organization formed in 1985 by the premiers of Ontario and Quebec and the governors of the 8 Great Lakes States in response to the increased interest in diverting Great Lakes water to arid regions of the U.S. The Charter does not encourage these diversion proposals, but has no enforcement powers to prevent their implementation.

Great Lakes Commission (GLC)
A Great Lakes states' organization formed in 1955 by the states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin to promote a cleaner environment, stronger economy, and better quality of life for residents of the Great Lakes states. Although Canada is not an official member of the Commission, it is on the task force. Through policy development, intergovernmental coordination, and advocacy, the Commission offers a variety of

services to member states, and provides a unified and influential regional voice on policy, program, and legislative matters affecting the Great Lakes. It maintains an active observer program with representation from federal agencies, provincial governments, regional organizations, and tribal authorities. The Commission also maintains the Great Lakes Information Network and initiated the Ecosystem Charter for the Great Lakes Basin.

Great Lakes Critical Pollutants (GLCP)
Substances (a total of 138) currently identified as most critical to improving water quality under four major Great Lakes initiatives: the Great Lakes Water Quality Initiative, the Lake Michigan Lakewide Management Plan, the Lake Ontario/Niagara River Four Party Agreement, and the Lake Superior Binational Program Agreement. Each of the four initiatives may define critical pollutants differently.

Great Lakes Critical Programs Act
Amendments to Section 118 of the federal Clean Water Act in 1990 to improve the effectiveness of EPA's existing programs in the Great Lakes. The Critical Programs Act established the Great Lakes Water Quality Initiative and identified key treaty agreements between the United States and Canada in the Great Lakes Water Quality Agreement. The Act required the EPA to establish statutory deadlines for treaty activities and increased federal resources for the program. It also requires the EPA to publish proposed water quality guidelines for the Great Lakes System. The guidelines must specify minimum requirements for waters in the Great Lakes system in three areas: water quality standards; anti-degradation policies; and implementation procedures. Related programs: Clean Water Act, Great Lakes Initiative.

Great Lakes Enforcement Strategy
A federal program that is a joint effort of the eight Great Lakes States and the EPA. The strategy is a part of the process for implementing the Great Lakes Five-Year Strategy for the National Pollutant Discharge Elimination System program by reducing dischargers' non-compliance in the Great Lakes basin and reducing toxics loading. A key element of the strategy is the use of screening criteria that are more stringent than the national definition of significant non-compliance.

Great Lakes Environmental Research Laboratory (GLERL)
A federal research facility run by the National Oceanic and Atmospheric Administration located in Ann Arbor, Michigan. The GLERL's mission is to conduct integrated, interdisciplinary environmental research in support of resource management and environmental services in coastal and estuarine water, with special emphasis on the Great Lakes. GLERL's research provides federal, state, and international decision and policy makers with scientific understanding of:

1. sources, pathways, and fates of toxicants;
2. natural hazards;
3. ecosystems and their interactions;
4. hydrology and Great Lakes water levels; and
5. regional effects related to global climate change.

Related programs: National Oceanic and Atmospheric Administration.

Great Lakes Fishery Commission (GLFC)
An international organization established in 1955 by Canada and the United States. Located in

Ann Arbor, Michigan, the GLFC works to improve the Great Lakes fishery, coordinates efforts of the two nations, and implements management of the sea lamprey. The Commission also advises the two governments on other non-indigenous species. The USFWS is the U.S. agency that acts for the Commission. Related programs: United States Fish and Wildlife Service (Dept. of Fisheries and Oceans), Sea Lamprey Control Program.

Great Lakes Five-Year Strategy (1992)
A federal (EPA) program that commits the states, tribes, and U.S. federal agencies responsible for environmental protection and natural resource management in the Great Lakes basin to achieving specific environmental goals. This overarching EPA strategy provides a framework for EPA's Great Lakes Programs and contains three major areas of focus: reduction of toxic pollutants; restoration of habitat; and protection of the health of all species. Specifically, regarding toxics reduction (as set forth in the Great Lakes Water Quality Agreement with Canada), the Strategy calls for "...reducing the level of toxic substances in the Great Lakes System with an emphasis on persistent toxic substances, so that all organisms are adequately protected and toxic substances are virtually eliminated from the Great Lakes ecosystem." Related program: National Pollutant Discharge Elimination System.

Great Lakes Indian Fish and Wildlife Commission (GLIFWC)
An organization of Native American tribes from Michigan, Wisconsin, and Minnesota that assists member tribes in the management of natural resources, in the protection of ecosystems, and in the development of institutions of tribal self-government.

Great Lakes Information Network (GLIN)
A nationwide Internet information exchange service for the Great Lakes basin. GLIN ties together a host of databases and file servers from a wide range of government and academic groups in an easy-to-access format. Maintained by the Great Lakes Commission. Related Program: Great Lakes Commission.

Great Lakes Initiative (GLI)
GLI is the commonly used name for the Water Quality Guidance for the Great Lakes System. This federal guidance, drafted in 1993 and finalized on March 23, 1995, has regulatory implications, establishing minimum water quality standards, anti-degradation policies, and implementation procedures for waters in the Great Lakes system. Related programs: Great Lakes Toxic Reduction Initiative, Great Lakes Toxic Reduction Effort, Clean Water Act.

Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS)
As a component of the Bayfield Institute, this Canadian laboratory conducts research on the persistence and impacts of toxic chemicals on Great Lakes fish communities and food chains, and studies fish habitat for factors that affect production, species associations, and rehabilitation potential of fish stocks. It is also responsible for implementing the federal Fish Health Regulations for Ontario. Research helps support the 1987 Great Lakes Water Quality Agreement and binational concerns related to the long-range transport of atmospheric pollutants.

Great Lakes Maritime Industry Voluntary Ballast Water Management Plan for the Control of Ruffe in Lake Superior
Co-sponsored by the maritime shipping industry Great Lakes-wide, the plan is designed to reduce

the risk that commercial vessels will transport the Eurasian ruffe in ballast water from Duluth-Superior Harbor to other ports. It requires that ballast water be exchanged in deep, cold water areas of Lake Superior. Commonly referred to as the Voluntary Ballast Water Management Plan.

Great Lakes National Program Office (GLNPO)
A federal EPA office created in 1978 to oversee the U.S. fulfillment of its obligations under the Great Lakes Water Quality Agreement with Canada. It was mandated by the Clean Water Act in 1987 to be responsible for coordinating the U.S. response to the water quality agreement. Located in Chicago, Illinois, GLNPO is made up of scientists, engineers, and other professionals who work with staff throughout the EPA, Great Lakes states, other federal agencies, Environment Canada, Ontario provincial government, International Joint Commission, colleges, universities, and the public. GLNPO developed the Great Lakes Five-Year Strategy to focus the activities of these groups on the following objectives: reduction of toxic substance levels, protection and restoration of habitats, and the protection of health. Related programs: Great Lakes Water Quality Agreement, Environmental Protection Agency, Great Lakes Five-Year Strategy, International Joint Commission.

Great Lakes Natural Resource Center
This is a private wildlife protection group located in Ann Arbor, Michigan and run by the National Wildlife Federation. Their Lake Superior Project focuses on the environmental problems of Lake Superior.

Great Lakes Protection Fund (GLPF)
A program initiated by the governors of the Great Lakes states as the United States first multi-state environmental endowment, the Fund is guided by principles stressing regional cooperation and communication with the purpose of promoting a healthy and sustainable Great Lakes ecosystem.

Great Lakes Regional Office
See Great Lakes Water Quality Advisory Board.

Great Lakes Research Office
This federal office, administered by the National Oceanic and Atmospheric Administration, identifies issues relating to Great Lakes resources on which research is needed, inventories existing research programs, establishes a mechanism for information exchange, and conducts research through the Great Lakes Environmental Research Laboratories, the National Sea Grant College Program, and other federal labs and the private sector. Related programs: Clean Water Act, National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratories, National Sea Grant College Program.

Great Lakes Science Advisory Board (SAB)
See Science Advisory Board.

Great Lakes Sea Grant Network
A U.S. network consisting of Sea Grant programs in Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, and New York.

Great Lakes Sport Fishing Council
A binational organization of the Great Lakes sportfishing community concerned with the present and future health of sportfishing, natural resources, and the Great Lakes ecosystem in general.

Great Lakes States
The states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin.

Great Lakes States Air Permitting Agreement
A federal program signed by the environmental administrators of the Great Lakes states in 1988 to assure consistent implementation of the Toxic Substances Management in the Great Lakes basin through the permitting process agreement.

Great Lakes System
All the streams, rivers, lakes, and other bodies of water within the drainage basin of the Great Lakes.

Great Lakes Toxic Substances Control Agreement
An interstate agreement signed by the governors of the eight Great Lakes states in 1986, this agreement seeks uniform water quality standards for the Great Lakes. The purpose of the governors' agreement was to establish a framework for coordinated regional action in controlling toxic substances entering the Great Lakes system.

Great Lakes Toxics Reduction Effort (GLTxRE)
This is a federal/state partnership that seeks to reduce the generation and release of toxics to the Great Lakes basin, with an emphasis on nonpoint sources. It supports the Great Lakes Water Quality Agreement and Great Lakes Five-Year Strategy. EPA and the Great Lakes states have established a process to deal with gaps or barriers to effectively preventing, controlling, or eliminating toxics loadings from nonpoint sources. An EPA team works with federal and state Great Lakes agencies to enhance efforts to reduce Great Lakes critical pollutants through three parallel projects: Virtual Elimination, Lake Michigan Mass Balance, and source pathway analysis. Related program: Great Lakes Initiative.

Great Lakes Toxics Reduction Initiative (LtxRI)
The original name for the Great Lakes Toxics Reduction Effort.

Great Lakes Water Quality Advisory Board
A binational advisory group to the International Joint Commission to assist in evaluating progress by Canada and the U.S. in accomplishing the Great Lakes Water Quality Agreement goals and to make recommendations regarding the development and implementation of programs. Related programs: Great Lakes Water Quality Agreement, International Joint Commission.

Great Lakes Water Quality Agreement (GLWQA)
An international agreement signed by the United States and Canada in 1972 and updated in 1978 and in 1987. The Agreement seeks to restore and maintain full beneficial uses of the Great Lakes system. Language committing the two nations to virtually eliminate the input of persistent toxic substances in order to protect human health and living aquatic resources was included when the

agreement was updated in 1978. The philosophy adopted by the two governments is zero discharge of such substances. Related programs: Lakewide Management Program, Remedial Action Plans.

Great Lakes Water Quality Guidance (GLWQG)
See Water Quality Guidance for the Great Lakes System and the Great Lakes Initiative. Related programs: Great Lakes Toxic Reduction Initiative, Clean Water Act.

Great Lakes Water Quality Initiative (GLWQI)
A federal program initiated in 1989 by the EPA and the Great Lakes states to further address the environmental concerns identified in the Great Lakes Toxic Substances Control Agreement. The GLWQI was intended to provide a forum for the Great Lakes states and the EPA to develop uniform water quality criteria and implementation procedures for the Great Lakes basin so as to create an even playing field for all industries in the region. This was proposed in 1993 as the Water Quality Guidance for the Great Lakes System. Related programs: Great Lakes Toxic Reduction Initiative, Great Lakes Initiative.

Great Waters Program
This program was mandated by Title III of the 1990 Clean Air Act Amendments to assess the extent of atmospheric deposition of hazardous air pollutants to the Great Lakes and other designated waters. It includes setting up the Great Lakes Atmospheric Deposition Network and reporting the monitoring results from the network to investigate sources and deposition rates of air toxics, to find out what proportion of pollutants come from the atmosphere, and to evaluate any harmful effects to public health or the environment. Related program: 1990 Clean Air Act Amendments.

Great Waters Study
See Great Waters Program.

Ground Water
Water that occurs beneath the ground surface in soils and geologic formations.

Half-Life
The period of time necessary for one half of a substance introduced to a living system or ecosystem to be eliminated or disintegrated by natural processes.

Hazardous Air Pollutants (HAPs)
Any air pollutant listed as such in Title III of the 1990 Clean Air Act Amendments. These are chemicals that have the potential to cause serious health effects. HAPs are released by mobile sources and industrial sources. Also referred to as air toxics. Related program: Clean Air Act.

Hazardous Waste
A waste which, because of its quantity, concentration, or characteristics, may be hazardous to human health or the environment when improperly treated, stored, transported, or disposed. Specific definitions of hazardous waste vary by statute or regulation.

Heavy Metals
Metallic elements with relatively high atomic weights that can contaminate ground water and

surface waters, wildlife, and food. Heavy metals have the potential to be toxic at relatively low concentrations. Examples include arsenic, cadmium, chromium, copper, lead, mercury, selenium, and zinc.

Hexachlorobenzene (HCB)
A critical pollutant once used as a pesticide for grain protection until banned by the U.S. in 1976. It is still produced as a byproduct during the manufacture of other chlorinated hydrocarbons. It is a persistent toxic substance and is found in the tissues of fish, animals, and humans from the Great Lakes basin. Limited uses of HCB are still permitted. Related program: Binational Program.

House Great Lakes Task Force
A bipartisan coalition of U.S. Representatives from Great Lakes states that works to advance the economic and environmental health of the Great Lakes region.

Human Health Criteria
These are descriptive or numeric expressions that specify how much of a pollutant can be allowed in a water body and still allow for the protection of human health. *See also* water quality criteria. Related program: Great Lakes Initiative.

Hydric Soils
Soils that are saturated, flooded, or ponded long enough during the growing season to develop anoxic conditions in the upper part of the soil profile.

Hydrocarbons
A class of compounds that contain hydrogen and carbon. This group of compounds includes the naturally occurring hydrocarbons produced by plankton, as well as many petroleum-based products like gasoline and motor oil. Chlorinated hydrocarbons, a subclass of hydrocarbons, are human derived and generally toxic.

Hydrophytic Vegetation
Plant life capable of growing in wet conditions, such as in water or in soil or other substrate that is periodically saturated with water. The presence of hydrophytic plants is one of the indicators used in wetland identification and delineation. Related programs: Wetlands Conservation Act, Wetlands Conservation Act Rules.

Individual Permit
An Army Corps of Engineers permit that is issued following a case-by-case evaluation of an application to perform dredge or fill activities in the waters of the U.S., including wetlands. Related programs: Section 404, 33 CFR.

Industrial Waste
Any liquid, gaseous, or solid waste resulting from any process of industry, manufacturing, trade, or business or from the development of any natural resource.

Inflow and Infiltration (I and I)
The penetration of water from the soil into sewer or other pipes through defective joints or connections and/or the penetration of water through the ground surface into the subsurface soil.

Institute for Lake Superior Research (ILSR)
Original name for the Large Lakes Observatory.

Intake Credits
A process that allows a point source discharger to take into account the quality of its source water when determining its effluent limitation standards.

Integrated Great Lakes Atmospheric Deposition Network (IGLADN)
A joint effort of the U.S. and Canada to measure atmospheric deposition of toxic material to the Great Lakes. It was mandated by the Great Lakes Water Quality Agreement. The network also fulfills the requirements of the Great Waters Program mandated by the 1990 Clean Air Act Amendments calling for a Great Lakes atmospheric deposition network. One master sampling station was installed at each of the Great Lakes by the end of 1991 to monitor for deposition of selected toxic pollutants, including mercury. Related program: Great Lakes National Program Office.

Integrated Pest Management (IPM)
A management system that uses all suitable techniques in an economical and ecologically-sound manner to reduce pest populations and maintain them at levels that do not have an economic impact, while minimizing danger to humans and the environment.

International Association for Great Lakes Research (IAGLR)
An international association of scientists that studies the world's large lakes. They publish a research periodical called the Journal of Great Lakes Research and hold yearly meetings within the Great Lakes basin.

International Joint Commission (IJC)
An international organization formed by Canada and the United States in 1909 as a result of the Boundary Waters Treaty to assist in preventing disputes and resolving issues involving all water bodies shared by the U.S. and Canada and to make recommendations about their management, particularly water quality issues and the regulation of water levels. Three commissioners are appointed by each country. Under the Great Lakes Water Quality Agreement, the IJC is also required to monitor progress by Canada and the United States as the two countries implement the goals and objectives of the Agreement. The IJC analyzes and publishes data, provides advice and recommendations and undertakes other initiatives as requested. Two advisory boards, the Great Lakes Water Quality Advisory Board and the Science Advisory Board, exist to assist the Commission with the Agreement-related responsibilities. Related program: Great Lakes Water Quality Agreement

Interstate Waters
Rivers, lakes, and other waters that flow across state or international boundaries. These include waters of the Great Lakes.

Invertebrates
The classification for animals that do not have a backbone or internal skeleton. *See also* zooplankton and benthic invertebrates.

Lacey Act
This act, enforced by the U.S. Fish and Wildlife Service, is designed to control environmental releases of injurious fish and wildlife. This law includes species that threaten non-agricultural interests.

Lake Carriers Association
This organization, established in 1880, represents U.S. maritime shipping companies throughout the Great Lakes. Its mission includes safe, efficient shipping procedures; Great Lakes shipping statistics; consultation on ice-breaking issues; harbor and channel dredging; sediment disposal; and environment and commerce regulations and legislation.

Lake Michigan Mass Balance Study (LMMB)
This mass balance research project begun in 1994 is part of the Lake Michigan Lakewide Management Plan and is designed to develop a sound, scientific base of information that will guide future toxic pollutant load reduction and prevention activities. Related Programs: Great Lakes Toxic Reduction Effort, Lakewide Management Plan, Clean Air Act, Clean Water Act.

Lake Superior
At the head of the Great Lakes system, Superior is the world's largest freshwater lake by surface area and long considered the cleanest and most pristine of the Great Lakes. Industrial activity, shipping, and atmospheric inputs of persistent and bioaccumulative toxic substances have raised concerns about the lake's water quality.

Lake Superior Basin
Used to describe Lake Superior and the surrounding watersheds emptying into the lake.

Lake Superior Binational Forum
This international program consists of a cross-section of basin stakeholders, including representatives from environmental and native groups, industries, and municipalities in the Lake Superior basin. It provides citizen input into the Binational Program concerning reductions in the use and discharge of toxic substances into the basin. The Forum identifies barriers to reductions in pollutant use and proposes alternatives for overcoming those barriers. Related Program: Binational Program

Lake Superior Binational Program to Restore and Protect the Lake Superior Basin
See Binational Program.

Lake Superior Biosphere Reserve
An international undertaking that would identify portions of the lake for special protection or study. Proposals to create a binational Lake Superior Biosphere Reserve as part of the United Nations Man and the Biosphere program are under review by the United States and Canada.

Lake Superior Center (LSC)
An education/exhibition facility on freshwater systems and Lake Superior, located in Duluth, Minnesota. Home of Superior Lakewatch.

Lake Superior Lakewide Management Plan (LaMP)
A binational plan to address threats to the Lake Superior ecosystem. The LaMP embodies a

systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses. It is being developed in four stages. LaMP Stages 1 and 2 have been completed for the chemical portion of the LaMP. The Stage I LaMP (completed in September 1995) applies only to the nine designated critical pollutants from the zero discharge demonstration program for point source discharges. The Stage 2 LaMP (completed in July 1999) sets remediation goals or load reduction schedules for the nine virtual elimination pollutants identified in the Stage 1 LaMP. The Stage 3 LaMP (released for public comment in November 1999) selects pollutant load reduction strategies and remedial actions with respect to the nine virtual elimination pollutants. LaMP 2000 reflects the state of knowledge and progress of the LaMP at that time. The LaMP process will be an iterative process from 2000 forward and the LaMP will be updated biennially. *See also* State of the Lake Superior Basin Reporting Series. Related programs: Great Lakes Water Quality Agreement, Binational Program.

Lake Superior Partnership
A partnership between the state of Minnesota and the Western Lake Superior Sanitary District in Duluth that conducts multi-media inspections to insure compliance and identify pollution prevention opportunities for dischargers.

Lake Superior Pollution Prevention Strategy (P2 Strategy)
A federal/state action plan consisting of recommendations for achieving the goal of eliminating pollution at its source and evaluating recycling, treatment, and disposal options where source reduction is not possible. The focus of the Pollution Prevention Strategy is the nine critical pollutants identified by the Zero Discharge Demonstration Program. Commonly called the P2 strategy. Related programs: Binational Program, Great Lakes National Program Office.

Lake Superior Pollution Prevention Team
An organization that developed the Lake Superior Pollution Prevention Strategy. The team is made up of regulatory staff from Minnesota, Michigan, Wisconsin, and the Great Lakes National Program Office. Related program: Binational Program.

Lake Superior Project
An EPA-administered program that establishes a strategy and implementation plan for pollution prevention technical assistance for small and medium-sized businesses in the Lake Superior basin. Related program: Council of Great Lakes Governors.

Lake Superior Research Institute (LSRI)
A University of Wisconsin-Superior center that conducts research and education specifically on Lake Superior. Originally called the Center for Lake Superior Environmental Studies. Related program: University of Wisconsin-Superior.

Lake Superior Task Force
An international organization made up of the senior managers who developed the Binational Program to Restore and Protect Lake Superior and who continue to provide direction to the Superior workgroup of the Binational Program.

Lakewatch Program
See Superior Lakewatch.

Lakewide Management Plan (LaMP)
The binational programs called LaMPs provide a process for coordinating and prioritizing activities designed to reduce loadings of critical pollutants. The emphasis is on identifying the major sources of these pollutants and concentrating regulatory efforts where they will have the most impact. LaMPs are being developed for each of the Great Lakes. *See also* Lake Superior LaMP.

Large Lakes Observatory (LLO)
This University of Minnesota organization established in 1994 supports and performs research on large lakes of the world, including Lake Superior. It was formerly called the Institute for Lake Superior Research. Related program: University of Minnesota.

Leachate
The contaminated liquid resulting from water seeping through a landfill or other materials. Chemicals such as fertilizer are leached from the soil when rainwater travels through the soil.

Legislative Commission on Minnesota Resources (LCMR)
The LCMR recommends funding for natural resource programs to be financed by the Minnesota Future Resources Fund, the Minnesota Environment And Natural Resources Trust Fund, and Federal Oil Overcharge Funds. Funds have been used for a number of projects related to Lake Superior, such as public boat access improvement.

Lethal Concentration 50% (LC50)
A statistically or graphically estimated concentration that is expected to be lethal to 50% of a group of organisms under specified conditions.

Lethal Dose 50% (LD50)
A statistically or graphically estimated dose that is expected to be lethal to 50% of a group of organisms under specified conditions.

Levels Reference Study
A report that suggested methods to alleviate the adverse consequences of fluctuating water levels in the Great Lakes-St. Lawrence River System. The Levels Reference Study Board, appointed by the International Joint Commission, completed the report in 1993 after an intensive public involvement process in the U.S. and Canada.

Limited Resource Value Waters
Surface waters in Minnesota which are of limited value as a water resource and where water quantities are intermittent. These waters are protected to allow secondary body contact use, to preserve the ground water for use as a drinkable water supply, and to protect aesthetic qualities of the water. Related program: Minnesota Rule Chapter 7050.

Limnology
The scientific study of freshwater, especially the history, geology, biology, physics, and chemistry of lakes.

Load
An amount of water, sediment, nutrients, pollutants, heat, etc. that is introduced into a receiving

water. Loading may be either of anthropogenic origin (pollutant loading) or natural (natural background loading). Related programs: Water-related Code of Federal Regulations (parts in chapter 40 of the CFR), Clean Water Act, MN Rule Chapter 7050.

Load Allocation (LA)
The portion of a receiving water's load capacity that is attributed either to nonpoint sources of pollution or to natural background sources. Load allocations are best estimates depending on the availability of data and prediction techniques. Wherever possible, natural and nonpoint source loads are distinguished. Related program: Water-related Code of Federal Regulations (parts in chapter 40 of the CFR).

Load Capacity
The greatest amount of load that a water body can receive without violating water quality standards. Related programs: Water-related Code of Federal Regulations (parts in chapter 40 of the CFR), federal and state statutes.

Local Governmental Unit (LGU)
A county board, joint county board, watershed management organization, watershed district or a township, or city. Related programs: Wetlands Conservation Act, Wetlands Conservation Act Rules.

Lowest Observable Effect Concentration (LOEC)
For toxic substances, it is the lowest tested concentration at which adverse effects are observed in aquatic organisms at a specific time of observation.

Macrophytes
This term literally means "large plant." Usually refers to rooted, seed-producing aquatic plants.

Management Measures (MM)
A management measure is an economically achievable way to control the addition of pollutants from existing and new nonpoint sources. These measures call for the best available nonpoint pollution control practices, technologies, processes, site specific criteria, operation methods, or other alternatives. Related programs: Coastal Zone Management Act, Clean Water Act.

Mass Balance
A scientific approach that studies the sources, movement, and destination of any substance, for example a contaminant, that enters a lake system. A mass balance budget for a particular pollutant is the amount that enters a lake minus the amount that is tied-up in the sediment, broken down by chemical or biological processes, or removed by some other means. This should equal the amount that flows out of the lake system. This exercise enables scientists to assess the possible long-term effects of a pollutant and possible remediation actions. *See also* Lake Michigan Mass Balance Study. Related programs: Great Lakes Toxic Reduction Effort, Lakewide Management Programs.

Mercury (Hg)
A heavy metal, mercury is a neurotoxin that is toxic if breathed or ingested at sufficiently high concentrations. Mercury is present naturally in the environment. It has commonly been used in a wide variety of applications including thermometers, fluorescent bulbs, mirrors, hide

preservation, paints, plastic coloring, inks and stains, and golf course pesticides. Because of its common use, mercury is released during garbage incineration. It is also released through the combustion of fuels such as coal and wood for energy production. Mercury readily bioaccumulates in all aquatic organisms, especially fish and shell fish and in humans and wildlife that consume fish. Many lakes in the Great Lakes region have fish consumption advisories due to high levels of mercury primarily caused by atmospheric deposition. Mercury is one of the nine critical pollutants addressed by the Lake Superior LaMP. Related program: Binational Program.

Mesotrophic
A term used to describe a lake of moderate primary productivity. *See also* eutrophic and oligotrophic.

Mid-Continent Ecology Division (MED)
The EPA's freshwater ecology and water pollution research laboratory in Duluth, Minnesota. Established in 1967, the lab develops methods for predicting and assessing the effects of pollutants on freshwater resources. It is also involved in Great Lakes research, such as work in food chain contaminants, modeling, coastal wetlands, and the Environmental Monitoring and Assessment Program. MED was formerly called the Environmental Research Lab-Duluth. Related program: Environmental Protection Agency.

Minnesota Acid Deposition Control Act
A Minnesota law passed in 1982 that required the MPCA to (1) identify the areas of the state containing resources sensitive to acid deposition, (2) develop a standard to protect these resources, (3) adopt a control plan to reduce sulfur dioxide emissions, and (4) ensure that all Minnesota emission sources subject to the control plan were in compliance by January 1, 1990.

Minnesota Air Toxics Strategy
A program developed by the Minnesota Pollution Control Agency to help achieve smooth, fair implementation of air toxics provisions of the 1990 Clean Air Act Amendments, protection of public health and the environment, and the collection of air toxics information. The strategy mirrors the federal program somewhat, but has not gone through rule-making. It is a shift in focus for the state away from air toxics rules.

Minnesota Department of Health (MDH)
The state agency responsible for human health protection in Minnesota. Among other duties, the MDH prepares the fish consumption advisory each year and establishes drinking water standards.

Minnesota Department of Natural Resources (MN DNR, DNR)
A Minnesota state agency responsible for the management of the state's timber, waters, minerals, and wildlife. The Department is organized by division according to the resources it manages: forestry, fish and wildlife, parks and recreation, minerals, trails and waterways, enforcement, and waters.

Minnesota Environmental Response and Liability Act (MERLA)
This Minnesota state legislation was patterned after the Comprehensive Environmental Response, Compensation, and Liability Act, and provides the state with the authority to deal with uncontrolled releases of hazardous substances to the environment (MN Statute 115B).

Minnesota Interagency Exotic Species Task Force Committee
Established by Minnesota state legislation in 1989, this task force established a state-wide communications network between agencies that are involved with regulations, management, research, technical assistance, public awareness, and educational programming regarding potential and existing exotic species.

Minnesota Pollution Control Agency (MPCA, PCA)
A Minnesota state agency responsible for setting standards and authorizing permits for air quality, solid waste, hazardous waste disposal, water quality, and noise pollution. The focus of the MPCA is on compliance to these standards through technical assistance, education, and information. The agency is organized into four major divisions: air quality, water quality, ground water and solid waste, and hazardous waste.

Minnesota Rule Chapter 6280
A Minnesota rule that requires permits for activities which are meant to control aquatic plants and submerged vegetation. These rules are administered by the MN DNR.

Minnesota Rule Chapter 7001
A Minnesota state regulation that contains the permit process and permit requirements for hazardous waste facilities, National Pollutant Discharge Elimination System, and water quality certification (Section 401 Certification). This regulation is administered by the MPCA. Related program: Clean Water Act.

Minnesota Rule Chapter 7007
A Minnesota state regulation that contains requirements for a facility to obtain an air emission facility permit. It is administered by the MPCA. Related program: Clean Air Act.

Minnesota Rule Chapter 7009
A Minnesota state regulation that contains the state ambient air quality standards and methods of measurement to meet those standards. The programs are administered by the MPCA. Related program: Clean Air Act.

Minnesota Rule Chapter 7021
The Minnesota rule that includes the acid deposition standard and control requirements which apply to the electric power generating utilities. Also known as the Minnesota Acid Deposition Control Rule. The rule is administered by the MPCA. Related program: Clean Air Act.

Minnesota Rule Chapter 7050
A Minnesota rule that sets standards for protecting the quality and purity of the waters of the state. These standards are administered by the MPCA. Related program: Clean Water Act.

Minnesota Rule Chapter 7060
A Minnesota rule that protects and preserves the underground waters of the state. This rule is administered by the MPCA.

Minnesota Rule Chapter 8420
A Minnesota rule that identifies replacement plan criteria for wetland drain and fill activities

which require mitigation under the Wetland Conservation Act. These rules are administered by the Board of Water and Soil Resources. Related program: Wetland Conservation Act Rules.

Minnesota Sea Grant (Sea Grant)
This University of Minnesota-based program supports research, extension, and education about Lake Superior, the other Great Lakes, and inland waters of Minnesota, making research accessible to citizens, resource managers, and policy makers. Related programs: National Oceanic and Atmospheric Administration, National Sea Grant College Program.

Minnesota Toxic Pollution Prevention Act (TPPA)
State legislation passed into law in 1990, this act creates policies and sets up ways to prevent the release of toxic pollutants into the environment by reducing or eliminating toxic pollutants at their source through pollution prevention.

Mitigation
See wetland mitigation.

Mixing Zone
A limited area or volume of water where initial dilution of a point source pollutant discharge takes place. The zone is extended to cover the secondary mixing in the surrounding waterbody. Numeric water quality criteria can be exceeded, but acutely toxic conditions are prevented from occurring in this zone. Related programs: Clean Water Act, National Pollutant Discharge Elimination System.

Multi-media Inspections
These are inspections of a discharger's effect on water and air quality and the generation of solid waste. Related program: Western Lake Superior Sanitary District.

Multi-media Risk
The human health risk due to exposure to a pollutant through all pathways, such as inhalation, ingestion, or skin contact.

Municipal Industrial Strategy for Abatement (MISA)
A program initiative of the province of Ontario intended to reduce water pollution.

Mutagen
A substance that is known or suspected to cause mutations.

Mutation
A permanent change in the hereditary material involving a physical change in chromosomes or genes.

Nation's Waters
See Waters of the United States.

National Ambient Air Quality Standards (NAAQS)
Standards that EPA sets under the Clean Air Act to protect public health with an adequate margin of safety (primary standards) and to protect the environment (secondary standards). These

standards apply to sources that emit pollutants into the atmosphere. Related program: Clean Air Act.

National Environmental Policy Act (NEPA)
A federal law passed in 1990 that promotes efforts to prevent or eliminate damage to the environment and biosphere and stimulates the health and welfare of people. It established a Council on Environmental Quality. It is comprised of two Titles: Title I - Declaration of National Environmental Policy; Title II - Council on Environmental Quality.

National Oceanic and Atmospheric Administration (NOAA)
A federal agency, NOAA's mandate is to conserve and manage wisely the nation's coastal and marine resources, and describe and predict changes in the earth's environment to ensure sustainable economic opportunities. NOAA administers the National Sea Grant College Program, National Underseas Research Program, National Marine Fisheries Service, National Coastal Resources Research and Development Institute, National Weather Service, and others.

National Park Service (NPS)
An agency of the U.S. Department of the Interior that manages the national park system. Active participant in the Binational Program.

National Pollutant Discharge Elimination System (NPDES)
Federal regulations that constitute the national program for issuing, modifying, revoking, re-issuing, terminating, monitoring and enforcing permits, and enforcing pretreatment requirements for point source discharges to surface waters under the Clean Water Act, Section 402. Related programs: Clean Water Act, 40 CFR.

National Priorities List (NPL)
A list of inactive, hazardous waste sites designated under Superfund as needing long-term remedial actions. Currently, there are about 1,200 sites on the NPL. Related program: Comprehensive Environmental Response, Compensation, and Liability Act.

National Sea Grant College Program (NSGCP)
A nation-wide partnership with public and private sectors combining research, education, and technology transfer for public service. A national network of universities meeting changing environmental and economic needs of people, industry, and government in coastal, ocean, and Great Lakes states. The program is administered by National Oceanic and Atmospheric Administration. *See also* Minnesota Sea Grant. Related program: National Oceanic and Atmospheric Administration.

Nationwide Permit (NWP)
A type of general permit issued by the Army Corps of Engineers allowing certain activities to take place in the waters of the U.S. If certain conditions are met, the specified activities can take place without the need for an individual or regional permit. Related programs: Section 404, 33 CFR.

Natural Resources Conservation Service (NRCS)
A federal agency within the United States Department of Agriculture that provides technical assistance to land users in cooperation with other federal, state, and local agencies in carrying out

a variety of natural resources-related programs designed to promote protection and wise use of these resources on private lands. Formerly the Soil Conservation Service.

Natural Resources Research Institute (NRRI)
A University of Minnesota research institute established in 1983 by the Minnesota legislature to foster economic development of Minnesota's natural resources in an environmentally-sound manner and promote private sector employment. *See also* Center for Water and the Environment. Related program: University of Minnesota.

Naturalized Species
An intentionally or unintentionally introduced species that has adapted to and reproduces successfully in its new environment. Some Great Lakes examples include the rainbow smelt, the alewife, and some salmon and trout species.

Navigable Waters
Navigable waters of the United States are waters subject to the ebb and flow of the tide and/or used to transport interstate or foreign commerce. Once the determination of navigability is made, it applies over the entire surface of the water body, and is not changed by later actions or events which impede or destroy navigable capacity. Also referred to as waters of the U.S. Related program: 33 CFR.

Neurotoxin
A substance that is known or suspected to be poisonous to nerve tissue.

Nitrogen Oxides (NOx)
Pollutants that can be a component of smog and also can contribute to acid rain. One of the criteria pollutants regulated by the 1990 Clean Air Act Amendments. Sources include automobiles and industrial point sources.

No Net Loss
A federal and Minnesota state policy to achieve no overall net loss of the nation's remaining wetlands base as defined by acreage and function and to restore and create wetlands where feasible, to increase the quality and quantity of the nation's wetland resource base. Related programs: Wetland Conservation Act, Section 404.

No Observable Effect Concentration (NOEC)
For toxic substances, it is the highest tested concentration at which no adverse effects are observed in an aquatic organism at a specific time of observation.

Non-Chemical Stressors
Physical and biological factors that can impact water quality or ecosystem health. Examples include heat, sediment, and non-indigenous species.

Non-Indigenous Aquatic Nuisance Prevention and Control Act of 1990
A federal law to prevent the unintentional introduction and dispersal of non-indigenous species into the waters of the U.S. The act mandates the establishment of: a national ballast water control program; the Aquatic Nuisance Species Task Force; initial research funding; technical assistance and education for federal and state agencies; state management plans; and grant

programs to prevent, monitor, and control the spread of zebra mussels and other exotic species. It also provides for the establishment of regulations that control the introduction of and dispersal of these organisms. *See also* aquatic nuisance species.

Non-Indigenous Species
Those species found beyond their natural ranges or natural zone of potential dispersal. Also referred to as exotic species. *See also* aquatic nuisance species.

Nonpoint Source
See nonpoint source pollution.

Nonpoint Source Pollution (NPS)
Pollution where the sources cannot be traced to a single, distinct, identifiable point. Nonpoint source pollution can come from atmospheric deposition, erosion, and runoff from parking lots, farms, and streets.

North Shore Management Board (NSMB)
A Minnesota joint powers board that represents local governments in decisions about coastline management on Minnesota's north shore. The board implements the North Shore Management Plan.

North Shore Management Plan (NSMP)
A Minnesota plan for the environmental protection and orderly growth of the north shore of Lake Superior developed by the residents of the area. Consists of several planning elements, each dealing with an area needing special attention, such as shoreland management, harbors of refuge, transportation, recreation, tourism, and economic development.

Northeast Minnesota Waste Exchange (NMWE)
A local program administered by the Western Lake Superior Sanitary District, this organization recycles household waste such as paint. Its primary effort is aimed at getting businesses that have unwanted products in touch with potential users of those products. Related program: Western Lake Superior Sanitary District.

Northeastern Minnesota Environmental and Economic Council (NEMEEC)
An organization of northeastern Minnesota citizens formed in the 1970's in response to the potential for Minnesota's enrollment in the federal Coastal Zone Management Program. NEMEEC's approach is to ensure that CZM does not ignore or hamper economic development.

Nutrients
Elements or compounds essential as raw materials for organism growth and development, such as carbon, nitrogen, and phosphorus.

Octachlorostyrene (OCS)
A toxic substance and critical pollutant that is a by-product of high temperature industrial processes involving chlorine. Like dioxin, OCS is not produced intentionally. Release to the environment occurs in effluent from chlorine and gas production, aluminum smelting, and other metal production. OCS has been found in leachate from industrial landfills and fly ash from waste incinerators. Related program: Binational Program.

Oligotrophic
Refers to an unproductive, nutrient poor lake that typically has very clear water. Lake Superior is classified as an ultra-oligotrophic lake.

Ontario Federation of Anglers and Hunters (OFAH)
An Ontario conservation organization that promotes sustainable use of natural resources by providing boater education programs on exotic species, fish, wildlife, forestry research and management, and timber management policy.

Ontario Ministry of Natural Resources (OMNR)
This provincial agency is responsible for management of Canadian waters of the Great Lakes to help sustain a healthy ecosystem. Responsibilities of the OMNR include: coordinating resource planning with other entities; protecting and enhancing biological resources; managing fish harvest; protecting and rehabilitating habitat and fish communities; enforcing legislation; increasing public awareness of exotic species through educational programming; and monitoring ecosystem health through assessment and research programs.

Ordinary High Water Mark (OHW)
The elevation marking the highest water level which has been maintained for a sufficient time to leave evidence upon the landscape. Defined in Minnesota statutes as the boundary of protected waters. Generally, it is the point where the natural vegetation changes from predominately aquatic to upland species. For streams, the OHW is generally the top of the bank of the channel. The OHW is the elevation from which building and sewage setbacks are measured. OHWL means the ordinary high water level.

Organic Chemicals
Nearly all of the millions of compounds that contain carbon atoms are organic chemicals. More than 90% of all known compounds are organic. The few carbon compounds that are not considered organic include carbon dioxide and bicarbonate. Hydrocarbons like methane are simple organic chemicals that contain only hydrogen and carbon. Other organic chemicals include most pesticides and chemicals based on benzene.

Outfall
The location or structure where wastewater or drainage empties into the surface water from a sewer, drain, or other conduit.

Outstanding International Resource Waters (OIRW)
This proposed designation by the Binational Program and the Great Lakes Initiative would protect the entire Lake Superior basin from new or expanded point source discharges of persistent toxic substances.

Outstanding National Resource Waters (ONRW)
This proposed designation contained in the Clean Water Act Reauthorization would establish special areas within the U.S. portion of the Lake Superior basin where new or expanded point source discharges of persistent toxic substances would be prohibited as part of the Binational Program and Great Lakes Initiative. *See also* MN Rule Chapter 7050. Related program: Clean Water Act.

Outstanding Resource Value Waters (ORVW)
Waters of the state of Minnesota with high water quality, wilderness characteristics, unique scientific or ecological significance, exceptional recreation value, or other special qualities that warrant stringent protection from pollution. *See* MN Rule Chapter 7050.

Ozone
A pollutant formed in the lower atmosphere by the reaction of nitrogen oxides and hydrocarbons in sunlight, commonly called smog, for which National Ambient Air Quality Standards have been established. Ozone is also found naturally in the upper atmosphere where it acts as a protective filter, screening out ultra-violet rays.

PAHs
See Polycyclic Aromatic Hydrocarbons.

Part 70 Permit
A federal regulation that defines the requirements for permitting facilities for air emissions. States with federally-approved permit programs administer the permitting of facilities within their state. Related programs: Minnesota Rule Chapter 7007, 1990 Clean Air Act Amendments.

Particulates
Very small separate particles composed of organic or inorganic matter.

Parts per Billion (ppb)
The number of parts of a substance per billion parts of another substance into which it is combined. Often expressed as micrograms per liter for water and micrograms per kilogram for fish and sediments.

Parts per Million (ppm)
The number of parts of a substance per million parts of another substance into which it is combined. Often expressed as milligrams per liter water or milligrams per kilogram for fish tissue and sediments.

Parts per Thousand (ppt)
The number of parts of a substance per thousands parts of another substance into which it is combined. Often expressed as grams per liter of water or grams per kilogram for fish tissue and sediments.

Periphyton
Algae that grow attached to surfaces such as rocks or larger plants.

Persistent Toxic Substance
A toxic pollutant that remains in the environment for a substantial period of time, potentially causing injury to ecosystem health.

pH
A numeric value that indicates relative acidity and alkalinity on a scale of 1 to 14. A pH of 7.0 is neutral, higher values indicate increasing alkalinity; lower values indicate increasing acidity.

