STATE OF THE GREAT LAKES 2003

Environment Canada
and
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The *State of the Great Lakes 2003* carries the Canadian State of Environment (SOE) reporting symbol, because this report satisfies the guidelines for the Government of Canada's reporting program. The two purposes of SOE reports are to 1) foster the use of science in policy- and decision-making and 2) to report to Canadians on the condition of their environment. The *State of the Great Lakes 2003* meets SOE reporting requirements by providing an easily understood overview of the state of the Great Lakes basin ecosystem for the non-scientist; examining the key trends in the Great Lakes basin ecosystem; providing a set of environmental indicators; and discussing links among issues.

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STATE OF THE GREAT LAKES 2003

by the Governments of
Canada
and
The United States of America

Prepared by
Environment Canada
and the
U.S. Environmental Protection Agency

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Preface

The governments of Canada and the United States are committed to providing public access to environmental information that is reported through the State of the Great Lakes reporting process. This commitment is integral to the mission to protect ecosystem health. To participate effectively in managing risks to ecosystem health, all Great Lakes stakeholders (e.g., federal, provincial, state and local governments; non-governmental organizations; industry; academia; private citizens, tribes and First Nations) should have access to accurate information of appropriate quality and detail.

The information in this report, **State of the Great Lakes 2003**, has been assembled from various sources with the participation of many people throughout the Great Lakes basin. The data are based on indicator reports and presentations from the State of the Lakes Ecosystem Conference (SOLEC), held in Cleveland, Ohio, October 16-18, 2002. The sources of the information are acknowledged within each section.

Implementing Indicators 2003-A Technical Report presents the full indicator reports as prepared by the primary authors. It also contains detailed references to the data sources found throughout the **State of the Great Lakes 2003** report. The reader is encouraged to obtain the referenced literature or to converse with the identified point of contact for details or additional information.

This approach of dual reports, one summary version and one with details and references to data sources, also satisfies *the Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies*, OMB, 2002, (67 FR 8452). The guidelines were developed in response to U.S. Public Law 106-554; H.R. 5658, Section 515(a) of the Treasury and General Government Appropriations Act for Fiscal Year 2001.

Executive Summary

This *State of the Great Lakes 2003* report is the fifth biennial report issued by the governments of Canada and the United States (the Parties) pursuant to the reporting requirements of the Great Lakes Water Quality Agreement. In the *State of the Great Lakes 2001* report, the Parties presented information based on a set of agreed-upon indicators from a suite assembled by Great Lakes experts. The 2003 report builds on this format, providing more up to date information.

The 2003 report assesses the environmental status of each Great Lake, the St. Lawrence River, and the St. Clair River-Lake St. Clair-Detroit River Ecosystem, as well as provides assessments on 43 of approximately 80 indicators proposed by the Parties. These particular indicators were selected because basinwide data or data available for a portion of the basin were readily available. A full description of the entire suite of Great Lakes indicators can be found in the *Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 4,* at http://www.binational.net.

The conclusion of this* State of the Great Lakes 2003 *report is that the status of the chemical, physical, and biological integrity of the Great Lakes basin ecosystem is mixed, based on Lake by Lake and basinwide assessments of 43 indicators.

The positive signs of recovery leading to the "mixed" conclusion include:

+ **Lake trout stocks in Lake Superior have remained self-sustaining.**
+ **Reproduction of lake trout in Lake Ontario is now evident.**
+ **Bald eagles nesting and fledging along the shoreline are recovering.**
+ **Persistent toxic substances are continuing to decline.**
+ **Phosphorus targets have been met in all the Lakes except Lake Erie.**

The negative signs of degradation leading to the "mixed" conclusion include:

- **Phosphorus levels are increasing in Lake Erie.**
- **Long range atmospheric transport is a continuing source of contaminants to the basin.**
- **Non-native species are a significant threat to the ecosystem and continue to enter the Great Lakes.**
- **Scud (*Diporeia*) are continuing to decline in Lakes Ontario and Michigan.**
- **Type E Botulism outbreaks, resulting in the deaths of fish and aquatic birds, are continuing in Lake Erie.**
- **Native mussel species are being lost throughout Lake Erie and Lake St. Clair as a result of invasive zebra mussels.**
- **Land use changes in favor of urbanization continue to threaten natural habitats in the Lake Ontario, Lake Erie, St. Clair River-Lake St. Clair-Detroit River and Lake Huron ecosystems.**

Because only a portion of the full suite of indicators were used to draw the "mixed" conclusion, one challenge for Great Lakes managers is to work cooperatively toward monitoring, assessing and reporting on all the indicators. Several binational efforts are leading the way. The Lakewide Management Plan (LaMP) teams are adapting the basinwide indicators to the Lake basins. Lake by Lake assessments of these adapted indicators are providing valuable, detailed information needed to assess the whole of the Great Lakes basin ecosystem, but at a regional scale.