Phytoplankton
Algae that grow suspended in the water column or open waters of a lake.

Plankton
A term used to describe bacteria, tiny plants (phytoplankton), and animals (zooplankton) that live in the water column of lakes.

Point Source
See point source pollution.

Point Source Pollution
Pollution from a distinct, identifiable source, such as a pipe, smokestack, or exhaust.

Pollutant
Chemicals or refuse material released into the atmosphere, water, or onto the land.

Pollution Prevention (P2)
This is defined in the Minnesota Toxic Pollution Prevention Act as eliminating or reducing at the source the use, generation, or release of toxic pollutants. Methods of reducing pollution include, but are not limited to, industrial process modification, inventory control measures, feedstock substitutions, various housekeeping and management practices, and improved efficiency of machinery. The federal version of this term is source reduction.

Pollution Prevention Act of 1990
A federal law that establishes a national policy of pollution prevention, and requires the EPA to develop and implement a strategy to promote source reduction. This act declares as national policy that pollution prevention is the preferred approach to environmental protection.

Polychlorinated Biphenyls (PCBs)
One of the nine critical pollutants, PCBs are a group of over 200 nonflammable compounds formerly used in heating and cooling equipment, electrical insulation, hydraulic and lubricating fluids, and various inks, adhesives, and paints. These compounds are highly toxic to aquatic life, persist in the environment for long periods of time, and are bioaccumulative. PCBs are suspected carcinogens, and are linked to infant development problems. Fish from some lakes and streams in Minnesota contain measurable amounts of PCBs. *See also* Fish Consumption Advisory. Related program: Binational Program.

Polycyclic Aromatic Hydrocarbons (PAHs)
A family of organic chemicals based on the chemical structure of benzene which result from incomplete combustion of organic chemicals and are associated with grease and other components derived from petroleum byproducts. Some examples of the many PAH compounds include: benzo(a)anthracene, benz(b)fluoranthene, benzo(a)pyrene, chrysene, phenanthrene, and pyrene.

Pretreatment
Partial wastewater treatment required for some industries. Pretreatment removes some types of industrial pollutants before the wastewater is discharged to a municipal wastewater treatment plant.

Primary Productivity
The amount of production of living organic material through photosynthesis by plants, including algae, measured over a period of time.

Primary Treatment
The first step in wastewater treatment in which most of the debris and solids are removed mechanically.

Priority Pollutants
Pollutants identified in certain federal and state regulations. Priority pollutants have different definitions in air, water, and waste programs.

Program Office
See Great Lakes National Program Office.

Protected Waters
Minnesota waters of the state identified as public waters or wetlands under Minnesota statutes.

Public Waters
Generally, public waters are water bodies determined by Minnesota statutes to have significant public value. They are controlled by the state.

Public Waters Wetlands
A class of wetlands defined by the state of Minnesota as public waters deserving of a certain level of protection under the Wetland Conservation Act. These include all Types 3, 4, and 5 wetlands, as defined in U.S. Fish and Wildlife Service Circular No. 39 (1971 edition), that are ten or more acres in size in unincorporated areas, or 2-1/2 or more acres in size in incorporated areas.

Publicly Owned Treatment Works (POTW)
Any device or system that is used in treatment, including recycling and reclamation, of municipal sewage. Related programs: Clean Water Act, 40 CFR.

Purple Loosestrife
A wetland plant from Eurasia that quickly invades water bodies, including the Great Lakes, forming dense stands unsuitable as cover, food, or nesting sites for fish, amphibians, waterfowl, and wildlife. Imported as an ornamental plant, it spread quickly across North America along roads, canals, and drainage ditches. Research on the use of European beetles that attack only purple loosestrife shows promise for biological control in North America.

Quagga Mussel
A close cousin to the zebra mussel, this exotic mussel was brought into the Great Lakes in the ballast water of transoceanic ships and is expected to have impacts similar to those of the zebra mussel. Although some evidence suggests that it prefers the deeper waters of the Great Lakes, it has, like the zebra mussel, quickly infested inland river systems. The name quagga comes from an extinct member of the zebra family.

Receiving Waters
Rivers, streams, lakes, or any body of water into which wastewater is discharged.

Region 5
The EPA's regional office that covers Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. Related program: Environmental Protection Agency.

Regional Environmental Monitoring and Assessment Program (REMAP)
Environmental Monitoring and Assessment Program work on a regional scale. The St. Louis River is a Great Lakes example of a REMAP study. Cooperators include MED, GLNPO, NRRI, MPCA, UWS, and EPA Region 5. Related programs: Environmental Protection Agency, Environmental Monitoring and Assessment Program.

Regional Permit
A type of general permit that may be issued by a division or district engineer (Army Corps of Engineers), after compliance with other procedures, for activities in navigable waters of the U.S. or wetlands. Related programs: Section 404, 33 CFR.

Regulation
Rules that outline specific procedures developed by federal or state agencies which are used to implement laws.

Remedial Action Plan (RAP)
These are federally-mandated local plans designed to restore environmental quality to Areas of Concern on the Great Lakes (there are 8 in Lake Superior and there were initially 43 throughout the Great Lakes). The Areas of Concern were identified for their persistent pollution problems. Remedial Action Plans were called for by a protocol added to the Great Lakes Water Quality Agreement in 1987. Related program: Great Lakes Water Quality Agreement.

Report to Congress on Toxic Air Deposition to the Great Waters
See Great Waters Study.

Residence Time
The time required for a water body to exchange its entire volume of water. Lake Superior takes about 173 to 191 years to flush its entire volume. This is an important factor used in determining the residence time of toxic pollutants in the lake. Also referred to as flushing time.

Resource Conservation and Recovery Act (RCRA)
A federal law that established a comprehensive cradle-to-grave system for regulating hazardous waste.

Riparian Area
Vegetated ecosystems found along any stream or river. These areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent water body.

Riprap
Rock or other large material that is placed to protect streambanks or lakeshores from erosion due to runoff or wave action.

Risk Assessment
A complex process by which scientists determine the harm that a substance, activity, lifestyle, or

natural phenomenon can inflict on human health or the environment. The process involves analyzing scientific data to describe the form, dimension, and characteristics of risk. Assessments are usually predictive estimates of how risky a particular situation is. *See also* risk management, ecological risk assessment, comparative risk analysis.

Risk Management
The process by which risk assessment results are used with other information to make regulatory decisions. Risk management asks, "What shall we do about this risk?" *See also* risk assessment and ecological risk assessment.

Risk Reduction
Anything, such as education, regulation, or remediation, that reduces the adverse effects of exposure to risks from a substance, activity, lifestyle, or natural phenomenon.

Rivers and Harbors Act of 1899
A federal statute that allows the Army Corps of Engineers to regulate the creation of obstructions and filling of navigable waters of the U.S.

River Watch
A citizen-based volunteer water monitoring, education, and outreach program on Lake Superior sponsored by the EPA. The primary emphasis of the program is to work with secondary school teachers and students to incorporate River Watch concepts into existing course curricula. *See also* St. Louis River Watch.

Ruffe
See Eurasian ruffe.

Ruffe Control Plan
The Ruffe Control Task Force Committee (appointed by the Aquatic Nuisance Species Task Force) developed this integrated plan encompassing the legal requirements mandated by the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 to control the Eurasian ruffe. The program provides assessment and control measures including range reduction by chemical treatments, prevention of ballast water transport, and monitoring and surveillance. The plan also emphasizes research and public education as essential components of a ruffe control effort.

Ruffe Control Task Force Committee
An organization representing academic, business, shipping, fisheries management, and fishing interests Great Lakes-wide that developed a five-part plan aimed at controlling the spread of ruffe to western Lake Superior. Chaired by the U.S. Fish and Wildlife Service, this task force was established in 1991 by the Great Lakes Fisheries Commission.

Rule
See Regulation.

St. Louis River Management Plan
A local management plan developed by the St. Louis River Board to provide adequate protection to the Whiteface, Cloquet, and St. Louis rivers ecosystems in the areas of land use, forestry management, and land acquisition. Once implemented, the plan will result in increased lot sizes,

a no-cut zone along the river corridor, mandated forestry management plans, and public purchase of 22,000 acres of river front land. Also known as the St. Louis, Cloquet, Whiteface Corridor Management Plan.

St. Louis River Remedial Action Plan (St. Louis River RAP)
A two-state (MN and WI) group representing industry, environmental groups, academic institutions, government, researchers, and community leaders coordinated by the MPCA and WDNR. The goal is to develop a plan to combat pollution sources and to protect natural areas on the St. Louis River, an Area of Concern and the largest U.S. tributary to Lake Superior. Related program: Remedial Action Plan.

St. Louis Riverwatch
A citizen-based water quality monitoring, outreach, and education program administered by the MPCA. Students and teachers from the communities along the river conduct water chemistry tests and survey the benthic invertebrate community as well as monitor frog populations and sediment toxicity. *See also* River Watch.

Science Advisory Board (SAB)
A binational advisory group that provides advice on the adequacy of Great Lakes science and research to the International Joint Commission and the Water Quality Board. The board is responsible for developing recommendations on all matters related to research and the development of scientific knowledge pertinent to the identification, evaluation, and resolution of current and anticipated problems related to Great Lakes water quality. Related programs: Great Lakes Water Quality Agreement, International Joint Commission.

Scientific and Natural Areas (SNA)
These are areas set aside to preserve the ecological diversity of Minnesota's natural heritage. They include landforms, fossil remains, plant and animal communities, rare and endangered species or other biotic features and geologic formations. The areas are preserved for scientific study and public edification as components of a healthy environment. The program is administered by the MN DNR, Division of Fish and Wildlife.

Sea Grant
See Minnesota Sea Grant and National Sea Grant College Program.

Sea Lamprey
An exotic, eel-like animal that attaches to fish with a sucking disk and sharp teeth. A native of the Atlantic Ocean, the lamprey made its way into all the Great Lakes following the opening of the Welland Canal in 1829 and its deepening in the 1900's. By the 1930's, sea lamprey were found in all of the Great Lakes. During the 1940's and 1950's, lamprey caused the collapse of lake trout, whitefish, and chub populations in all the Great Lakes with the exception of Lake Superior. It has been estimated that one sea lamprey can kill up to 40 pounds of lake trout during its lifespan. *See also* Sea Lamprey Control Program.

Sea Lamprey Control Program
The U.S. Fish and Wildlife Service and the Department of Fisheries and Oceans in Canada work together, under the direction of the Great Lakes Fishery Commission, to minimize sea lamprey

populations in the Great Lakes. Lamprey are controlled by applying a selective toxicant, TFM, to streams during the lamprey's most vulnerable life stage. Other control techniques include barriers, pheromone release, and sterilization of male lamprey.

Seaway Port Authority of Duluth
The Authority, consisting of seven members representing state, county, and city (Duluth) interests, promotes growth of international and domestic maritime commerce for Minnesotas World Port, and strives to strengthen the financial condition of the Port while enhancing the regional economy through industrial development and construction of port facilities. The Authority co-sponsored, along with the Lake Carriers Association, the Voluntary Ballast Water Exchange Plan for the Control of Ruffe in Lake Superior.

Secchi Disk Depth (SDD)
An estimate of the transparency of a lake, obtained by lowering a small (20 cm) disk into the water until it is no longer visible and noting the depth at which it disappears from view. Oligotrophic lakes are typically more transparent (and have a greater Secchi depth) than more productive, or eutrophic lakes. *See also* Superior Lakewatch.

Secondary Treatment
The second step in most publicly-owned treatment systems, where bacteria consume the organic parts of the waste.

Section 10
Refers to Section 10 of the federal Rivers and Harbors Act of 1899.

Section 118
A term used to refer to Section 118 of the federal Clean Water Act that identifies program requirements for the Great Lakes. Related program: Clean Water Act.

Section 305 (b)
The term refers to Section 305 (b) of the federal Clean Water Act, which requires a report on the status of fishable, swimmable waters. The states submit a biennial report to the EPA, which compiles the reports into a report to Congress. Related program: Clean Water Act.

Section 319
A term used to refer to Section 319 of the federal Clean Water Act that identifies the program requirement for nonpoint source management programs. Related program: Clean Water Act.

Section 401
A term used to refer to Section 401 of the federal Clean Water Act which requires water quality certification by the appropriate state agency, for example, the Minnesota Pollution Control Agency. Under Section 401, no federal permit to discharge pollutants into the waters of the U.S. is valid unless the state where the discharge occurs grants or waives its right to certify that the permit will not violate the state water quality standards. A federal agency cannot issue a permit when the state has denied water quality certification. Related program: Clean Water Act.

Section 402
A term used to refer to Section 402 of the federal Clean Water Act that identifies permit

requirements for point source discharges, known as the National Pollutant Discharge Elimination System. Related program: Clean Water Act.

Section 404
A term used to refer to Section 404 of the federal Clean Water Act that outlines permit requirements for dredging and other filling activities in waters of the U.S.. This is the primary federal law that regulates activities affecting wetlands. The Section 404 program is administered by the Army Corps of Engineers in accordance with the EPA. Related program: Clean Water Act.

Section 6217
A federal regulation that is a part of the Coastal Zone Act Reauthorization Amendments of 1990 entitled, Protecting Coastal Waters. This provision requires states with Coastal Zone Management Programs that have received federal approval under Section 306 of the Coastal Zone Management Act, to develop and implement Coastal Nonpoint Pollution Control Programs. These programs are to be used to control sources of nonpoint pollution which impact coastal water quality. Related programs: Coastal Zone Act Reauthorization Amendments of 1990, Coastal Zone Management Act.

Sediments
Soil particles that are or were at one time suspended in and carried by water as a result of erosion and/or resuspension. The particles are deposited in areas where the water flow is slowed such as in harbors, wetlands, and lakes.

Seiche
Seiches are lakewide displacements of water that are wind-induced. Water pushed by the wind can pile up on shore causing noticeable increases in water depth. When the wind is reduced the water mass continues to slosh back and forth like water in a bathtub. “The Seiche” is also the name of Minnesota Sea Grant’s quarterly newsletter.

Sequencing
A term used in wetlands regulations to define a process that involves avoiding, minimizing, and mitigating impacts. Related programs: Wetland Conservation Act, Wetland Conservation Act Rules.

Shorelands
Refers to Minnesota lands located 1000 feet from the ordinary high water level of a lake, pond, or flowage, and 300 feet from a river, stream, or the landward extent of floodplains.

Shoreland Management Program
A Minnesota program administered by a local government unit that meets minimum standards and criteria for the subdivision, use, and development of the shorelands of public waters.

Sigurd Olson Environmental Institute
A regional, private, non-profit organization of Northland College in Ashland, Wisconsin. Its mission is to protect environmental quality in the greater Lake Superior region and to build a future that is ecologically, socially, and economically sustainable.

Site-Specific Criteria
Water quality criteria that have been developed to be specifically appropriate to the water quality characteristics and/or species composition at a particular location. Related programs: Great Lakes Initiative, National Pollutant Discharge Elimination System.

Soil and Water Conservation Districts (SWCDs)
Local county units of government in Minnesota that assist landowners with implementation of soil and water conservation measures and practices. Related program: Board of Water and Soil Resources.

Soil Conservation Service (SCS)
See Natural Resources Conservation Service.

Source Reduction
A term that means reducing pollution at its source. It includes management systems, technologies, and other practices which reduce or eliminate the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment prior to recycling, treatment, or disposal. The term includes equipment or technology modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control. *See also* Pollution Prevention. Related programs: Pollution Prevention Strategy, Clean Water Act, Great Lakes Initiative.

Special Designation
As part of the Binational Program to Restore and Protect the Lake Superior Basin, governments are encouraged to make special designations which: favor zero discharge of human made toxins and protect and enhance the unique character and pristine nature of the lake basin. The U.S. policy on special designation includes enhanced anti-degradation approaches (including best available technology) for new or proposed expansions to facilities. Related program: Binational Program.

Standard
See water quality standard.

State Implementation Plan (SIP)
A state plan that sets out the process for complying with the Clean Air Act requirements. If approved by the EPA it will give the state the authority to run the federal clean air program for the state. Related program: Clean Air Act.

State of the Lake Superior Basin Reporting Series (SOTLSBRS)
A series of reports prepared by the Superior Work Group that will communicate progress on the Lake Superior Binational Program. When completed, the series will consist of 5 volumes.

- Vol I: Introduction to the Basin, Its Economy, and Its Inhabitants;
- Vol II: Lakewide Management Plan (Stages I-IV);
- Vol III: Lakewide Management Plan for Nonchemical Stressors;
- Vol IV: Ecosystem Principals and Objectives for Lake Superior; and

- Vol V: Comprehensive Management Plan to Protect the Lake Superior Ecosystem (an amalgamation of volumes I-IV).

Related programs: Lake Superior Binational Program, Great Lakes Water Quality Agreement.

State of the Lakes Ecosystem Conference (SOLEC)
A conference sponsored by Environment Canada and EPA, held every two years to review and make available information on the state of the chemical, physical, and biological integrity of the Great Lakes basin ecosystem. A major purpose of the conference is to cooperate in implementing the Great Lakes Water Quality Agreement by supporting better decision-making through improved availability of information on the condition of the living components of the system and the stresses which affect them. Working papers are prepared as background for the conference.

State Shoreland Management Plan
See Shoreland Management Program.

Statute
An enactment of the legislative body of a government that is formally expressed and documented as a law.

Storm Sewers
The underground infrastructure designed to collect storm runoff from urban areas which is typically not treated by sewage treatment facilities before being discharged into nearby surface waters. Storm sewer runoff has been found to be a major contributor to nonpoint source pollution in the Great Lakes.

Storm Water
Rainwater runoff, snow melt runoff, surface water runoff, and discharges that are collected by storm sewers. Related programs: National Pollutant Discharge Elimination System, CFRs, Minnesota Rules.

Stressor
Any chemical, physical, or biological entity that can induce adverse effects on individuals, populations, communities, or ecosystems.

Sulfur Dioxide (SO_2)
A chemical compound that when emitted to the atmosphere is considered to be a major component of acid rain. One of the criteria pollutants regulated by the 1990 Clean Air Act Amendments, SO_2 is emitted mainly by anthropogenic sources. Sources include industrial point sources, such as coal fired electric utilities.

Sunsetting
A process to restrict, phase out, and eventually ban the manufacture, generation, use, storage, discharge, and disposal of a persistent toxic substance.

Superfund
See Comprehensive Environmental Response, Compensation, and Liability Act, and Minnesota Environmental Response and Liability Act.

Superfund Amendment Reauthorization Act (SARA)
See Comprehensive Environmental Response, Compensation, and Liability Act

Superior Lakewatch
A binational organization coordinated by the Lake Superior Center, the Ontario Ministry of Environment and Energy, and the Sea Grant Offices of Michigan, Wisconsin, and Minnesota that offers volunteers the opportunity to help in monitoring the water quality of Lake Superior by measuring Secchi disk depth throughout the lake.

Superior Work Group
A binational organization that assembles technical and scientific professionals from each of the six jurisdictions (U.S. and Canada) and key national agencies surrounding Lake Superior to coordinate Binational Program implementation. Related program: Binational Program.

Surface Water
All water above the surface of the ground including, but not limited to lakes, ponds, reservoirs, artificial impoundments, streams, rivers, springs, seeps, and wetlands.

Teratogen
A substance that can cause malformation in the fetus following exposure of the mother. The malformation or abnormality may be biochemical or anatomic and be of genetic or environmental origin.

Tertiary Treatment
The advanced cleaning of wastewater that goes beyond secondary treatment. This process removes nutrients, such as phosphorus and nitrogen, and most biological oxygen demand and suspended solids.

Thermal Stratification
The layering of warmer waters over colder waters that can occur in lakes, usually in the summertime. This layering occurs because as surface waters are warmed they become less dense than the underlying colder waters.

Total Maximum Daily Load (TMDL)
TMDLs are set by regulators to allocate the maximum amount of a pollutant that may be introduced into a water body and still assure attainment and maintenance of water quality standards. Related programs: water-related CFRs and rules, federal and state statutes.

Toxaphene
One of the nine critical pollutants, toxaphene is an insecticide that was developed as a substitute for DDT. Its use is now restricted in the U.S. and Canada. Toxaphene has been detected in wildlife as far north as the Arctic and levels in Lake Superior appear to be increasing in fish and sediments. Related program: Binational Program.

Toxic Pollutant
A substance or combination of substances, including disease-causing agents, which may cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including reproductive malfunctions), or physical deformation in organisms or their offspring.

Also refers to those substances listed under Section 307(a) of the Clean Water Act. Related programs: Clean Water Act, parts of chapter 40 of the CFR.

Toxic Substances
See Toxic Pollutants.

Toxic Substances Management in the Great Lakes Basin Through the Permitting Process Agreement
A binational agreement entered into by the environmental administrators of the Great Lakes States in 1986 requiring that best available control technology be installed wherever possible on all new and existing sources of persistent air toxic pollutants which impact the Great Lakes. This agreement is pursuant to implementing the governors' Great Lakes Toxic Substances Control Agreement.

Toxicity
The inherent potential of a substance to cause adverse effects in a living organism. *See* acute toxicity and chronic toxicity.

Toxicity Test
A procedure that measures the degree of effect caused by a chemical or effluent, by exposing living test organisms to the substance. *See also* acute toxicity and chronic toxicity.

U.S. Army Corps of Engineers (ACOE)
See Army Corps of Engineers.

U.S. Ballast Water Management Regulation
Mandatory regulations, enforced cooperatively by the U.S. and Canadian Coast Guards, that prohibit a commercial trans-oceanic vessel from importing ballast water having salinity values less than 30 parts per thousand into the Great Lakes in an effort aimed at preventing further introductions of harmful exotic species.

U.S. Coast Guard (USCG)
As mandated by federal law, the Coast Guard promotes safe and efficient passage of marine and air traffic in coastal waters by providing: (1) a continuous, accurate, all-weather radio navigation service; (2) warnings of dangers and obstructions by providing visual or electronic signals, buoys, and lights; and (3) search and rescue services for commerce and recreation. They also help prevent pollution by inspecting vessels and aiding in pollution clean-up efforts.

U.S. Coast Guard Auxiliary (CGAUX)
A volunteer civilian organization established by Congress in 1939 to assist the U.S. Coast Guard in promoting safety in U.S. recreational boating.

United States Code (USC)
An abbreviation used to identify federal statutes. It is used when referring to a specific code section(s). For example, the Clean Water Act is 33 U.S.C. 1251-1387.

U.S. Department of Agriculture (USDA)
A federal agency that administers the Natural Resources Conservation Service and the U.S. Forest Service, among others.

U.S. Department of Agriculture - Animal and Plant Health Inspection Service (APHIS)
An agency that inspects incoming agriculture, livestock, and produce for disease and pest-related disease.

U.S. Environmental Protection Agency (EPA, U.S. EPA)
See Environmental Protection Agency.

U.S. Fish and Wildlife Service (USFWS)
A federal agency whose mission is to conserve, protect, and enhance the Nation's fish and wildlife and their habitats for the continuing benefit of people.

U.S. Geological Survey (USGS)
A federal agency that performs surveys, investigations, and research covering topography, geology, and the mineral and water resources of the U.S.

U.S. Geological Survey - Biological Resources Division (USGS - BRD)
A federal division within the USGS. The mission of the BRD is to provide, with others, the scientific understanding and technologies needed to manage the nation's biological resources.

Variance
A mechanism or provision that allows modification to or waiver of requirements or standards.

Virtual Elimination
A term that refers to the elimination of inputs and discharges of persistent toxic substances with the end goal being their elimination from the Great Lakes Ecosystem. Because it is not practical to completely remove persistent toxic substances, especially from contaminated sediments, the qualifier virtual is appropriate. It may not be possible to achieve total elimination from the Great Lakes System for some persistent toxic substances produced by natural processes and/or by the release of toxins from contaminated sediments. Because of these impediments, virtual elimination is seen by many as a more realistic objective than zero discharge. *See also* Zero Discharge.

Virtual Elimination Pilot Project
A federal project undertaken by the EPA in response to the Great Lakes Water Quality Agreement, that has as its goal the virtual elimination of persistent bioaccumulative chemicals of concern from the Great Lakes basin. Related program: Great Lakes National Program Office.

Virtual Elimination Strategy
A binational report produced by the Virtual Elimination Task Force for the International Joint Commission that outlines a conceptual framework to achieve the virtual elimination of persistent toxic substances from the Great Lakes basin. Related programs: International Joint Commission, Great Lakes Water Quality Agreement.

Virtual Elimination Task Force
A binational organization established by the International Joint Commission to address specific virtual elimination issues in the Great Lakes ecosystem.

Volatile Organic Compounds (VOCs)
Organic chemicals that evaporate readily into the atmosphere, providing a path for transport through the environment.

Voluntary PCB Phasedown Program
A federal program initiated by EPA Region 5 requesting electric utilities in the Great Lakes basin to voluntarily remove from service all electrical equipment containing PCBs at levels greater than 500 parts per million.

Wasteload Allocation (WLA)
The portion of a receiving waters total maximum daily load that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation. Related programs: water-related CFRs and rules, federal and state statues.

Wastewater Treatment Plant (WWTP)
A facility that receives sewage and stormwater from collection structures, then uses various levels of treatment to purify the water. Most modern publicly-owned treatment works in larger municipalities provide primary treatment, secondary treatment, tertiary treatment, and disinfection techniques to kill disease-producing organisms. Related Program: Western Lake Superior Sanitary District.

Water Quality Advisory Board
See Great Lakes Water Quality Advisory Board.

Water Quality Agreement of 1987
A binational agreement that amends the Great Lakes Water Quality Agreement of 1978. Related program: Great Lakes Water Quality Agreement.

Water Quality Board
See Great Lakes Water Quality Advisory Board.

Water Quality Criteria
Numeric or narrative expressions that specify concentrations of water constituents (such as toxic chemicals or heavy metals) which, if not exceeded, are expected to support an ecosystem suitable for protecting life in water and life dependent on water for its existence. States incorporate water quality criteria into their water quality standards to protect public health or welfare, enhance the quality of water, and serve the purposes of the Clean Water Act. Related programs: Clean Water Act, parts of chapter 40 of the CFR.

Water Quality Guidance for the Great Lakes System
The official name for the Great Lakes Initiative. The final version of the guidance was published on March 23, 1995 and has regulatory implications. The guidance establishes minimum water quality standards, anti-degradation policies, and implementation procedures for waters in the

Great Lakes system. Related programs: Great Lakes Toxic Reduction Initiative, Great Lakes Toxic Reduction Effort, Clean Water Act.

Water Quality Standard
A water quality standard defines the water quality goals of a water body, or portion thereof, by designating the use or uses to be made of the water, by setting water quality criteria necessary to protect the uses, and by preventing degradation of water quality through anti-degradation provisions. States adopt water quality standards to protect public health or welfare, enhance the quality of water, and serve the purposes of the Clean Water Act. Related programs: Clean Water Act, parts of chapter 40 of the CFR.

Water Table
The upper surface of the ground water or that level below which the soil is saturated with water.

Water Use Classification
A classification of waters of the state contained in MN Rule Chapter 7050 for the purpose of water quality protection, consideration of the best use in the interest of the public, and other considerations. Water quality standards for each class of waters prescribe the quality of the water that is necessary for the designated uses, as follows: Class 1 waters are for domestic consumption; Class 2 waters for aquatic life and recreation; Class 3 waters for industrial consumption; Class 4 waters for agriculture and wildlife; Class 5 waters for aesthetic enjoyment and navigation; Class 6 waters for other uses; and Class 7 waters for limited resource value waters.

Waters of the State
A term used in Minnesota statutes and regulations that refers to all water bodies regulated by the state. They include streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, reservoirs, aquifers, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface or underground, natural or artificial, public or private, which are contained within, flow through, or border upon the state of Minnesota or any portion thereof.

Waters of the United States
A term used in federal regulations that defines all water bodies regulated as waters of the U.S. It includes: (1) all waters which may be susceptible to use in interstate or foreign commerce; (2) all interstate waters, including interstate wetlands; (3) all other waters, such as intrastate lakes, rivers, streams (including intermittent streams), mud flats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation, or destruction of which could affect interstate or foreign commerce including any such waters; (4) all impoundments of waters otherwise defined as waters of the United States; (5) tributaries of waters identified in this section; (6) the territorial seas; (7) wetlands adjacent to waters (other than waters that are themselves wetlands) identified in this section. Related programs: Clean Water Act, 33 CFRs.

Watershed
The drainage basin or area in which surface water drains toward a lake, stream, or river at a lower elevation. Related programs: Coastal Zone Management Act, Wetland Conservation Act, Clean Water Act.

Western Lake Superior Region Resource Management Cooperative (WLSRRMC)
A multi-agency/university assemblage established to coordinate programs in the Lake Superior basin. It provides coordinated research, information exchange, and outreach and education program support. Its goal is to achieve full benefits of Lake Superior regional waters, air, fish, wildlife, forests, and wildlands and associated resources for their cultural, social, commercial, economic, and recreational utilization and enjoyment. Formed in 1989, the cooperative represents eight federal agencies, Wisconsin and Michigan DNRs, Great Lakes Indian Fish and Wildlife Commission, and six academic instituitions.

Western Lake Superior Sanitary District (WLSSD)
A local agency responsible for sewage treatment, hazardous household and solid waste collection, recycling, and waste disposal for a number of municipalities in the greater Duluth, Minnesota area.

Wet Deposition
The deposition of pollutants from the atmosphere that occurs during precipitation events. Acid rain is one form of wet deposition. Wet deposition is calculated by multiplying precipitation amounts by the pollutant concentration. Wet deposition rates are often very different than dry deposition rates.

Wetland Conservation Act (WCA)
A Minnesota statute that requires regulation for draining and filling activities in wetlands. This act amended various Minnesota statues (namely 103A, 103B, and 103C). Also referred to as Chapter 354.

Wetland Conservation Act Rules (WCAR)
See Minnesota Rule Chapter 8420.

Wetland Mitigation
A regulatory requirement to replace or enhance wetland areas destroyed or impacted by proposed land disturbances with artificially created or restored wetlands.

Wetlands
The lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have a predominance of hydric soils and be inundated or saturated by surface water or ground water at a frequency and duration sufficient to support a prevalence of hydrophytic vegetation. This is a legal definition and controversy still exists among scientists and policy makers as to how many of these characteristics must be present in order for an area to be defined as a wetland. Related programs: Wetland Conservation Act, Wetland Conservation Act Rules, Clean Water Act, Section 404.

Whole Effluent Toxicity Test (WET)
The total toxic effect of a complex effluent measured directly by a toxicity test. Related programs: 40 CFR, Great Lakes Initiative.

Wildlife Criteria
Water quality criteria designed to protect wildlife. These are surface water concentrations of toxic substances that will cause no significant reduction in the viability or usefulness (in a

commercial or recreational sense) of a population of animals that use the waters of the Great Lakes system as a drinking and/or foraging source over several generations. Related program: Great Lakes Initiative.

Wisconsin Department of Natural Resources (WI DNR)
A Wisconsin state agency responsible for overall management of the state's natural resources and environmental quality.

Wisconsin Lake Superior Basin Water Quality Management Plan
Wisconsin's five-year blueprint for water quality. This plan, prepared by the WDNR, will be used to set water quality management priorities in the Lake Superior basin.

Zebra Mussel
An exotic species originally introduced into the Great Lakes via the ballast water of transoceanic ships. This small bivalve mussel poses a multibillion dollar threat to industrial, agricultural, and municipal water supplies across North America by clogging water intake pipes. It can also have impacts on fisheries, native freshwater mussels, and natural ecosystems. By moving along contiguous waters of the Great Lakes, attached to ships, barges, and recreational boats, this Eurasian native has rapidly spread throughout the Mississippi River basin and many of its major tributaries, such as the Ohio River. Free-swimming larvae are also spread by river currents. Boater education campaigns focus on preventing further spread of this species.

Zero Discharge
Zero discharge refers to halting all inputs from all human sources and pathways to prevent any opportunity for persistent toxic substances to enter the environment from human activity. To completely prevent such releases, the manufacture, use, transport, and disposal of these substances would have to stop. The Binational Program has designated nine toxic substances (critical pollutants) to be part of the Zero Discharge Demonstration Program for the Lake Superior Basin. These substances are chlordane, dieldrin, dichloro-diphenyl-trichloro-ethane (DDT and its metabolites), hexachlorobenzene (HCB), mercury, octachlorostryrene (OCS), polychlorinated biphenyls (PCBs), 2, 3, 7, 8 tetrachlorodibenzo-p-dioxin (TCDD), and toxaphene.

Zero Discharge Demonstration Program
This international program is in response to the recommendation by the International Joint Commission that Lake Superior be designated a zero discharge demonstration zone where no point source discharge of any persistent bioaccumulative toxic substance be permitted. Nine persistent toxic substances (critical pollutants) have been designated as critical for the program. The first priority of the program is the goal of achieving zero discharge of the nine substances from point sources. To completely prevent such releases, the manufacture, use, transport, and disposal of these substances must stop. This objective is to be met by:

1. pollution prevention;
2. enhanced controls and regulations, and;
3. protection through special designations of all or part of the basin. (*See also* Outstanding International Resource Waters and Outstanding National Resource Waters.)

Related program: Binational Program.

Zone of Initial Dilution (ZID)
The region of initial mixing surrounding or adjacent to the end of an outfall pipe or diffuser. The ZID may not be larger than allowed by mixing zone restrictions in applicable water quality standards.

Zooplankton
Small, mostly microscopic animals that swim or float freely in open water. Zooplankton eat algae, detritus, and other zooplankton and in turn are eaten by fish.

ACRONYMS

AEOLOS	Atmospheric Exchange Over Lakes and Oceans Study
AFRI	Acute febrile respiratory illness
AHA	American Hospital Association
AIS	Aquatic invasive species
ALC	American Land Conservancy
ANS	Aquatic nuisance species
APHIS	Animal and Plant Health Inspection Service
AOCs	Areas of Concern
A/OFRC	Anishnawbec/Ontario Fisheries Resource Center
AOX	Adsorbable Organic Halides
APE	Alkylphenol ethoxylates
ATSDR	U.S. Agency for Toxic Substances and Diseases Registry
BEC	Binational Executive Committee
BIA	Bureau of Indian Affairs
BLS	Bureau of Labor Statistics
BMIC	Bay Mills Indian Community
BMP	Best Management Practice
BNP	Binational Program
BOD	Biological oxygen demand
BR	Bad River Band of Lake Superior Chippewa
BRI	Biodiversity Research Institute
BRNRD	Bad River Natural Resources Department
BSC	Bird Studies Canada
BTS	Binational Toxics Strategy
BWCAW	Boundary Water Canoe Area Wilderness
CAA	Clean Air Act (U.S.)
CAMNet	Canadian Atmospheric Mercury Measurement Network
CARD	Community Awareness Review and Development
CBG	Census Block Group
CCL	Contaminated Candidates List
CC/WQR	Consumer Confidence Report/Water Quality Report
CDD	Chlorinated dibenzo-p-dioxins
CEA	Conservation Easement Agreements
CEC	North American Commission for Environmental Cooperation
CEPA	Canadian Environmental Protection Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (U.S.)

CFR	Code of Federal Regulations
CFS	Cubic feet per second
CITES	Committee on International Trade in Endangered Species
CLSLC	Central Lake Superior Land Conservancy
CLSWP	Central Lake Superior Watershed Partnership
CLSWP	Central Lake Superior Watershed Partnership
COTFMA	Chippewa/Ottawa Treaty Fishery Management Authority
CREP	Conservation Reserve Enhancement Program
CSD	Census Subdivision
CSO	Combined sewer overflow
CTC	Connecting-the-Coasts
CUE	Catch per Unit Effort
CWA	Clean Water Act (U.S.)
CWAP	Clean Water Action Plan
CWRP	Corporate Wetlands Restoration Partnership
CWS	Canadian Wildlife Service
DAPTF	Declining Amphibian Population Task Force
DDE	1,1-dichloro-2,2-bis (p-chlorophenyl) ethylene
DDT	1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethane
DSC	Developing Sustainability Committee
DU	Ducks Unlimited
DWA	Drinking Water Academy
DWSP	Ontario Ministry of Environment's Drinking Water Surveillance Program
E. coli	Escherichia coli
EA	Enumeration Area
EAB	Emerald Ash Borer
EC	Environment Canada
EPA	United States Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act (U.S.)
EPO	Ecosystem Principles and Objectives for Lake Superior
ESRI	Environmental Systems Research Institute
FAQs	Frequently Asked Questions
FCM	Federation of Canadian Municipalities
FDL	Fond du Lac Band of Lake Superior Chippewa
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act (U.S.)
FON	Federation of Ontario Naturalists
FSL	Forest Science Laboratory
FT	Feet

FWCA	Fish and Wildlife Conservation Act
FWS	United States Fish and Wildlife Service
g	Grams
GEOSS	Global Earth Observation System of Systems
GHG	Green House Gas
GI	Gastro-intestinal
GIS	Geographical Information Systems
GLBA	Great Lakes Beach Association
GLBTDP	Great Lakes Ballast Water Technology Demonstration Project
GLC	Great Lakes Commission
GLERL	Great Lakes Environmental Research Laboratory
GLFC	Great Lakes Fishery Commission
GLFMP	Great Lakes Fish Monitoring Program
GLFT	Great Lakes Fishery Trust
GLI	Great Lake Initiative
GLIFWC	Great Lakes Indian Fish and Wildlife Commission
GLIN	Great Lakes Information Network
GLLA	Great Lakes Legacy Act
GLNPO	Great Lakes National Program Office
GLPHN	Great Lakes Public Health Network
GLRC	Great Lakes Regional Collaboration
GLWQA	Great Lakes Water Quality Agreement
GLSC	Great Lakes Science Center
GLSF	Great Lakes Sustainability Fund
GP	Grand Portage Band of Lake Superior Chippewa
Ha	Hectare
HCB	Hexachlorobenzene
Hg	Mercury
HYSPLIT	Hybrid Single Particle Langrangian Integrated Trajectory
IADN	Integrated Atmospheric Deposition Network
IEOS	Integrated Earth Observation System
IJC	International Joint Commission (IJC)
IMAR	Inventory, Monitoring, Assessment and Reporting
IOOS	Integrated Ocean Observing System
ITFAP	Inter-Tribal Fisheries and Assessment Program
KBIC	Keweenaw Bay Indian Community
km	Kilometer
L	Liter

LaMP	Lakewide Management Plan
LCO	Lac Courte Oreilles
LPBO	Long Point Bird Observatory
LNFAU	Lake Nipigon Fisheries Assessment Unit
LSB	Lake Superior Basin
LSBP	Lake Superior Binational Program
LSC	Lake Superior Chippewa
LSDSS	Lake Superior Decision Support System
LSHC	Habitat Committee of the Lake Superior Binational Program
LSLTP	Lake Superior Land Trust Partnership
LSSU	Lake Superior State University
LVD Tribe	Lac Vieux Desert Tribe
m	Meters
MAC	Maximum Acceptable Concentration
MACT	Maximum Available Control Technology
MAS	Michigan Audubon Society
MCL	Maximum Contaminant Level
MCR	Midcontinent rift
MCRBMA	Mercury-Containing and Rechargeable Battery Management Act of 1996
MDEQ	Michigan Department of Environmental Quality
MDN	Mercury Deposition Network
ME	Maine
MED	U.S. EPA’s Mid-Continent Ecology Division in Duluth
MEI	Morphoedaphic Index
MI	Michigan
MI DNR	Michigan Department of Natural Resources
MI LPA	Michigan Loon Preservation Association
MI NFI	Michigan Natural Features Inventory
MINGF	Michigan Non Game Fund
MITA	Michigan Trappers Association
MN	Minnesota
MN DNR	Minnesota Department of Natural Resources
MOH	Medical Officers of Health
MOHLTC	Ontario Ministry of Health and Long-Term Care
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MPCA	Minnesota Pollution Control Agency
MSU	Michigan State University

MTU	Michigan Technological University
MVEC	Mean vertical extinction coefficients
NABS	National Ballast Survey
NAFEC	North American Fund for Environmental Cooperation
NAFTA	North American Free Trade Agreement
NANPCA	Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990
NATA	National Air Toxics Assessment
NCES	Northcentral Experiment Station
NGO	Non Government Organization
NHIC	Natural Heritage Information Center
NISA	National Invasive Species Act
NL	National Lakeshore
NMCA	National Marine Conservation Area of Canada
NMU	Northern Michigan University
NOAA	National Oceanic and Atmospheric Administration
NOBOB	“no ballast on board”
NP	National Park
NPDES	National Pollutant Discharge Elimination System
NPDWR	National Primary Drinking Water Regulations
NPS	National Park Service
NRCS	Natural Resource Conservation Service
NRRI	Natural Resources Research Institute
NWF	National Wildlife Federation
NWI	National Wetland Inventory
NWR	National Wildlife Refuge
NYSDEC	New York State Department of Environmental Conservation
OAR	Office of Air and Radiation
OCS	Octachlorostyrene
OFMF	Ontario Fur Managers Federation
OFO	Ontario Field Ornithologists
OGWDW	Office of Groundwater and Drinking Water
OIA	Ottawa Interpretive Association
OIRW	Outstanding International Resource Water
OME	Ontario Ministry of the Environment (OME)
OMEE	Ontario Ministry of Environment and Energy
OMNR	Ontario Ministry of Natural Resources
OMOE	Ontario Ministry of the Environment
ON	Ontario

ONRW	Outstanding National Resource Waters
ORD	Office of Research and Development
OST	Office of Science and Technology
OTA	Office of Technology Assessment
OW	Office of Water
P2	Pollution Prevention
PACs	Public Advisory Committees
PAHs	Polycyclic Aromatic Hydrocarbons
PBB	Polybrominated biphenyls
PBDEs	Polybrominated Diphenyl Ethers
PBT	Persistent bioaccumulative toxic
PCBs	Polychlorinated biphenyls
PCNs	Polychlorinated Naphthalenes
PCP	Pentachlorophenol
PEAC	Pacific Environmental Advocacy Center
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
POM	Polycyclic organic matter
POP	Persistent organic pollutants
POTW	Publicly Owned Treatment Works (wastewater treatment)
RAPs	Remedial Action Plans
RC	Red Cliff Band of Lake Superior Chippewa
RCFD	Red Cliff Fisheries Department
RCRA	Resource Conservation and Recovery Act (U.S.)
RD	Ranger District
REMAP	Regional Environmental Monitoring and Assessment Project
RETAP	Retired Engineer Training and Assistance Program
RGS	Ruffed Grouse Society
SARA	Superfund Amendments and Reauthorization Act (U.S.)
SDWA	Safe Drinking Water Act
SERC	Smithsonian Environmental Research Center
SGNIS	Sea Grant Nonindigenous Species Site
SLC	Sea Lamprey Control
SOEI	Sigurd Olson Environmental Institute
SOLEC	State of the Lakes Ecosystem Conference
SSO	Sanitary Sewer Overflow
SWAP	Source Water Assessment and Protection Program
SWG	Superior Work Group

SWMRS	Seasonal Water Monitoring and Reporting System
SWPP	Source Water Protection Program
TAS	Treatment as State
TCBO	Thunder Cape Bird Observatory
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCDF	2,3,7,8-tetrachlorodibenzofurans
TEA	Toronto Entomologists Association
TEACH	Toxicity and Exposure Assessment for Children's Health
TEQ	Toxic equivalence quotient
THMs	Trihalomethanes
TIE	Toxicity identification and evaluation
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TSCA	Toxic Substances Control Act (U.S.)
TU	Trout Unlimited
TWC	Terrestrial Wildlife Committee
TWCC	Terrestrial Wildlife Community Committee
U of MN	University of Minnesota
UNDERC	University of Notre Dame Environmental Research Center
UP	Upper Peninsula
UPPCO	Upper Peninsula Power Company
UPRCD	Upper Peninsula Recreation, Conservation and Development
U.S.	United States
USCG	United States Coast Guard
USDA	United States Department of Agriculture
US EPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USGS-BRD	United States Geological Survey - Biological Resources Division
UV-B	Ultraviolet Radiation
UWSP	University of Wisconsin Stevens Point
VMS	Volcanogenic massive sulphide
WCMP	Wisconsin Coastal Management Program
WDNR	Wisconsin Department of Natural Resources
WET	Whole effluent toxicity

WI	Wisconsin
WI DNR	Wisconsin Department of Natural Resources
WL	Wildlife
WLSSD	Western Lake Superior Sanitary District
WPBO	Whitefish Point Bird Observatory
WPS	White Pine Society
ZWAT	Zero Waste Action Team

Appendix A:

Lake Superior Areas of Concern/ Remedial Action Plan Summary Matrix and Fact Sheets

This document replaces LaMP 2004 Appendix A.