The Great Lakes Coastal Wetlands Consortium, a binational group of scientific and policy experts, is designing a long-term program to monitor Great Lakes coastal wetlands. This includes refining coastal wetlands indicators, collecting all existing wetland inventory data, organizing a monitoring implementation team, and creating an accessible coastal wetlands database.

Although the work of the Parties in indicator development and reporting is ongoing, several management challenges based on the indicators reported at the State of the Lakes Ecosystem Conference (SOLEC) 2002 are clear:

- First, land use decisions throughout the basin are affecting chemical, physical and biological aspects of the ecosystem. What land use decisions will sustain the ecosystem over the long term, thereby contributing to improved water and land quality?

- Second, many factors, including the spread of non-native species, degrade plant and animal habitats. How can essential habitats be protected and restored to preserve the species and unique and globally significant character of the Great Lakes ecosystem?

- Third, climate change has the potential to impact Great Lakes water levels, habitats for biological diversity, and human land uses such as agriculture. What actions will be needed to respond to potential climate change impacts?

- Finally, the Great Lakes community has been addressing toxic contamination in water, fish, sediments, air, and people for more than 30 years, yet problems persist. How will the economic and practical issues of continued removal of toxic contamination from our ecosystem be addressed?

As the experts begin to sort and analyze the indicator data that will contribute to SOLEC 2004, the Great Lakes community is aware of emerging as well as recurring environmental issues to contend with over the next decades. The global demand for accessible fresh water, the recognition that quality of life requires a healthy ecosystem, and the needs of two countries for competitive markets based on Great Lakes resources, will all impact what the indicators tell us. As such, SOLEC will undertake a two part review of the Great Lakes indicators. The first part will consider the process for selecting and reviewing the indicators. The second part will be a management review of the indicators and their effectiveness in influencing management decisions, including monitoring programs. The review will consider recent reports such as the US governments's GAO report on indicators.

The status of the chemical, physical, and biological integrity of the waters of the Great Lakes ecosystem is dependent on a binational response grounded in science, cooperation, and tenacious adherence to the goal of a sustainable ecosystem.

Section 1
Introduction

This *State of the Great Lakes 2003* report represents the gathering, analysis, and interpretation of data about the Great Lakes ecosystem by many organizations in both the United States and Canada. The basis for the report is a suite of ecosystem health indicators developed by participants in the 2002 State of the Lakes Ecosystem Conferences (SOLEC).

Hosted by the U.S. Environmental Protection Agency (USEPA) and Environment Canada as representatives of the Governments (Parties) in response to the reporting requirements of the Great Lakes Water Quality Agreement (GLWQA), SOLEC conferences report on the status of the Great Lakes ecosystem and the major factors impacting it. Scientists and managers from federal, provincial, state, tribal, and local governments, non-governmental organizations, academic institutions, and industry, contribute to a scientific analysis and interpretation of data from a variety of sources, then share this interpretation for the purpose of better managing the resources of the Great Lakes ecosystem. The year following each conference, a *State of the Great Lakes* report, based on information presented and discussed at the conference and post-conference comments, is prepared by the Parties. Additional information about SOLEC and indicators is available at http://www.binational.net.

The fifth in a series of reports beginning in 1995, the *State of the Lakes 2003* provides an assessment of each of the five Great Lakes, the St. Lawrence River, the St. Clair River to Detroit River Ecosystem, and assessments of 43 of approximately 80 basinwide indicators. The Lake and connecting channel assessments were the result of the work of the Lakewide Management Plan teams. The 43 indicators were selected because data were available for at least a portion of the basin. Comprehensive indicator reports prepared for SOLEC 2002 are found in the full technical report, *Implementing Indicators 2003 A Technical Report.*

Streaming video of the presentations about the indicators from SOLEC 2002 are available at: http://www.epa.gov/glnpo.solec.2002/plenaries.html. A full description of the entire suite of Great Lakes indicators, including proposed indicators, can be found in the *Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 4*, at http://www.binational.net.

In addition to reporting on the status of each Lake, the connecting channels, and the 43 indicators, SOLEC 2002 placed special emphasis on biological integrity, which is not specifically defined in the GLWQA. A well attended pre-SOLEC workshop used a definition of biological integrity from Dr. James Karr, modified by Dr. Douglas Dodge:

> **"The capacity to support and maintain a balanced, integrated and adaptive biological system having the full range of elements (the form) and process (the function) expected in a region's natural habitat."**

A subset of the overall suite was proposed as a candidate set of biological indicators.

At SOLEC 2002, Great Lakes indicators were also proposed for assessing the state of agriculture, forest land health, and groundwater. Societal response indicators were proposed to assist in the assessment of community contributions to ecosystem health. These new indicators will be further refined and screened against the SOLEC criteria for indicators necessary, sufficient and feasible to convey a picture of Great Lakes basin health.

The conclusion of this* State of the Great Lakes 2003 *report is that the status of the chemical, physical, and biological integrity of the Great Lakes basin ecosystem is mixed, based on Lake by Lake and basinwide assessments of 43 indicators.

The positive signs of recovery leading to the "mixed" conclusion include:

- + **Lake trout stocks in Lake Superior have remained self-sustaining.**
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The negative signs of degradation leading to the "mixed" conclusion include:

- **Phosphorus levels are increasing in Lake Erie.**
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- **Non-native species are a significant threat to the ecosystem and continue to enter the Great Lakes.**
- **Scud (*Diporeia*) are continuing to decline in Lakes Ontario and Michigan.**
- **Type E Botulism outbreaks, resulting in the deaths of fish and aquatic birds, are continuing in Lake Erie.**
- **Native mussel species are being lost throughout Lake Erie and Lake St. Clair as a result of invasive zebra mussels.**
- **Land use changes in favor of urbanization continue to threaten natural habitats in the Lake Ontario, Lake Erie, St. Clair River-Lake St. Clair-Detroit River and Lake Huron ecosystems.**

One challenge for Great Lakes managers is to work cooperatively toward monitoring, assessing and reporting on the entire suite of indicators. Several binational efforts are leading the way. The Lakewide Management Plan (LaMP) teams are adapting the basinwide indicators to the Lake basins. Lake by Lake assessments of these adapted indicators are providing valuable, detailed information needed to assess the whole of the Great Lakes basin ecosystem, but at a regional scale. The Great Lakes Coastal Wetlands Consortium, a binational group of scientific and policy experts, is designing a long-term program to monitor Great Lakes coastal wetlands. This includes refining SOLEC coastal wetlands indicators, collecting all existing inventory data, organizing a monitoring implementation team, and creating an accessible coastal wetlands database. Progress is being made toward being able to fully report on the status of the Great Lakes ecosystem.

The *State of the Great Lakes 2003* report is a report to managers and decision makers. The four sections that follow succinctly update previous reports. Section 2 offers a discussion of management challenges resulting from the conclusion of the *State of the Lakes 2003* report. Section 3 details the Lake and river assessments. Section 4 reports on each of the 43 indicators by state, pressure, and societal response category. Section 5 looks forward to the future of SOLEC, indicators, and management priorities.

Section 2
Management Challenges

At a special session of SOLEC 2002, managers from Great Lakes government and non-governmental entities met to discuss the Lake and river basin assessments and basinwide indicator reports. Several management challenges based on the assessments and reports were identified. The five general areas of discussion were land use, habitat degradation, climate change, toxic contamination, and indicator development. A summary of these challenges is presented below.

Land Use
Management Challenge: What land use decisions will sustain the ecosystem over the long term, thereby contributing to improvements in the quality of land and water?