Islands off of Thunder Bay.
Photo Credit: John Marsden, Environment Canada.

Lake Superior Lakewide Management Plan
2006

Appendix A Contents

Appendix A
Lake Superior Areas of Concern/Remedial Action Plan Summary Matrix and Fact Sheets

A.0 INTRODUCTION

As noted in Chapter 1, Section 1.3.1, entitled Remedial Action Plans for Areas of Concern, the Remedial Action Plans (RAPs) and LaMPs are similar in that they both: use an ecosystem approach to assessing and remediating environmental degradation, consider the 14 beneficial use impairments outlined in Annex 2 of the Great Lakes Water Quality Agreement, and rely on a structured public involvement process. Forging a strong relationship between the LaMPs and the RAPs is important to the success of both efforts. The Areas of Concern (AOCs) can, in many cases, serve as point source discharges to the lake as a whole. Improvements in the AOCs will, therefore, eventually help to improve the entire lake. Much of the expertise related to the use impairments and possible remedial efforts resides at the local level; cooperation between the two efforts is essential in order for the LaMPs to remove lakewide impairments. Information on the progress of RAPs for the eight AOCs in Lake Superior is presented in both a summary matrix and individual AOC information sheets in this Appendix.

A.1 AREAS OF CONCERN SUMMARY MATRIX

AOC Name	Primary Contaminants	Geographic Area	Stressors	Beneficial Use Impairments	Funding Programs and Partners	Clean-Up Actions Completed	Key Activity Needed	Barriers	Next Steps
St Marys River **Michigan/ Ontario**	▪ PAHs ▪ Oil and grease ▪ Bacteria	From the head of the river at Whitefish Bay (Point Iroquois - Gros Cap), downstream through the St. Joseph Channel to Humburg Point on the Ontario side, and to the straits of Detour on the Michigan side.	▪ Combined sewer overflows ▪ Loss of wetlands ▪ Point and nonpoint source pollution ▪ Wastewater discharges ▪ Urban/industrial development ▪ Navigational structures ▪ Contaminated Sediment and sediment resuspension	▪ Fish and wildlife consumption restrictions ▪ Fish and wildlife degradation ▪ Fish tumors or other deformities ▪ Degradation of benthos ▪ Dredging activities restrictions ▪ Eutrophication or undesirable algae ▪ Beach closings ▪ Aesthetics degradation ▪ Loss of fish and wildlife habitat	▪ Superfund ▪ Clean Water Act ▪ Navigational dredging ▪ Canada Ontario infrastructure program ▪ Great Lakes Sustainability Fund ▪ Canada-Ontario Agreement ▪ Great Lakes Legacy Act	▪ Steel and paper mills in Sault Ste. Marie, ON improved quality of effluent ▪ Steel mill improvements through 2000-2005 Environmental Management Agreement among Algoma Steel, Canada and Ontario ▪ Infrastructure upgrades (Combined sewer separation and overflow storage tanks) by Sault Ste. Marie, Ontario ▪ Upgrade East End STP to secondary treatment	▪ Complete contaminated sediment assessment ▪ Complete Tannery Bay Legacy Act contaminated sediment Restoration ▪ Complete sediment remediation at former MGP site ▪ Monitor key fish and wildlife populations to confirm progress	▪ Resource limitations	▪ Monitoring to confirm restoration at cleaned contaminated sediment sites. ▪ Development and implementation of sediment management plan ▪ Update delisting criteria
Deer Lake **Michigan**	▪ Mercury ▪ Historic Nutrient Loadings	A 906-acre impoundment in central Marquette County, Michigan. The AOC includes Carp Creek, Deer Lake, and the Carp River downstream 20 miles to Lake Superior at Marquette.	▪ Contaminated sediments from waste materials associated with historic iron, gold and silver mining practices	▪ Fish and wildlife consumption restrictions ▪ Eutrophication ▪ Degradation of Eagle Populations	▪ Michigan DEQ Water Bureau	▪ Sewer separation; primary treatment plants replaced by advanced secondary wastewater treatment ▪ Deer Lake was drawn down and refilled to allow methylation of mercury from exposed sediments	▪ Identify and restore beneficial uses of the Carp River watershed	PRP and state negotiations nearing completion. Unknown	▪ Sediment remediation ▪ Complete analysis of beneficial use impairments ▪ Have begun Delisting Determination Document using state developed delisting guidance to determine which BUIs are eligible for delisting.
Torch Lake **Michigan**	▪ Copper ▪ Mercury ▪ Arsenic ▪ Lead ▪ Chromium ▪ Heavy metals	Torch Lake and immediate environs.	▪ Contaminated sediments from mine tailings associated with historic copper mining and milling practices ▪ Upland mine tailings deposits from historic copper mining	▪ Fish and wildlife consumption restrictions ▪ Degradation of benthos ▪ Fish Tumors	▪ Superfund ▪ MDEQ, AOC and District	▪ Superfund - recommended remedial actions have been completed – coverage of exposed mine tailings and stamp sands	▪ Identification of potential PCB source related to fish consumption advisories	▪ PCB source remediation if necessary	▪ Have begun Delisting Determination Document using state developed delisting guidance to determine which

AOC Name	Primary Contaminants	Geographic Area	Stressors	Beneficial Use Impairments	Funding Programs and Partners	Clean-Up Actions Completed	Key Activity Needed	Barriers	Next Steps
			activities which have been deposited into area lakes and streams						BUIs are eligible for delisting.
St. Louis River **Minnesota/ Wisconsin**	▪ PAHs ▪ Mercury ▪ Suspended sediment ▪ PCBs ▪ Other metals ▪ Oil and grease ▪ Pathogens ▪ Nutrients	St. Louis Bay, the Nemaji River basin and the St. Louis River basin to Cloquet, MN, including urban areas of Duluth, MN, and Superior, WI	▪ Contaminated sediments ▪ Abandoned hazardous waste sites ▪ Poorly designed or leaky landfills ▪ Industrial discharges and chemical spills ▪ Infiltration and inflow ▪ Point and nonpoint sources ▪ Municipal and industrial runoff ▪ Turbidity ▪ Sedimentation ▪ Exotics ▪ Loss of habitat/wetland fills ▪ Sediment runoff, particularly from urban or construction sources ▪ Transportation sources and dredging	▪ Fish and wildlife consumption restrictions ▪ Fish and wildlife degradation ▪ Fish tumors or other deformities ▪ Degradation of benthos ▪ Dredging activities restrictions ▪ Excess loadings of nutrients and sediment to Lake Superior ▪ Beach closings ▪ Aesthetics degradation ▪ Loss of fish and wildlife habitat	▪ Superfund ▪ Navigational dredging ▪ GLNPO ▪ States ▪ Great Lakes Legacy Act ▪ Cities ▪ WI and MN Coastal Management ▪ Great Lakes Commission ▪ Other miscellaneous grant funding sources	▪ Wastewater treatment ▪ Sediment contamination studies to identify hotspots ▪ Evaluation of cleanup options at two Superfund sites ▪ Contaminated sediment database ▪ Habitat Management Plan ▪ Key habitat area acquisition ▪ Newton Creek /Hog Island Cleanup ▪ Grassy Point Wetland Restoration project	▪ Assessment of fish and wildlife health (body burden and health implications) ▪ Assessment of nonpoint sources of pollution to AOC and stormwater controls ▪ AOC specific wetlands protection and restoration program ▪ Selective clean up of contaminated sediments ▪ Cost-benefit analyses of clean up and habitat restoration alternatives ▪ Control of vessel discharges (ballast and bilge water) ▪ Updating of RAP documents – delisting goal development ▪ Reduction of invasive species	▪ Lack of dedicated resources for projects and staffing ▪ Lack of funding source to manage sediment contamination issues on an AOC-wide, bi-state basis ▪ Greater financial support from the federal government is needed ▪ Lack of cost estimates for protection, restoration, or clean up activities ▪ Lack of long term horizon - policies and funding ▪ Organizations focused on short term ▪ Difficulty in maintaining public support over the long term	▪ Contaminated site remediation ▪ Mercury reduction ▪ Water quality protection ▪ Habitat restoration and protection ▪ Stormwater and infiltration and inflow control ▪ Update AOC-wide contaminated sediment strategy ▪ Develop "delisting roadmap" to identify ultimate goals and steps needed ▪ Outreach and education campaign
Thunder Bay **Ontario**	▪ Mercury	About 28 km along the shoreline and up to 9 km offshore, including the watershed	▪ Contaminated sediments ▪ Industrial and municipal effluent ▪ Industrial development	▪ Fish and wildlife consumption restrictions ▪ Fish and wildlife degradation ▪ Degradation of benthos ▪ Dredging activities restrictions ▪ Beach closings ▪ Aesthetics degradation	▪ Great Lakes Sustainability Fund ▪ Canada Ontario Infrastructure Programs ▪ Canada-Ontario Agreement	▪ Secondary treatment installed for a number of pulp and paper mills ▪ clean up and rehabilitation of contaminated sediment at Northern Wood site	▪ Monitor fish and wildlife populations to confirm progress (eg. Kam River Sturgeon)	▪ Resource limitations	▪ Complete sediment assessment at north end of harbour ▪ Update delisting criteria

AOC Name	Primary Contaminants	Geographic Area	Stressors	Beneficial Use Impairments	Funding Programs and Partners	Clean-Up Actions Completed	Key Activity Needed	Barriers	Next Steps
				▪ Phytoplankton and zooplankton pops. Degradation ▪ Loss of fish and wildlife habitat		▪ Various habitat creation and enhancement projects ▪ Chippewa Beach restoration ▪ STP upgraded to secondary treatment			
Nipigon Bay **Ontario**	▪ None	A large portion of Nipigon Bay and the Nipigon River downstream of Alexander Dam. Two communities are located in the vicinity of the Bay: Red Rock (population: 1,300) and Nipigon (population: 1,900).	▪ Water level and flow fluctuations ▪ Wastewater discharges	▪ Fish and wildlife degradation ▪ Eutrophication or undesirable algae ▪ Loss of fish and wildlife habitat	▪ Great Lakes Sustainability Fund ▪ Canada Ontario Infrastructure Programs ▪ Canada-Ontario Agreement	▪ Created water management plan for Nipigon River to regulate hydroelectric facilities' water use to help restore brook trout ▪ Various habitat restoration projects ▪ Secondary treatment installed at Norampac	▪ Upgrade primary STPs in Redrock and Nipigon (underway) ▪ Monitor fish and wildlife populations to confirm progress (coaster brook trout)	▪ Resource limitations	▪ Assist communities to obtain funding and/or undertake STP upgrades ▪ Update delisting criteria
Jackfish Bay **Ontario**	▪ Solids (i.e. wood fiber) ▪ Dioxin	The 14 km reach of Blackbird Creek between Kimberly-Clark Canada Inc. pulp mill and Jackfish Bay, including Lake A, Moberly Lake and Jackfish Bay itself.	▪ Industrial discharge ▪ Contaminated sediments	▪ Fish and wildlife consumption restrictions ▪ Fish and wildlife degradation ▪ Fish tumors or other deformities ▪ Bird or animal deformities or reproductive problems ▪ Aesthetics degradation ▪ Loss of fish and wildlife habitat	▪ Great Lakes Sustainability Fund ▪ Canada-Ontario Agreement ▪ National Sciences and Engineering Research Council of Canada (NSERC)	▪ Effluent quality from paper mill improved ▪ Chlorine dioxide bleaching plant upgraded resulting in lower AOX levels	▪ Assess status of natural recovery	▪ Time for Natural recovery ▪ Best Available technology needs to be utilized at all times	▪ Continued natural recovery and monitoring ▪ Update sediment monitoring data ▪ Update delisting criteria

Peninsula Harbour **Ontario**	▪ Mercury ▪ PCB	Peninsula Harbour proper, and a portion of open Lake Superior immediately south of the peninsula.	▪ Contaminated sediments	▪ Fish and wildlife consumption restrictions ▪ Fish and wildlife degradation ▪ Degradation of benthos ▪ Dredging activities restrictions ▪ Loss of fish and wildlife habitat	▪ Great Lakes Sustainability Fund ▪ Canada-Ontario Agreement ▪ Marathon Pulp Inc.	▪ Pulp kraft mill installed secondary treatment for effluent,; discharge moved out of AOC	▪ Complete Ecological risk assessment (underway)		▪ Complete sediment management strategy ▪ Update delisting criteria

A.1 AREAS OF CONCERN FACT SHEETS

A.2.1 Canadian Fact Sheets

A.2.1.A Thunder Bay

Thunder Bay Area of Concern

General Information

Where?

The Thunder Bay Area of Concern (AOC) extends approximately 28 km along the shoreline of Lake Superior and up to nine kilometres offshore from the City of Thunder Bay. The Thunder Bay watershed is drained by the Kaministiquia River system and a number of smaller rivers and creeks.

Why was this area listed?

Major environmental issues of concern in the area included:

- Fish consumption restrictions
- Negative pressures on fish populations
- Degradation of Phytoplankton and Zooplankton Populations
- Degradation Benthos
- Dredging restrictions
- Loss of species abundance and diversity
- Reduced recreational opportunities
- Decline in aesthetic values
- Loss of Fish and Wildlife Habitat

What is being done? How is it being done?

In order to improve the environmental conditions noted above, a Remedial Action Plan (RAP) has been developed for Thunder Bay. The Thunder Bay RAP is a partnership between the federal and provincial governments. Public involvement and participation in the RAP to date has been coordinated by a Public Advisory Committee which represents a variety of interests in the Thunder Bay community (e.g. private citizens, academia, industry, labour, recreational groups and property owners). The PAC has provided public input and advice throughout the RAP process, in addition to endorsing both the Stage 1 and 2 documents.

This plan[It was the RAP program that was initiated in 1987, not the Th B RAP] involves the following steps:

- defining the problem (Stage 1 – completed in 1991)
- planning for implementation (Stage 2 – completed in 2004)
- implementing the actions (Stage 2 – underway)

- monitoring the restoration of the environment and eventual delisting (Stage3)

The Stage 2 Report contains a list of recommended remedial actions to restore the above environmental conditions. It was developed through the RAP process, which included consultation with the public. Many of the actions have already been implemented.

HIGHLIGHT of the RAP

Contaminated sediments are recognized as significant contributors to impaired water quality in the Great Lakes. Thunder Bay Harbour sediment contamination from polycyclic aromatic hydrocarbons (PAHs), chlorophenols, dioxins and furans around Northern Wood Preservers contributed to the International Joint Commission 's (IJC) identification of the Harbour as an Area of Concern. A biological assessment study was conducted to establish site specific clean up criteria. Based on measured biological effects related to PAHs, three cleanup zones were identified corresponding to areas of acute toxicity, chronic toxicity and no measurable toxicity.

Abitibi Consolidated Inc., Northern Wood Preservers Inc., Canadian National Railway Co., Environment Canada and the Ontario Ministry of the Environment worked together to remediate the area around the Northern Wood Preservers site. The project, referred to as the Northern Wood Preservers Alternative Remediation Concept (NOWPARC), was a plan to isolate the contaminant source, clean-up the contaminated sediment, and enhance fish habitat. Extensive public consultation was undertaken to ensure public acceptance of the plan.

The primary components of the project have been completed. These improvements in the "integrity" of the local ecosystem were:

- A 1000 meter long rockfill containment berm to contain a portion of the contaminated sediment
- Environmental dredging to remove 11 000 m^3 of contaminated sediment from the harbour
- Thermal treatment and off site disposal of 17 000 tonnes of contaminated sediment
- A Waterloo steel wall and environmental clay barrier were constructed around the NWP pier to prevent the movement of on-site contaminants back into the harbour
- A buffer zone of clean fill within the containment berm
- Stormwater controls to collect drainage and channel it through a settling pond prior to discharge into Thunder Bay Harbour
- 48,000 m^2 of fish habitat were created as compensation for the infilling activities
- A groundwater treatment plant to treat contaminated groundwater that accumulates behind the clay barrier.

The Northern Wood Preservers Alternative Remediation Concept (NOWPARC) was a significant project for the RAP. As such, it contributes to the objectives of the Lake Superior Binational Program's Lakewide Management Plan (LaMP), which includes the Zero Discharge Demonstration Program.

Through this project, the areas of highest sediment contamination were removed and treated, and additional fish habitat was created. Project implementation, including public consultation, has taken seven years to complete at a cost of $20 million, forging linkages between the economy, the environment, and the community. Now that implementation is complete, the site has been decommissioned and a post-remediation monitoring plan is in place. To demonstrate adequate monitoring of effectiveness, the focus has now shifted to long-term monitoring of the isolation barriers, natural recovery of sediments outside the berm and fish habitat development.

This is a major achievement in the restoration and remediation of this once highly contaminated sediment site. This project, in concert with other RAP initiatives, will help to improve water quality and sediment conditions in the harbour, and will provide a more hospitable environment for plants, animals and people.

RAP Development/History

The Thunder Bay Remedial Action Plan (RAP) was developed by Environment Canada and the Ontario Ministry of the Environment, with support from the general public.

The Remedial Action Plan adopted an ecosystem approach to environmental problems that incorporated land, water, air, plants, animals and ultimately people. Therefore, the cooperation and involvement of other federal and provincial government agencies has been key to RAP progress.

Members of the public, including individuals and organizations, participated in the RAP process as members of the Public Advisory Committee (PAC). The PAC provided a forum for community stakeholders and included private citizens, academia, industry, labour, recreational groups and property owners.

The Thunder Bay RAP was developed to identify use impairments, define specific goals for the region and describe appropriate remedial and regulatory measures to rehabilitate the AOC. Incorporating the needs identified by the PAC will ensure that the plan responds to the community needs and enjoys a high level of public support and implementation.

RAP Status

Strategies to address beneficial use impairments have been designed to increase aquatic and terrestrial habitat, enhance recreational opportunities, and to improve the aesthetic value of the harbour and its tributaries. The highest profile remediation project has been the Northern Wood Preservers Alternative Remediation Concept (NOWPARC). NOWPARC was designed to mitigate sediment contamination and to enhance existing habitat and aesthetic values. This project, in concert with other RAP initiatives, will help to improve water quality and sediment conditions in the harbour, and provide a hospitable environment for diverse biotic communities.

Many water quality issues have been addressed as a result of process changes and improved effluent treatment at local pulp and paper mills. Secondary treatment and 100 percent chlorine dioxide substitution at the Bowater pulp and paper mill have resulted in dramatic improvements in effluent quality. Likewise, the installation of secondary treatment at Abitibi Consolidated has resulted in the effluent being non-toxic since 1999. These improvements are expected to enhance sediment and water quality conditions and encourage the return of healthy biotic communities.

Various fish and wildlife habitat rehabilitation projects have been completed along the waterfront and on tributary streams. These have included improving walleye spawning habitat, restoring habitat diversity along floodways, creating nearshore nursery habitat and wetland sites, alleviating water quality barriers to fish migration, and enhancing habitat diversity within dredged navigation channels. These efforts will increase the extent of productive aquatic and terrestrial habitat by rehabilitating and protecting wetland and riparian environments.

The involvement of the public and their commitment to both rehabilitation and continued vigilance of the ecosystem are important to the success of the Thunder Bay RAP. Community involvement has been evident in such projects as organized cleanups of the Thunder Bay waterfront and participation in Lake Superior Day celebrations and waterfront development workshops. The Public Advisory Committee played a lead role in this process, making the public aware of progress towards the final goal of a healthy, balanced ecosystem and the ways in which this can be accomplished.

RAP Implementation

The Thunder Bay RAP Stage 2 Report contains a complete list of recommended remedial actions for the AOC, many of which are in progress or completed. A monitoring strategy will be developed to measure progress towards delisting. With the support of federal and provincial governments and the community, the remaining recommended actions will be completed and the monitoring strategy will be implemented.

Scientists are completing an assessment of sediment and bottom-dwelling animals from a site near Cascades Fine Paper Inc. To date, benthic community impairment, toxicity and biomagnification have been found at some locations within this site. Environmental Effects Monitoring data for the Cascades Fine Paper mill supports the conclusions that the sediment is toxic and the benthic community is impaired in the vicinity of the mill outlet. The results of this assessment will better delineate the zone of contamination and help to evaluate the potential risks posed by contaminated sediments at that location. This information is critical to the identification of any appropriate remedial actions to address contaminated sediment in the AOC.

A strategy has been implemented to address beach closures at Chippewa Beach, and as a result of this, the number of closures has been considerably reduced.

For the most part, recommended remedial actions to address the Northern Wood Preservers site are complete. The last remaining action, a post-remediation monitoring plan, is being implemented to evaluate the success of the project and to track the progress of natural recovery over time.

There is a commitment to ensure the gains realized through RAP implementation are maintained and progress towards restoration and ultimate delisting of Thunder Bay as an AOC continues.

RAP Accomplishments

Many projects have built on the notable successes in the Thunder Bay AOC. Several fish and wildlife habitat rehabilitation projects have been completed in wetlands, riverine shorelines, along the Thunder Bay waterfront, and within the river mouths draining into Thunder Bay. Contaminated sediments have been removed at the Northern Wood Preservers site and have undergone treatment and disposal. In 2005, the City of Thunder Bay, with assistance from the Canada Strategic Infrastructure Fund, completed construction of the Secondary Sewage Treatment facility at the Water Pollution Control Plant. In addition to secondary sewage treatment, the new facility includes nitrification to eliminate ammonia from the wastewater. In 2006 the disinfection process will be upgraded from chlorine treatment to ultraviolet radiation, which will eliminate the discharge of chlorine into the waters of Lake Superior.

RAP Participants

Cooperation is critical to the RAP process. Undertaking environmental restoration requires a large amount of local knowledge, scientific expertise and hard work. One agency or group cannot undertake such a large task on their own, without the help of others. Listed below are participants that contribute to the RAP program.

- Environment Canada
- Fisheries and Oceans Canada
- Great Lakes Sustainability Fund
- Ontario Ministry of Natural Resources
- Ontario Ministry of the Environment

- City of Thunder Bay
- Lakehead Region Conservation Authority
- Lakehead University

A.2.1.B Nipigon Bay

Nipigon Bay Area of Concern

General Information

Where?

The Nipigon Bay Area of Concern (AOC) is in the most northerly area of Lake Superior. The AOC encompasses a large portion of Nipigon Bay and, the largest tributary to Lake Superior, the Nipigon River.

Why was this area listed?

When listed in the late 1980s, the major environmental issues of concern in the area included:

- degradation of fish and wildlife populations - particularly the loss of walleye and yellow perch fisheries and decline in the brook trout and lake trout stocks
- degradation of benthos (bottom dwelling organisms)
- Restrictions on Dredging Activities (no longer a concern)
- undesirable algal growth on substrates in the lower Nipigon River
- degradation of aesthetics on the waterfront
- losses of habitat in the Nipigon River. Water level fluctuations from the generation of electricity continue to affect streambank erosion and sediment load

What is being done? How is it being done?

In order to improve the environmental conditions noted above, a Remedial Action Plan (RAP) has been developed for the Nipigon Bay. Implementation of the Nipigon RAP is being achieved through a partnership between the Government of Canada and the Province of Ontario, with support from a Public Advisory Committee. Many linkages and alliances have been developed as part of the RAP process between the RAP team and various other groups in the community including recreational groups, industry, municipalities and citizens.

This plan was initiated by the formalized establishment of RAPs under the 1987 revision of the Canada-United States Great Lakes Water Quality Agreement (GLWQA), and involves the following three stages:

1. defining and documenting the problem (Stage 1 Report completed in 1991)
2. developing and documenting a strategy of action to rehabilitate and protect the ecosystem (Stage 2 Report completed in 1995)
3. implementing the strategy of remedial and preventive actions and monitoring and confirming the eventual restoration of the impaired beneficial uses (Stage 3).

Thirty-five recommended remedial actions to restore the above environmental conditions were selected through the RAP process, which includes consultation with the public. The actions fall within five main areas including: municipal and industrial point source discharges, fish and wildlife population dynamics, benthic (bottom dwellers) population dynamics, aesthetics and education and stewardship. Most actions have already been implemented.

HIGHLIGHTS of the RAP

The federal government has provided support to environmental projects in the Nipigon Bay AOC. Since 1990, the Government of Canada's Great Lakes Sustainability Fund has made significant contributions towards restoring impaired beneficial uses in the Nipigon Bay Area of Concern. A number of projects have been completed to enhance fish and wildlife communities and to rehabilitate degraded aquatic and terrestrial habitat. Logs and debris were removed from historic spawning areas in the lower Nipigon River. The clean up of a former wetland site has resulted in natural regeneration of wetland features. A fish-stocking program was used to increase adult spawning potential in Nipigon Bay with more than 12 000 adult fish stocked over 3 years. A community-based effort was used to clean up and restore habitat in and around a once productive and aesthetic brook trout stream. These efforts are a step towards enhancing fish and wildlife populations in the AOC.

RAP Development/History

Public Advisory Committee (PAC) involvement in the Nipigon Bay RAP has been extensive and integral to the success of the process. The combination of local knowledge and community-based goals with scientific data and expertise has resulted in a pragmatic and defensible strategy to rehabilitate the remaining problems in the AOC ecosystem.

Early in the RAP process, the PAC evaluated and identified environmental impairments and developed a list of objectives for the remediation of the area. These objectives were incorporated into the Stage One document: *Environmental Conditions and Problem Definition*. An Options Discussion Paper then developed a list of remedial measures to address the identified environmental problems, carefully weighing each option and identifying preferences. The discussion paper went out for public comment, to assist in the selection of a preferred course of action.

The Stage Two document, *Remedial Strategies for Ecosystem Restoration*, used the selected options to outline stakeholder commitment and implementation timetables necessary to restore impaired beneficial uses.

RAP Status

A number of projects in the AOC have led to significant advances towards reducing the beneficial use impairments identified in the first stage of the RAP process. The projects have been completed to enhance fish and wildlife communities and to rehabilitate degraded aquatic and terrestrial habitat. Logs and debris were removed from historic spawning areas in the lower Nipigon River. Clean up of a former wetland site has resulted in natural regeneration of wetland features. A fish-stocking program was used to rejuvenate the walleye population in Nipigon Bay with more than 12 000 adult fish stocked over three years. Community based restoration projects to clean up and restore brook trout habitat in and around Clearwater and Kama Creeks are being implemented by the Ontario Ministry of Natural Resources. These efforts are a step towards enhancing fish and wildlife populations in the AOC.

Most recommended specific remedial actions have been implemented in Nipigon Bay. The Town of Nipigon has undertaken an environmental study report which identifies options for upgrading its primary municipal wastewater treatment plant and has been successful in obtaining funding under phase one of the Canada-Ontario Municipal Rural Infrastructure Fund (COMRIF). Similarly, the Township of Red Rock completed a class environmental assessment for its wastewater treatment plant and has applied for funding in the next phase of COMRIF. Full implementation is contingent on funding availability.

RAP Implementation

Most of the recommended remedial actions have been completed, but until the municipal point source discharges have been addressed, Nipigon Bay will continue to be an Area of Concern. Upgrading the Nipigon and Red Rock Wastewater Treatment Plants is a key recommended action in the Stage 2 Report. Once this action has been implemented, the AOC will be able to move ahead to the formal delisting procedures of Stage Three.

On April 25, 2005, the Government of Canada, the Government of Ontario and the Township of Nipigon announced funding to upgrade the Nipigon sewage treatment plant. The governments of Canada and Ontario will each invest up to $1,900,000 in the project. The Township of Nipigon will contribute the balance of the total eligible project cost of up to $4,000,000. The Government of Canada's contribution is contingent on the successful completion of an environmental assessment of the proposed project under the Canadian Environmental Assessment Act. This investment, made under the first phase of the Canada-Ontario Municipal Rural Infrastructure Fund (COMRIF), will improve the quality of life for local residents. Work includes designing and constructing a rotating biological contractor secondary treatment system and a six-month sludge storage capacity lagoon.

The township of Red Rock has submitted a application for funding in the second phase of COMRIF and is prepared to proceed with the upgrade of their treatment plant if the application is successful.

Once these two infrastructure projects have been completed, the status of the beneficial use impairments will be reviewed in order to determine if the delisting targets have been met. Some of this review has already been completed. For example, scientists at Environment Canada have completed an assessment of sediment and bottom-dwelling organisms in the Area of Concern. The results of all these assessments will form the basis of the final Stage 3 delisting process.

RAP Accomplishments

The Nipigon River Water Management Plan was established, through public involvement, to reduce the impacts of the operation of hydroelectric dams on the Lake Nipigon/Nipigon River watershed and particularly on the Nipigon River fishery. The plan was in response to water level fluctuations that resulted in the exposure of brook trout spawning beds and affected the groundwater supply critical to the survival of brook trout embryos. The plan expands on an interim agreement between the Ministry of Natural Resources and Ontario Power Generation to maintain minimum flows. By these actions directed at brook trout, other fish, wildlife, and benthic populations in the ecosystem will benefit by a more natural cycle of river flow.

Notable successes have included the development of a bioengineered marina at Red Rock that features armour stone breakwalls that incorporate public access and fish and wildlife habitat; the Nipigon River Water Management Plan has provided a workable solution to water use conflicts arising from regulated flows; and improvements to brook trout habitat at Clearwater Creek.

There is a commitment to ensure the gains realized to date are maintained and progress towards restoration and ultimate delisting of Nipigon Bay as an AOC continues.

RAP Participants

Cooperation is critical to the RAP process. Undertaking environmental restoration requires a large amount of local knowledge, scientific expertise and hard work. One agency or group cannot undertake such a large task on their own, without the help of others. Listed below are participants that contribute to the RAP program.

- Environment Canada
- Ministry of Northern Development and Mines

- Ontario Ministry of Natural Resources
- Ontario Ministry of the Environment
- Canada-Ontario Municipal Rural Infrastructure Fund (COMRIF)
- Ontario Ministry of Education
- Township of Nipigon
- Township of Red Rock
- Domtar Packaging
- Ontario Hydro
- Public Advisory Committee

A.2.1.C Jackfish Bay

Jackfish Bay Area of Concern

General Information

Where?

The Jackfish Bay Area of Concern (AOC) is located on the north shore of Lake Superior approximately 250 km northeast of Thunder Bay. The AOC consists of a 14-kilometre stretch of Blackbird Creek between the Neenah Papers (formerly Kimberly–Clark) pulp mill and Jackfish Bay, and includes Lake "A" , Moberly Lake, and Jackfish Bay. The town of Terrace Bay is the closest community.

Why was this area listed?

Major environmental concerns in the area included:

- Restrictions on fish consumption
- Degradation of fish populations and fish habitat
- Fish tumours and other deformities
- degraded aesthetics
- condition of the sediments and the aquatic communities which utilize them

What is being done? How is it being done?

In order to improve the environmental conditions noted above, a Remedial Action Plan (RAP) has been developed for Jackfish Bay. The Jackfish Bay RAP was developed through a partnership between the Government of Canada and the Province of Ontario, with support from the Jackfish Bay Public Advisory Committee (PAC). Many linkages and alliances have been developed as part of the RAP process between the RAP team and various other groups in the community including private citizens, recreational groups, industry and municipalities.

The remedial action planning, implementation, and reporting process, which was initiated in 1988, involves the following three stages, each of which, when completed, results in a corresponding report:

1. defining the problem (Stage 1 Report completed in 1991)
2. developing a strategy of action to rehabilitate and protect ecosystem quality (Stage 2 RAP Report completed in 1997)
3. implementing the strategy of remedial and preventive actions (i.e., the RAP), and monitoring and confirming the eventual restoration of the impaired beneficial uses (Stage 3 Report)

In order to determine the actions required for remediation of the AOC, both the identification of the use impairments and the water use goals, developed by the PAC, were utilized. A number of potential solutions were developed and assessed in an Options Discussion Paper. Natural recovery, where the ecosystem is allowed to recover on its own, was selected as the preferred strategy.

This was decided due in large part to achievement of higher standards of effluent quality at the Neenah pulp mill resulting from improved treatment of effluent and changes in mill processes between 1987 and 1997. Acceptance of this plan is based on the fact that recovery is already occurring in many areas.

HIGHLIGHT of the RAP

The Government of Canada's Great Lakes Sustainability Fund and its partners have made significant contributions to sediment rehabilitation options and assessment of restoration of lake trout spawning habitat.

RAP Development/History

The Jackfish Bay Remedial Action Plan (RAP) was developed by Environment Canada and the Ontario Ministry of the Environment between 1988 and 1997, with support from the general public.

The Remedial Action Plan adopted an ecosystem approach to environmental problems that incorporated land, water, air, plants, animals and ultimately people. Therefore, the cooperation and involvement of many other federal and provincial government agencies has been key to RAP progress.

The general public (both individuals and organizations) participated in the RAP process as members of the Public Advisory Committee (PAC), providing a forum for the spectrum of interests existing within a community. The Jackfish Bay PAC encompassed the interests of private citizens, industry, labour, tourism operators and property owners.

Within the Stage One document, environmental impairments and objectives for the remediation of the AOC were identified. Upon completion, federal and provincial agencies and the International Joint Commission reviewed the document. An Options Discussion Paper then presented a list of remedial measures to address the identified environmental problems, carefully weighing each option and identifying preferences.

The Stage Two document was completed in 1997. This document recommends a "natural recovery" plan to address most of the impaired beneficial uses in the Area of Concern.

The natural recovery plan does not require the removal of contaminated sediment from the environment. This plan relies on natural processes to bury contaminants in the sediment, effectively isolating them from the water column and food web.

Essential to the natural recovery plan is the maintenance of higher standards of effluent quality by Neenah, and continued monitoring of the effects of contaminated sediments on the ecosystem. In this way, progressive changes in the ecosystem can be evaluated, and delisting of the AOC can occur at the earliest opportunity.

RAP Status

Effluent, spills, and sediment contamination have deteriorated the ecosystem of the AOC. Sportfish consumption restrictions are based on a variety of chemicals, including dioxins and furans attributed to mill effluent. White suckers collected from Jackfish Bay prior to the installation of secondary effluent treatment at the mill had an increased incidence of liver cancer, and sediments in Moberly Lake were acutely toxic to bottom dwelling organisms. Lake trout spawning habitat in Moberly Bay has been destroyed through the deposition of organic materials and chemical contamination of sediments. Overfishing and sea lamprey predation have also contributed to the decline of trout populations.

The treated effluent from the Neenah pulp mill currently meets all Provincial Municipal/Industrial Sewage Abatement (MISA) and Canadian Environmental Protection Act (CEPA) requirements. This effluent is discharged directly into Blackbird Creek and comprises most of its flow. However, due to historical discharges the creek is still considered to be contaminated along its entire length.

RAP Implementation

Ongoing monitoring and reporting are needed to evaluate the progress of natural recovery. It is recommended that changes in sediment and benthos be evaluated at least once every ten years. Environmental impacts of the pulp and paper industry are evaluated every four years to determine the effectiveness of mitigative measures. Contaminant levels in sport fish are evaluated at least every five years until consumption advisories can be removed. Sediment contamination and aquatic communities in Moberly Lake require regular evaluation to evaluate progress towards recovery.

Environment Canada and the Ontario Ministry of the Environment and the Ontario Ministry of Natural Resources cooperate to lead implementation actions.

RAP Accomplishments

Contaminant levels in effluent and receiving waters have decreased since the installation of secondary treatment and changes in mill processes to chlorine dioxide bleaching. Mill effluent presently tested has significantly reduced biological effects and is characterized as non-acutely toxic. Previously Lake A was clogged with extensive accumulation of organic material. Ten years ago effluent flow was diverted away from the lake, recovery has occurred and the lake is now a productive wetland.

Separate studies by Environment Canada, the Ontario Ministry of the Environment and Kimberly-Clarke during 1999-2003 showed that mill-related effects were continuing. The 2000 Kimberly-Clarke study found that the community of bottom-dwelling organisms continued to show effects that were unchanged since a 1995 survey. In the 2002 Environment Canada study, sediment toxicity was observed at some sites. The 1999 Ontario Ministry of the Environment study showed little change in sediment quality, or water quality (for some parameters) at the mouth of Blackbird Creek, since the late 1980s. In general, however, studies in Jackfish Bay proper suggest that modest recovery of contaminated sediment is occurring.

Sub-lethal effects in benthic invertebrates and fish have been reported. The Neenah mill is therefore involved with a voluntary study of its various effluent streams in order to identify the cause. Significant biological effects measured to date in fish include delayed spawning, reduced egg production and increased deformities.

RAP Participants

Cooperation is critical to the RAP process. Undertaking environmental restoration requires a large amount of local knowledge, scientific expertise and hard work. One agency or group cannot undertake such a large task on their own, without the help of others. Listed below are participants that contribute to the RAP program.

- Environment Canada
- Great Lakes Sustainability Fund
- Ontario Ministry of Natural Resources
- Ontario Ministry of the Environment
- Municipality of Terrace Bay
- Kimberly-Clark

A.2.1.D Peninsula Harbour

Peninsula Harbour Area of Concern

General Information

Where?

Peninsula Harbour is located on the northeastern shore of Lake Superior midway between Sault Ste. Marie and Thunder Bay. The Area of Concern (AOC) extends approximately four kilometres from the Peninsula into Lake Superior.

Why was this area listed?

Major environmental issues of concern in the area included:

- fish consumption advisories due to high levels of toxic contaminants
- degraded fish communities
- fish habitat destruction
- degraded lake bottom communities
- dredging restrictions due to contamination of the bottom sediments

The environmental impairments in Peninsula Harbour result, almost exclusively, from the presence of a substantial area of mercury contaminated sediments. This sediment contamination is particularly severe in Jellico Cove and is the result of historic discharges from the James River-Marathon chlor-alkali plant which closed in 1977. Other contaminants such as PCBs, as well as wood fibre, are found in the sediments, and are also of concern, although a lower priority compared to the mercury.

What is being done? How is it being done?

In order to improve the environmental conditions noted above, a Remedial Action Plan (RAP) is being developed for Peninsula Harbour. The Peninsula Harbour RAP is a partnership between the federal and provincial governments with cooperation from a Public Advisory Committee (PAC). Linkages and alliances have been made between the RAP team and various other groups in the community, including environmental groups, recreational groups, industry and municipalities.

This plan, which was initiated in 1987, involves the following steps:

- defining the problems (Stage 1 – completed in 1991)
- identifying and planning the required remedial actions (Stage 2 draft completed)
- implementing the actions (Stage 2)
- monitoring the restoration of the environment and eventual delisting (Stage 3)

Currently, the RAP is planning for implementation, and a list of remedial actions is being developed to address the environmental problems in the AOC.

The most important of these problems is, of course, the mercury contaminated sediment. A list of potentially feasible remediation options to solve this problem has been compiled in the draft Stage 2 report, along with the advantages, disadvantages, and conditions of applicability for each. Included in this list are the following:

1. Removal or removal and treatment of the contaminated sediments
2. In situ treatment of contaminated sediments (treating the sediment without removing it)
3. Natural recovery and monitoring for incremental progress; no further intervention at this time.

After considering the alternative options, it was decided that, unless monitoring studies indicate otherwise, the preferred course of action should be to dredge and dispose of the sediments from the area of highest contamination (i.e. Jellico Cove) and allow for the natural recovery of the remaining areaWhen the planning process for the remedial actions has been completed, and the necessary reviews carried out, the Remedial Action Plan for Peninsula Harbour will be published in the final RAP Stage 2 Report. This Report will guide the restoration and monitoring efforts until Peninsula Harbour is no longer considered an Area of Concern.