Current land use decisions throughout the basin are affecting the chemical, physical and biological aspects of the ecosystem. Each Lake and river assessment presented at SOLEC 2002 cited the need for improved land use decisions to counter the detrimental effects of urban sprawl and increased population growth (http://www.epa.gov/glnpo/solec/2002/plenaries.html). One approach to analyzing land use, the "ecological footprint," has been applied to the Great Lakes basin by the originators of the approach, Mathis Wackernagel and William Rees (*Our Ecological Footprint*, 1996). They estimate that an area equivalent to 50 percent of the land mass of the United States is needed to support the current lifestyle of Great Lakes basin citizens. Managers are keenly aware of the importance of using the most current information when making land use decisions that may contribute to either the sustenance or degradation of the ecosystem.

Habitat Degradation
Management Challenge: How can essential habitats be protected and restored to preserve the species and unique and globally significant character of the Great Lakes ecosystem?

Many factors, including the spread of non-native species, degrade plant and animal habitats. For example: mussel species are facing extinction due to pressures from non-native zebra and quagga mussels; hydrological alterations are impacting the functioning of wetland habitats; and, poorly planned development is degrading or destroying essential habitats. Ecological protection and restoration actions are needed to sustain these essential Great Lakes habitats. Managers need current data, research to determine appropriate ecological protection and restoration tools and technologies, monitoring programs to understand species trends, and educational programs that provide the public with a broad spectrum of actions.

Climate Change
Management Challenge: What research is needed to respond to potential climate change impacts?

Climate change has the potential to impact Great Lakes water levels, habitats for biological diversity, and human land uses such as agriculture. In Ohio, for example, a string of mild winters has contributed to an infestation of slugs in corn and soybean crops. Farmers may be faced with a return to tillage plowing or the use of molluscicides to control the infestation. Either choice would reverse some of the most encouraging progress toward controlling non-point source pollution. A management challenge is the need to research further the potential impacts of climate change on the basin and to adapt to those changes as required.

Toxic Contamination
Management Challenge: How will we address the economic and practical issues of the continued removal of toxic contamination from our ecosystem?

The Great Lakes community has been remediating toxic contamination in water, fish, sediments, air, and people for more than 30 years, yet problems persist. Although loadings of contaminants to the Lakes have been greatly reduced from their peak in the 1970s, pathogens in the water at swimming beaches, for example, are an continuing concern. Controls on industrial emissions of contaminants have been legislated and enforced, resulting in reductions in levels of contaminants in the environment. Non-point source runoff reductions are significant, and optimal reductions are not yet being achieved. The approach to dealing with agricultural practices to reduce runoff of pesticides and fertilizers may require a mix of approaches including voluntary measures and incentives. A management challenge is to economically and practically continue to remove toxic contamination and excess nutrients from the ecosystem.

Indicator Development

Management Challenge: What method for developing indices will assist Great Lakes managers to better interpret indicator information?

Given the large number of current and potential indicators, it is difficult to sort and interpret findings in a way that is expedient and productive for managers. Managers and others prefer a few scientifically sound indices, based on the suite of indicators, so that they can make appropriate management decisions, or can better interpret the information presented in the State of the Great Lakes reports. A management challenge is to find a method for indexing groups of indicators in a way that leads to more informed management decision making.

Section 3
Lake and River Assessments

This section of the *State of the Lakes 2003* provides an assessment of the St. Lawrence River, each of the five Great Lakes, and the St. Clair River-Lake St. Clair-Detroit River Ecosystem. The St. Lawrence River assessment was conducted by a team from Environment Canada. Data were collected, reviewed and interpreted by the Great Lakes Fishery Commission and Lakewide Management Plan (LaMP) teams for Lakes Ontario, Erie, Michigan, and Superior. The Lake Huron Initiative and Great Lakes Fishery Commission teams assessed Lake Huron data. The St. Clair River-Lake St. Clair-Detroit River assessment was completed by the Lake St. Clair Comprehensive Management Plan Advisory Committee. These status assessments were based on reviews of all available recent scientific data, reports, and the best professional judgment of scientists and policy makers involved in the Lake or river, along with the Great Lakes basinwide indicator assessments found in Section 4.