HIGHLIGHT of the RAP

Currently the planning process for the “Peninsula Harbour Contaminated Sediment Removal and Carden Cove Waterfront Project” is nearing completion. The planning project is being funded by the Government of Canada's Great Lakes Sustainability Fund, the Ontario Ministry of the Environment, FedNor, the Great Lakes Renewal Foundation and the Town of Marathon. The project addresses the issue of mercury-contaminated harbour sediment.

RAP Development/History

The Peninsula Harbour Remedial Action Plan (RAP) is being developed by Environment Canada and the Ontario Ministry of the Environment, with support from Fisheries and Oceans Canada, Ontario Ministry of Natural Resources, and the general public.

The Remedial Action Plan will adopt an ecosystem approach to environmental problems that incorporated land, water, air, plants, animals and ultimately people. Therefore, the cooperation and involvement of other federal and provincial government agencies has been key to RAP progress.

The general public (both individuals and organizations) participated in the RAP process as members of the Public Advisory Committee (PAC), providing a forum for the spectrum of interests existing within a community. The Peninsula Harbour PAC encompassed the interests of environmental groups, recreational groups, industry and municipalities.

The Stage One RAP Report provided a definition and detailed description of the environmental problems with the AOC and identified the beneficial use impairments for the harbour. The PAC evaluated the use impairments and developed specific water use goals and objectives designed to assist in the restoration and protection of the AOC. These goals provided community-based guidelines for the remediation of impairments in Peninsula Harbour.

The Stage One document was reviewed by federal and provincial agencies and was submitted to the International Joint Commission (IJC) in 1991. The International Joint Commission concluded that there was sufficient information to proceed with Stage Two.

When completed, the Stage Two RAP Report will present the remedial options to address the environmental problems within the harbour. In the report, each option will be evaluated and the preferred course of action for the AOC will be identified.

RAP Status

Currently, a detailed ecological risk assessment is being planned to address mercury contaminated sediment in the vicinity of Jellicoe Cove.

Remedial strategies for Peninsula Harbour focus on the shallow water areas of the harbour, while leaving remediation of the deeper areas to natural sedimentation processes. The high levels of mercury found in the nearshore areas may provide a reservoir for the contamination of offshore sediments, and contribute to long term restrictions on fish consumption. Remediating sediments in the area of highest contamination may prevent further migration of nearshore mercury to offshore areas. For this reason, this area is being considered for the development of a sediment management strategy and is the focus of an ecological risk assessment.

RAP Implementation

The Stage One RAP Report provided a definition and detailed description of the environmental problems with the AOC and identified the beneficial use impairments for the harbour. The PAC evaluated the use impairments and developed specific water use goals and objectives designed to assist in the restoration and protection of the AOC. These goals provided community-based guidelines for the remediation of impairments in Peninsula Harbour.

The Stage One document was reviewed by federal and provincial agencies and was submitted to the International Joint Commission (IJC) in 1991. The International Joint Commission concluded that there was sufficient information to proceed with Stage Two.

A draft Stage 2 RAP was prepared in 1999. When finalized, the Stage Two RAP Report will present the remedial options to address the environmental problems within the harbour. In the report, each option will be evaluated and the preferred course of action for the AOC will be identified.

The draft version of the Peninsula Harbour Stage 2 Remedial Action Plan (RAP) Report was developed by Environment Canada and the Ontario Ministry of the Environment, with support from Fisheries and Oceans Canada, Ontario Ministry of Natural Resources, and the general public.

The Remedial Action Plan adopted an ecosystem approach to environmental problems that incorporated land, water, air, plants, animals and ultimately people. Therefore, the cooperation and involvement of other federal and provincial government agencies has been key to RAP progress.

The general public (both individuals and organizations) participated in the RAP process as members of the Public Advisory Committee (PAC), providing a forum for the spectrum of interests existing within a community. The Peninsula Harbour PAC encompassed the interests of environmental groups, recreational groups, industry and municipalities.

RAP Accomplishments

The former chlor-alkali plant, which operated adjacent to the pulp mill from 1952 to 1977, was the main source of mercury contamination to the harbour. Mercury contaminated material has since been removed from the plant itself and safely deposited at the facility's own mercury disposal site. Effluent from the Marathon kraft pulp mill is now treated to remove organic pollutants.

Recent studies have confirmed the severity of the mercury contamination problem. A 2002 biomagnification study completed by Environment Canada concluded that there was biotic uptake of mercury from the sediments, and an Ontario Ministry of the Environment sport fish collection in 2002 found elevated PCB and mercury levels in white suckers.

Additional work has been completed to analyze results from 2003 field work on sport fish, caged clams and sediment sampling conducted by Ontario Ministry of the Environment. Additional sediment studies of core chemistry and sediment stability have been carried out by the National Water Research Institute.

The assessment and management of contaminated sediment is an intensive process. All participants will continue to work together to ensure that an acceptable outcome is achieved.

RAP Participants

Cooperation is critical to the RAP process. Undertaking environmental restoration requires a large amount of local knowledge, scientific expertise and hard work. One agency or group cannot undertake such a large task on their own, without the help of others. Listed below are the participants that have contributed to the RAP program.

- Environment Canada
- Great Lakes Sustainability Fund
- Ontario Ministry of Natural Resources
- Ontario Ministry of the Environment
- Town of Marathon
- Marathon Pulp Inc.

A.2.1.E St. Marys River

St. Marys River Area of Concern

General Information

Where?

The St. Marys River is the 112 km connecting channel from Lake Superior to Lake Huron. The Area of Concern (AOC) extends from the head of the river at Whitefish Bay downstream approximately two-thirds of the river and includes the Canadian and U.S. cities of Sault Ste. Marie.

Why was this area listed?

Major environmental issues of concern in the area included:

- Restrictions on fish and wildlife consumption
- Unhealthy fish and wildlife populations
- Fish tumours and other deformities
- Unhealthy populations of bottom-dwelling organisms
- Restrictions on dredging
- Undesirable algae due to excess nutrients in the water
- Beach closures
- Poor aesthetics
- Loss of fish and wildlife habitat

What is being done? How is it being done?

In order to improve the environmental conditions noted above, a Remedial Action Plan (RAP) was developed for the St. Marys River. The St. Marys River RAP is a partnership between Canadian and U.S. federal governments, provincial (Ontario) and state (Michigan) governments, with cooperation from the Binational Public Advisory Committee (BPAC).

The Remedial Action Planning process, which was initiated in 1988, involves the following three stages:

- defining the problem (Stage 1)
- determining what remedial actions are needed to rectify the impairments (Stage 2)
- implementing the actions (Stage 2)
- monitoring the restoration of the environment and eventual delisting of the AOC (Stage 3)

The final Stage 2 Report was released in 2003. More than 60 recommended actions, including a large number of restoration and protection measures already completed or in progress, were included in the report.

Activities in the American portion of the AOC are being coordinated by US agencies, and more information about those activities can be found on the US EPA Web site (http://www.epa.gov/grtlakes/aoc/stmarys.html).

HIGHLIGHT of the RAP

Algoma Steel Inc. (ASI) signed a three party Environmental Management Agreement (EMA) with Environment Canada and the Ontario Ministry of the Environment in early 2001. The objective of this EMA was to clearly define a list of initiatives with negotiated timelines for environmental activities which Algoma Steel agreed to undertake. The activities identified in the agreement dealt with issues which the three stakeholders agreed are priorities but which had specific objectives which were beyond the compliance regime administered by Environment Canada or the Ministry of the Environment. It was a voluntary initiative which complemented the existing regulatory process and assisted Algoma Steel in planning and prioritizing a multi year environmental program. The agreement covered the period from date of signing to December 31, 2005. Prior to its expiration, negotiations were initiated to renew the Environmental Management Agreement for another term.

As of August 2004, the following achievements had been reported under the EMA:

- air emissions reduced from 1993 levels by 80.4 percent for benzene, 71.4 percent for PAHs
- reduced visible emissions from blast furnace
- developed annual Cokemaking Environmental Plans. The “year 2004 plan” was implemented January 1, 2004
- Total destruction of PCB since 1999 is 51,674.104 litres, or equivalent to 116.3 percent of stored PCB waste inventory .
- boat slip survey and sediment assessment completed in 2001(this was repeated in 2005 - results pending).
- landfill groundwater survey planned for 2005, and closure plan completed
- Waste mercury inventory removal completed. Direct removal policy in place.
- 80 percent of Environment Code of Practice for Integrated Steel Mills Recommendations met

The complete text of the agreement may be found on Environment Canada's Internet site.

RAP Development/History

Since the Area of Concern includes an international waterway, the St Marys River RAP requires a cooperative effort between Canadian and U.S. governments to coordinate the remedial action process.

Environment Canada, U.S. Environmental Protection Agency, Ontario Ministry of the Environment and Michigan Department of Environmental Quality have worked in partnership to further clarify areas of joint leadership and responsibility.

The cooperation and involvement of the Four Agencies, along with the Ontario Ministry of Natural Resources, Fisheries and Oceans Canada, and Michigan Department of Natural Resources has been fundamental to the St. Marys River RAP program.

The Binational Public Advisory Committee (BPAC) was formed in 1988 to provide informed and continuous public participation in the St. Marys River RAP. The citizen based group represents interests from both Ontario and Michigan. Members work with and advise RAP participants on key aspects of the planning process. Members have included representatives from industry, academia, First Nations, and elected officials.

It is important to acknowledge the contributions of the BPAC, which has played a crucial role in the development of the RAP during its 12 year history. These accomplishments include:

- Identification of Impairments and Conditions
- Development of Water Use Goals
- Identification of Remediation Needs and Options
- Assessment of Community Programs and Projects
- Development of Delisting Criteria
- Establishment of BPAC Office and Library
- Creation of the Friends of the St. Marys River

The Stage One report of the RAP described the environmental conditions and identified the use impairments in the Area of Concern. Federal, state and provincial agencies and the International Joint Commission reviewed this document.

There have been a number of workshops within the Stage Two process of the RAP, to ensure there has been broad based public involvement. These have been the basis for developing the strategic plans for the restoration of impaired beneficial uses. The brochure, which was concurrently released with the Stage 2 Report, outlines the plans for restoration that will be implemented in the future.

RAP Status

Delisting criteria have been drafted for many of the beneficial use impairments in the St. Marys River AOC. The criteria are used to guide the development of remedial actions, preventative measures, regulatory programs and to direct monitoring efforts. These guidelines will assist in measuring progress towards achievement of water use goals and remediating use impairments in the AOC. This brochure contains a complete list of the recommended remedial actions for the St. Marys River AOC as of December 2002.

Improvements to the City's wastewater treatment system are being supported under the Canada-Ontario Infrastructure Program through a joint project announced in 2001. Through this project, the City of Sault Ste. Marie, Ontario has installed sewage overflow tanks and rehabilitated sewers in areas of high infiltration. Work has been completed to re-route sewers and upgrade two sewage pumping stations and sewage containment tanks. Furthermore, the East End Water Pollution Control Plant is being upgraded to increase primary treatment capacity and secondary treatment will be added. When the last of these improvement projects have been completed, it is expected that there will be no more raw sewage by-passes into the storm water collection system.

The bottom sediments of the river including the Algoma Steel boat slip are contaminated and a contaminated sediment management strategy is being developed.

Sea lamprey control efforts will help restore impaired fisheries in the St. Marys River as well as northern Lake Huron and Lake Michigan. A long term, continuing effort is needed since the opportunistic lamprey can take quick advantage of any lapse in larvae and adult control measures.

RAP Implementation

On April 17, 1998, Environment Canada, U.S. Environmental Protection Agency, Ontario Ministry of the Environment and Michigan Department of Environmental Quality signed a Four Agency Letter of Commitment. The Letter outlined agency roles and responsibilities during implementation of the Remedial Action Plans for the St. Clair River, Detroit River and St. Marys River binational Areas of Concern.

The Agencies have worked in partnership to further clarify areas of joint leadership and responsibility. A Compendium of Position Papers has been written and describes how the agencies work together to provide leadership for the RAPs, by involving the public, monitoring and reporting on progress, with the ultimate goal of delisting the Areas of Concern. The Compendium was signed on February 2, 2000.

Implementation of the actions recommended in the Stage 2 Report have not all proceeded at the same pace. Some actions are still in the early stages, while others are either complete or have been ongoing for some time.

Some of the projects already implemented or being implemented by individual stakeholders are:

- Process improvements, water treatment improvements and air quality monitoring at Algoma Steel
- Improvements to water treatment and air emissions at St. Marys Paper
- Improvements to pump stations, installation of combined sewer overflow tanks, ongoing improvements to the East End Wastewater Treatment Plant in Sault Ste. Marie, Ontario that will upgrade it to secondary treatment.
- Land based investigations and remedial actions are ongoing at the site of a decommissioned manufactured gas plant downstream of the Sault Edison power plant beside MCM Marine. Consumers Energy is removing about 5,000 cubic yards on-shore. River-based sediment investigations are done, and in the first phase of in-water dredging 2,000 to 4,000 cubic yards of sediment will be removed.
- Pilot test of chemical injection system to treat contaminated sediments
- Remediation of the Cannelton Industries Superfund site
- Bellevue Marina Sediment Management Strategy
- Little Rapids restoration project
- Enhanced fish access to Munuscong Bay Waterfowl Sanctuary
- The Chippewa/East Mackinaw Conservation District, with funding from MDEQ, has started work on a non-point source Watershed Planning project for the St. Marys River watershed. This project will assess urban pollution impacts to water quality and the nonpoint source pollutants for the St. Marys River originating from the Sault Ste. Marie watershed.
- Securement of 1500 hectares of wetlands through conservation agreements and landowner tax incentive programs
- The "Partners In Wetland Conservation" (PIWC) program, managed by Ducks Unlimited Canada (DUC), with funding from EC, is:
    - Empowering municipalities to conserve wetlands by increasing cooperation, data sharing and by helping them to identify and map wetlands within their boundaries and formally protect them through Official Plan revisions.
    - Evaluating additional wetlands within the AOC. Increasing efforts to secure wetland acres through the Conservation Land tax Incentive Plan (CLTIP) and the Managed Forest Tax Incentive Plan (MFTIP) incentive programs and DUC conservation agreements.
    - Engaging the public through a stronger public education component to value and conserve wetlands.
    - Gathering and facilitating volunteer participation in Canada's "Marsh Monitoring Program"
- establishment of Lake George wetland interpretive site

Two RAP reviews were completed in 2004. The first was focused on synthesizing existing scientific data on contaminated sediment in order to identify data gaps and begin the development of sediment management options. The second was a broader review of the RAP which re-engaged stakeholders, reported on progress, and made a number of recommendations including a risk management decision making framework for the clean-up of contaminated sediments.

MDEQ recently released its 1992-2003 Great Lakes Connecting Channels Data Evaluation and Trend Analysis Report. The report is a summary of spatial and temporal water quality trends in the St. Marys, St. Clair and Detroit River connecting channels. In 2004, MDEQ conducted chemical and biological sampling on Charlotte River, Ashmun Creek, and Wilmar creek on Sugar Island. Reports are now complete, and available from MDEQ.

In 2005, MNR and MIDNR carried out a fish harvest survey of the lower St. Marys River. MNR and DFO also partnered to collect "young of the year" walleye along the east side of Lake George to look at recruitment and stocking. US agencies also completed sites on the US side.

The BPAC draft document "Report on Scope of Contaminated Sediments in the St. Marys River Area of Concern," was released April 5, 2005, and has been reviewed by the agencies and comments provided to BPAC**.** .

As the St. Marys River RAP evolves further into the implementation phase, even more stakeholders will get involved, and the administration of projects and relationships between stakeholders will evolve as well.

RAP Accomplishments

Although implementation of some remedial actions is just beginning, important steps forward have already been made in the St. Marys River RAP.

Notable successes have included the sixty million dollar Canada-Ontario Infrastructure project through which the City of Sault Ste. Marie, Ontario installed sewage overflow tanks, made upgrades to increase primary treatment capacity, rehabilitated sewers in areas of high infiltration, and is adding secondary treatment to the East End water pollution control plant. These upgrades should drastically reduce the probability of future sewage overflows.

Other achievements include the development of wetland protection strategies, fostering the recovery of walleye populations and supporting the design of habitat features in the city's waterfront development.

A complete list of notable achievements is published in the St. Marys RAP Stage 2 Brochure.

RAP Participants

Cooperation is critical to the RAP process. Undertaking environmental restoration requires a large amount of local knowledge, scientific expertise and hard work. One agency or group cannot undertake such a large task on their own, without the help of others. Listed below are participants that contribute to the RAP program.

- Environment Canada
- Fisheries and Oceans Canada
- Health Canada
- Ontario Ministry of the Environment
- Ontario Ministry of Natural Resources
- United States Environmental Protection Agency
- Michigan Department of Environmental Quality
- Michigan Department of Natural Resources
- Great Lakes Sustainability Fund

- City of Sault Ste. Marie, Ontario
- City of Sault Ste. Marie, Michigan
- Algoma Steel
  - Environmental Management Agreement
- St. Marys Paper
- Binational Public Advisory Committee
- Friends of St. Marys River
- Sault Ste. Marie Region Conservation Authority
- Local First Nations and Native American communities
- Lake Superior State University

A.2.2 U.S. Fact Sheets

A.2.2.A Torch Lake

Torch Lake Area of Concern

Torch Lake AOC Boundary Map
(click on map to view in separate window)
Torch Lake shape file

Background

Torch Lake became an Area of Concern (AOC) due to fish tumors of unknown origin which resulted in fish consumption advisories. The 1987 RAP document identified three Beneficial Use Impairments (BUIs) for the Torch Lake AOC. Fish Tumors; Degraded Benthos; Fish Consumption Advisories.

Mason Stamp Sand Parcel of Torch Lake AOC after remediation

The Torch Lake Area of Concern is located on the Keweenaw Peninsula within Houghton County on the northwestern shore of Michigan's Upper Peninsula and on Lake Superior's southern shore. The region is locally known as the Copper Country. Deposits of native (elemental) copper are found in the Portage Lakes Lava Series, a long narrow bedrock formation which extends from the tip of the

Keweenaw Peninsula southwest to the Michigan-Wisconsin border covering a distance of over one hundred miles.

Copper-bearing ore on the Keweenaw Peninsula contains copper in its native or natural metallic form. For this reason, it has been a source of copper for people for thousands of years. More recently, it is the waste products from the industrial milling, smelting, and leaching operations of the mined copper bearing ore that have created the present environmental concern. These industrial processes began during the 1840s and continued for more than a century until all mining and related operations ceased in 1968. Those processes left stamp sands and slags deposited either on the surface of the surrounding landscape or in adjacent lakes and streams. Portions of the surficial materials eroded into nearby waterbodies.

Mason Stamp Sand Parcel of Torch Lake AOC before remediation

It is estimated that more than 10.5 billion pounds of copper were produced in the Copper Country between the mid-1840s and 1968. Half of this output was processed at sites scattered across the Copper Country landscape. The remainder was processed along the western shoreline of Torch Lake, a 2,700 acre body of water in Houghton County. About 200 million tons of copper ore tailings were deposited in Torch Lake, displacing about 20 percent of the lake's original volume (MDNR 1987).

The Torch Lake Area of Concern Boundary was described in the 1987 Torch Lake Remedial Action Plan (RAP) document "…..Torch Lake and its immediate environs." Immediate environs can be described as those areas along the shore of Torch Lake proper where wastes from the production of copper contributed directly to the contaminate loadings of Torch Lake. These areas had stamp sands and water quenched slags dumped on the shore and into the lake during the copper production process. The AOC boundary was formally agreed to by the Torch Lake Public Advisory Council (TLPAC), US EPA and the Michigan Department of Environmental Quality in 2005.

Beneficial Use Impairments

The 1987 RAP document identified three Beneficial Use Impairments (BUIs) for the Torch Lake AOC:

- Fish Tumors
- Degraded Benthos
- Fish Consumption Advisories

Torch Lake Beneficial Use Impairments

• ***Restrictions on fish and wildlife consumption***	Eutrophication or undesirable algae (unknown)
Tainting of fish and wildlife flavor (likely)	Restrictions on drinking water consumption, or taste and odor problems
Degradation of fish and wildlife populations (likely)	Beach closings
• ***Fish tumors or other deformities***	Degradation of aesthetics
Bird or animal deformities or reproduction problems (likely)	Added costs to agriculture or industry
• ***Degradation of benthos***	Degradation of phytoplankton and zooplankton populations
Restrictions on dredging activities	Loss of fish and wildlife habitat

Delisting Criteria/Restoration Targets

The Torch Lake AOC Public Advisory Council has requested that the State of Michigan begin the AOC delisting process for their AOC. A technical committee was developed comprised of staff from state and federal agencies and the PAC. The technical committee determined to use delisting criteria based on the recently released Guidance for Delisting Michigan's Great Lakes Areas of Concern document, released January 2006.

RAP Development and Status

- December 2005: First draft of the Delisting Determination Document for the Torch Lake Area of Concern completed. (unavailable)
- 2002: Draft Remedial Action Plan Update completed. (unavailable)
- 1987: Michigan Department of Natural Resources Remedial Action Plan for the Torch Lake Area of Concern completed.

RAP Implementation

Remedial Actions

The Torch Lake Area of Concern included four of 14 Superfund Areas that were divided into operable units (OU). Two of three OUs, i.e. OU 1 and OU2, as designated under the two Superfund Record of Decisions, were applicable to the Torch Lake Area of Concern. These were:

- OU 1 - includes the stamp sands, water quenched slags and other mining wastes deposited along the Torch Lake shoreline.
- OU 2 - includes ground water, surface water and submerged stamp sands and sediments in Torch Lake, Portage Lake, the Keweenaw Waterway/Portage Ship Canal, the Lake Superior Shoreline from south of the North Entry to Freda/Red Ridge, Boston Pond and Calumet Lake

Mason Stamp Sand Parcel of Torch Lake AOC after Superfund remediation. Note dredge and smelter leftover from the copper mining days.

The selected remedy for OU 1 was to cover with soil and seed down to prevent erosional actions by wind and water. Remedial actions for the Torch Lake Superfund Site were completed by September 2005. Some parcels have already been deleted from the National Priorities List (NPL). Once all parcels are deleted, planned for 2008, the state will assume Operation and Maintenance of the areas which includes long term monitoring of all OUs. Under the ROD for OU 2, natural attenuation was the selected remedy for the lakes. OU 2 has been deleted from the NPL.

The selected remedy for OU 1 was to cover with soil and seed down to prevent erosional actions by wind and water. Remedial actions for the Torch Lake Superfund Site were completed by September 2005. Some parcels have already been deleted from the National Priorities List (NPL). Once all parcels are deleted, planned for 2008, the state will assume Operation and Maintenance of the areas which includes long term monitoring of all OUs. Under the ROD for OU 2, natural attenuation was the selected remedy for the lakes. OU 2 has been deleted from the NPL.


Hubbell/Tamarack City Stamp Sand Parcel of Torch Lake AOC during remediation (left)
Hubbell/Tamarack City Stamp Sand Parcel of Torch Lake AOC after remediation (right)

Current Projects and Outlook

- Delisting Determination Document under development.

RAP-Related Publications

- 2005: NPL Fact Sheets for Michigan: Torch lake, US EPA Region 5
- 2001: Baseline Study Report: Torch Lake Superfund Site, Houghton County, Michigan, US EPA-Superfund.
- 1996: A Mining Legacy: Torch Lake and Area of Concern (18-minute video), Houghton/Keweenaw Soil and Water Conservation District.
- 1994: Declaration for the Record of Decision for Operable Unit II, Houghton County, Michigan, US EPA.
- 1992: Declaration for the Record of Decision for Operable Units I & III, Houghton County, Michigan, US EPA.

Community/Local RAP Group Involvement

Public election of the members of the Torch Lake Public Advisory Council (TLPAC) took place in the spring of 1997. In less than one year the group adopted its by-laws, mission statement, goals and objectives, and incorporated as a tax-exempt, nonprofit Michigan corporation. It has received contributions from local governments, businesses, environmental groups, and private individuals to help defray logistical expenses. In addition, TLAPAC has been awarded over $24,000 from agency grants and private foundations.

Currently, there are seven schools within the AOC that have instituted Adopt-A-Stream projects. The Keweenaw Waterway Trail Association, in cooperation with local and state agencies, has developed a series of low-impact boating campsites along the waterway.

Wildlife abounds on the newly vegetated stamp sands of Torch Lake AOC. Small mammal survey results show wildlife is quite abundant on newly revegetated stamp sands compared to unremediated stamp sands where we did not find any wildlife at all.

Partners and Stakeholders

- Adams Township
- Calumet Township
- Chassell Township
- City of Hancock
- City of Houghton
- Elm River Township
- Franklin Township
- Hancock Township
- Houghton Co. Natural Resources Conservation Service
- Houghton County Board of Commissioners
- Keweenaw Bay Indians, Band of Chippewa
- Keweenaw National Historical Park
- Lake Linden Village
- Michigan Department of Environmental Quality
- Michigan Department of Natural Resources
- Michigan Statewide Public Advisory Council
- Michigan Technological University, Center for Science and Environmental Outreach
- Osceola Township
- Portage Township
- Quincy Township
- Schoolcraft Township
- Stanton Township
- Torch Lake Public Advisory Council
- Torch Lake Township
- US EPA - Great Lakes National Program Office
- US EPA - Superfund

Torch Lake AOC Contacts

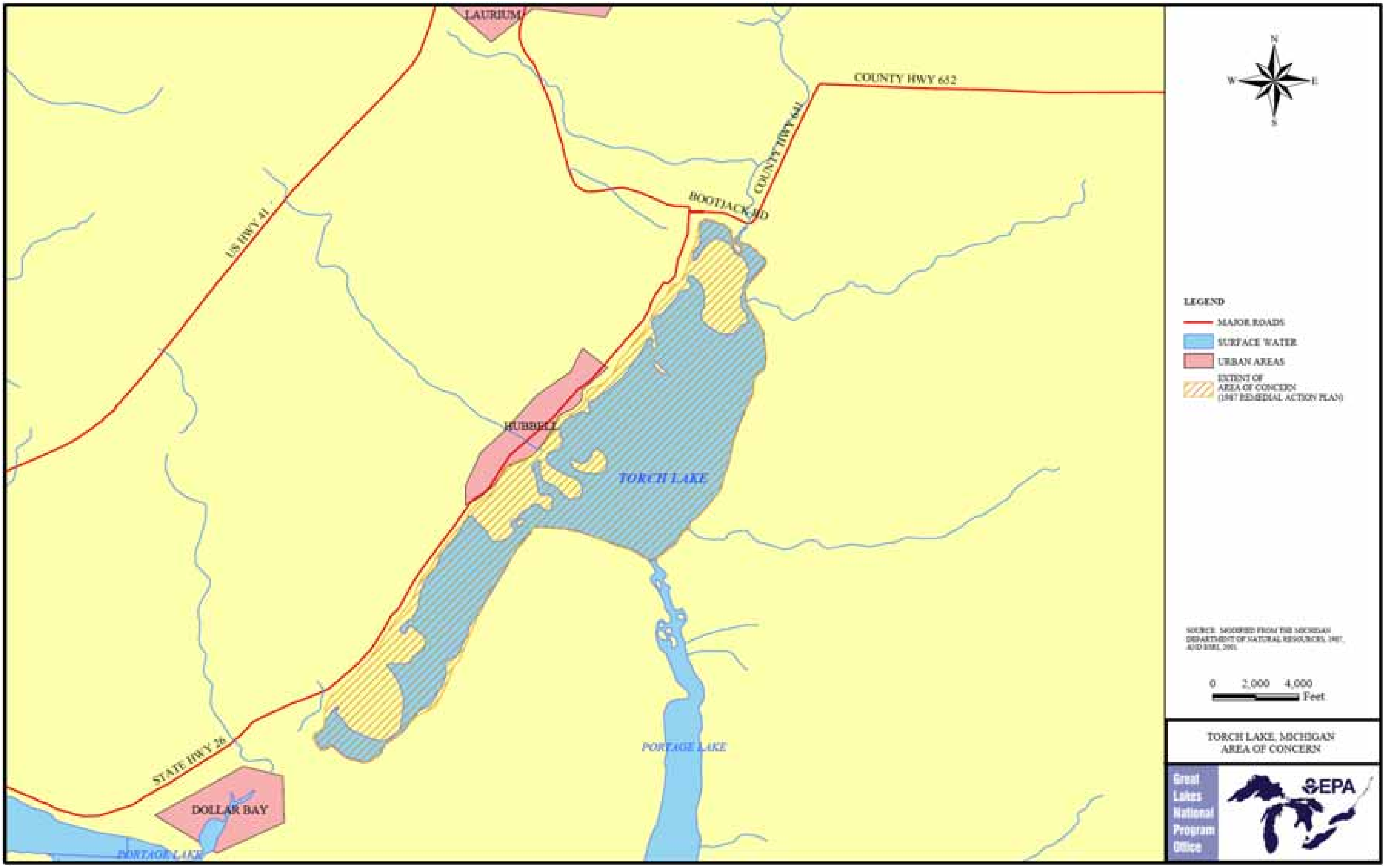
US EPA RAP Liaison:
Brenda R. Jones, RAP Liaison
U.S. Environmental Protection Agency
77 West Jackson Blvd. (SR-6J)
Chicago, IL 60604
(312) 886-7188 phone
(312) 886-4071 fax
jones.brenda@epa.gov

State RAP Contact:
Sharon Baker, RAP Contact
Michigan Department of Environmental Quality
Water Bureau
P.O. Box 30273
Lansing, MI 48909-7773
PH: 517-335-3310
FAX: 517-373-9958
BAKERSL@michigan.gov

Torch Lake Public Advisory Council:
Dave Jukuri, Chair
1100 Century Way
PO Box 97
Houghton, MI 49931
Ph: 906-482-0001
Fax: 906-482-1310
c21ncah@up.net

Dan Lorenzetti, Secretary
100 Isle Royal Sands
Houghton, MI 49931
Ph: 906-482-2731
Fax: 906-482-49931
Dan@superiorblock.com

Local Coordinator:
James Trevethan, SPAC Representative
17463 Osma Plat Rd.
Houghton, MI 49931
Ph: 906-482-4951


LAURIUM
COUNTY HWY 652
COUNTY HWY 641
BOOTJACK RD
US HWY 41
HUBBELL
TORCH LAKE
STATE HWY 26
DOLLAR BAY
PORTAGE LAKE
PORTAGE LAKE
N
W
E
S
LEGEND
MAJOR ROADS
SURFACE WATER
URBAN AREAS
EXTENT OF
AREA OF CONCERN
(1987 REMEDIAL ACTION PLAN)
SOURCE: MODIFIED FROM THE MICHIGAN DEPARTMENT OF NATURAL RESOURCES, 1987, AND ESRI, 2001.
0 2,000 4,000
Feet
TORCH LAKE, MICHIGAN
AREA OF CONCERN
Great Lakes National Program Office
EPA

A.2.2.B St. Louis River

St. Louis River Area of Concern

St. Louis River AOC Boundary Map
(click on map to view in separate window)
St. Louis River shape file

Background

The St. Louis River, the largest U.S. tributary to Lake Superior, drains 3,634 square miles, entering the southwestern corner of the lake between Duluth, Minnesota and Superior, Wisconsin. The river flows 179 miles through three distinct areas: coarse soils, glacial till and outwash deposits at its headwaters; a deep, narrow gorge at Jay Cooke State Park; and red clay deposits in its lower reaches. As it approaches Duluth and Superior, the river takes on the characteristics of a 12,000 acre freshwater estuary. The upper estuary has some wilderness-like areas, while the lower estuary is characterized by urban development, an industrial harbor and a major port. The lower estuary includes St. Louis Bay, Superior Bay, Allouez Bay, Kimball's Bay, Pokegama Bay, Howards Bay and the lower Nemadji River.

The St. Louis River System Area of Concern (AOC) is the area being addressed by the St. Louis River System Remedial Action Plan (RAP). While system-wide in its approach, the St. Louis River AOC focuses primarily on the lower 39 river miles and the entire 360 square mile Nemadji River watershed. The Nemadji River is split almost equally between Minnesota and Wisconsin and discharges into the Duluth-Superior Harbor near the natural outlet of the St. Louis River.

The RAP began in 1989 as a collaborative effort between the Minnesota Pollution Control Agency (MPCA) and the Wisconsin Department of Natural Resources (WDNR). At that time, the agencies created a Citizens Advisory Committee (CAC). In 1997, with agency assistance, the CAC opened its doors as an independent nonprofit organization known as the Citizens Action Committee. Many of the original citizen and agency partners are still active in the RAP and CAC.

Beneficial Use Impairments

The RAP process determined that nine of 14 identified beneficial uses were impaired. Some impairments were associated with the physical loss and degradation of habitat, with an estimated 7,700 acres of wetland and open water habitat altered or destroyed since settlement. Other problems were related more to pollution and toxicity. For years, the river smelled bad from industrial discharges. That changed in 1978, when the Western Lake Superior Sanitary District (WLSSD) wastewater treatment plant began operation. Nevertheless, pollution continues to come from sources such as contaminated sediments, abandoned hazardous waste sites, poorly designed or leaky landfills, airborne deposition, industrial discharges, chemical spills, improperly sewered wastes, and surface runoff.

St. Louis River Beneficial Use Impairments

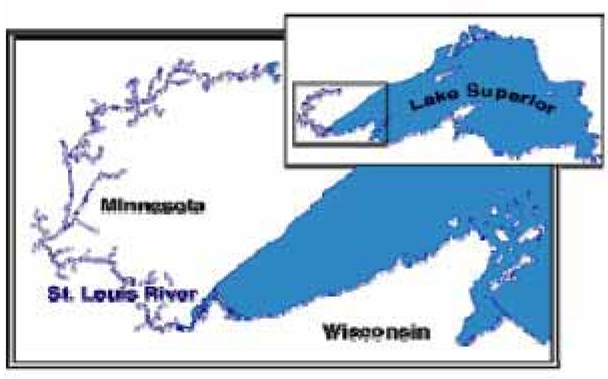
• ***Restrictions on fish and wildlife consumption***	• ***Excessive Loading of Sediment and Nutrients***
Tainting of fish and wildlife flavor (unclear)	Restrictions on drinking water consumption, or taste and odor problems
• ***Degradation of fish and wildlife populations***	• ***Beach closings***
• ***Fish tumors or other deformities***	• ***Degradation of aesthetics***
Bird or animal deformities or reproduction problems (unclear)	Added costs to agriculture or industry
• ***Degradation of benthos***	Degradation of phytoplankton and zooplankton populations
• ***Restrictions on dredging activities***	• ***Loss of fish and wildlife habitat***

For further information and details on all of the BUIs, see a corresponding St. Louis River Beneficial Use Impairments document, the Restoration Goals for Beneficial Use Impairments SLRCAC web page, and the Remedial Action Plan (RAP) documents listed in the RAP Development and Status section below.

Delisting Criteria/Restoration Targets

In 2004, the SLRCAC proposed restoration goals for many of the impaired uses through a citizen process and submitted them to the Wisconsin Department of Natural Resources (WDNR) and the Minnesota Pollution Control Agency. The agencies will review the proposed goals in light of environmental data and potential actions. The state agencies' review, revisions and clarifications, and adoption of the delisting targets is the next phase that needs to be accomplished. The targets will serve as the roadmap for actions to lead to delisting the AOC.

The SLRCAC has been awarded a grant through the WDNR to facilitate work on the delisting roadmap document for the St. Louis River AOC. During this project, SLRCAC will coordinate information exchange between federal, state, tribal agencies and local governments. SLRCAC will guide public participation in the roadmap development process. In brief, the SLRCAC will craft, facilitate public and agency review, publish, post on websites, and distribute the delisting roadmap document for the St. Louis River AOC.



RAP Development and Status

A progress report containing the CAC's 43 Stage Two recommendations was published in 1995. Implementation began immediately and continues today. Some recommended actions are well underway or completed, such as: (1) land acquisition, with 34,000 acres bordering the river permanently protected by purchase or donation, (2) connection of Fond du Lac, MN, responsible for a high percentage of failing septic systems, to the WLSSD, (3) programs to reduce sewage bypasses by keeping stormwater out of sanitary sewer systems, (4) completion of a habitat plan for the lower St. Louis River, and (5) implementation of a three-phase sediment strategy to reduce impairments associated with sediment contamination.

The Stage One document was published and reviewed in 1992. The IJC gave the RAP high marks for broadening the geographic scope of the AOC and expanding the definition of the use impairments in order to fully encompass local environmental concerns.

Significant RAP Milestones

- **2004:** The SLRCAC proposed restoration goals for many of the impaired uses through a citizen process and submitted them to the Wisconsin Department of Natural Resources (WDNR) and the Minnesota Pollution Control Agency.
- **2002**: Lower St. Louis River Habitat Plan completed. The CAC worked with several partners from city, county, state, and federal agencies and entities on this document.
- **1999**: The CAC received funding to implement the habitat plan recommendation.
- **1996**: St. Louis River Citizens Action Committee formed.
- **1995**: RAP Recommendation Implementation Status document drafted.
- **1995**: St. Louis River System RAP Progress Report completed.
- **1992**: The St. Louis River System RAP Stage One document completed.

RAP Implementation

Recent Progress and Achievements

Hog Island Great Lakes Legacy Act Project Completed: November 28, 2005 marked the completion of the Great Lakes Legacy Act sediment cleanup at Hog Island in Superior, Wisconsin. Great Lakes National Program Office Director Gary Gulezian joined Wisconsin Governor Jim Doyle and 85 residents, local officials, and legislative aids to celebrate this event. The $6.3 million project removed nearly 55,000 tons of petroleum-contaminated sediment from Newton Creek and parts of Hog Island Inlet. Further replanting and re-seeding will occur in the spring of 2006, and the local community is developing plans for further restoration of the area.

Hog Island Inlet. Because of past pollution, the inlet has not been safe for swimming or fishing.

Cleanup of this Great Lakes Legacy Act site, a joint project of the U.S. Environmental Protection Agency's Great Lakes National Program Office and Wisconsin Department of Natural Resources, began in July 2005 and the sediment cleanup portion was completed in November 2005. The banks of the creek and inlet were landscaped to prevent erosion. The result will be a healthier habitat for fish and other aquatic life, and the inlet will be safe for recreation.

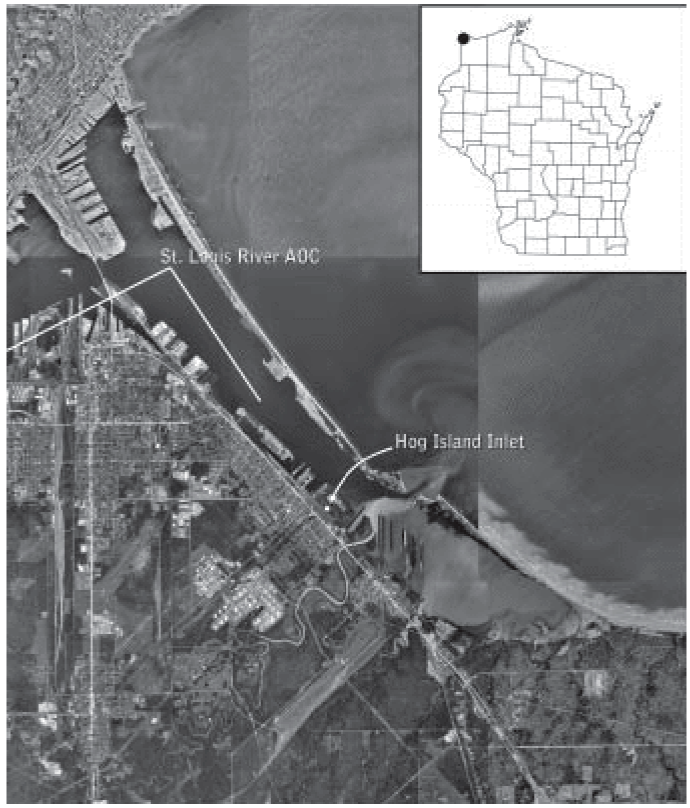
Approximately $4.1 million of the funds to pay for this project are provided by the Great Lakes Legacy Act. The act authorizes $270 million over a five-year period to clean up contaminated sediment in Great Lakes Areas of Concern." The state of Wisconsin and other parties are providing 35 percent of the project's cost, or about $2.2 million. These are nonfederal matching funds required by the Legacy Act.

Close-up view of the contaminated sediments being removed from Hog Island Inlet.

Remediation of Contaminated Sediments: Surveys conducted in recent years have provided a great deal of useful information about local sediment contamination.

In Minnesota, clean ups are underway at the two state Superfund sites on the river (USX and Interlake). Each site has a community work group.

In Wisconsin, WDNR and Murphy Oil are working together to clean up the Newton Creek System, which includes Hog Island Inlet. This is a staged clean-up process that began with Murphy Oil building a new waste water treatment plant. In fall 1997, Murphy Oil began cleaning up the headwaters of Newton Creek.



This is an aerial view of the area where contaminated sediment and soil were removed from Newton Creek and Hog Island Inlet.

Pollution Prevention:
The RAP helped Oliver, Wisconsin, solve its wastewater treatment problems. Oliver and the Western Lake Superior Sanitary District (WLSSD) in Duluth agreed to lay a pipe under the river and treat Oliver's waste at WLSSD.

Water quality continues to improve, due to pollution prevention efforts, better pre-treatment programs and new stormwater management activities, including efforts to control storm-related "inflow and infiltration," which has caused sewage bypasses in Duluth, with untreated sewage flowing directly into Lake Superior.

MPCA, WDNR and WLSSD are encouraging pollution prevention in outreach programs aimed at citizens and businesses.