Five broad ranking categories were used to characterize the assessment:

> **Good**. The state of the ecosystem component is presently meeting ecosystem objectives or otherwise is in acceptable condition.
>
> **Mixed, improving**. The ecosystem component displays both good and degraded features, but overall, conditions are improving toward an acceptable state.
>
> **Mixed**. The state of the ecosystem component has some features that are in good condition and some features that are degraded, perhaps differing between Lake basins.
>
> **Mixed, deteriorating**. The ecosystem component displays both good and degraded features, but overall, conditions are deteriorating from an acceptable state.
>
> **Poor**. The ecosystem component is severely negatively impacted and it does not display even minimally acceptable conditions.

In addition to the assessment, this section includes a summary narrative of the state, an identification of the pressures on the system leading to the assessment, future and emerging management issues, and the physical statistics of the resource. Additional information about the status of the Lakes and rivers can be found at the following websites:
http://www.slv2000.gc.ca/
http://www.glc.org/stclair/heart/
http://www.epa.gov/glnpo/gl2000/lamps/index.html

St. Lawrence River

Assessment
The state of the St. Lawrence River ecosystem system is mixed.

Continuing problems include introductions of non-native species and contaminants, in part from municipal effluent. Many research initiatives are underway to characterize this dynamic River system better in order to understand both how it functions and what controlling factors influence its functioning. A more comprehensive assessment of the state of this area can be found in the report "Monitoring the State of the St. Lawrence River".

Summary of the State of the St. Lawrence River System
The St. Lawrence River flows to the Atlantic Ocean and is the main outlet of the Great Lakes. It was one of the first areas settled in North America. About 5 million people live along its shores in Quebec, and in smaller communities along the New York and Ontario sections of the River. The River is the primary navigational access route for trade and commerce in the Great Lakes basin. Ten thousand registered vessels move nearly 100 million tons of goods on these waters to inland ports every year, although vessel traffic has declined in recent years. As a result of both historical and present day human activities, the River's natural ecosystems have been negatively impacted.

For example, studies show that 80% of the wetlands in the Montreal area have been lost since initial settlement. Of the original shoreline ecosystems between Cornwall, Ontario and Quebec City, Quebec, more than 50% have been altered by agriculture and urbanization. A significant portion of the 63,000 hectares of the remaining wetlands is located in Lake St. Pierre and Lake St. Francis. These wetland areas continue to be impacted by water level manipulation caused by the operation of the St. Lawrence Seaway and dredging activities. In addition, ballast water introductions of non-native species to the River are continuing at a greater rate than introductions to the Great Lakes, and these introductions are expected to continue in the near future.

Pressures on the System
The St. Lawrence River system is dynamic, particularly in terms of water level changes. Water level fluctuations are one determinant of wetland structure. Healthy wetlands experience variations in water levels, both in terms of frequency and amplitude. These variations destroy encroaching

Figure 1. St. Lawrence River
Source: Environment Canada

terrestrial plants, allow a variety of wetland plant species to become established, and permit reestablishment of plants from reserves of buried seeds. However, modifications of the water regime may alter the natural dynamic of the vegetation, either by favoring the invasion of non-native species (unusual amplitude of water levels) or by the establishment of terrestrial plant vegetation (stabilization of water levels).

In the Boucherville Islands near Montreal, low-lying marshes have been transformed into higher and drier marshes as a result of human activities. One hypothesis for this transformation is related to the dredging of Montreal Harbour. Dredging diverts water to the ship channel and consistently lowers the volume of water flowing through the marshes, resulting in alteration of the original marsh. This example demonstrates the impact of human activities on the long-term sustainability of the River's wetland ecosystems.

Increasingly, non-native species are becoming more dominant in wetlands and in some terrestrial areas. In the Boucherville Islands study site, the common reed has increased in areas where low marshes have been replaced by high marshes. This species was very rare on the islands in 1980, but increased to 25 hectares of coverage by 1999. This trend continues in

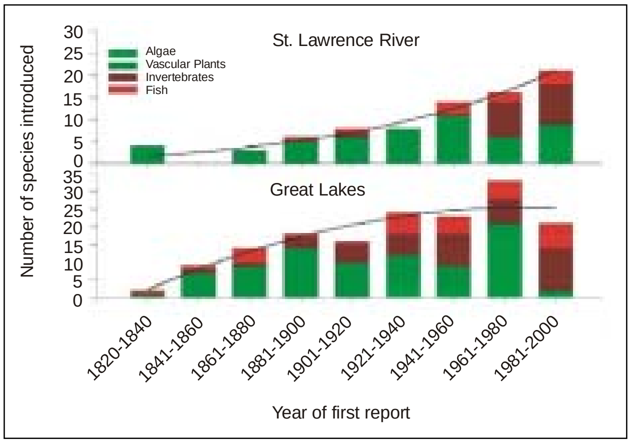


Figure 2. Non-native species in the Great Lakes relative to the St. Lawrence River.
Source: De Lafontaine, 2000