Habitat Protection and Improvement:
In 2002, the Lower St. Louis River Habitat Plan was completed. The CAC worked with several partners from city, county, state, and federal agencies and entities on this document. The Plan is being used to protect and restore the river. The plan classifies specific areas of the entire estuary into habitat types and recommends what actions are needed to restore, protect or enhance the river. The Plan has been embraced by all levels of government and by other groups and organizations. Most recently it was a basis for the part of the remediation of a Superfund site cleanup located in the river at Stryker Bay on the Minnesota side of the river. Recommendations in the Habitat Plan were also used in the Great Lakes Legacy Act contaminated sediment cleanup site on the Wisconsin side, Hog Island Inlet. (See above.)

The RAP was instrumental in the creation of WDNR's St. Louis River Streambank Protection Project, upstream of Oliver, which purchased 6,900 acres, including shorelands bordering five miles along the St. Louis River and 13 miles along the Red River and its main tributaries. The project includes most of the Red River watershed, which is characterized by steep slopes and highly erodible red clay soils.

The St. Louis River Board developed an even larger protection project along the St. Louis, Cloquet and Whiteface River (all in the St. Louis River watershed). Some 22,000 acres were acquired and transferred to the Minnesota Department of Natural Resources.

Bio-control is being used on purple loosestrife infestations in wetlands on both the Minnesota and Wisconsin sides of the lower estuary.

Current Projects and Outlook
See Priority Action Items in the St. Louis River AOC for a look at current projects and what the RAP partners hope to accomplish in the near future.

RAP-Related Publications

- Natural & Cultural History of the Lower St. Louis River: On-the-Water Guide for Canoeists, Kayakers & Boaters. St. Louis River Citizens Action Committee, August 2001.
- Historic Reconstruction of Property Ownership and Land Uses along the Lower St. Louis River. St. Louis River Citizens Action Committee, October 1999.
- Lake Superior/Duluth-Superior Harbor Toxics Loading Study. Minnesota Pollution Control Agency, September, 1999.
- Issue Paper Concerning Wet Weather Flow Issues: Sanitary Sewer Overflows Developed For the WLSSD Effluent Quality Master Plan Project. Western Lake Superior Sanitary District, 1999.
- Wisconsin's Lake Superior Coastal Wetlands Evaluation: A Report to the Great Lakes National Program Office, US EPA. Wisconsin DNR PUB ER-09599, 1999.
- Lake Superior Basin Water Quality Management Plan. Wisconsin DNR PUBL-WT-278-99-REV, March 1999.
- Lake Superior Lakewide Management Plan 2000. Lake Superior Binational Program, April 2000.
- Erosion and Sedimentation in the Nemadji River Basin. Natural Resources Conservation Service and U.S. Forest Service, 1998.
- Newton Creek System Sediment Contamination Site Characterization Report. Wisconsin Department of Natural Resources, December 1995.

More information on these publications can be obtained by contacting the individuals listed in the St. Louis River AOC Contacts section below.

Community/Local RAP Group Involvement

The St. Louis River Citizens Action Committee, or SLRCAC, consists of people of all ages and walks of life who work together to improve the St. Louis River. The independent nonprofit organization incorporated as a 501(c)(3) organization in 1996 to encourage implementation of the RAP and restoration of the AOC. The SLRCAC has a successful track record of bringing parties together to implement projects and facilitate multi-jurisdictional strategies for the AOC. A prime example is the Lower St. Louis River Habitat Plan (2002) developed by the SLRCAC with federal, state, tribal, and local resource management professionals and citizens. This plan is used extensively by the resource management agencies and local communities.

The St. Louis River System RAP has been recognized since its inception for its high level of citizen participation and community involvement. Hundreds of individuals, representing a broad cross-section of the community, have worked together to identify problems, develop and/or implement recommendations and encourage environmental stewardship. They have provided crucial support for the RAP process and helped to improve the health of the St. Louis River ecosystem.

Just as the St. Louis River and estuary are important components of the Lake Superior Basin Ecosystem, the RAP activities are important to the Lake Superior Binational Program and the Lakewide Management Plan. RAP actions, from contaminated sediment cleanup to habitat protection, pollution prevention, and community involvement are all important to meet the Lake Superior basin goals.

Public Outreach and Education:
River Watch Program in Minnesota and Water Watch Program in Wisconsin have involved numerous area teachers and school children in hands-on, field-oriented, water-quality education and monitoring. These efforts have also included a spring River Congress, annual stormdrain stenciling and several art/science collaborations.

The sign at the entrance to the Newton Creek/Hog Island Inlet Great Lakes Legacy Act Cleanup.

The RAP helped get signs posted to warn recreational users about contaminated sediments at Stryker Bay in Duluth and at Hog Island Inlet in Superior.

The SLRCAC has organized clean ups at the Connors Point Recreation Area and Wisconsin Point in Superior as well as Grassy Point and Erie Pier in Duluth.

Partners and Stakeholders

- 1854 Authority(www.1854authority.org)
- Arrowhead Regional Development Commission (www.ardc.org)
- City of Duluth, MN (http://www.ci.duluth.mn.us)
- City of Superior, WI (www.ci.superior.wi.us)
- Fond du Lac Tribe (www.fdlrez.com)
- Harbor Technical Advisory Committee
- Lake Superior Binational Program
- Minnesota Department of Natural Resources
- Minnesota Pollution Control Agency
- Minnesota Sea Grant
- River Watch Project
- River Quest
- St. Louis River Citizens Action Committee
- The Nature Conservancy
- U.S. Army Corps of Engineers
- US EPA
- U.S. Fish and Wildlife Service
- Western Lake Superior Sanitary District (www.wlssd.com)
- Wisconsin Department of Natural Resources
- Wisconsin Sea Grant

St. Louis River AOC Contacts

US EPA RAP Liaison:
Liz LaPlante
US EPA, GLNPO
77 West Jackson Blvd. (T-13J)
Chicago, IL 60604-3590
Ph: 312-353-2694
Fax: 312-886-9697
laplante.elizabeth@epa.gov

Wisconsin AOC Contact:
Duane Lahti – Basin Supervisor
Wisconsin Department of Natural Resources
1401 Tower Avenue
Superior, WI 54880
Ph: 715-395-6911
Fax: 715-392-7993
lahtid@dnr.state.wi.us

Minnesota AOC Coordinator:
Marc Hershfield
Minnesota Pollution Control Agency
525 Lake Avenue South, Suite 400
Duluth, MN 55802
Ph: 218-723-2358
Fax: 218-723-4727
marc.hershfield@pca.state.mn.us

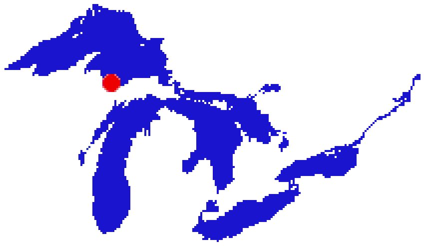
St. Louis River Citizens Action Committee:
Philip Monson, Chair
University of Minnesota Extension
179 University Rd
Cloquet, MN 55720
Ph: 218-726-6471
Fax: 218-879-0857
monso044@umn.edu

Lynelle Hanson
Executive Director
St. Louis River Citizens Action Committee
394 S. Lake Ave., Suite 303B
Duluth, MN 55802-2325
Ph: 218-733-9520
Fax: 218-723-4794
slrcac@stlouisriver.org

Fond du Lac Tribe:
Nancy Schuldt
Water Projects Coordinator
1720 Big Lake Road
Cloquet, MN 55720
(218) 878-8010

A.2.2.C Deer Lake

Deer Lake Area of Concern



Deer Lake AOC Boundary Map
Not Yet Available/Pending Approval

Background

Early fall in South Basin looking toward the narrows.

Deer Lake is a 1,000-acre impoundment in central Marquette County near Ishpeming, Michigan. The Area of Concern (AOC) boundary is considered to be Carp Creek from the discharge point of the old Ishpeming Township A Wastewater Treatment Plant flowing downstream to the south basin of Deer Lake. The AOC also includes Deer Lake, and the Carp River flowing downstream through the dam from the north basin of Deer Lake about twenty miles to Lake Superior near Marquette. International Joint Commission, Environmental Protection Agency, and Michigan Department of Environmental Quality guidance materials describe that AOCs should be considered on a watershed basis. In most AOCs the watershed is considered a potential source area to that AOC. Contaminant sources to Beneficial Use Impairments (BUIs) that are identified within the watershed, even if not located within the defined AOC boundaries, would be given every consideration for remedial actions, when meeting all federal and state guidance.

In 1981 fish in Deer Lake were discovered to have concentrations of mercury that exceeded the 1.5 mg/kg "ban on total consumption" by the Michigan Department of Community Health (MDCH). Mercury concentrations in Deer Lake fish also exceeded the mercury levels found in fish from similar lakes at that time.

There were two known industrial sources of mercury to the Deer Lake AOC. The first industrial use of mercury occurred in the 1880s in the northwestern portion of the Deer Lake AOC watershed by the Ropes Gold and Silver Company. Liquid (elemental) mercury was used to recover gold from ore between 1882 and 1897 at a location west of the north basin of Deer Lake.

The second industrial use of mercury occurred in the Carp Creek watershed. Mercury salts were used in iron ore assays in laboratories of The Cleveland-Cliffs Iron Company (CCIC). Mercury-containing wastewater from the CCIC laboratories was discharged to the City of Ishpeming wastewater treatment system between 1929 and 1981. During that time the City wastewater treatment plant discharged primary-treated municipal wastewater into Carp Creek which then flows into the south basin of Deer Lake.

Sunset view of the South Basin of Deer Lake looking toward the Narrows.

From 1929 to 1963 all wastewater generated in the City of Ishpeming and Ishpeming Township discharged without treatment through combined sanitary and storm sewers into Carp Creek. From 1964 to 1985 three Primary Treatment Plants treated municipal wastewater before it was discharged into Carp Creek. In 1970 these primary treatment systems were determined to be inadequate by the State Water Resources Commission. The combined sewers were separated into sanitary sewers and storm sewers by 1985. An Enhanced Secondary Wastewater Treatment Plant replaced the three Primary treatment plants in April 1986. The new wastewater treatment system significantly decreased nutrient loading into Deer Lake; for example, phosphorus loading decreased by 86 percent.

Beneficial Use Impairments

Three beneficial use impairments (BUIs) have been identified for the Deer Lake AOC. These include:

Deer Lake Beneficial Use Impairments

• ***Restrictions on fish and wildlife consumption***	• ***Eutrophication or undesirable algae***
Tainting of fish and wildlife flavor	Restrictions on drinking water consumption, or taste and odor problems
Degradation of fish and wildlife populations	Beach closings
Fish tumors or other deformities	Degradation of aesthetics
• ***Bird or animal deformities or reproduction problems***	Added costs to agriculture or industry
Degradation of benthos	Degradation of phytoplankton and zooplankton populations (unknown)
Restrictions on dredging activities	Loss of fish and wildlife habitat

Restrictions on Fish and Wildlife Consumption

Some fish sampled from Deer Lake contain mercury concentrations that exceed the 1.5 mg/kg "do not consume" threshold that has been established by the MDCH. Currently, there is a possession ban for all fish from Deer Lake. There is no fish consumption advisory for brook trout in Carp Creek and the Carp River, however, consumption of other species in these streams is not advised. There are no consumption advisories for wildlife in the Deer Lake AOC.

Bird or Animal Deformities of Reproductive Problems
Bald eagles maintained a nest at Deer Lake between 1963 and 1980, but did not successfully rear young during that time. Eagles were documented to be reproducing successfully again beginning in 1998.

Eutrophication or Undesirable Algae
Deer Lake was characterized as eutrophic (nutrient-rich) by the U.S. Environmental Protection Agency (US EPA) during a national lake survey in 1972. A 1974-75 study by Northern Michigan University concluded that Deer Lake was hypereutrophic (excessively nutrient-rich). Dissolved oxygen (DO) concentrations have been used to assess and monitor the trophic (nutrient) status of the AOC.

Delisting Criteria/Restoration Targets

The Deer Lake AOC Public Advisory Council has requested that the State of Michigan and the U.S. Environmental Protection Agency (EPA) begin the delisting process for the AOC. An AOC Technical Committee was developed comprised of staff from state and federal agencies and the PAC's technical committee. The technical committee determined to use delisting criteria based on the January 2006 Guidance for Delisting Michigan's Great Lakes Areas of Concern document. The AOC Technical Committee is initiating the development of a Delisting Determination Document based on the State of Michigan delisting guidance. This document will determine the status of the BUIs. The Technical Committee will develop a timeline to set goals and track progress. The timeline will use elements from the PAC's delisting checklist.

RAP Development and Status

A Remedial Action Plan (RAP) for Deer Lake Area of Concern was published by the MDEQ in 1987. The Deer Lake PAC drafted a RAP Update in 2002 that is being reviewed by the MDEQ.

The Deer Lake RAP Update is currently in draft form and will be used as the basis for the Deer Lake Delisting Determination Document.

Significant RAP Milestones

As described in the original 1987 RAP, several restoration milestones were achieved prior to the AOC listing process. In addition, many more milestones have been achieved since the RAP was published. The table below provides a chronological list of the RAP implementation milestones for each BUI.

A loon swimming during Autumn; from Fred Minnich's Wildlife Survey conducted July 2004- June 2005.

Chronological List of BUI RAP Milestones in the Deer Lake Area of Concern

Year	Fish Consumption BUI milestones	Eagle reproduction BUI milestones	Eutrophication BUI milestones
2006	Michigan published Delisting Guidelines		
2006	Fish Consumption BUI identified in the State Delisting Guidance as a BUI for the AOC based on the 1987 RAP	Eagle Reproduction BUI identified in the State Delisting Guidance as a BUI for the AOC based on the 1987 RAP	Eutrophication BUI identified in the State Delisting Guidance as a BUI for the AOC based on the 1987 RAP
2005	Deer Lake PAC requested that the DEQ and EPA begin investigating the delisting process for the AOC		
2005	PAC monitored Deer Lake water quality; PAC completed a wildlife study; PAC water quality data report concluded that valve operation has reduced in-lake methylation by 65 percent	One adult occupied territory	MDEQ observed additional improvements in winter DO compared with 1999
2004	PAC monitored Deer Lake water quality and began a wildlife study	Eagle nest occupied; two eaglets fledged	
2003	Fish study completed at Deer Lake AOC; valve opened to minimize mercury methylation during summer stratification; MDEQ identified that Partridge Creek is a conduit that transports mercury from an unknown source to the AOC	Eagle nest occupied; two eaglets fledged;	
2002	MDEQ drafted a Focused Feasibility Study for AOC; PAC set a goal for Fish Consumption BUI based on large fish; PAC drafted RAP update; PAC monitored Deer Lake water quality; PAC recommended remedies for AOC	Eagle nest occupied; two eaglets fledged	
2001		Eagle nest occupied; two eaglets fledged	
2000	MDEQ concluded that small fish in Deer Lake were similar in mercury content as comparable fish from nearby lakes (Day 2000)	Eagle nest occupied; two eaglets fledged	
1999	CCIC and MDEQ studies confirm that large Deer	Eagle nest occupied; two eaglets fledged	CCIC study observed additional improvements

Year	Fish Consumption BUI milestones	Eagle reproduction BUI milestones	Eutrophication BUI milestones
	Lake fish contain more mercury than comparable fish from nearby lakes; (Day 2000)		in winder DO compared with 1989
1998		Eagle nest occupied; two eaglets fledged	
1995			The Kerfoot 1995 Study indicated that Deer Lake had become mesotrophic-27 ug/l Total Phosphorus in the south basin.
1994	Brook trout consumption advisory lifted from Carp Creek and Carp River		
1991	Fish consumption advisory changed to catch-and-release only		
1990	Slot cut in the spillway to assist in maintaining a stable water level		
1989			MDEQ monitoring observed improvements in Winter DO compared with 1974 DEQ data
1987	The Deer Lake reservoir refilled; and a stable water level is maintained; yellow perch and walleye were stocked; MDEQ published the RAP that identified fish consumption as the sole BUI; RAP remedy is natural attenuation of sediments and maintenance of a stable water level to minimize mercury methylation		
1986	Carp Creek diverted around vestige of Deer Lake; remaining fish eradicated with rotenone, eradicated fish returned to Deer Lake under the ice		New Enhanced Secondary Wastewater Treatment Plant (with nitrogen and phosphorus removal) replaced 3 old primary plants
1985	Deer Lake remained drawn down to facilitate mercury de-gassing from sediments		Separation of septic and storm sewers in Ishpeming completed
1984	Deer Lake drawn down and fish eradicated by MDNR; eradicated fish returned to Deer Lake under the ice.		
1982	Fish consumption advisory extended to Carp Creek	Laboratory analysis of Deer Lake fish	

Year	Fish Consumption BUI milestones	Eagle reproduction BUI milestones	Eutrophication BUI milestones
	and Carp River	determined that only trace amounts of DDT and PCBs were present in eagle food	
1981	CCIC laboratory ceased discharge of mercury-containing reagents to City of Ishpeming wastewater treatment system; Fish consumption advisory implemented for Deer Lake; standard pike[1] contained 2.13 mg/kg mercury (DEQ data)	One adult eagle occupied territory; standard white sucker[2] contained 0.96 mg/kg mercury	Ludwig 1981 Study concluded Deer Lake was eutrophic- 86 ug/l Total Phosphorus in south basin.
1976-1980		New eagle nest location occupied but failed	
1977			Bills, Northern Michigan University pub.1977 Study from 1974 -1975 concluded Deer Lake was hypereutrohic- 278 ug/l Total Phosphorus in south basin
1973-1975		Eagle nest occupied, but failed	Study by Northern Michigan University observed severe winter oxygen depletion in Deer Lake
1972		Eagle nest unoccupied	
1971		Eagle nest occupied, outcome uncertain	
1970		Eagle nest occupation uncertain	Michigan Water Resources Commission ordered the City and Township to remove phosphorus from wastewater
1965-1969		Eagle nest occupied, but failed	
1964		Eagle nest occupied, but failed	Three (one City and two Township) Primary Wastewater Treatment Plants began operation in Ishpeming area

RAP Implementation

Recent Progress and Achievements

- **2006**: The AOC Technical Committee was developed with representatives from the Michigan Department of Environmental Quality, Michigan Department of Natural Resources, the Deer Lake PAC, and US EPA to investigate BUI status and potential for delisting individual BUIs or the entire AOC.
- **2005**: The Deer Lake PAC requested that the State of Michigan and US EPA begin the AOC delisting process for the AOC based on the 2006 MDEQ Guidance for Delisting Michigan's Great Lakes Areas of Concern.
- **2003**: Valve operation in the Deer Lake dam was resumed to minimize methylation of mercury within the reservoir. The PAC water quality monitoring program provided data that were used to monitor hypolimnion water withdrawals evaluate the valve settings and monitor lake conditions relative to mercury methylation.
- **2002**: The Deer Lake PAC drafted a Remedial Action Plan Update. The PAC developed a delisting goal for the fish consumption BUI, recommended remedies to decrease fish mercury concentrations, and began monitoring Deer Lake water quality on a weekly basis.
- **2001**: A study by Michigan State University concluded that there is evidence of natural attenuation of sediments in Deer Lake, although natural attenuation is presently arrested. If natural attenuation again starts, and if the rates are similar to historical patterns, 21 to 24 years are estimated for recovery (based on accumulation of six inches of clean sediment). The report indicated that some natural attenuation had occurred in both basins of Deer Lake, with slightly faster recovery in the south basin.
- **2000**: MDEQ determined that small fish in Deer Lake have mercury concentrations that are equal to comparable fish from reference (Day 2000) lakes, but the mercury content of large fish in Deer Lake remained elevated.
- **1998-2004**: Bald eagles begin reproducing successfully at Deer Lake.
- **1997**: Deer Lake PAC was formed.
- **199**4: Mercury content of "standard" (24-inch) northern pike decreased below 1.5 mg/kg, which is the MDCH trigger for "no consumption." The fish consumption advisory for brook trout in Carp Creek and Carp River was removed.
- **1993**: Mercury content in brook trout collected from the Carp River is well below 0.5 mg/kg, which is the MDCH trigger for restricting consumption.
- **1989**: MDEQ monitoring determined that the dissolved oxygen content of Deer Lake during the winter had improved, only three years after the improvements in wastewater treatment were implemented.
- **1987**: MDEQ published the RAP for Deer Lake AOC.

Eaglet in tree near nest on Deer Lake North Basin, hatched and fledged 2004; from Fred Minnich's Wildlife Survey.

Mink on Rocky shore; from Fred Minnich's Wildlife Survey.

Current Projects and Outlook

The Technical Committee is initiating the development of a Delisting Determination Document which will be based on the Guidance for Delisting Michigan's Great Lakes Areas of Concern. This document will evaluate the status of the BUIs in the AOC. The Technical Committee is currently developing a timeline for the document's development.

RAP-Related Publications

- **2002**: Draft RAP update developed by PAC, work continues on this document.
- **1999**: Updated AOC brochure produced.
- **1987**: Remedial Action Plan for Deer Lake Area of Concern completed.

Community/Local RAP Group Involvement

A Public Advisory Council (PAC) was formed for the Deer Lake AOC in 1997. The formation of the PAC was a very positive step, with strong community support from a large stakeholder base. The PAC has 21 voting members, plus three non-voting state agency representatives who serve in an advisory capacity. PAC membership represents a broad cross-section of interests, including:

- City of Ishpeming
- Cleveland-Cliffs Iron Company
- Education
- Environmental Organizations
- Fishing (2 members)
- Human Health Resources
- Lakeshore Residents (4 members)
- Local Businesses (2 members)
- Marquette County
    - Board of Commissioners
    - Drain Commissioner

    - Road Commission
- Native Americans
- Recreation
- Township of Ishpeming
- Wastewater Treatment
- Watershed residents at large

Additional Outreach Projects:

- Yearly water quality monitoring provided by the PAC.
- Local community and PAC members continue monitoring Carp Creek to control beaver populations to maintain the coldwater fisheries by removal of beaver dams. PAC supplied waders to support these efforts.
- Ongoing volunteer streambank, lakeshore, public access site, and island cleanup projects.
- Water quality signage related to fish consumption advisories maintained by PAC.
- Fish spawning bed established by PAC pass-through grant.

Partners and Stakeholders

- Deer Lake Public Advisory Council
- Michigan Department of Community Health
- Michigan Department of Environmental Quality
- Michigan Department of Natural Resources
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency, Great Lakes National Program Office

Deer Lake AOC Contacts

US EPA RAP Liaison:
Mary Beth Ross
US EPA (G-17J)
77 W. Jackson Blvd.
Chicago, IL 60604
Ph: 312-886-2253
Fax: 312-353-2018
ross.marybeth@epa.gov

David M. Gerczak
U.S. Army Corps of Engineers
477 Michigan Avenue
Detroit, Michigan 48226
Ph: 313-226-3387
Fax: 313-226-7095
david.m.gerczak@lre2usace.army.mil

State RAP Contact:
Sharon Baker
Michigan Department of Environmental Quality – Water Bureau
525 W. Allegan Street
PO Box 30273
Lansing, MI 48909-7773

Ph: 517-335-3310
Fax: 517-373-9958
bakersl@michigan.gov

Deer Lake Public Advisory Council:

Jerry Ely,Chair
13 Ely Drive
Negaunee, MI 49866
Ph: 906-475- 7797
gely@nmu.edu

Local Coordinator:

Diane Feller
Deer Lake SPAC Representative
490 Deer Lake Road
Ishpeming, MI 49849
Ph: 906-486-9967
dkfeller@aol.com

Appendix B

Total Maximum Daily Load (TMDL) Development Strategy for Lake Superior

Pigeon River High Falls, MN-ON Border
Photograph by: Minnesota Sea Grant

Lake Superior Lakewide Management Plan
2000

Appendix B
Total Maximum Daily Load (TMDL) Development Strategy for Lake Superior

1.0 Introduction

This strategy planning document identifies the goals, objectives, processes, and key issues related to the development and use of Total Maximum Daily Loads (TMDL) for the open waters of Lake Superior. The procedures outlined in this document are consistent with those stipulated under the Water Quality Guidance for the Great Lakes System (40 CFR Part 132, Appendix F) and other U.S. Environmental Protection Agency (U.S. EPA) regulations, policy, and guidance promulgated or published under the authority of Section 303 of the Clean Water Act (CWA).

TMDLs for tributaries to Lake Superior are being addressed by the states. Nonetheless, TMDL activities relating to those tributaries are included in this document because of their importance to the quality of the open waters of the lake.

This document is intended to generate discussion and will guide the development of the final TMDL Strategy for Lake Superior. The strategy will map out a plan to coordinate the work of U.S. EPA, the states, and other interested stakeholders involved in the TMDL process. The strategy will not discuss TMDL implementation; that will be part of any TMDL that is ultimately developed. Furthermore, since a TMDL is only one of many tools discussed below for managing the Great Lakes, other protection and restoration efforts will not wait for the development of a TMDL and may eventually make a TMDL for the open waters of the lake unnecessary. As a result, this document is only the first step in a lengthy process.

This strategy planning document is organized in six sections and one appendix. Following this introduction, Section 2.0 provides background on the status of Lake Superior and 303(d) listed water segments within the Lake Superior watershed. Section 3.0 describes the TMDL process and compares it with the Lakewide Management Program (LaMP) program goals defined under the Great Lakes Water Quality Agreement (GLWQA). Section 4.0 describes the key issues to be resolved to develop a Lake Superior TMDL Strategy. Section 5.0 presents a framework for a TMDL strategy to serve as a "strawman" for generating discussion and comment. Section 6.0 briefly describes the next steps in the TMDL strategy development process. Finally, Appendix A lays out the key steps in the TMDL process.

General Relationship Among a TMDL Strategy and Other Management Programs and Tools

The TMDL Strategy will address one of many tools that can be used to manage Great Lakes ecosystem quality. The following discussion generally outlines the statutory basis for water quality management and the variety of tools for addressing water quality impairment in the lakes.

The Lake Superior LaMP describes those programs and activities in greater detail. This introductory discussion is intended to place the TMDL program within the larger context of Great Lakes management.

Statutory Authorities: Setting Goals

The CWA provides the overall goals (fishable, swimmable, and drinkable) and authority for regulating certain activities that affect clean water in this country. In addition, the GLWQA between the United States and Canada defines more specific and common goals for the Great Lakes basin. The states and tribes use provisions of the CWA for designating water body uses and the necessary standards to be met to support those uses. Any request for a National Pollutant Discharge Elimination System permit (NPDES) to discharge into a water body is judged against the designated use for the receiving water body and the adopted state standards. Within the Great Lakes Basin, those water quality standards must meet the Great Lakes Water Quality Guidance objectives, including: 1) being no less restrictive than the limits on pollutants that protect human health, aquatic life and wildlife; 2) encompassing anti-degradation policies; and 3) incorporating implementation procedures.

Tools: Regulatory, Non-regulatory, and Voluntary Approaches for Pollution Control

Under the statutory authorities governing lake water quality management, a variety of regulatory and non-regulatory programs are implemented at the federal, state, and local levels. In addition, the public and private sectors implement voluntary pollution reduction programs and strategies to reduce pollutant load to the lakes. Several of these programs are described below.

Water Discharge Permitting. The CWA prohibits discharges of "pollutants" through a "point source" into a "water of the United States" unless the discharge is authorized under a NPDES permit. The permit specifies limits on effluent concentrations and loads, monitoring and reporting requirements, and other provisions to ensure that the discharge does not impair water quality or human health. In essence, the permit translates general CWA requirements into specific provisions tailored to the operations of each entity discharging pollutants. Michigan, Minnesota, and Wisconsin all have been delegated their NPDES permit programs and are authorized to issue permits.

TMDL - Achieving Water Quality Standards. For those waters not meeting quality standards after application of wastewater treatment technology mandated through an NPDES permit, states are required to calculate a TMDL. TMDL calculations are usually complex and may address a variety of pollutant sources. Although the States have primary responsibility for performing TMDLs, U.S. EPA will provide resources for technical assistance to assist in developing TMDLs, including TMDLs for interstate waters like the Great Lakes.

Technical and Economic Assistance. Pollutant load reductions to the Great Lakes are also supported through technical and economic assistance provided by the basin governments. For example, Section 319 of the CWA authorizes U.S. EPA to provide funds to the States for nonpoint source control project grants. Similarly, the U.S. Department of Agriculture provides economic assistance through the Environmental Quality Incentives Program to aid in controlling agricultural runoff. Overall, scores of federal, state, local, and private assistance programs are available to help reduce pollutants and control pollutant load to the lakes.

Pollution Prevention Partnerships. Partnerships among governments, the private sector, and other interested stakeholders help achieve voluntary pollution reductions. For example, through Partners for the Environment, EPA collaborates with more than 7,000 organizations that use voluntary goals and commitments to achieve measurable environmental results in a timely and cost-effective way. Partners include small and large businesses, citizens groups, state and local governments, universities and trade associations.

The results of voluntary actions taken through more than 20 distinct partnership programs are impressive. Focusing on pollution prevention, organizations set and reach environmental goals such as conserving water and energy or reducing greenhouse gases, toxic emissions, solid wastes, indoor air pollution and pesticide risk.

Tools: Assessing Watershed Conditions

In addition to placing controls on pollutant load to the lake, new programs are in place to improve the long-term assessment of water quality conditions in the basin. The 1998 Clean Water Action Plan (CWAP) began the process of developing *unified watershed assessments* based on the consolidation of information for a whole *watershed* from multiple federal, state, tribal and intergovernmental groups assessment tools. These assessments build upon the data collection, assessment, and reporting activities mandated under Sections 305(b), 303(d), and 304(l) of the CWA. The plan identifies unified watershed Categories I through IV . The categories are: I) not meeting clean water and other natural resources goals, II) prevention action is needed to sustain water quality and aquatic resources, III) outstanding resource waters deserving of the highest protection and IV) watersheds with insufficient data.

Tools: Restoring Degraded Portions of the Lake Superior Ecosystem

Finally, restoration activities administered by the federal government and the states are also an integral part of Great Lakes management. In particular, CERCLA has provided authority and funding to support sediment and other remediation in the Areas of Concern and other degraded areas within the basin. The CWAP calls for states and tribes, working with all appropriate agencies, organizations and the public to identify the Category I watersheds most in need of restoration beginning in the 1999-2000 period. A schedule will be developed and coordinated with the list of waters that do not meet adopted State Water Quality Standards under section

303(d) of the CWA.

Coordinating Lake Management Activities through Planning

The CWAP and the Lake Superior LaMP both call for working with the numerous federal agencies, states, tribes and other organizations to address the impairments. For the portions of Lake Superior requiring a TMDL, a convening and coordinating committee will be identified to address the Lake Superior issues. The time frame for filling the data gaps and the resources available will help determine the TMDL strategy and schedule for Lake Superior. The following discussion provides a starting point for the TMDL Strategy development process.

2.0 Background - Status of Lake Superior and State TMDL Programs

Lake Superior supports many beneficial uses, including recreation, drinking water supply, ecological habitat, and certain industrial and commercial uses. Nonetheless, despite overall reductions in conventional and toxic pollutant loads to Lake Superior over the past 20 years, data indicate that pollutants still exert negative impacts on the chemical, physical, and biological components of the Lake Superior ecosystem. The remaining problems in Lake Superior are significantly related to legacy contamination. Specifically, the lake ecosystem contains contaminants at levels that result in fish consumption advisories, impairments to aquatic organisms and wildlife, impacts on dredging, eutrophication, and contamination of drinking water sources.

Fish consumption advisories are generally the result of elevated PCB, mercury, dioxin-like furans, chlordane, DDE, dieldrin, and toxaphene levels in fish tissue. These advisories also exist in many of the Lake Superior tributaries.

Other pollutants cause or contribute to use impairment on a local or regional scale in Lake Superior. The Stage 1 LaMP identified critical pollutants and pollutant groups present at harmful levels in the ecosystem that require reductions at the source or removal from the ecosystem to restore beneficial uses or to achieve ecosystem objectives or environmental quality criteria. The Lake Superior critical pollutants include the following that are targeted for zero discharge:

- Chlordane
- DDT and metabolites
- Dieldrin/aldrin
- Hexachlorobenzene
- Octachlorostyrene
- PCBs
- 2,3,7,8-TCDD
- Toxaphene
- Mercury

The Lake Superior critical pollutants also include the following critical pollutants that are not targeted for zero discharge and emissions but impair beneficial uses, exceed environmental criteria, and/or do not meet ecosystem objectives:

- Alpha-BHC
- Heptachlor epoxide
- PAHs
- Aluminum
- Arsenic
- Cadmium
- Chromium
- Copper
- Iron
- Lead
- Manganese
- Nickel
- TCDD (TEQ) dioxins and furans
- Zinc

Some pollutant loadings are of concern in Lake Superior and have properties (bioaccumulative, persistent, and toxic) that give them the potential to impair the lake. These chemicals have been found below water quality standards or have not been monitored in Lake Superior. The Stage 1 LaMP identified these pollutants as prevention pollutants. The Stage 2 LaMP proposed a list of prevention pollutants. These prevention pollutants include:

- 2-chloroaniline (4,4-methylenebis)
- 1,4- dichlorobenzene
- 3,3'-dichlorobenzidine
- Hexachlorobutadiene
- beta-BHC
- delta-BHC
- gamma-BHC (Lindane)
- Mirex
- Pentachlorobenzene
- Pentachlorophenol
- Photomirex
- 1,2,3,4-tetrachlorobenzene
- 1,2,4,5-tetrachlorobenzene
- Tributyl tin

303(d) Listed Water Segments

Lake Superior and many of its tributaries are impaired due to fish consumption advisories for mercury and PCBs and do not meet water quality standards for other constituents. Waters that do not meet water quality standards require a state-developed TMDL for each water body and pollutant. There are no lists for degraded waterbodies in Ontario, nor are there timetables for improving such waters. Table 1 lists the impaired water bodies, both Lake Superior segments and U.S. tributaries discharging directly into Lake Superior, the parameters of concern resulting in the State's identification of the impaired or threatened water body under Section 303(d) of the Clean Water Act, and the schedule for completing the TMDL for the water body. Table 1 includes those listed water bodies discharging to Lake Superior.

Table 1. Lake Superior State 303(d) List Summaries

State	Water Body	Schedule	Parameters of Concern								
			WQS-PCBs	WQS-Mercury	FCA-PCBs	FCA-Mercury	E. Coli	Lead	Pesticides	D.O.	Other
MN	Beaver River	1999-2010, 2007-2010		✓							Turbidity
	Brule River	1999-2010		✓							
	Knife River	1999-2010, 2001-2004		✓							Turbidity
	Lester River	1999-2010, 2004-2007		✓							Turbidity
	Poplar River	1999-2010		✓							
	St. Louis Bay	1999-2010		✓							
	St. Louis River	1999-2010		✓							
	Talmadge River	2005-2010								✓	
MI	Carp Creek and River	2003				✓					
	Eagle River, East and West branches	2008									Poor macroinvertebrate, WQS-copper
	Mineral River	2003									Poor macroinvertebrate, WQS-TDS
	Lake Superior										FCA
WI	Allouez Bay				✓	✓					FCA
	Crawford Creek										PAH, petroleum, aquatic toxicity
	Hog Island inlet										PAH, petroleum
	St. Louis Bay				✓	✓					
	St. Louis River				✓	✓					
	Superior Bay				✓	✓					

Notes:

CSO = Combined sewer overflows; D.O. = Dissolved oxygen; FCA = Fish consumption advisory; WQS = Water quality standard

Water Quality Standards Applicable to Lake Superior

Under the Water Quality Guidance for the Great Lakes System, the Great Lakes states and tribes are to adopt numeric water quality criteria and water quality programs that are consistent with 40 CFR Part 132. As a result, once approved by U.S. EPA, water quality standards (WQS) for constituents identified under 40 CFR 132.3 promulgated by the states and tribes for waters in the Lake Superior system will be consistent with the minimum requirements of 40 CFR Part 132. Water quality standards currently promulgated by the states are found at the following:

Minnesota

Minnesota Rules (MR) Chapter 7050.0200 groups surface waters in to one or more usage classes:

- Class 1: Domestic consumption waters
- Class 2: Aquatic life and recreation waters
- Class 3: Industrial consumption waters
- Class 4: Agriculture and wildlife waters
- Class 5: Aesthetic enjoyment
- Class 6: Other uses
- Class 7: Limited resource value waters

MR Chapter 7050.0470 subpart 1 identifies the water use classifications for specific waters in the Lake Superior basin. General WQS applicable to the waters in the Lake Superior basin are found in MR Chapters 7050 and 7065. Minnesota sets WQS specific to for class 2A, 2Bd, 2B, 2C, and 2D waters in the Lake Superior Basin in MR Chapter 7052 for the Great Lakes Initiative pollutants.

Michigan

The State of Michigan sets WQS and methods for calculating standards and criteria for the Great Lakes, the connecting waters, and all other surface waters of the state under Part 4 of the Natural Resources and Environmental Protection Act, Act 451 of 1994.

Wisconsin

The State of Wisconsin sets WQSs and methods for calculating standards and criteria for Wisconsin surface waters under the Wisconsin Administrative Code (WAC) Chapter Natural Resources (NR) 102. WAC Chapter NR 104 sets uses and designated standards for intrastate and interstate waters and WAC Chapter NR 105 sets surface water quality criteria and secondary values for toxic substances. All surface waters within the drainage basin of the Great Lakes are to be protected from the impacts of persistent, bioaccumulating toxic substances by avoiding or limiting to the maximum extent practicable increases in those substances.

3.0 The Relationship Between the TMDL and LaMP Processes

This section first describes the key elements that a Lake Superior TMDL strategy would need to address. The section then provides an overview of the 12 key components or steps in TMDL development. The section concludes with a comparison of the TMDL and LaMP processes.

Key Elements of a TMDL Strategy

Any TMDL strategy developed for Lake Superior should focus on five key elements: 1) Goals and Objectives, 2) Scope and Scale, 3) Monitoring and Data, 4) Coordinated Planning Efforts, and 5) Partnerships.

GOALS AND OBJECTIVES: If the TMDL process is to be successful, sound and achievable goals and objectives must be identified. Several statutory and planning processes have established goals and objectives, along with specific substances identified as critical pollutants that need to be controlled or eliminated. Strategically, it will be important to evaluate all of the associated goals and objectives under the various planning processes to ensure that there are no conflicts. It is also important to evaluate all of the substances identified as pollutants to determine which ones can or should be readily controlled through a TMDL process, and which ones will need to be managed though some other process. As part of a strategic planning process, it will be important to narrow down the goals and objectives, as well as the substances identified as critical pollutants into a clear and concise suite that meets the guidelines for waterbodies or waterbody segments needing TMDLs. The TMDL process is just one of many tools used to address specific goals and objectives and certain critical pollutants that are currently causing an impairment to meeting the designated uses of the Great Lakes and their basins. The development of TMDLs does not preclude the use of other mechanisms to attain the other goals and objectives that have been set forth for the Great Lakes and their basins by the various planning and statutory processes.

Those statutory and planning processes that have identified goals and objectives along with identified critical pollutants include:

1) The designated uses of the waterbody or waterbody segment, as established by the states along with the applicable water quality standards and criteria associated with the identified designated uses (which are to be consistent with the Water Quality Guidance for the Great Lakes System, 40 CFR Part 132).

2) The Great Lakes Initiative which established final water quality guidance for the Great Lakes Systems for criteria limits or methodologies for the control of bioaccumulative chemicals of concern (BCCs), USEPA, March 1995.

3) The Great Lakes Water Quality Agreement which identifies both the 14 beneficial uses for the Great Lakes and the requirement for no increase in toxic loads, 1972, and the amendments of 1978 and 1987.

4) The Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA), 1994, which identifies specific substances to be controlled.

5) The International Joint Commission (IJC), 1987, which identified substances as critical pollutants.

6) The Great Lakes Binational Toxics Strategy, which focuses on the virtual elimination of persistent toxic substances in the Great Lakes.

7) The Area of Concerns and their corresponding Remedial Action Plans (RAPs) which have identified goals and objectives.

8) The goals and objectives identified in the LaMPs, along with the substances designated as lakewide critical pollutants.

9) The goals and objectives of the Source Water Protection Planning process.

10) The goals and objectives as set forth by the CWAP which has defined key actions and milestones.

11) The goal of zero discharge and zero emission for the nine designated chemical as set forth by the Binational Program to restore and protect the Lake Superior basin.

SCOPE AND SCALE: Because of the large geographic size of the Great Lakes and their basins, and the complexity of impairments and sources of those impairments, it is necessary to clearly identify both the scope and scale that can be managed by the TMDL process. It is also important to understand that the TMDL process functions through the use of a mathematical model that at best can only predict possible results, but not necessarily actual results.

First, the scope of the overall TMDL process within the lake and its basin should be defined. Beyond defining the impairments, it is important that both the causes and sources of the impairments be identified. Therefore, the initial scope should focus on three main categories as possible sources of impairment: tributaries, air deposition, and in-place or legacy pollutants. Under each one of these categories, additional sources can be further defined, such as point and nonpoint sources for tributaries, local and distant point and nonpoint sources for air deposition, and sites for in-place pollutants such as AOCs or Superfund sites. Each of those issues could then be addressed by the TMDL process within an identified scale.

MONITORING AND DATA: Because the Great Lakes are a very complex system, the need for sound, scientifically credible data is critical to being able to produce TMDLs that result in reasonable load allocations that fall within an acceptable confidence range. It is also important that the data used in the modeling component of a TMDL is scientifically sound and credible. That consideration is especially important because the loads that are to be allocated for control are in some cases regulatory.

It is also very important that the data be of high quality, since the implementation plans associated with the load allocations should reasonably result in water quality improvement and meet WQSs. COORDINATED PLANNING EFFORTS: Because of the many issues associated with maintaining and protecting the water quality of the Great Lakes and their associated basins, numerous planning efforts are currently ongoing. Some of these planning efforts were defined under the goals and objectives section of this document. Other planning efforts will include the TMDL implementation plans and any program activities that may or may not be incorporated into the TMDL implementation plans.

Effectively implementing this process will require committed leadership and the ability to develop and maintain good partnerships.

PARTNERSHIPS: To develop Great Lake TMDLs, and ensure effective implementation of the TMDL implementation plans, effective partnerships must be developed. To establish effective partnerships for both the development and the implementation of TMDLs within the Great Lakes and their associated basins, the following strategic approach is presented.