other wetland areas as well. Recent field surveys of non-native plant species coverage showed that non-native species made up 42-44% of the plant cover in the area of the River near Montreal, but much lower percentages (6-10%) were observed in estuarine areas. Purple loosestrife is the most common non-native species, but flowering-rush, reed canary grass, and common reed are the most invasive.

Future and Emerging Management Issues
The introduction of non-native species to the St.

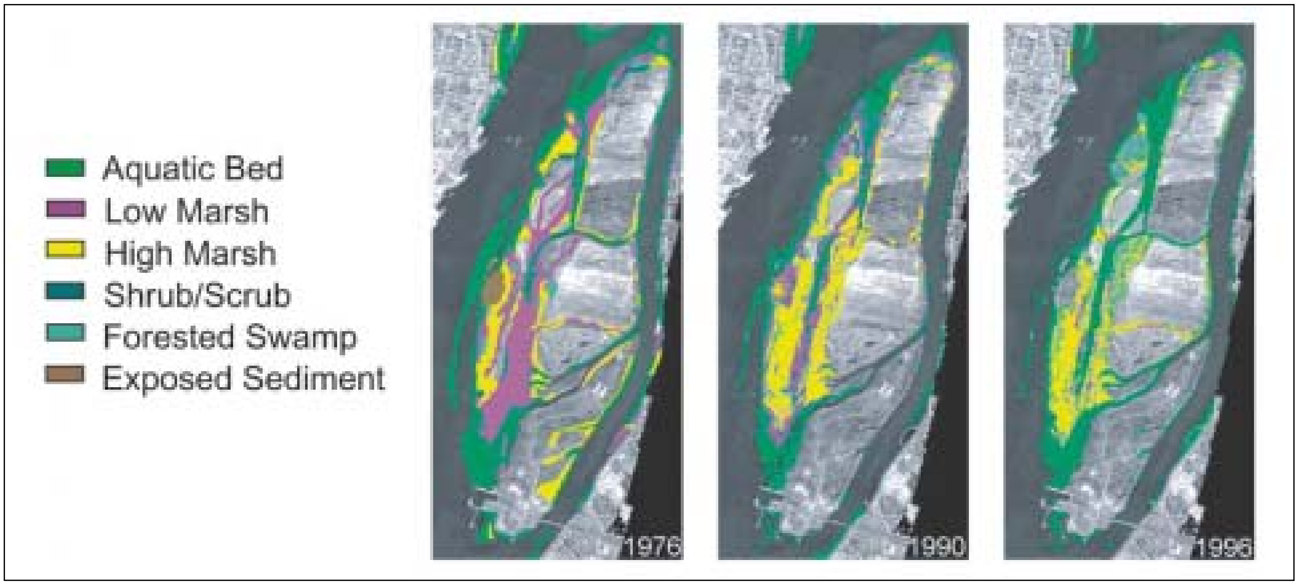


Figure 3. Reduction of wetland area on Boucherville Island, 1976-1996.
Source: modified after Jean, M., G. Létourneau, C. Lavoie & F. Delisle. 2002

Lawrence River system is an ongoing concern. For vascular plants, the spread of common reed along the St. Lawrence River and the possible appearance of water chestnut from the Richelieu River will require special attention. Because introductions occur most frequently as a result of ballast water discharges from ships, the large shipping centers of Montreal and Quebec City are likely to provide the most opportunities for non-native species introductions relative to other areas of the Great Lakes-St. Lawrence Basin.

Estrogenic chemicals entering the water are an emerging issue in the St. Lawrence River system. In recent years, estrogenic chemicals have been identified in the effluent of municipal wastewater treatment plants. Experimental studies have determined that mussels exposed to estrogenic substances in these plumes show an increase of the female to male ratio.