1) Identify the lead agency or agencies that will be responsible for developing and maintaining the needed partnerships for developing and implementing the TMDL process.

2) Identify the needed partners and define their role and responsibility to ensure the effective development and implementation of the TMDLs and the TMDL implementation plans.

3) Identify the partners in two major categories: those that would function in a statutory or regulatory mode and those that would function in a voluntary mode.

4) Evaluate the partners' resource capability in being able to carry out their defined roles and responsibilities. When there is a lack of resources, determine the options that might be available to assist or reinforce resource capabilities for partners.

5) Develop and define a forum through which partners can be brought together to exchange information, and work effectively to develop and implement TMDLs.

Components of a TMDL

Section 303(d) of the CWA, EPA's implementing regulations at 40 CFR Part 130, and the Water Quality Guidance for the Great Lakes System (40 CFR Part 132) describe the statutory and regulatory requirements for approveable TMDLs. The minimum components of a TMDL are outlined in Addendum A of this document and include the following:

1) Description of Waterbody, Impairment or Standard Violation, Pollutant of Concern, Pollutant Sources and Priority Ranking

2) Description of TMDL Endpoints -- Applicable Water Quality Standards and Numeric Water Quality Targets
3) Loading Capacity - Linking Water Quality and Pollutant Sources
4) Load Allocations (LAs)
5) Wasteload Allocations (WLAs)
6) Margin of Safety (MOS)
7) Seasonal Variation
8) Monitoring Plan for TMDLs Developed Under the Phased Approach
9) Implementation Plans (recommended under current policy)
10) Reasonable Assurances of Implementation
11) Public Participation
12) Submittal Letter

In addition, 40 CFR Part 132 provides specific requirements relating to TMDL development in the Great Lakes basin.

Revisions to the TMDL process are expected in the year 2000. New regulations have been proposed that will change what is required for both the Section 303(d) lists and for an approvable TMDL. Under the proposed regulations, the States are responsible for developing the list of impaired or threatened waters every two years (this requirement may change). Impairment is defined as those waters that do not meet the designated use or the appropriate WQS.

The Lakewide Management Plan process is outlined under the GLWQA of 1978. Under the GLWQA, as amended by the Protocols of 1983 and 1987, the United States and Canada (the Parties) agreed “. . . to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem.” To achieve this purpose, the Parties agreed to develop and implement, in consultation with state governments, provincial governments, and tribes, LaMPs for open lake waters.

In the case of Lake Superior, the Lakewide Management Plan development effort has been led by the United States and Canada. As specified in Annex 2 of the GLWQA, the LaMP for Lake Superior is designed to reduce loadings of critical pollutants in order to restore 14 designated beneficial uses and prevent increases in pollutant loadings in areas where the specific objectives of the agreement are not exceeded. Moreover, the Specific Objectives Supplement to Annex I of the GLWQA requires the development of ecosystem objectives for Lake Superior. Pursuant to that charge, the Lake Superior LaMP embodies a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses by seeking a balance between critical pollutant reduction and ecosystem sustainability in open lake waters and the watersheds that comprise the lake basin.

Comparison of the TMDL and the LaMP Processes

The TMDL and LaMP processes are fundamentally similar, but there are several key distinctions between them:

1) Both processes are intended to achieve clearly defined endpoints -- a WQS or numeric water quality target in the case of a TMDL, and a set of ecosystem objectives under the LaMP. However, the TMDL endpoints focus solely on WQSs, while the LaMP considers other ecosystem objectives in addition to numeric water quality targets. For example, the LaMP calls for the removal of restrictions on fish and wildlife consumption, prevention of bird or animal deformities or reproduction problems, and protection of the benthos. As a result, the LaMP process has identified over 20 critical pollutants to serve as the focus for the management activities, while a TMDL for the open waters of the lake will focus on only those pollutants that are linked to water quality standard exceedances.

2) Both processes require a documented status of the ecosystem.

3) Management planning to achieve ecosystem objectives is a key component of the LaMP. Implementation planning is recommended under the TMDL process and may be a required part of an approvable TMDL under the proposed regulations. However, planning is currently not the central focus of a TMDL.

4) Developing a direct link between pollutant load and achievement of the endpoint, often through water quality modeling, is a critical component of a TMDL. In contrast, the LaMP describes the relationship between loading and achievement of an ecosystem objective as a partnership effort involving the governments, tribes, and non-governmental sectors of the basin.

5) Both processes require an integrated monitoring plan for the lake.

6) Both processes require data, but the data are to be measured against different objectives.

7) The Lake Superior Binational Program goal of zero discharge is incorporated in the LaMP. This goal of zero discharge and zero emission goes beyond the TMDL requirement of allocating loads in such a way that WQSs are met.

In sum, the TMDL and LaMP processes are intended to achieve the common objective of restoring the Lake Superior ecosystem. However, a TMDL defines ecosystem protection more narrowly through the application of water quality standards and places great emphasis on understanding the relationship between pollutant load and achievement of the standard. In contrast, the LaMP defines ecosystem protection and restoration more broadly and places greater emphasis on pollution control planning and developing implementation targets.

4.0 Issues to Be Resolved

A number of key issues have been identified to better coordinate LaMP and TMDL activities (options for addressing each of these issues will be developed under the TMDL Strategy).

Issue 1: Identifying roles and responsibilities for each of the listed waters: tributaries, nearshore waters, open waters of the lake.

Issue 2: Should the lake be partitioned into segments that would be easier and more efficient to address with TMDLs?

Issue 3: Encourage consistency in 303(d) listing procedures among the States.

Issue 4: Maintain consistency in endpoint determinations (water quality standards) among the States.

Issue 5: Review the use of mass balance and other special studies on the lake with regard to their applicability to support a TMDL.

Issue 6: Integrate with other Programs (e.g., Source Water Protection Program).

Issue 7: Clarify the relationship between LaMP restoration and protection goals and TMDL endpoints (water quality standards).

Issue 8: Investigate options for addressing air deposition of TMDL pollutants.

Issue 9: Develop approaches for determining margin of safety when addressing fish consumption advisories.

Issue 10: Maintain consistency among the five Great Lakes.

Issue 11: Define the role of the Tribes in the TMDL process.

5.0 Strawman Framework for a Lake Superior TMDL Strategy

As a a means of generating discussion on the likely components of a Lake Superior TMDL Strategy, the following "strawman" framework is offered.

Process

To develop the TMDLs for the Great Lakes, the process will include:

1) Identify the impairments.

2) If at all possible, identify impaired segments.

3) Approve the listing of the segment under Section 303(d).

4) Generate the TMDL.

A) Determination of sources - While air deposition of mercury and PCBs may pose the largest portion of the load of these two pollutants to the lakes, other sources will have to be identified, including natural background. In addition, there are other portions of the lakes identified on the 1998 lists for impairments other than fish consumption advisories.

B) Determination of loads from the sources - Significant amounts of data already exist regarding the Great Lakes, much of it generated during the LaMP process. Additional information is being gathered regarding air deposition of mercury in the Devil's Lake Pilot Project. Data from this project, as well as other air deposition mercury projects, will be incorporated as generated in the development of any appropriate TMDL.

Numerous TMDLs are scheduled on tributaries to the various Great Lakes. These will certainly result in the generation of addition data regarding loading of pollutants to the Great Lakes, as well as result in lower loadings as the TMDLs are implemented.

Although much data exists, there are significant data gaps that have been identified. These include:

1) Relevant information on TMDLs or Mass Balance Activities for interstate or other waters that may contribute insight into TMDLs for Great Lakes listed waters.

2) Discussion of impairments listed in LaMPs and the TMDL lists, and the relationship to State Standards.

3) Air deposition data for mercury and PCBs in the Great Lakes basin

As the process moves forward, there will certainly be numerous data gaps noted. As they are noted, it will be important to determine if the data exists elsewhere, and if not, who should be working to gather the data (Feds, State, contractor, other, etc)

C) Determining the maximum load that will not cause a violation of WQS

D) Allocating the load to the various sources

E) Developing an implementation plan to ensure the TMDL is carried out

<u>Time Frame</u> -

A 15 year time frame is available to complete a TMDL. Is this timeframe consistent with state expectations?

Roles and Responsibilities -

Some states have written into their 303(d) lists that the U.S. EPA is responsible for developing the Great Lakes TMDLs for air deposition pollutants, while other states have made a more qualified statement.

> Federal role - The federal role in the Great Lakes TMDL process is at a minimum: 1) approve/disapprove 303(d) lists; 2) approve/disapprove the TMDLs. If the lists or TMDLs are disapproved, then the U.S. EPA has the responsibility to issue appropriate lists or TMDLs. However, the federal role will be much larger than that stated above. The U.S. EPA will take the lead on "open water" TMDLs, serve to facilitate the generation of the TMDLs, provide funding through various mechanisms, assist in data gathering (especially for air deposition pollutants), provide technical support, coordinate efforts among the states, serve as information repository, and provide legal analysis and support.
>
> State role - List impaired waters, take the lead on tributary water TMDLs, and provide support and data for "open water" TMDLs.

6.0 Next Steps in the TMDL Development Process

This document is only the first step in the process to develop a TMDL Strategy for Lake Superior. U.S. EPA envisions the following next steps in this process:

1) Gather comments on this strategy planning document and the issues identified in Section 4.0.

2) Convene regulators in the Fall of 2000 to begin discussions on the following:

    a) the outstanding issues identified in Section 4.0 of this document,
    b) plans for a Winter 2001 information meeting,
    c) plans for future stakeholder meetings,
    d) clarifying resource needs and availability, and
    e) investigating the formation of work groups.

3) Convene an information meeting in the Winter of 2001 to review information collected on pollutant load to the lake, including the preliminary results of the Devil's Lake Mercury Pilot Study. Review changes to the TMDL regulations and guidance.

4) Convene a series of stakeholder meetings and/or workshops to inform the development of a

draft Lake Superior TMDL Strategy.

U.S. EPA has not yet developed a final schedule for these next steps. U.S. EPA welcomes comments on these proposed next steps, a schedule of activities, and any issues raised in this strategy planning document.

ADDENDUM A

REVIEW ELEMENTS OF TMDLs

Section 303(d) of the Clean Water Act (CWA) and EPA's implementing regulations at 40 CFR Part 130 and the Water Quality Guidance for the Great Lakes System (40 CFR Part 132) describe the statutory and regulatory requirements for approvable TMDLs. The following information is generally necessary for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations, and should be included in the submittal package. Use of the verb "must" below denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation.

1. Description of Waterbody, Pollutant of Concern, Pollutant Sources and Priority Ranking

The TMDL analytical document must identify the waterbody as it appears on the State/Tribe's 303(d) list, the pollutant of concern and the priority ranking of the waterbody. The TMDL submittal must include a description of the point and nonpoint sources of the pollutant of concern, including the magnitude and location of the sources. Where it is possible to separate natural background from nonpoint sources, a description of the natural background must be provided, including the magnitude and location of the source(s). Such information is necessary for EPA's review of the load and wasteload allocations which are required by regulation. The TMDL submittal should also contain a description of any important assumptions made in developing the TMDL, such as: (1) the assumed distribution of land use in the watershed; (2) population characteristics, wildlife resources, and other relevant information affecting the characterization of the pollutant of concern and its allocation to sources; (3) present and future growth trends, if taken into consideration in preparing the TMDL; and, (4) explanation and analytical basis for expressing the TMDL through *surrogate measures*, if applicable. *Surrogate measures* are parameters such as percent fines and turbidity for sediment impairments, or chlorophyl *a* and phosphorus loadings for excess algae.

2. Description of the Applicable Water Quality Standards and Numeric Water Quality Target

The TMDL submittal must include a description of the applicable State/Tribe water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the antidegradation policy. Such information is necessary for EPA's review of the load and wasteload allocations which are required by regulation. A numeric water quality target for the TMDL (a quantitative value used to measure whether or not the applicable water quality standard is attained) must be identified. If the TMDL is based on a target other than a numeric water quality criterion, then a numeric expression, usually site specific, must be developed from a narrative criterion and a description of the process used to derive the target must be included in the submittal.

3. Loading Capacity - Linking Water Quality and Pollutant Sources

As described in EPA guidance, a TMDL identifies the loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water can receive without violating water quality standards (40 CFR § 130.2(f)). The loadings are required to be expressed as either mass-per-time, toxicity or other appropriate measure (40 CFR § 130.2(I)). The TMDL submittal must identify the waterbody's loading capacity for the applicable pollutant and describe the rationale for the method used to establish the cause-and-effect relationship between the numeric target and the identified pollutant sources. In most instances, this method will be a water quality model. Supporting documentation for the TMDL analysis must also be contained in the submittal, including the basis for assumptions, strengths and weaknesses in the analytical process, results from water quality modeling, etc. Such information is necessary for EPA's review of the load and wasteload allocations which are required by regulation.

In many circumstances, a *critical condition* must be described and related to physical conditions in the waterbody as part of the analysis of loading capacity (40 CFR § 130.7(c)(1)). The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. *Critical condition*s are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence. *Critical conditions* are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards. Stream design guidelines for Great Lakes tributaries are specified under 40 CFR Part 132, Appendix F.

4. Load Allocations (LAs)

EPA regulations require that a TMDL include LAs, which identify the portion of the loading capacity allocated to existing and future nonpoint sources and to natural background (40 CFR. § 130.2(g) and 40 CFR 132, Appendix F). Load allocations may range from reasonably accurate estimates to gross allotments (40 CFR. § 130.2(g)). Where it is possible to separate natural background from nonpoint sources, load allocations should be described separately for background and for nonpoint sources.

If the TMDL concludes that there are no nonpoint sources and/or natural background, or the TMDL recommends a zero load allocation, the LA must be expressed as zero. If the TMDL recommends a zero LA after considering all pollutant sources, there must be a discussion of the reasoning behind this decision, since a zero LA implies an allocation only to point sources will result in attainment of the applicable water quality standard, and all nonpoint and background sources will be removed.

5. Wasteload Allocations (WLAs)

EPA regulations require that a TMDL include WLAs, which identify the portion of the loading capacity allocated to existing and future point sources (40 CFR § 130.2(h) and 40 CFR 132, Appendix F). If no point sources are present or if the TMDL recommends a zero WLA for point sources, the WLA must be expressed as zero. If the TMDL recommends a zero WLA after considering all pollutant sources, there must be a discussion of the reasoning behind this decision, since a zero WLA implies an allocation only to nonpoint sources and background will result in attainment of the applicable water quality standard, and all point sources will be removed.
In preparing the wasteload allocations, it is not necessary that each individual point source be assigned a portion of the allocation of pollutant loading capacity. When the source is a minor discharger of the pollutant of concern or if the source is contained within an aggregated general permit, an aggregated WLA can be assigned to the group of facilities. But it is necessary to allocate the loading capacity among individual point sources as necessary to meet the water quality standard.

The TMDL submittal should also discuss whether a point source is given a less stringent wasteload allocation based on an assumption that nonpoint source load reductions will occur. In such cases, the State/Tribe will need to demonstrate reasonable assurance that the nonpoint source reductions will occur within a reasonable time.

6. Margin of Safety (MOS)

The statute and regulations require that a TMDL include a margin of safety to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA § 303(d)(1)(C), 40 CFR §130.7(c)(1), and 40 CFR 132, Appendix F). EPA guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS must be described. If the MOS is explicit, the loading set aside for the MOS must be identified.

7. Seasonal Variation

The statute and regulations require that a TMDL be established with consideration of seasonal variations. The method chosen for including seasonal variations in the TMDL must be described (CWA § 303(d)(1)(C), 40 CFR § 130.7(c)(1)).

8. Monitoring Plan for TMDLs Developed Under the Phased Approach

EPA's 1991 document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA 440/4-91-001), recommends a monitoring plan when a TMDL is developed under the phased approach. The guidance recommends that a TMDL developed under the phased approach also should provide assurances that nonpoint source controls will achieve expected load reductions. The phased approach is appropriate when a TMDL involves both point and nonpoint sources and the point source is given a less stringent wasteload allocation based on an assumption that nonpoint source load reductions will occur. EPA's guidance provides that a TMDL developed under the phased approach should include a monitoring plan that describes the additional data to be collected to determine if the load reductions required by the TMDL lead to attainment of water quality standards.

9. Implementation Plans

On August 8, 1997, Bob Perciasepe (EPA Assistant Administrator for the Office of Water) issued a memorandum, "New Policies for Establishing and Implementing Total Maximum Daily Loads (TMDLs)," that directs Regions to work in partnership with States/Tribes to achieve nonpoint source load allocations established for 303(d)-listed waters impaired solely or primarily by nonpoint sources. To this end, the memorandum asks that Regions assist States/Tribes in developing implementation plans that include reasonable assurances that the nonpoint source load allocations established in TMDLs for waters impaired solely or primarily by nonpoint sources will in fact be achieved. The memorandum also includes a discussion of renewed focus on the public participation process and recognition of other relevant watershed management processes used in the TMDL process. Although implementation plans are not approved by EPA, they help establish the basis for EPA's approval of TMDLs.

10. Reasonable Assurances

EPA guidance calls for reasonable assurances when TMDLs are developed for waters impaired by both point and nonpoint sources. In a water impaired by both point and nonpoint sources, where a point source is given a less stringent wasteload allocation based on an assumption that nonpoint source load reductions will occur, reasonable assurance that the nonpoint source reductions will happen must be explained in order for the TMDL to be approvable. This information is necessary for EPA to determine that the load and wasteload allocations will achieve water quality standards.

In a water impaired solely by nonpoint sources, reasonable assurances that load reductions will be achieved are not required in order for a TMDL to be approvable. However, for such nonpoint source-only waters, States/Tribes are strongly encouraged to provide reasonable assurances regarding achievement of load allocations in the implementation plans described in section 9, above. As described in the August 8, 1997 Perciasepe memorandum, such reasonable assurances should be included in State/Tribe implementation plans and "may be non-regulatory, regulatory, or incentive-based, consistent with applicable laws and programs."

11. Public Participation

EPA policy is that there must be full and meaningful public participation in the TMDL development process. Each State/Tribe must, therefore, provide for public participation consistent with its own continuing planning process and public participation requirements (40 CFR § 130.7(c)(1)(ii)). In guidance, EPA has explained that final TMDLs submitted to EPA for review and approval must describe the State/Tribe's public participation process, including a summary of significant comments and the State/Tribe's responses to those comments. When EPA establishes a TMDL, EPA regulations require EPA to publish a notice seeking public comment (40 CFR § 130.7(d)(2)).

Inadequate public participation could be a basis for disapproving a TMDL; however, where EPA determines that a State/Tribe has not provided adequate public participation, EPA may defer its approval action until adequate public participation has been provided for, either by the State/Tribe or by EPA.

12. Submittal Letter

A submittal letter should be included with the TMDL analytical document, and should specify whether the TMDL is being submitted for a *technical review* or is a *final submittal*. Each final TMDL submitted to EPA must be accompanied by a submittal letter that explicitly states that the submittal is a final TMDL submitted under Section 303(d) of the Clean Water Act for EPA review and approval. This clearly establishes the State/Tribe's intent to submit, and EPA's duty to review, the TMDL under the statute. The submittal letter, whether for technical review or final submittal, should contain such information as the name and location of the waterbody, the pollutant(s) of concern, and the priority ranking of the waterbody.

Appendix C:

The Lake Superior Zero Discharge Demonstration Program and Relationship to Chemical Contaminants in Lake Superior

Silver Islet. Photo Credit: John Marsden, Environment Canada.

Lake Superior Lakewide Management Plan
2006

INTRODUCTION

As noted in Chapter 4, Section 4.1, entitled Pollutant Concentrations in the Environment, enforcement of environmental regulations, changes in industrial development patterns, implementation of pollution prevention, and the efforts of individual citizens have significantly reduced releases to Lake Superior. The Zero Discharge Demonstration Program (ZDDP), and other programs, reduce toxic chemicals at their sources, resulting in their eventual reduction in the ecosystem. The assessment of monitoring data on concentrations of a suite of toxic organic contaminants in various media is within the purview of the LaMP. To that end, the Chemical Committee of the Lake Superior LaMP Work Group prepared a presentation on both the current status and trends of Lake Superior contaminants and the relationship to the ZDDP. This presentation is provided in this Appendix.

The following conclusions about Lake Superior contaminant levels and trends were drawn:

- In general, concentrations of many legacy PBT contaminants have declined over time (i.e., government intervention has been effective).
- In most cases, concentrations in various media are decreasing at much slower rates or have leveled off over time.
- Lake Superior's physical, thermal, and biological properties make it unique and particularly sensitive to retaining PBT chemicals.
- Atmospheric deposition is the main source of PBTs to the lake – some source regions have been identified.
- New chemicals of concern such as PBDEs are increasing in fish and sediments in Lake Superior.
- Fish consumption advice is continually changing due to new monitoring data and new information on toxicological interactions of individual contaminants and contaminant mixtures.

Implications for management include the following:

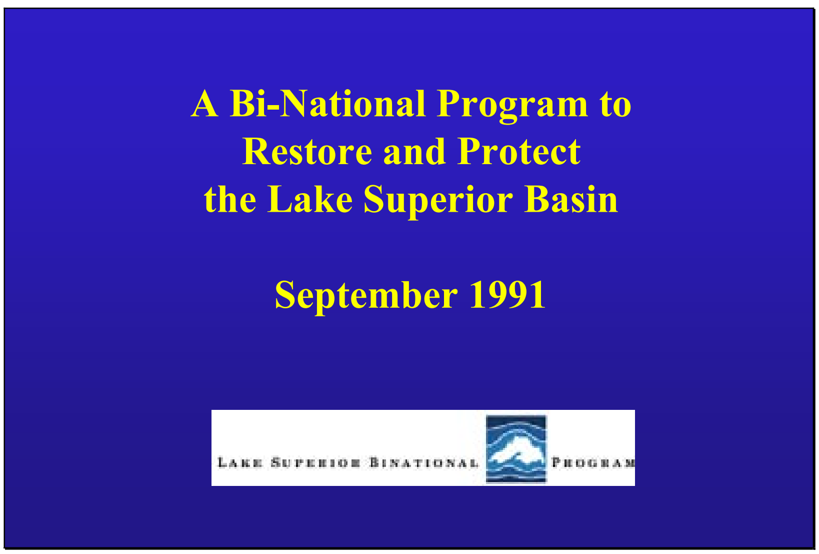
- Lake Superior is sensitive! Prevention and preservation critical (toxaphene example).
- Stop introduction of invasives - it affects contaminant transport as well as the biology of the Lakes.
- 2005-2006 coordinated monitoring effort is a great start!
- Coordinated monitoring needs to continue as agreed to by the rotational schedule - next Lake Superior monitoring year will be 2011.
- Statistical design of monitoring programs may need to change to reflect lower environmental concentrations – i.e., have greater power to detect changes in concentrations.
- Tie contaminant reduction outreach efforts to issues identified in the Community Awareness Review and Development (CARD) study.
- Action needed beyond the basin! ZDDP is critical for the basin but will have limited impact on PBTs in the Lake Superior environment in the face of regional and global sources.
- There are many positive recommendations identified in the work of the Great Lakes Regional Collaboration on the U.S. side. These need to be implemented.

- How can we learn from our past mistakes? Advocating for pollution prevention, conservation, recycling, local and renewable energy sources, and reduced dependence on synthetic chemical substances are ways to ensure a sustainable society and a healthy Lake Superior.

Slide 1

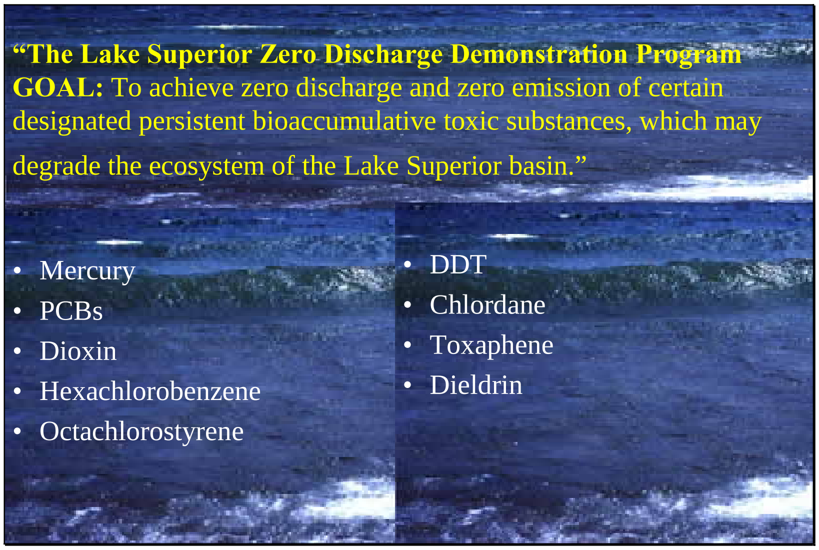
The main focus of our presentation today is chemical contaminants in Lake Superior. Before we start, we want to give a brief review of the zero discharge demonstration program for Lake Superior, which has been the main focus of the chemical committee. We will briefly discuss its relationship to chemical contaminants in the Lake. Matt Hudson will give the presentation on status and trends of contaminants in the Lake.

Slide 2



The Binational Program Agreement was signed by the governments at the IJC meeting in September 1991, in response to the challenge issued by the IJC for a zero discharge demonstration for Lake Superior.

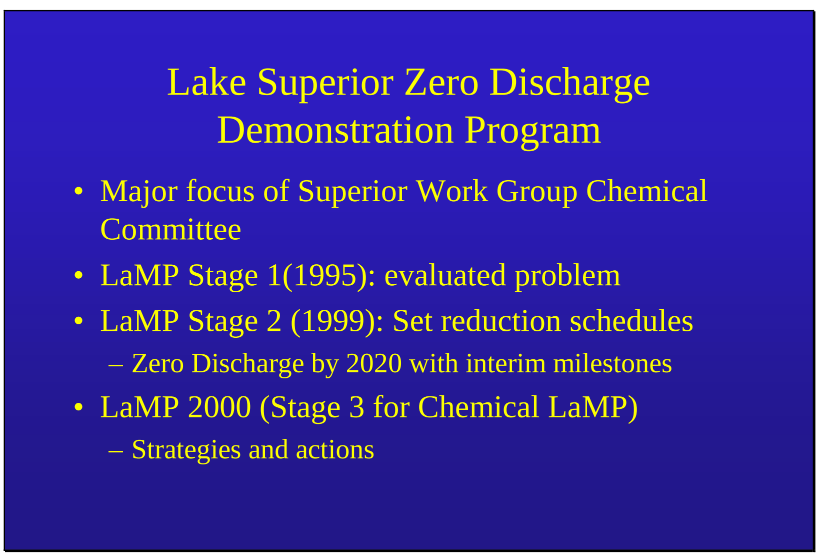
Slide 3



The goal statement is taken from the 1991 agreement. It is a very pro-active goal. Nine chemicals were targeted.

Zero Discharge is considered a strategy toward the virtual elimination goal for the environment.

Slide 4



Work on the LaMP began in 1992: Stage 1 was finalized in 1995. The Stage 2 has the reduction schedules, developed jointly with the forum and with significant public input. LaMP 2000 and the update we are working on include estimates for sources within the basin. We use these estimates to judge progress toward the reduction goals of the Stage 2 LaMP.

Slide 5

The Lake Superior Zero Discharge Demonstration Program

- Scope: sources **within** the Lake Superior basin
- Reduction schedules are “action goals” rather than goals for levels in the environment
- “Demonstration” is important component of Zero Discharge in Lake Superior Basin
- Local sources are only one component of chemical loadings to Lake Superior
- We do not have information to predict changes in chemical concentrations in the Lake Superior ecosystem based on reductions from local sources

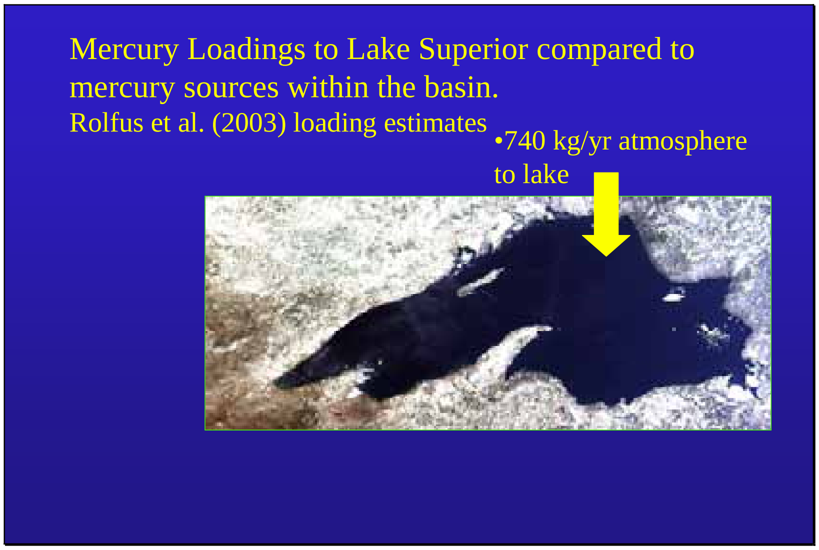
From the beginning, it was understood that the ZDDP was not going to “fix” Lake Superior since “out of basin” sources are also important. The “demonstration” aspect was a very important part of the ZDDP concept. We do not have the environmental data or predictive models to predict the effect that local source reduction will have on chemical concentrations in the Lake Superior environment.

Slide 6

Mercury Loadings to Lake Superior compared to mercury sources within the basin.
Rolfus et al. (2003) loading estimates

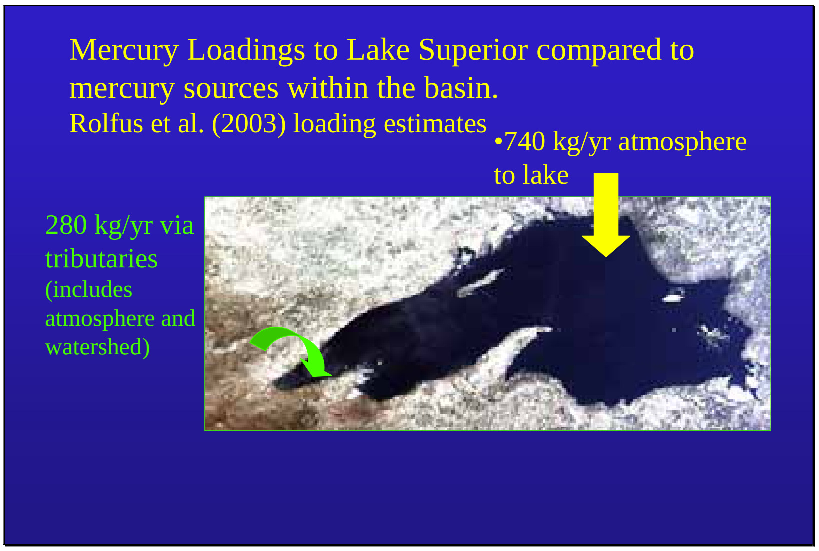
Taking mercury as an example, we can look at the work of Rolfus and colleagues in developing a mercury mass balance for L. Superior.
This summarizes where mercury enters the Lake, but does not distinguish local vs. distant sources.

Slide 7



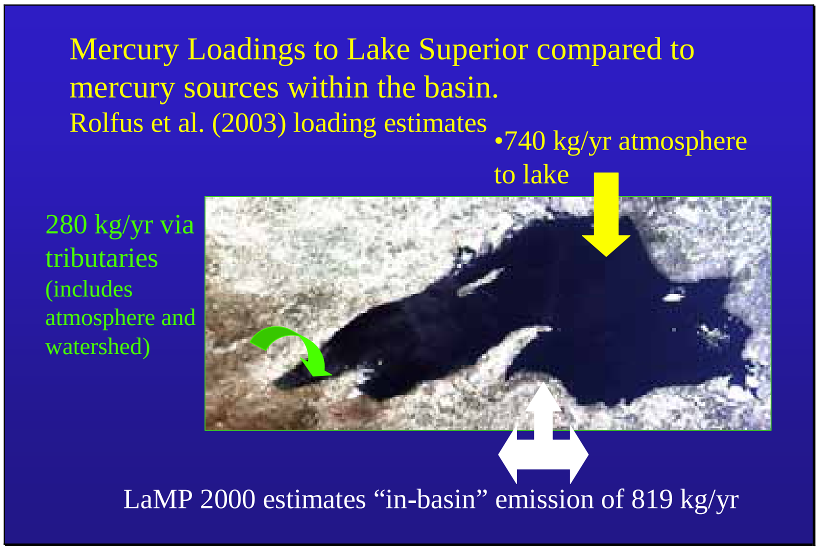
Although most of the mercury entering Lake Superior is deposited directly from the atmosphere to the surface of the Lake, that mercury comes from distant as well as local sources.

Slide 8



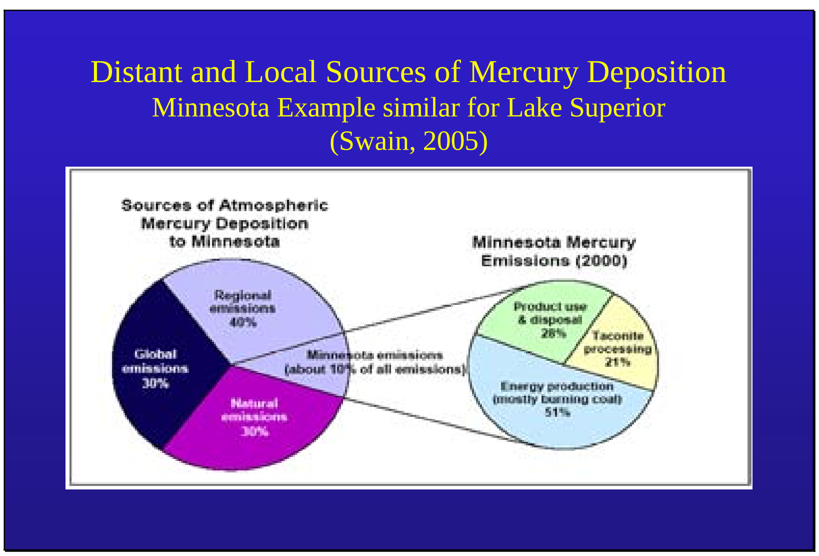
Mercury also enters via tributaries. This number includes atmospheric deposition to the watershed as well as potential sources within the watershed.

Slide 9



The ZDDP focuses on “in-basin” sources. Local sources also contribute to the regional and global pool of mercury. We emit roughly 80% of what we receive. Even though the actual impact of the ZDDP on chemical levels in L. Superior may be small, the philosophy of the ZDDP is to put our own house in order, as one of the steps to protect Lake Superior.

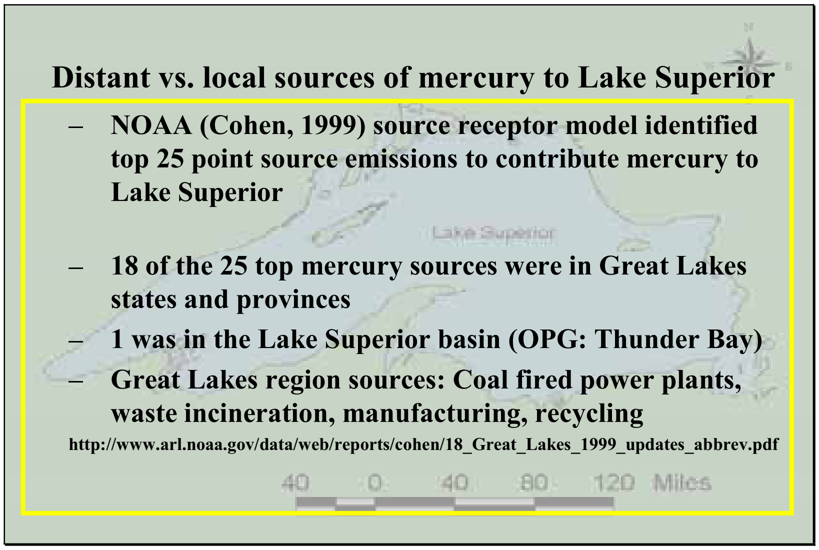
Slide 10



What are the sources of the atmospheric deposition to the Lake Superior basin? This Minnesota example is a reasonable stand-in for the Lake Superior basin. Only 10% of the mercury deposition in Minnesota comes from emission sources within the state. Global emissions account for 30% of the mercury deposited on the state; regional emissions account for 40%.

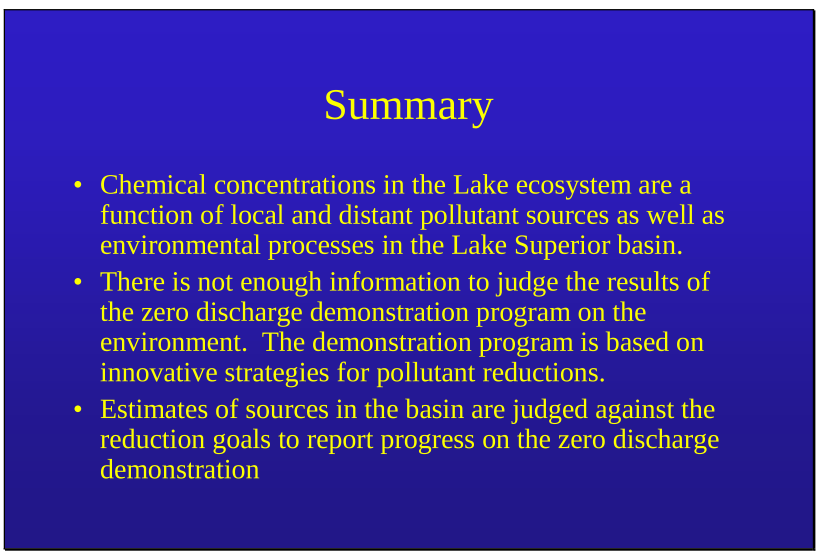
We don’t have the info to make a similar chart for the Lake Superior basin, but this Minnesota information gives us a reasonable idea that local and regional emissions may account for about half of the mercury deposited in the basin.

Slide 11



Cohen's 1999 source receptor model identified top atmospheric point sources contributing mercury to Lake Superior. This work shows the importance of sources in the Great Lakes region as a whole.

Slide 12



Slide 13

Slide 14

Slide 15

FOCUS OF PRESENTATION

- Task Force request on status of chemical contaminants in Lake Superior ecosystem.
- Provide potential management implications related to these data
- Contaminant concentrations in various media, trends, relation to available yardsticks, transport mechanisms, new concerns.
- Focus on Persistent, Bioaccumulative, and Toxic (PBT) chemicals
  - Great Lakes long term trend monitoring programs
  - Peer-reviewed literature
  - Monitoring data across media allows temporal comparisons

New Concerns refers to “emerging contaminants” and issues surrounding them.

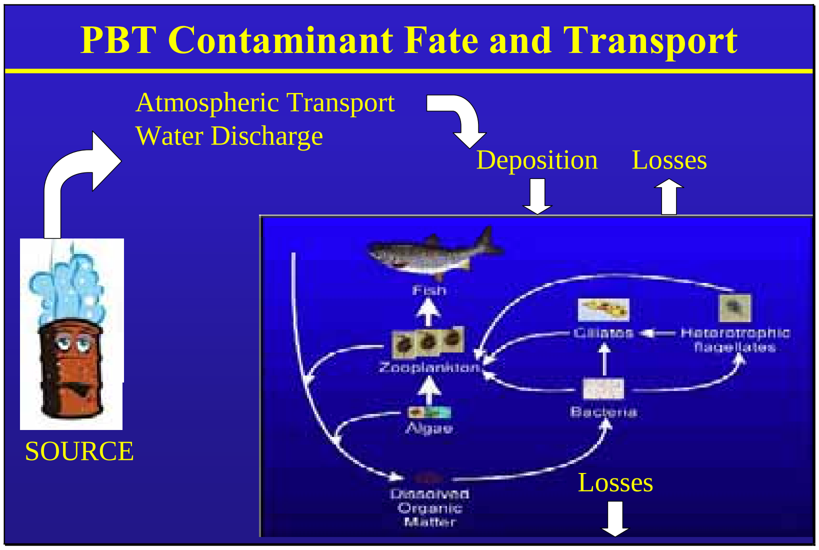
Slide 16

PBT Chemicals of Interest

- **Lake Superior Zero Discharge Chemicals**
  - Polychlorinated Biphenyls (PCBs)
  - Toxaphene
  - Mercury
  - Dioxins
  - Chlordane
  - Dieldrin
  - DDT
  - Hexachlorobenzene (HCB)
  - Octachlorostyrene
- **Other PBTs**
  - **α-HCH (banned)**
  - **γ-HCH (lindane – in use)**
- **Some Chemicals of “Emerging Concern”**
  - Polybrominated diphenyl ethers (PBDE)
  - Polybrominated biphenyls (PBB)

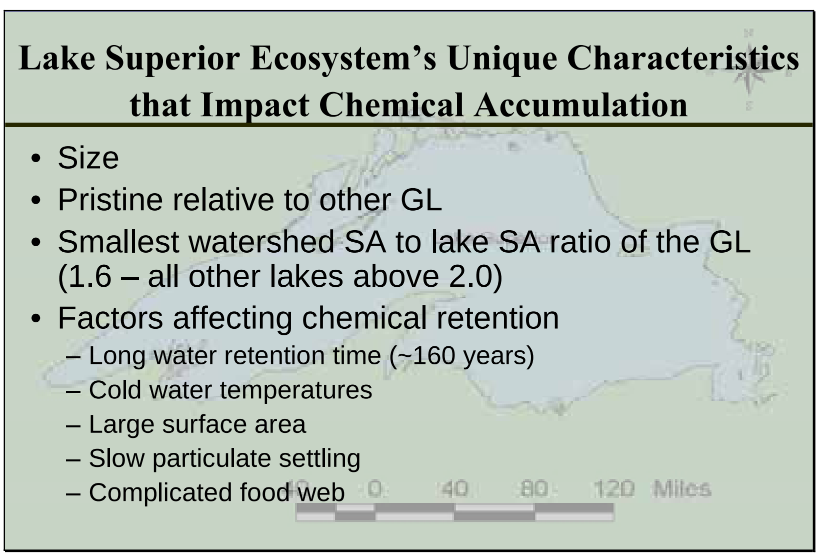
Describe chemicals:

Slide 17



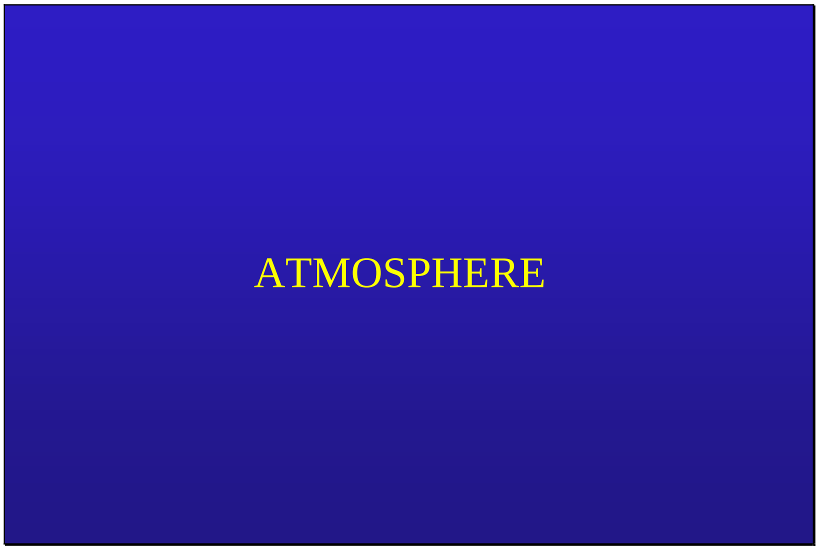
Overall source transport pathways are much more complicated. This is a simplification. "Source" is an example meant to represent all sources, point and non-point. Deposition could be through precipitation, dry deposition, gas/air exchange, surface runoff. Losses include volatilization, sedimentation, and outflow. Food web is complicated and different between water bodies.