There are insufficient data to determine long-term effects of a variety of stresses impacting the St. Lawrence River system. As a result, it is difficult to predict the effects of non-native species, estrogenic chemicals, and future stresses (such as climate change) on the biodiversity of the River. To begin to understand the impacts of stressors, long-term monitoring activities were merged in 1999 to assess the River's health. Specific studies are documenting the River's water, riverbed, and biological characteristics. The monitoring program will aid in understanding how the ecosystems of the St. Lawrence River function and will assist managers to anticipate and interpret the impacts of continued pressures on the system.

St. Lawrence River Statistics

Elevation	Kingston 246 ft. 75 m Lake St. Francis 151 ft. 46 m Lake St. Louis 66 ft. 20 m Montreal 18ft. 5.5 m
Length	
miles	599
kilometers	964 [a]
Mean Annual Discharge	
$ft.^3/s$	44,965
m^3/s	12,600 [b]
Land Drainage Area	
sq.mi.	78,090
km^2	204,842 [c]
Water Surface Area	
sq.mi.	6,593
km^2	17,077 [d]
Shoreline Length	North Shore 305 mi. 490 km South Shore 280 mi. 450 km
Transient Time	
hours (minimum)	100 [e]
Outlet	Gulf of St. Lawrence

[a] Length of 964 km is from Kingston to Points-des-Monts
[b] The mean annual discharge of 12,600 m^3/s is at Quebec City level
[c] The land drainage area of 204,842 km^2 represents the freshwater section in the Quebec Region (Cornwall to Orléans Island)
[d] Total water surface area from Cornwall to Pointe-des-Monts
[e] The transient time applies to Quebec and does not include New York State and Ontario

Source: The River at a Glance, Environment Canada - Quebec Region

Figure 4. St. Lawrence Statistics
Source: The River at a Glance, Environment Canada, Quebec Region

Acknowledgments/Sources of Information

Serge Villeneuve, Yves de Lafontaine, Christiane Hudon, Jean-Pierre Amyot, David Marcogliese, François Gagné, Christian Blaise, Patricia Potvin, François Boudreault

Presentation at SOLEC 2002 in Cleveland, Ohio by Martin Jean, St. Lawrence Centre, Environment Canada, Quebec Region. (October 2002)

To obtain a copy of "Monitoring the State of the St. Lawrence River" contact:
St. Lawrence Vision 2000 Coordination Office
1141 Route de L'Église
P.O. Box 10100
Sainte-Foy, Quebec
G1V 4H5
http://www.slv200.gc.ca/

Lake Ontario

Assessment
The state of the Lake Ontario ecosystem is mixed.

Improvements include the decrease of nutrient loadings entering the Lake; a measurable reduction in contaminant levels; and the continued recovery of bald eagle populations. On the other hand, whitefish stocks are declining due to competition from invasive non-native species; additional habitat is being lost; and non-native species continue to impact Lake ecosystems.

Summary of the State of Lake Ontario
More than eight million people live in the Lake Ontario basin, concentrated in the northwest part of the Canadian shoreline. This region, commonly referred to as the "Golden Horseshoe", is highly urbanized and industrialized. Outside of this area, agriculture and forests dominate the land uses within the watershed. There are nine Areas of Concern (AOC) in the Lake Ontario basin (including the Niagara River AOC).

Toxic contaminants, which were considered a major stress a generation ago, have been reduced and the ecosystem has responded favorably. As a result of