Slide 18

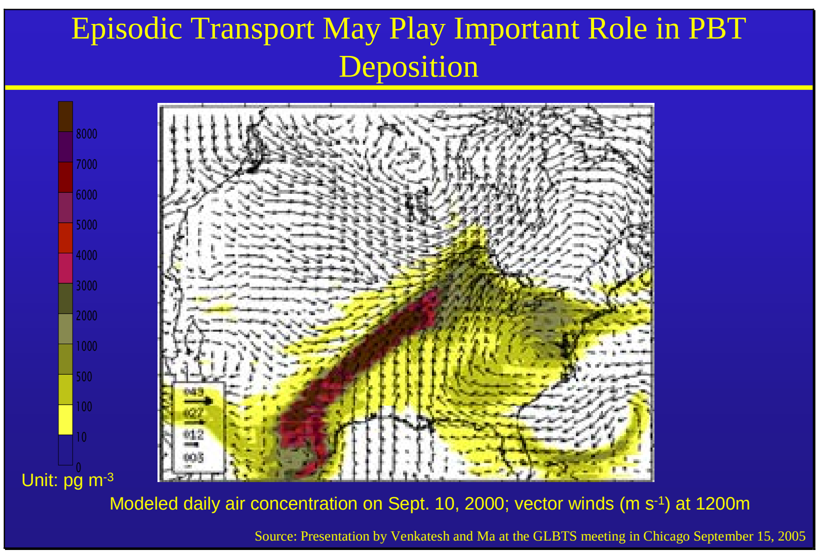


Largest freshwater body by surface area and 3rd largest by volume
List of characteristics that make Lake Superior susceptible to retaining chemicals for very long time, as well as the fact that the food web structure can impact concentrations in biota.

Slide 19

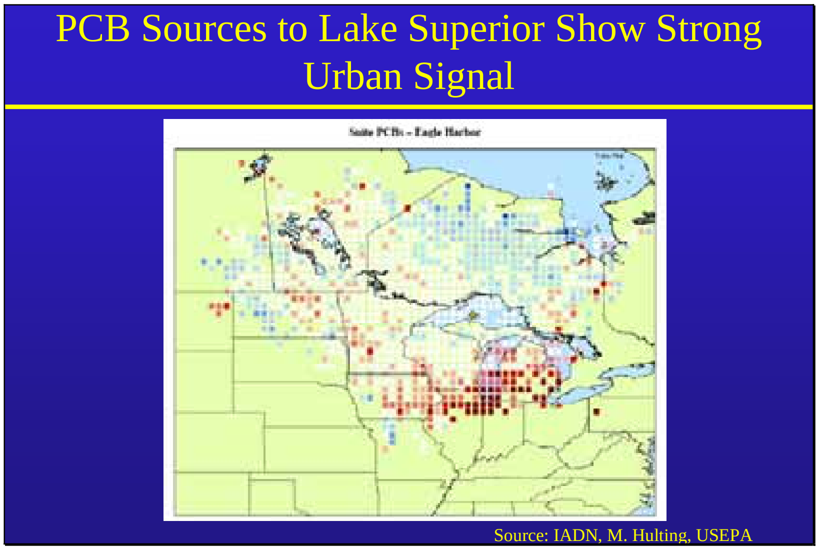


Slide 20



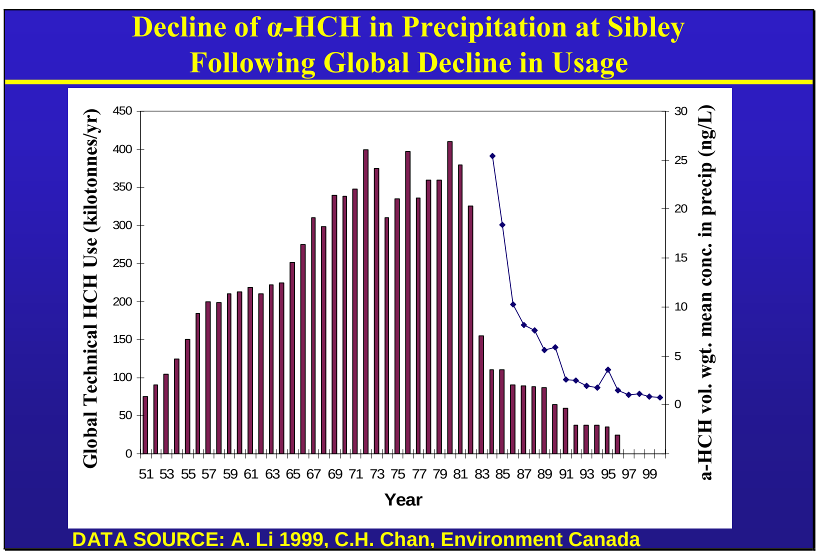
This modeling exercise was done for toxaphene. Note how reservoir sources in the soil of southeast states (where toxaphene was used on cotton crops) can be transported to the Great Lakes and other areas through these episodic atmospheric events.

Slide 21



This figure models the source regions for a suite of PCBs to the Eagle Harbor IADN station. The data show a strong urban signal from the southern Lake Michigan area.

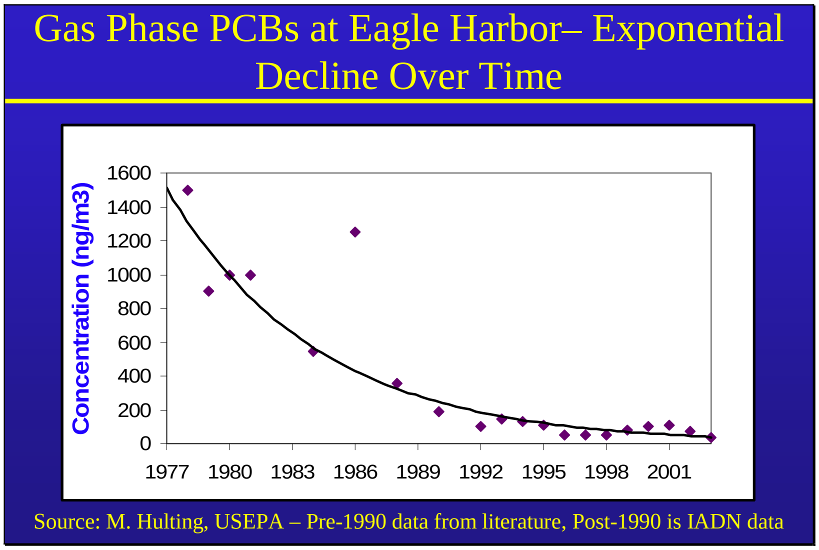
Slide 22



Long-term trends (1950-1996) in the global use of technical hexachlorocyclohexane (HCH) (from Li 1999) and the volume weighted mean concentration of a-HCH in precipitation (in ng/L) at Sibley, Ontario, Canada (from EHC, C.H. Chan). China dip in 1983 and India/Soviet Union dip in 1990. a-HCH is 60-70% of technical HCH.

Sibley is on the northern reach of Squaw Bay, about 90 km (56 miles) east of Thunder Bay and 300 km (186 miles) northeast of Duluth.

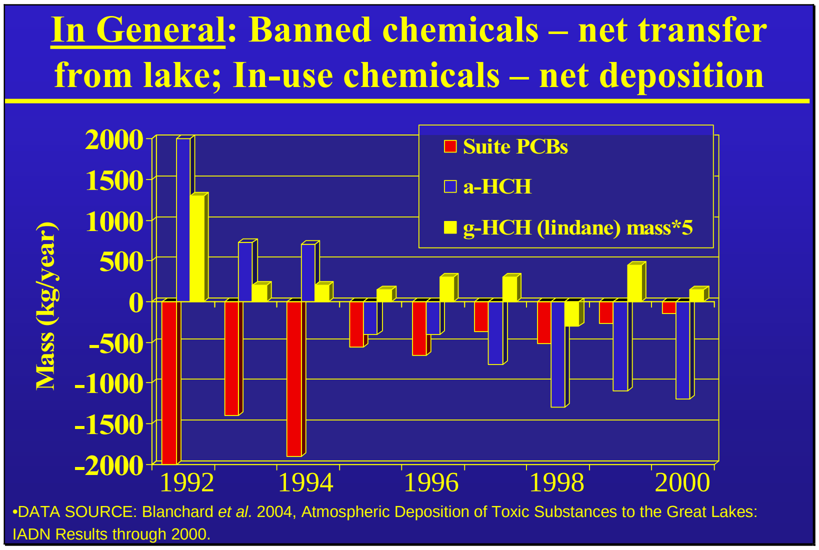
Slide 23



Pre-1990 data is non-IADN and is from the literature. Data through 1996 showed a general decline, followed by a slight increase for some Lakes during the late 90s. Preliminary 2000 data show another decline. Environment Canada is also seeing similar increases in PCB concentrations at Alert since 1998 which may further implicate the importance of global emissions.
EC researchers have found link between El Nino activity and increased PCB concentrations (perhaps increased transport from Asia). May also explain the increases during the same time period for HCB.

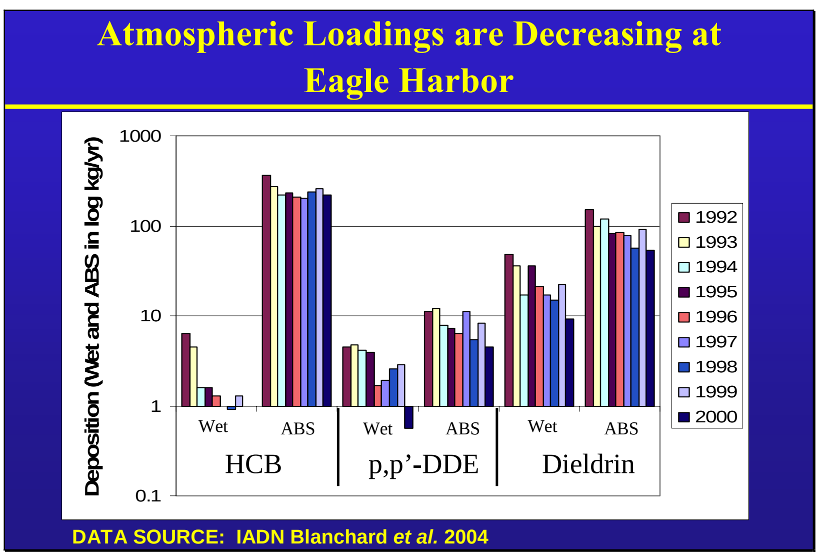
Sources for historical PCB data: Achman et al. 1993; Baker and Eisenreich 1990; Cotham and Bidleman 1995; Doskey and Andren 1981; Eisenreich et al. 1981; Eisenreich 1987; Hornbuckle et al. 1993; Hornbuckle et al. 1994; Manchester-Neesvig and Andren 1989; Monosmith and Hermanson 1996.

Slide 24



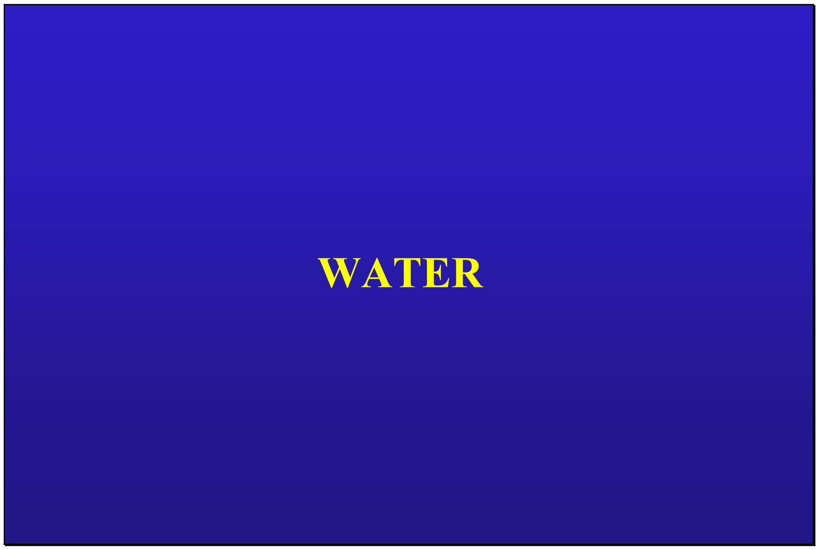
Note that lindane flows are multiplied by 5 to compensate for the scale of the graph. These data show how a lake responds slower than the atmosphere to reductions in use of a chemical. The lake is a “source” for chemicals such as PCBs and a-HCH, but over time the system moves toward steady state (shut off the spigot and the air responds quicker than the lake – aHCH from previous slide is a great example). Contrast this with lindane, which is still in use and the atmosphere is still largely a source to Lake Superior (spigot has not been shut off).

Slide 25

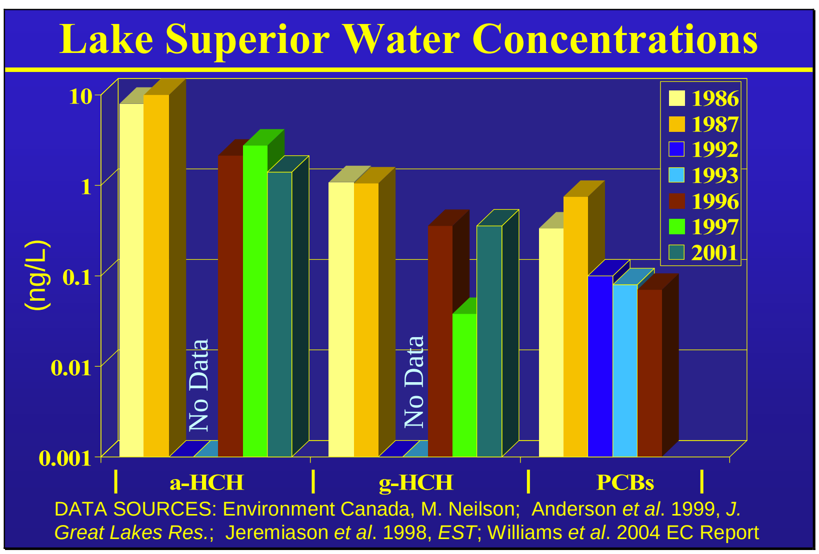


Describe Graph. Most PBT chemicals enter the lake via atmospheric deposition. Note the log scale - Gas phase absorption generally accounts for a much greater proportion of the overall loading than wet deposition for PCBs and pesticides, whereas wet and dry deposition account for the majority of PAH loading. Dieldrin, HCB, and p,p'-DDE demonstrate the typical trend for most regulated chlorinated PBT chemicals with declining concentrations. PCB loadings have shown less of a decline (Chicago source region??)

Slide 26



Slide 27



Describe Graph. Again, we have a similar set of PBT chemicals. a-HCH and PCBs have declined but g-HCH may not be (2001 data point) because it's still in-use.

Slide 28

Some Recent Open-water Contaminant Data Exceeds Most Protective Yardsticks (all data in ng/L)

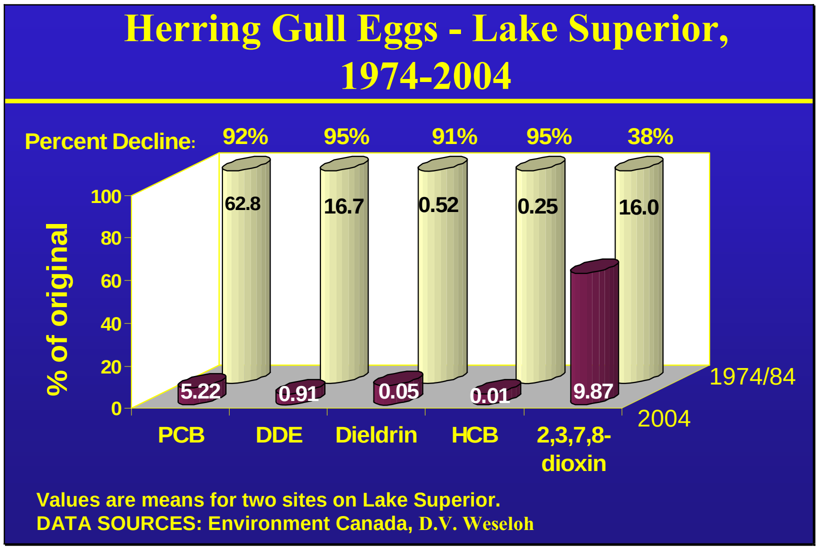
	MN	MI	WI	ON	Open Lake Conc.
PCBs	0.0045	0.026	0.003	1.0	0.0705[1]
HCB	0.074	0.45	0.22	6.5	0.014[2]
Dieldrin	0.0012	0.0065	0.0027	1.0 (+Aldrin)	0.126[2]
Chlordane	0.04	0.25	0.12	60	<0.03[3], 0.0099[4]
DDT	0.011	0.011	0.011	3.0	0.005[2] (p,p'DDE)
Mercury	1.3	1.3	1.3	200	0.71[5]
Toxaphene	0.011	0.068	0.034	8.0	0.7[6], 0.6[7]
g-BHC (lindane)	80	25	18	10	0.357

[1]Warren, US EPA, 1996 data [2]Williams *et al*., EC, 2001 data [3]Williams *et al*., EC, 1997 data [4]Jantunen, EC, 1996-1998 data [5]Dove, EC, 2003 data [6]Muir *et al*. 2004, 1998 data [7]Swackhamer, UofMN, 1998 data

All data are given in ng/L or PPB. Most protective yardsticks available for each jurisdiction are used. Red values are those that exceed one or more yardstick guidelines. The 95% confidence level of available concentrations that exceeded those yardsticks was criteria used for Stage II LaMP. We're looking at individual measurements or means rather than 95% limit. What does this say about contamination of the lake?

Slide 29

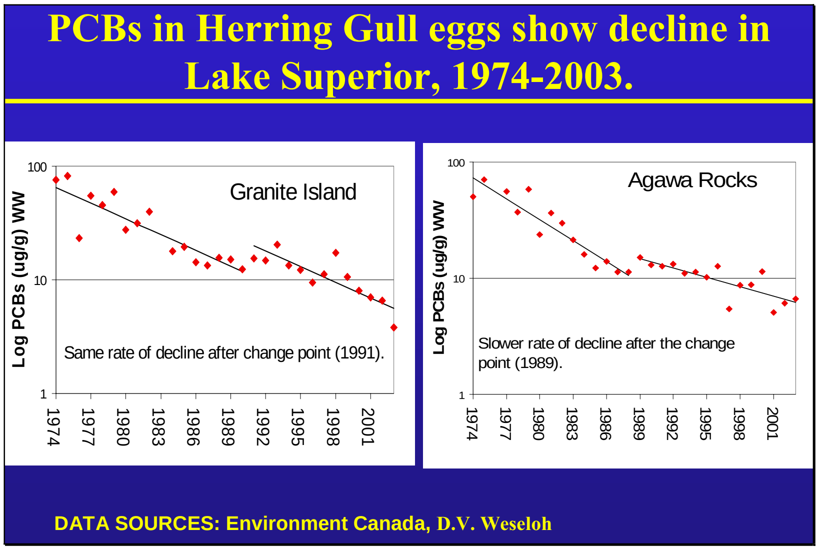
Slide 30



Again, to give similar set of chlorinated PBT chemicals, all have shown between **38 and 95**% declines over the last **20 to 30 years**. Make mention Dioxin (pg/g) , other chemicals (ug/g)

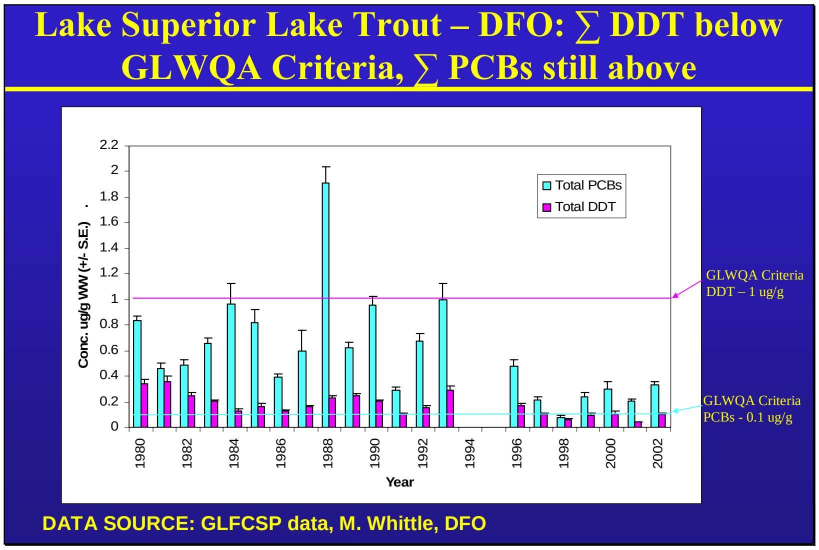
(text in bold was updated by Tania Havelka)

Slide 31



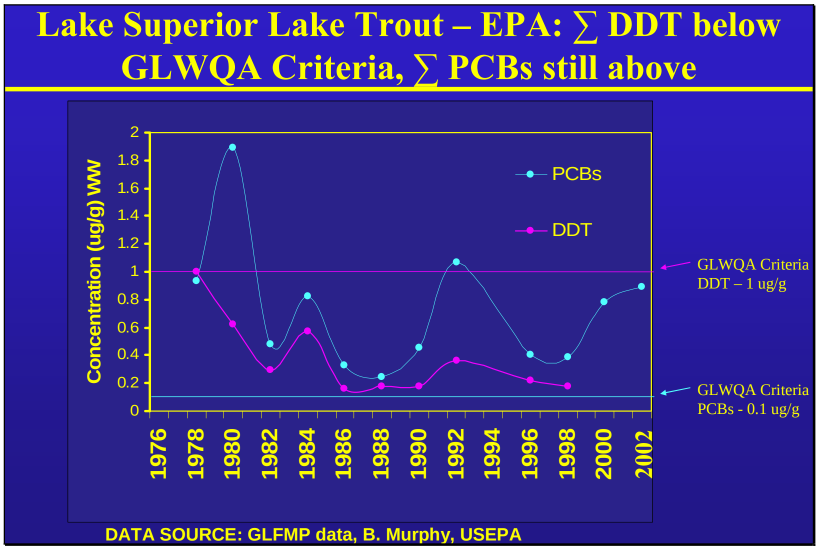
Sum PCBs in herring gull eggs show decline over past 30 years at L.S. sites. Note rate of decline remained the same at Granite Island after change point around 1991 while rate of decline slowed at Agawa Rocks after change point around 1989.

Slide 32



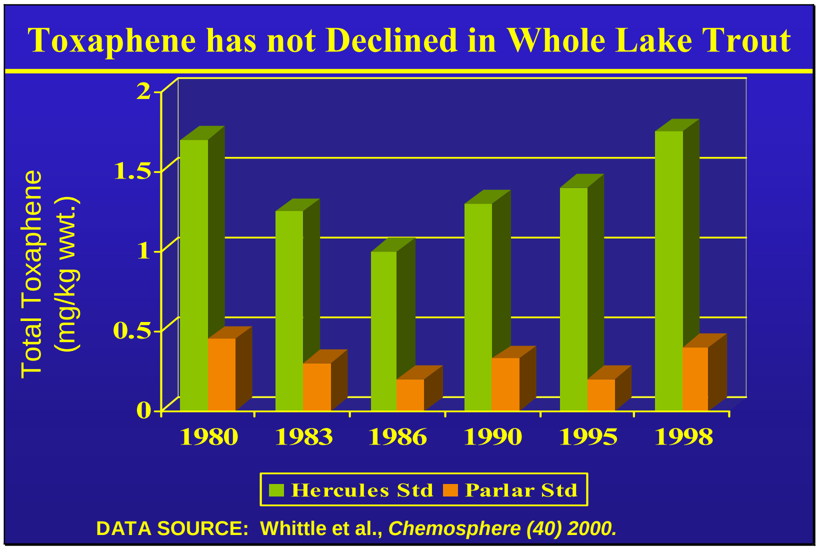
Here again, in whole lake trout we find declines in PBT concentrations between 1980 and 2000. PCBs still exceed GLWQA criteria but not DDT.
Oscillations in between years likely due to many reasons including food web changes, variability within the fish that are sampled and within the analytical method, etc.

Slide 33



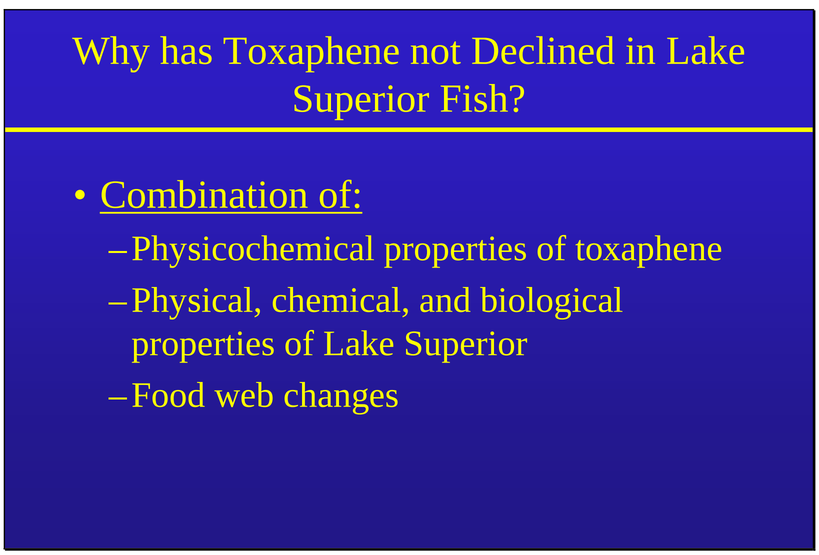
Point out that we are seeing the same types of trends in both the EPA and DFO lake trout monitoring data. Recent PCB increase likely due to change in sample location and thus now sampling a different population of lake trout. Unlikely that the increase is actually a real increase in the environment. Again PCBs above GLWQA criteria but not DDT.

Slide 34



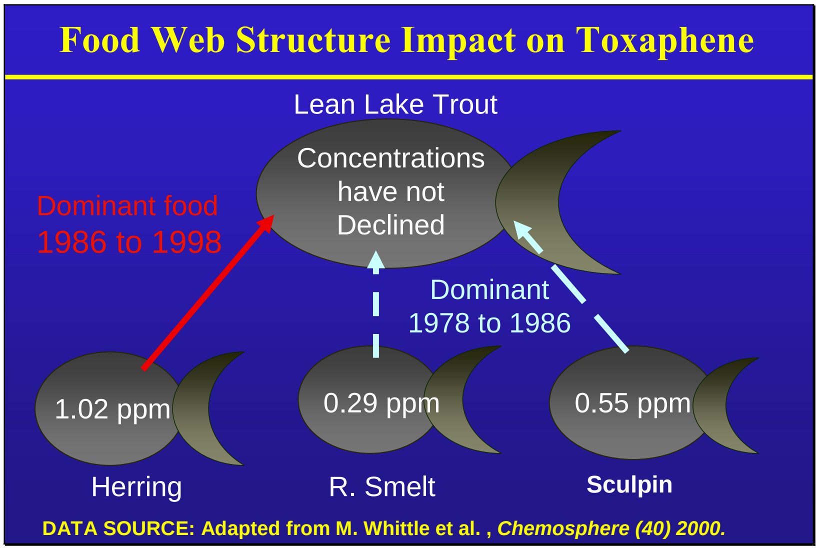
Toxaphene does not seem to be declining as the other PBT chemicals. No clear decline present.
Hercules std. was from the original manufacturer of toxaphene
Parlar std. was an original standard developed by a German researcher

Slide 35



The behavior of toxaphene based on its chemical properties leads it to persist more in an environment such as Lake Superior (relatively high vapor pressure, high solubility)
The lake is large, cold, and has a long water retention time compared to the other GLs, meaning rates of transformation of the chemical will be slower.
Biological community (food web) changes over time

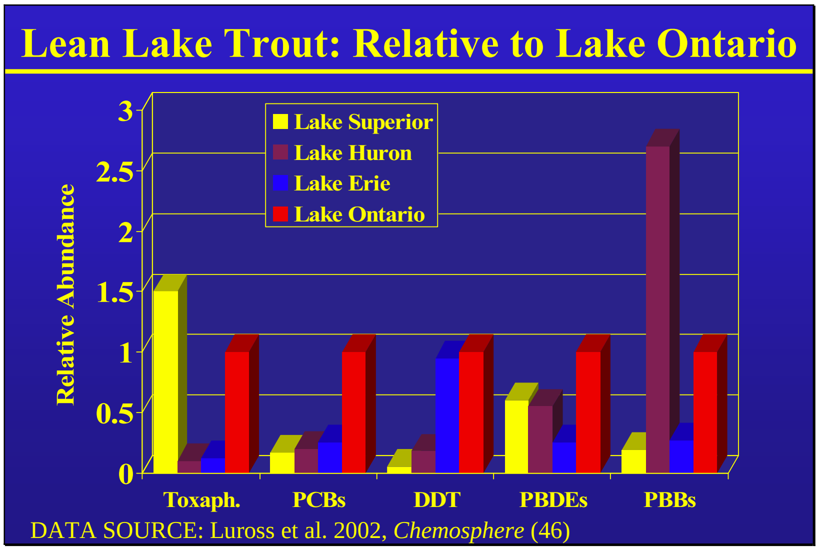
Slide 36



Describe Graph. One potential explanation is that Lake trout populations have experienced a change in their forage base shifting from feeding on mainly a smelt and sculpin dominated diet to one dominated by herring. As you can see by these numbers in herring are much higher in toxaphene than either sculpins or smelt. Thus the lake trout population, since about 1986, may have been experiencing a greater exposure to toxaphene due to their consumption of herring.

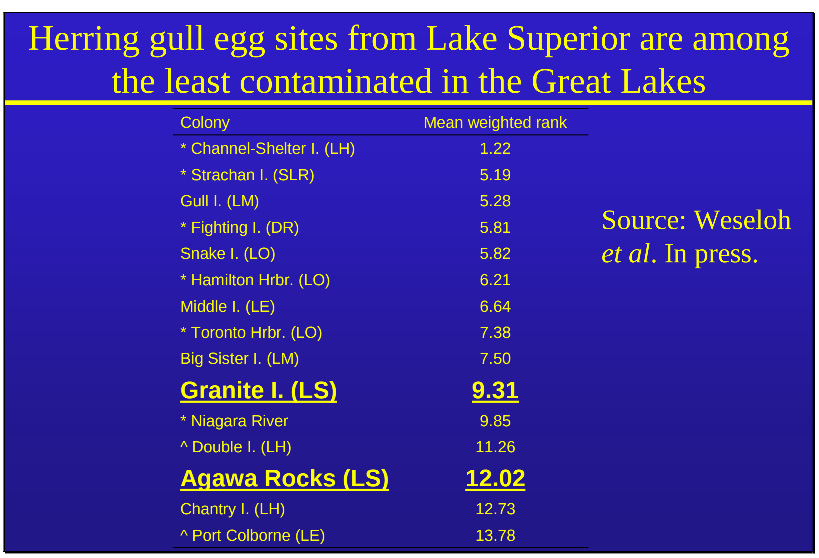
Slide 37

Slide 38



This slide shows a relative comparison among four of the Great Lakes using Ontario as the comparative standard. Therefore, Ontario, in tan, has a value of 1. If a lake, such as Superior, has a higher concentration of a chemical in whole lake trout (such as toxaphene), it will have a value greater than 1. So of these four lakes, Superior has the highest concentration of toxaphene. As we can see, Superior is lowest in PCBs and DDT relative to the other 3 lakes (These are Canadian data, so no Lake Michigan). And then, the last two are rather new or emergent chemicals of concern, PBDEs and PBB (classes of flame retardants). Notice Superior is only second to Lake Ontario, so it may be a chemical that needs to be carefully monitored over the next decade to determine its sources and if it is decreasing or increasing. We see the same general pattern with data from EPA's GLFMP program, where aside from toxaphene and alpha-HCH, Lake Superior generally has the lowest concentrations, consistent with the level of industrialization in the basin over time.

Slide 39


Herring gull egg sites from Lake Superior are among the least contaminated in the Great Lakes

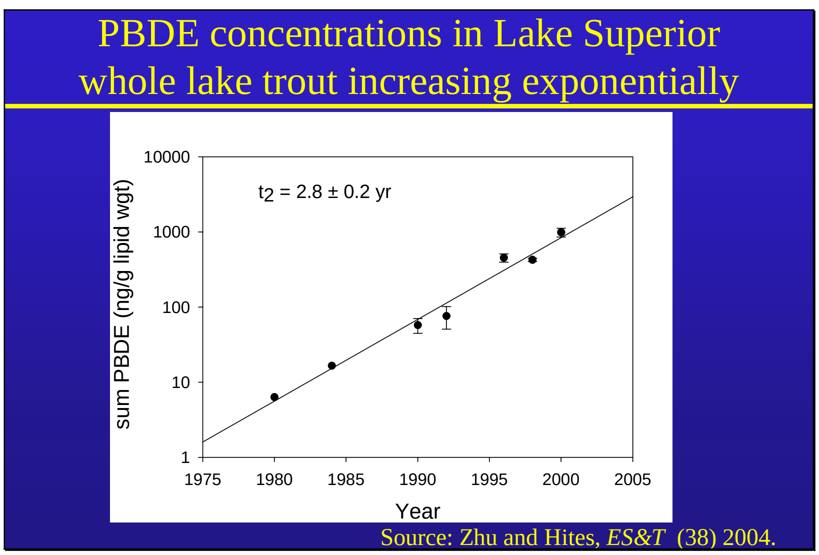
Colony	Mean weighted rank
* Channel-Shelter I. (LH)	1.22
* Strachan I. (SLR)	5.19
Gull I. (LM)	5.28
* Fighting I. (DR)	5.81
Snake I. (LO)	5.82
* Hamilton Hrbr. (LO)	6.21
Middle I. (LE)	6.64
* Toronto Hrbr. (LO)	7.38
Big Sister I. (LM)	7.50
Granite I. (LS)	**9.31**
* Niagara River	9.85
^ Double I. (LH)	11.26
Agawa Rocks (LS)	**12.02**
Chantry I. (LH)	12.73
^ Port Colborne (LE)	13.78

Source: Weseloh *et al*. In press.

The mean weighted rank of each site, 1998-2002, (arranged from most to least contaminated) and range in rank (1 = most, 15 = the least contaminated site). The ranks were weighted with a measure of contaminant toxicity using the ratio between mean egg concentrations of each compound and the corresponding fish flesh criteria for the protection of piscivorous wildlife (Newell et al. 1987). The ranking is based on: p,p'DDE, dieldrin, HCB, Heptachlor Epoxide, mirex, sum PCB, and 2378-TCDD. Dieldrin and Heptachlor Epoxide concentrations were among the highest from Lake Superior sites, all other contaminants were among the lowest.

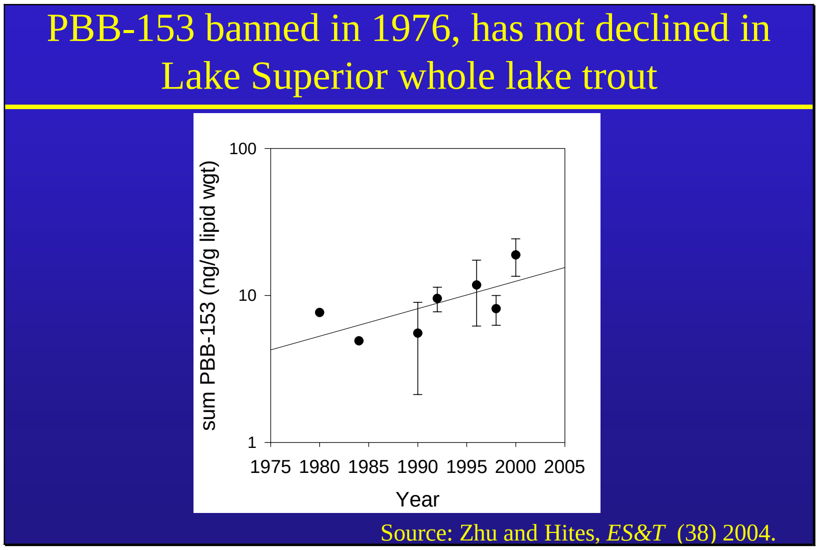
Slide 40

Slide 41



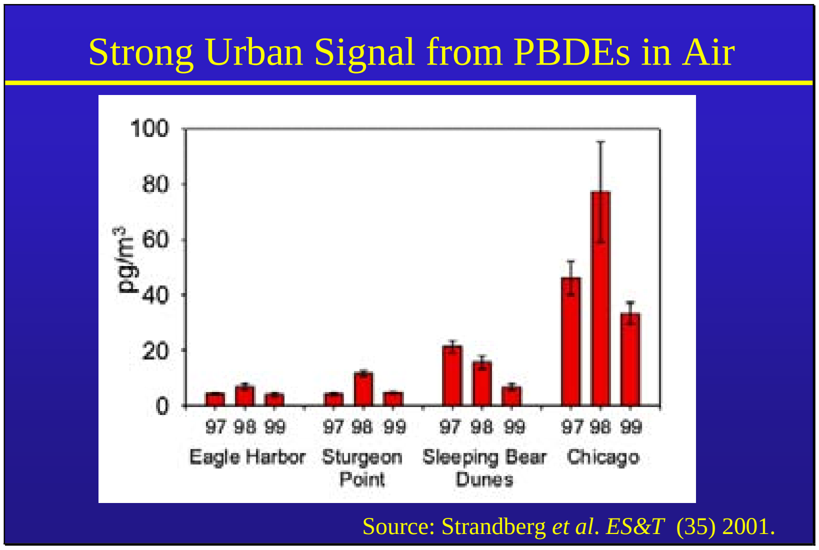
GLFMP archived fish were analyzed for PBDEs and PBB-153 (flame retardants). Exponential increase over time with doubling every 2.5-3 years! Most recent concentrations are about 5 times greater than those measured in fish from Europe. People in North America have about 20 times the level of PBDEs in their blood than Europeans (cite Zhu and Hites). Another study (Song et al.) shows PBDEs increasing in sediments over time while PCBs generally showing a decrease.

Slide 42



Looks like an increase, but it's not significant. Are there new sources of PBBs or do they behave similar to toxaphene in Lake Superior?

Slide 43



Note urban sources greater than rural

Slide 44

HUMAN HEALTH

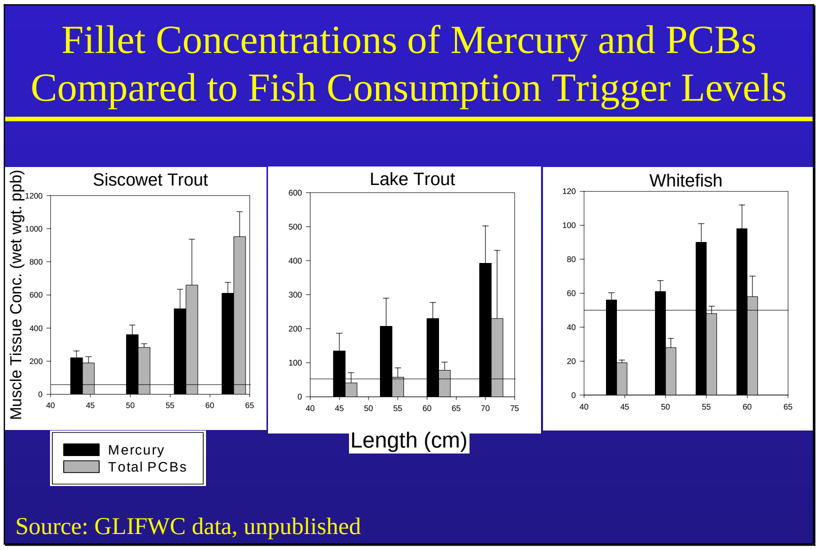
Slide 45

Sport Fish Consumption Trigger Concentrations (ppb)– Sensitive Population

Jurisdiction	Total PCBs		Mercury		Toxaphene		Dioxin-like chemicals	
	Trigger	DNE	Trigger	DNE	Trigger	DNE	Trigger	DNE
Wisconsin	50	>1900	50	>1000	-	-	10	BPJ
Minnesota	50	>1900	50	>1000	-	-	-	-
Michigan	50	>1900	500	>1500	5000	-	10	BPJ
Ontario	153	>305	260	>520	235	>469	1.62	>3.24

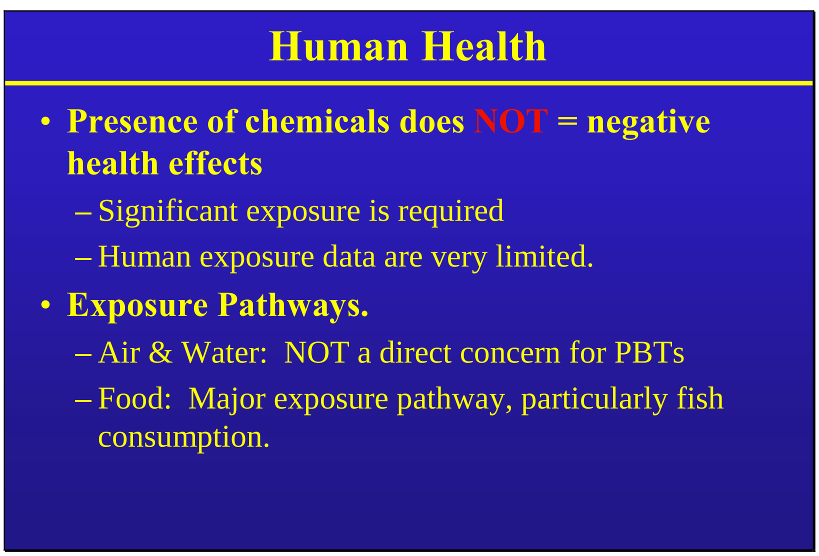
Sources: P. McCann, MN Dept. Health; C. Schrank, WI BFMHP; J. Bohr, MI DEQ; A. Hayton ON MOE

Slide 46



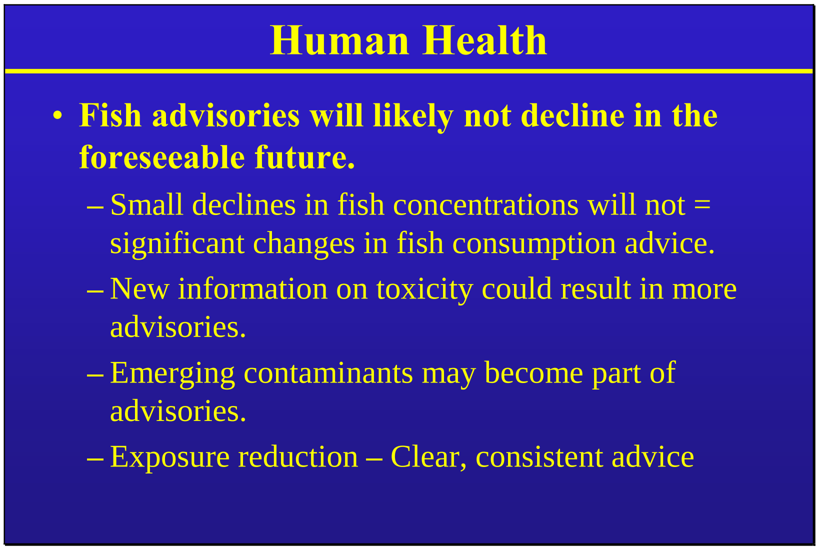
Note these are fillet concentrations and not whole fish like in previous slides. These figures show fish advisory trigger level concentrations used by one or more jurisdictions in the L.S. Basin for mercury and total PCBs, which drive most consumption advice on U.S. side of L.S. GLWQA goal is to be able to consume fish in unlimited quantities. All of these sizes and species of L.S. fish would still require some sort of consumption advice based on current trigger levels, meaning the GLWQA goal has not been met.

Slide 47

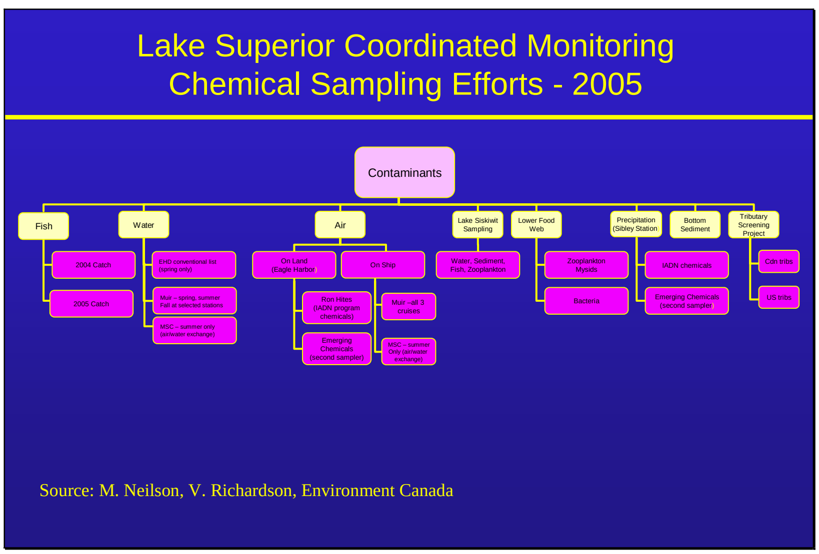


Exposure to PBTs is primarily from food, of which fish is typically the greatest source. In general and on average, exposure is similar over the US. Exceptions are for occupational exposures, those with a greater rate of consumption or for consumption of local foods which could either increase or decrease exposure based on contaminant concentrations in those foods.

Slide 48



Slide 49



Slide 50

Summary

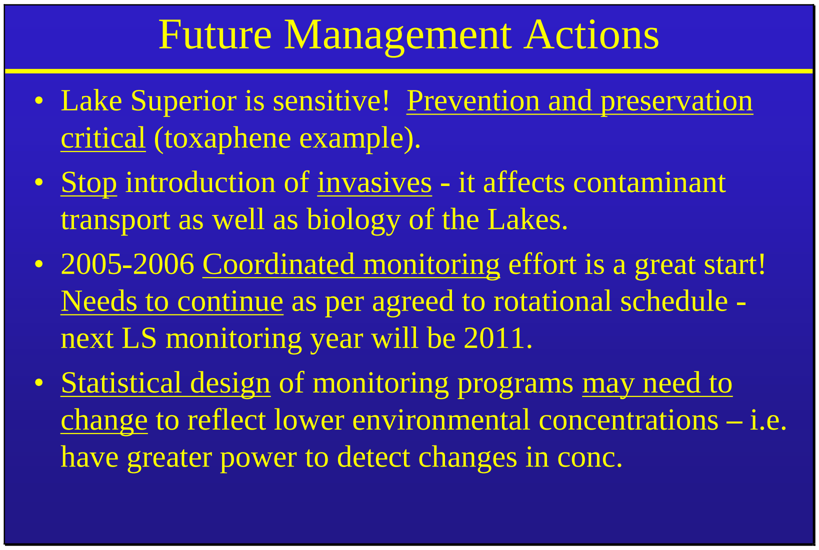
- In general, concentrations of many legacy PBT contaminants have declined over time – government intervention has been very effective.
- In most cases, concentrations in various media are decreasing at much slower rates or have leveled off over time
- Lake Superior’s physical, thermal, and biological properties make it unique and particularly sensitive to retaining PBT chemicals.

Slide 51

Summary

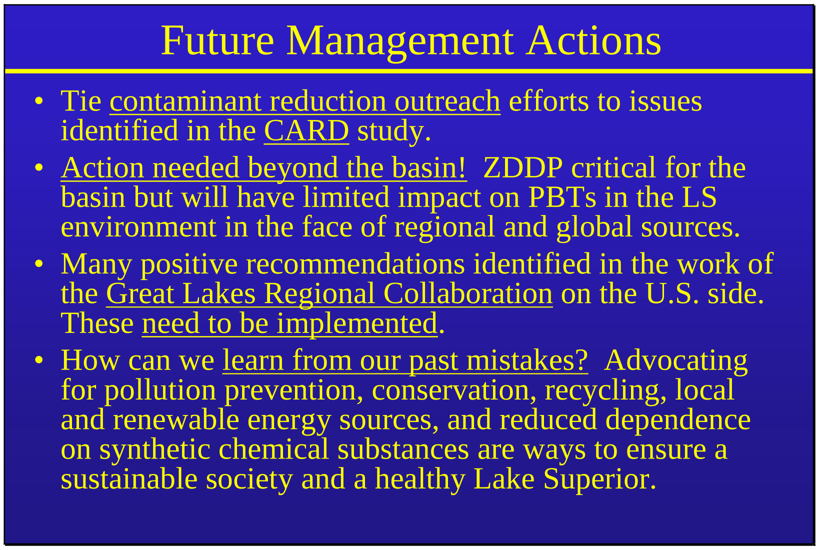
- Atmosphere is main source of PBTs to the lake – some source regions have been identified.
- New chemicals of concern such as PBDEs are increasing in fish and sediments in Lake Superior.
- Fish consumption advice is continually changing due to new monitoring data and new information on toxicological interactions of individual contaminants and contaminant mixtures.

Slide 52



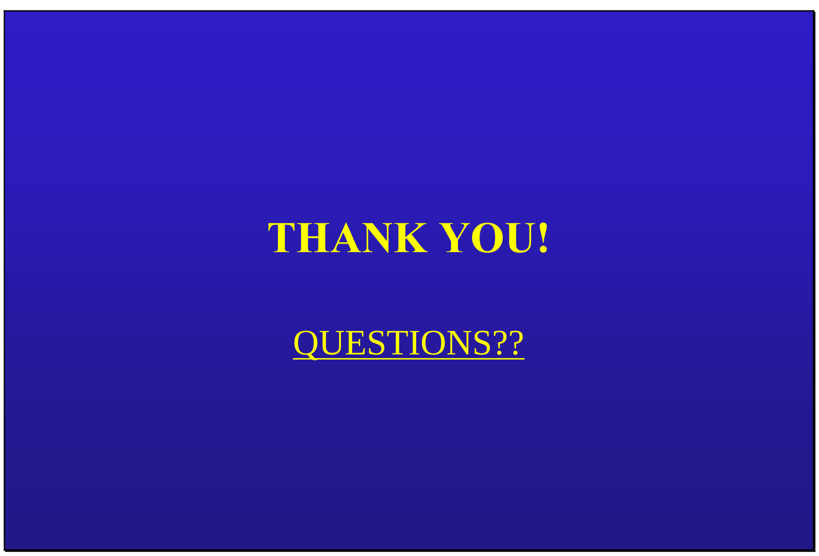
We've learned that LS is more sensitive to contaminant inputs than other GL and will take longer to recover from degradation. We can't take the viewpoint that LS is in good shape and not devote resources to protecting it.
2. Food web effects on contaminant transport are very important to observed concentrations. We have many studies that point to how food web changes impact contaminant concentrations in top predators (cite Whittle et al. study showing change in lake trout food from smelt and sculpin to herring). Invasives can add additional trophic levels to the food web and "mask" reduction of contaminants. There is a lag time for top predators to reflect food web changes via contaminant concentrations.
3. Will provide needed and valuable data to resource managers. These efforts need to continue into the future so groups are working together to provide comparable data across space and time as well as consistent management approaches aimed at protecting the lake.

Slide 53

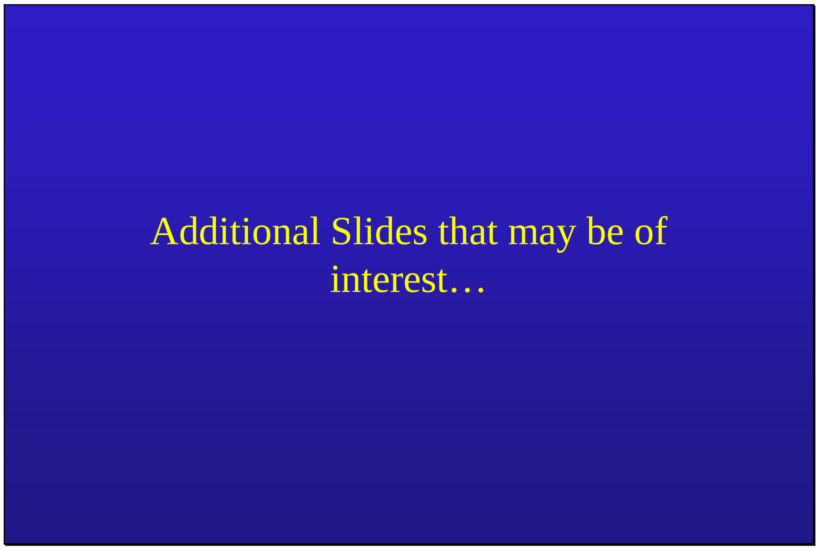


1. Personal responsibility at a grassroots level is critical to changes on a greater scale.
3. GLRC ideas: a. Adequate resources for rural trash and recycling, b. consistent and clear message on risks and benefits of fish consumption, c. adequate chemical screening and reduction in use of synthetic chemicals, d. Toxicity studies to evaluate exposure to emerging chemicals and chemical mixtures.

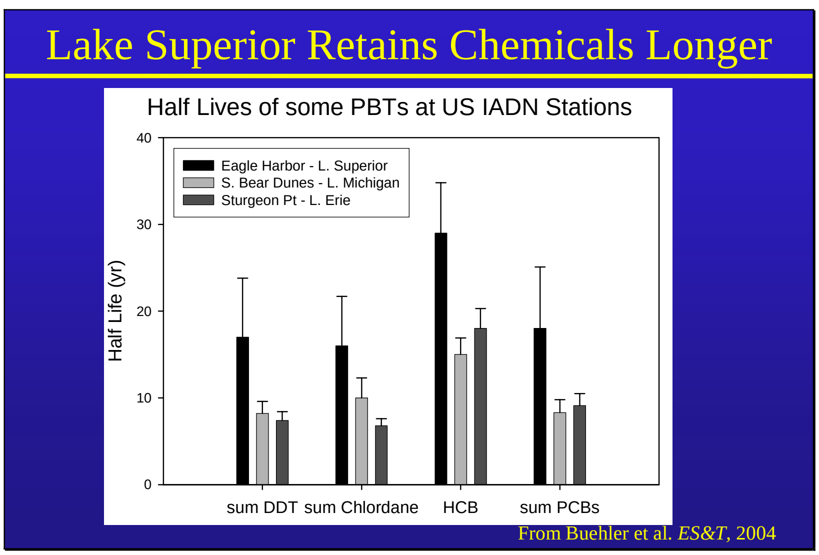
Slide 54



Slide 55

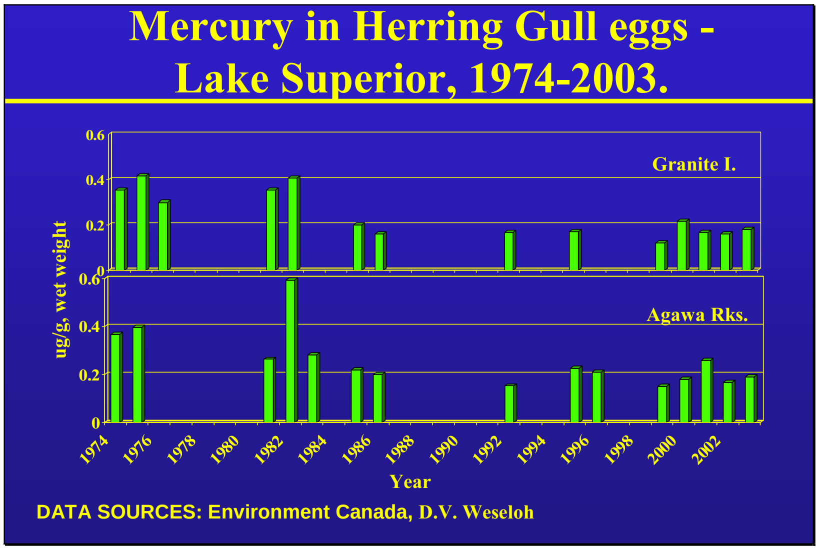


Slide 56



Shows the buffering capacity of each lake to retaining chemicals. Lake Superior has longest retention time for these chemicals. These data agree with others (cold temps, deep, long water retention time, little sedimentation, food web) and point out the greater susceptibility of L. Superior to contaminant inputs and subsequent “self cleansing”. While Superior may have had the lowest historical concentrations and still does of many contaminants, many are still above advisory levels and may take longer to drop below those levels than in other lakes.

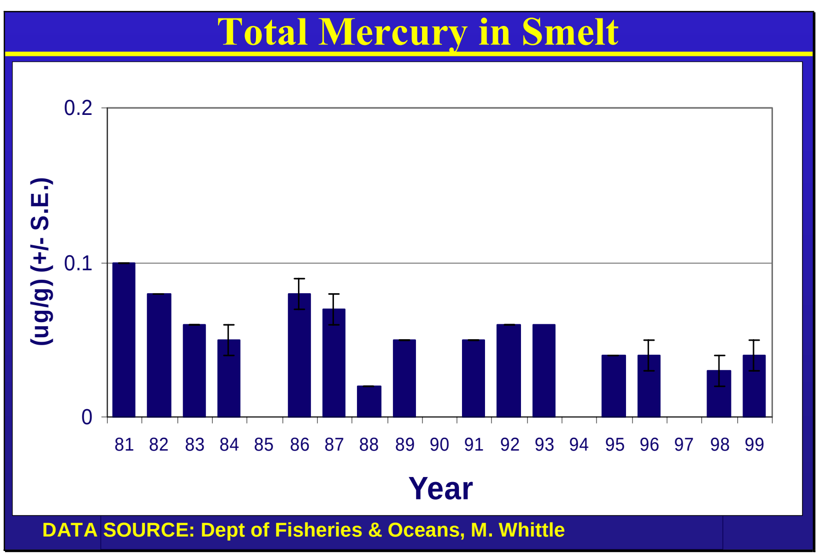
Slide 57



Mercury concentrations in herring gull eggs, show a potentially lower concentrations relative to the 1970s and early 80s however, very little change may have occurred in the past 17 years **(from 1992-2003 – no SIGNIFICANT declining (or increasing) trend in mercury concentrations)**.
Mercury as a slimicide, and chloralkylplants may account for early decline,

(text in bold was inserted by Tania Havelka)

Slide 58

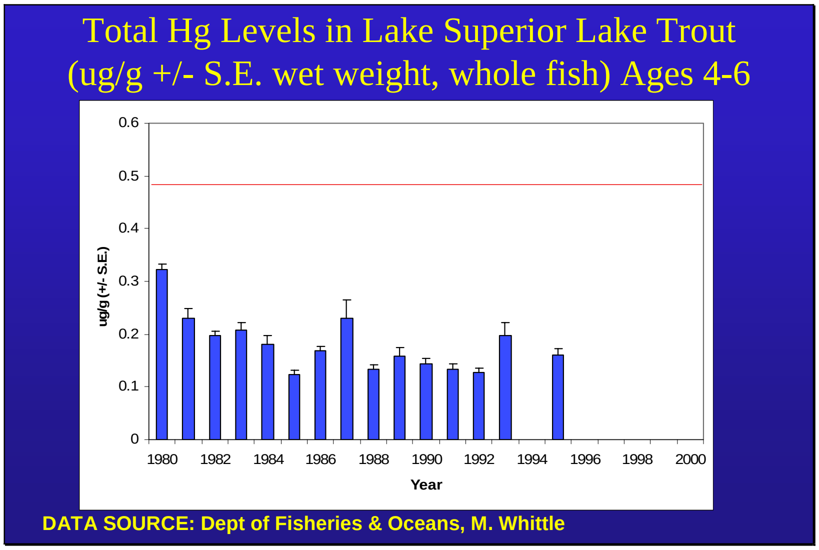


For Mercury in smelt we also seem to observe some amount of decrease in concentrations between 1981 and 1999, however, over the past decade or so the concentrations seem to be relatively stable.

Basic concentrations declined, restrictions placed on open systems, slimicides (p and P industry) and chloralkied plants to produce cl for bleaching.

Increase in importance atmospheric deposition sources (mike) similar over last 10 to 15 years, and oscillations in food web structure of Lake Superior.

Slide 59



Appendix D:

MERCURY REDUCTION FOR LAKE SUPERIOR: *A MERCURY REDUCTION ASSISTANCE PROJECT FOR LAKE SUPERIOR REGION FACILITIES*

Grand Portage, Minnesota - the Witch Tree.
Photo Credit: John Marsden, Environment Canada.

Lake Superior Lakewide Management Plan
2006

MERCURY REDUCTION FOR LAKE SUPERIOR

LAKE SUPERIOR

BINATIONAL PROGRAM

2005

A MERCURY REDUCTION ASSISTANCE PROJECT FOR LAKE SUPERIOR REGION FACILITIES

Why You Should Conduct a Mercury Inventory and Phase-Out at Your Facility and How to Receive Assistance

This booklet describes a project offering technical assistance to industries in the Lake Superior region to develop an inventory and phase-out plan for mercury. The project features special outreach to the Great Lakes shipping industry.

Technical assistance is available through a federally funded project available on the U.S. side of Lake Superior in 2005-2006. Canadian assistance is available starting in fall 2005.

This Lake Superior basin-wide mercury reduction project is a cooperative effort among environmental agencies in both countries and the Lake Superior Binational Program.

Many Lake Superior industries have already conducted mercury inventories and are offering to serve as "peer" mentors.

The last page of this booklet lists contacts for information and technical assistance

CONTENTS **Page**

THE LAKE SUPERIOR BINATIONAL PROGRAM AND THE ZERO DISCHARGE DEMONSTRATION CHALLENGE

We all determine the future of our lake. As the first in the chain of Great Lakes, Lake Superior is the cleanest, with a smaller population and industrial base. This makes it the best place to pioneer projects to eliminate sources of toxic chemicals for all the Great Lakes.

In 1991, the governments around the lake announced the Lake Superior Binational Program, which included an important challenge—the Zero Discharge Demonstration. The goal of this challenge was to have zero discharge of mercury and eight other toxic and persistent chemicals by 2020.

Since that time several organizations around the Lake Superior Basin have set up programs to remove, prevent or recycle these toxic chemicals.

Cities, schools, Indian Tribes and First Nations, provinces, states, businesses, and other groups have developed unique programs to reduce mercury and other toxic chemicals. Each event and project helps achieve the zero discharge goal and the Binational Program vision —***that water is life and the quality of water determines the quality of life.***

What We Are Offering

This project offers non-regulatory pollution prevention technical assistance to conduct inventories, develop change-out plans and provide the opportunity to recycle all mercury.

Industry members of the Lake Superior Binational Forum, a multi-stakeholder group of U.S. and Canadian citizens serve as mentors for this mercury inventory and phase-out project. One-on-one assistance is available from pollution prevention specialists. We offer:

- Mentoring and advice from industry peers
- Guidance in conducting an inventory
- Information on potential mercury devices
- Information about disposal options
- Opportunities for mercury product collections
- Assistance in complying with laws
- Recognition as a mercury reduction partner

4

THE MERCURY PROBLEM

Mercury In The Environment

Widespread mercury pollution has lead to consumption advisories for some fish taken from Lake Superior, and other waters in the basin, as well as for many waters throughout the U.S. and Canada. Mercury is found in the flesh and cannot be removed by trimming or cooking.

Mercury can harm the human nervous system. Young children, developing fetuses, and breast-fed babies are at most risk, because small amounts of mercury can damage a developing brain. People engaged in subsistence fishing have higher exposures than the rest of the population. Following health advisories minimizes risk. See the web site listing on the last page for more information.

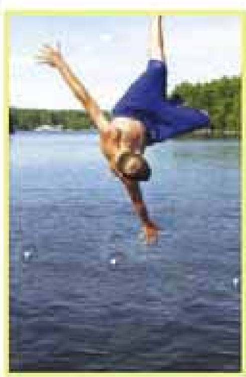
Mercury Spills Endanger Employee Health and Require Expensive Cleanup

Worker exposure in the Great Lakes Fleet.
Several workers on Great Lakes ore boats experienced mercury poisoning from exposure to mercury-bearing equipment and spills of mercury used to fill pressure gauges.

New England Gas Company, Pawtucket, RI, 2004, total price tag: $6.6 million.
The company stored mercury collected from natural gas gauges without proper notification to state and local officials. Vandals spilled an estimated 20 pounds of that mercury (about 2.8 cups) on company property and spreading it in a parking lot and an apartment complex. Evacuation of 150 residents, at company expense, lasted for nearly a month while the apartment building was cleaned.

Nicor Gas, Chicago, Il, 2001, total price tag: $4.1 million.
The company settled a lawsuit by removing natural gas gauges and cleaning up homes where gauges had leaked mercury.

Mercury Poisonings, Particularly In Children Are Documented In Medical Literature



In 2003 a Utah boy playing with what he thought was silver paint developed mercury poisoning. Seventeen-year old Michael Coleman noted, "If I stood up – dizziness. If I sat up, it would be harder to breathe. I have to do everything really slow or it will mess me up -- hands stay numb all the time."

In Oklahoma, two-year-old Maya Bailey suffered a severe case of mercury poisoning after she was exposed to mercury spilled in a carpet. In 2002, *Family Circle* magazine reported "They watched helplessly as their once-vivacious toddler became a listless 18-month-old who stumbled and fell out of her chair. Her hands and feet turned bright red. Then the red splotches on her hands became deep sores, which also spread to her mouth. Her teeth started to fall out, as did her fingernails. Worst of all, breathing became excruciatingly painful, especially at night."

INVENTORY AND PHASE OUT MERCURY AT YOUR FACILITY

Reduce Your Risk From Spills, Accidents, Worker Exposure, Lawsuits
Protect Community Health
Protect The Environment

Although widely used in the past, mercury is now known to be a threat to human health, fish, and wildlife when released into the environment.

Mercury has been used in thermometers, thermostats, monitors, manometers, and dilators to control electrical current and to measure and regulate temperature and pressure. Improper disposal at the end of product life can release significant amounts of mercury to the environment. In most cases, non-mercury alternatives are available.

Mercury devices with the highest spill risks:

- are portable and breakable, like thermometers
- spill mercury when tipped over, like many manometers
- require periodic refilling
- contain a large amount of mercury.

Mercury Reduction Supports Environmental Management Systems And Can Save Money

Many companies and public facilities have developed environmental management systems (EMS). An EMS is a holistic approach to evaluating and improving the environmental impact of business operations, following internationally accepted guidelines.

A mercury inventory and phase-out approach, with its emphasis on prevention, supports environmental management systems and can be incorporated into an existing EMS or other environmental program.

The insurance industry notes that industries with an EMS have fewer accidents and lower insurance costs. Adopting a preventive strategy reduces incidents that may result in liability.

The Mercury Bottom Line

A mercury spill can cause a plant evacuation, expose a company to liability, and in a worst case scenario cost millions of dollars. Mercury causes significant environmental and community health problems.

An effective approach is to:

- Inventory mercury bearing products
- Remove those products that can be conveniently and inexpensively replaced or that pose a high risk of causing a spill
- Tag the remaining equipment
- Train workers to properly handle and decommission the equipment at the end of service
- Implement a mercury-free purchasing policy
- Train staff to handle mercury spills appropriately and legally.
- Obtain mercury spill kits and report spills to authorities. In the U.S., mercury spills over two lbs (2 tablespoons) must be reported to the U.S. Environmental Protection Agency. http://www.epa.gov/mercury/

Lake Superior Businesses and Organizations Taking the Initiative to Reduce Mercury

Lakehead University, Thunder Bay ONT

Hugh Briggs, Mechanical/Electrical Systems Manager, reported: "Lakehead University recently removed mercury-containing boiler control panels as part of our Facility Renewal Project with Johnson Controls LP. The mercury removal was very straight-forward and easy with the assistance of local qualified contractors. The project assisted Lakehead University in dealing with a designated substance under the Occupational Health and Safety Act."

Cascades Fine papers, Inc. Thunder Bay ONT

"At Cascades, we have introduced procedures that have reduced the use of mercury-containing feedstocks. We are confident that we can eventually phase out our use of mercury-containing equipment," Nicholas Lewis, Environmental Coordinator.

Sappi Fine Paper, Cloquet MN

In 1994, the former Potlatch paper mill (now owned by Sappi Fine Paper) in Cloquet, Minnesota and the Western Lake Superior Sanitary District teamed up with chemical engineering students from the University of Minnesota–Duluth to track down the source of mercury in its wastewater. They discovered that sulfuric acid delivered to the mill from a lead smelter had mercury levels as high as 10,000 ppb. Switching to an alternative source reduced the mill's wastewater mercury concentration by 98%.

The mill developed a certificate of analysis requirement for chemical suppliers to assure that future purchases of all feedstock chemicals would have low mercury content. In the last decade, Sappi has recycled more than 400 kg of mercury from instruments and devices in the plant and replaced many with mercury-free alternatives. Kevin Kangas, Environmental Manager for Sappi Fine Paper is a member of the Lake Superior Binational Forum.

Bad River Clinic Bad River Band of Lake Superior Chippewa Ashland, WI

"Bad River Clinic strives to be mercury free. 94 % of elemental mercury has been eliminated from the clinic. All mercury thermometers have been disposed of and the clinic is in the process of changing from mercury sphygmomanometers to digital ones. Bad River should be 100% mercury free by the year 2010," reported Dennis J. Sullivan, M.D., Bad River Health Director.

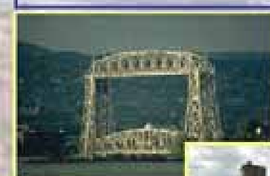
Northshore Mining, Silver Bay MN

Nancy Smith, Senior Environmental Engineer at Northshore Mining described the company's Minnesota Voluntary Mercury Reduction project. Since 1992 Northshore has shipped for recycling over 405 kg (900 pounds) of elemental mercury used to run instruments such as manometers and 2,000 to 3,000 fluorescent and mercury vapor lamps.

In 1994 the company switched from a lab method using mercuric oxide to assay iron content in ore and pellets. This saved six to nine kg (15 – 20 pounds) of mercury compound wastes per year. Northshore also launched several community-wide mercury collection programs in Silver Bay, Beaver Bay, and the surrounding communities.

Ontario Power Generation, Thunder Bay ONT

Jane Todd, Program Manager Northwest, reported that the Thunder Bay Generating Station has removed about 100 kg of mercury. "In January 2005 we shipped out the last of the "removable" mercury on site: 27 kg [59 pounds] of liquid mercury, mercury relays and mercury switches. All our spent fluorescent lamps are collected and shipped to a recycler."



Minnesota Power, Duluth MN

Since 1990, Minnesota Power has removed at least 306 kg (681 pounds) of bulk mercury and 1,470 kg (3,265 pounds) of mercury bearing materials (e.g., thermometers, switches, batteries, chemicals, wetted contacts, floats, and other devices).

The company also recycles over 10,000 fluorescent lamps per year. Minnesota Power is testing mercury control technologies for their coal fired power plants and operates an energy efficient model home. Keith Hanson, Environmental Compliance Specialist for Minnesota Power, is also a member of the Lake Superior Binational Forum.

8

MERCURY MANAGEMENT AT YOUR FACILITY

The following is based on a brochure, *Conducting an Internal Mercury Audit for Manufacturing Facilities,* prepared by the Solid and Hazardous Waste Education Center at Stevens Point, WI.
Environment Canada has a manual on mercury containing product stewardship for federal facilities, which contains information on facility audits, it is available at: **www.ec.gc.ca/MERCURY/ffmis-simif.**

Why conduct a mercury inventory?

Comply with environmental regulations
Identify opportunities for pollution prevention
Prevent the release of mercury into the environment

How to best conduct an inventory?

Obtain management approval
Communicate goals to employees
Set up teams to collect, interpret and communicate findings
Conduct the inventory

What are the steps of an inventory?

Understand the processes in the plant
Inventory possible sources of mercury
Identify discharges/emissions that could contain mercury

What are potential sources of mercury?

Laboratory
Electrical equipment
Pressure gauges / Manometers
Contaminant in feedstock
By-products
Elemental mercury
Batteries
Raw product
Low points in sewer systems where mercury from historical spills may collect

What are methods of best managing and preventing mercury waste?

Prevent spills and breakage
Modify processes and close loops to prevent releases to the wastestream
Investigate mercury-free alternatives and fuel sources
Recycle fluorescent bulbs
Manage removable sources, i.e. switches and instruments

What are the goals of a mercury inventory?

Define sources, quantities and types of mercury in the facility
Collect information on processes, products and waste generation
Encourage development of effective release minimization and waste management
Share reduction efforts with all employees to highlight proper management
Prevent mercury spills and the related high cleanup costs
Protect the environment

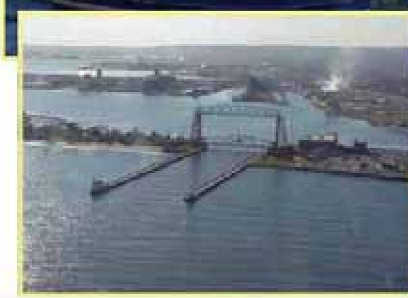
Regulatory Implications of Mercury at Your Facility

Establishing a mercury management plan that reflects relevant regulations can help assure that a business stay in compliance with regulations governing disposal of mercury-containing waste. By avoiding the purchase of new mercury-containing equipment, a company can reduce its future hazardous waste management burden.

In Canada all certified waste haulers and disposal facilities must abide by provincial and federal regulations. The hauler should be instructed to recycle the mercury that they collect rather than dispose of it in a landfill. In the United States, mercury-containing products may be classified as hazardous waste and regulated by federal and state government when they are disposed. Paperwork requirements may be reduced for certain items such as batteries, fluorescent bulbs, thermostats, and other mercury-containing equipment, when managed for recycling or proper disposal .

THE SHIPPING INDUSTRY and MERCURY

Shipping is a major industry on the Great Lakes. In addition to the usual measurement and control devices, ships and loading facilities may have mercury devices such as ballast gauges, belt scales, counterweights, and many switches. Each ship may have several pounds of mercury in the gauges that are used to control ballast and several pounds of elemental mercury to replenish these gauges. It is important to keep this mercury out of the environment as well as to purchase non-mercury alternatives.



Ballast gauges may contain two pounds or more of mercury each.

Today's Great Lakes fleet is aging: its youngest ships are over 25 years old. In May 2005, a preliminary survey of the *SS Irving*, a decommissioned ore boat built in 1938, found 19 manometers and several mercury thermometers, totaling an estimated 38 pounds of mercury.

Winter layover is the best time for an inventory and possible retrofitting on Great Lakes boats. In 2001, 16 vessels overwintered in Duluth-Superior and 10 in Thunder Bay. This project has the potential to collect hundreds of pounds of mercury. Removing this toxin will make these vessels a safer place to work and assure that this mercury will not end up in the Great Lakes

Shipping is a mainstay in the Lake Superior region. The Twin Ports of Duluth, Minnesota and Superior, Wisconsin, together with Thunder Bay, Ontario, ship over 49 million metric tons annually.

The Twin Ports host 1,100 calls annually from lakers and oceangoing salties. Principle cargos are ore (40%), coal (40%) and grain (10%). Fifteen cargo dock facilities handle coal, taconite/iron ore, grain, cement, lumber and other bulk cargo.

Thunder Bay is the largest Canadian outbound port in the St. Lawrence Seaway System, and handles over 400 vessels annually. Principal cargos are grain (70%) and coal (15%).

LAKE SUPERIOR COMMUNITIES and MERCURY

Several rural communities in the Lake Superior basin have not had access to household hazardous waste collections. A surprisingly large number of citizens have substantial quantities of elemental mercury stored in their homes. Recent collections in communities in Michigan and Ontario netted over 100 pounds of elemental mercury.

Western Lake Superior Sanitary District (WLSSD), Duluth MN

The WLSSD developed the "Blueprint for Mercury Elimination" guide for wastewater treatment plants based on its proactive approach to preventing mercury from reaching the sewer. This pioneering work has received national recognition. WLSSD replaced mercury-bearing equipment, worked with dentists to properly dispose of waste amalgam, and set up the Clean Shop program, which took in 410 kg (910 pounds) of mercury between 2000 and 2003. Mercury in WLSSD effluent dropped from 0.58 ppb in 1990 to 0.015 ppb in 1996. Tim Tuominen, Sr Chemist

City of Superior, WI

Jane Edwards, pollution prevention specialist, reports that over 400 pounds of elemental mercury, over 10,000 fluorescent bulbs, and thousands of mercury devices have been collected and recycled. Thousands of mercury thermometers have been exchanged for digital thermometers.

The City of Superior received the National Pollution Prevention Roundtable's Most Valuable P2 Award for its outstanding Educational Outreach Programs. Wisconsin State Senator Russ Feingold met with Diane Thompson (Pretreatment/Safety Coordinator, Superior WWTP) in Washington D.C. shortly before the presentation during Pollution Prevention Week in September 2004.

City of Thunder Bay, ONT

"The City of Thunder Bay is striving to eliminate the use of mercury in its operations," states Ross Churchman, Chief Chemist, Environment Division. "We have removed 126 mercury switches. We also encourage the public to drop off mercury-containing consumer products at the special waste depot."

EcoSuperior, Thunder Bay ONT

""The number of mercury-switch thermostats collected at the depots we've set up with the co-operation of local heating equipment wholesale outlets and Honeywell Inc. is absolutely amazing," comments Jim Bailey of EcoSuperior. "We've now collected several kilograms through this program."

City of Ashland, WI

In 2002, the City of Ashland followed the City of Duluth, MN in banning the sale of all mercury fever thermometers. Ashland went one step further, banning the sale of any device that had over 50 milligrams of mercury and putting in place a requirement to remove all mercury devices from any building prior to demolition.

11

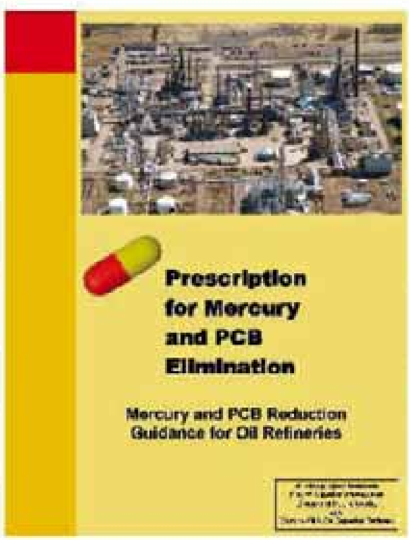
THE MURPHY OIL REFINERY CASE STUDY

MURPHY
OIL USA, INC.
SUPERIOR REFINERY

In 2001, Murphy Oil USA and the city of Superior, Wisconsin, entered into a partnership to develop a pollution prevention guidebook for refineries and other industries interested in reducing the use of mercury and PCBs. Listed below are the steps taken to ensure a complete inventory.

STEPS TAKEN TO INVENTORY AND REDUCE MERCURY AT MURPHY OIL

1) Researched general information about mercury and oil refineries.
2) Learned about everyday procedures and mercury management practices at Murphy.
3) Conducted an inventory of all products and processes that contained or used mercury within the plant.
    a) Searched various resources and locations in the refinery with the help of Murphy Oil staff.
    b) Identified chemicals in use at the refinery that contained mercury. In some cases the supplier of the chemical had to be contacted to request a Certificate of Analysis detailing the concentration of mercury in their product.
    c) Identified mercury-containing devices or processes; logged them onto a data sheet.
4) Labeled mercury-containing equipment that remain in use. Labels notify employees to properly recycle end-of-life equipment.
5) Brought elemental mercury found on site to a recycling facility in Spooner, WI.
6) Identified cost-effective alternatives to many of the mercury-containing products and processes at the refinery.
7) Developed a mercury management policy and a mercury-free purchasing policy.
8) Developed a standardized mercury spill policy as part of the safety procedures at the plant.



Non-mercury switch (left) used to replace a mercury switch at Murphy Oil Refinery.

The final report, "Prescription for Mercury and PCB Elimination", was completed and printed in 2005. This project was funded by the U.S. EPA. To receive a copy of the "Prescription for Mercury" brochure, contact the City of Superior or visit their website at: http://www.ci.superior.wi.us/

Contacts for Information and Technical Assistance

In Canada:

Barb Nicol
Lake Superior Binational Forum, Canadian Secretariat
Toll free: 888-301-LAKE
Fax: 807-343-8873
bnicol@lakeheadu.ca

In the U.S.:

Diane Thompson, City of Superior, WI Pretreatment and Safety Coordinator
715-394-0392
thompsond@ci.superior.wi.us

Carri Lohse-Hanson, Minnesota Pollution Control Agency
651-296-9134
carri.lohse-hanson@pca.state.mn.us

Lake Superior Binational Program and Forum web sites

Lake Superior Binational Program

www.epa.gov/glnpo/lakesuperior/index.html

www.on.ec.gc.ca/greatlakes/

www.binational.net

Lake Superior Binational Forum

www.superiorforum.info/

Fish Consumption Advice

Ontario: www.ene.gov.on.ca/envision/guide/index.htm

Michigan: http://www.michigan.gov/documents/FishAdvisory03_67354_7.pdf

Wisconsin: http://dnr.wi.gov/org/water/fhp/fish/pages/consumption/index.shtml

Minnesota: http://www.health.state.mn.us/divs/eh/fish/index.html

Great Lakes Indian Fish and Wildlife Commission: http://www.glifwc.org

This document was developed through a grant under the Wisconsin DNR Great Lakes Protection Fund to the City of Superior with assistance by the Lake Superior Binational Program work group and the Lake Superior Binational Forum. Printing provided by the U.S. Environmental Protection Agency.

Photo Credits: Bonita Martin, City of Superior
Kenneth Newhams, Duluth Shipping News
John Marsden, Environment Canada
Jim Bailey, EcoSuperior

LAKE SUPERIOR

BINATIONAL PROGRAM