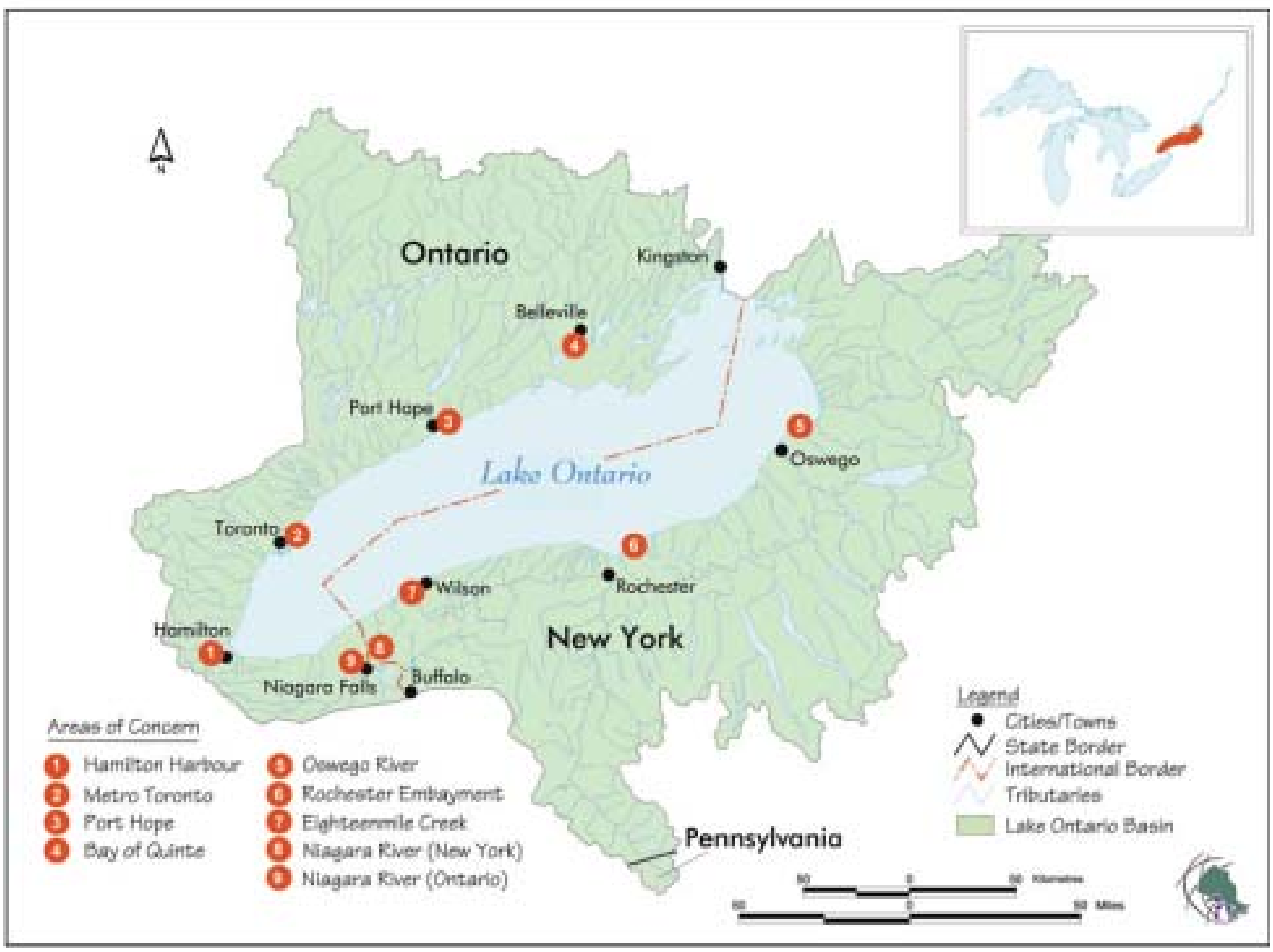


Figure 5. Lake Ontario Drainage Basin
Source: Environment Canada

actions taken by Canada and the U.S. to ban and control contaminants, such as mercury and PCBs entering the Great Lakes, levels of these contaminants in the Lake Ontario ecosystem have decreased significantly over the last 20 to 25 years. Since the 1970s, there has been a significant reduction in the levels of critical pollutants measured in fish tissues. Populations of fish-eating waterbirds in Lake Ontario have recovered and are reproducing normally. Recent data have shown that several other key indicator species such as bald eagle (within the basin), otter, and mink are also making a comeback.

Regardless of the remarkable recovery of the Lake in terms of toxic contaminant reductions, much of the watershed, tributaries and nearshore lands remain degraded, particularly in the western basin, and new concerns continue to emerge to further complicate recovery efforts.

Pressures on the System

Prior to the arrival of zebra mussels, scud (*Diporeia*, a small shrimp-like organism) was the dominant bottom (benthic) organism in the Lake. Typically, a few thousand of these organisms were present in a square meter of Lake bottom, and they provided an important source of food for many species of fish. A decade after zebra mussels were introduced, however, fewer than ten of these organisms per square meter can be found in waters up to 200 meters deep. The result is less food to support lake trout, whitefish and other native fish.

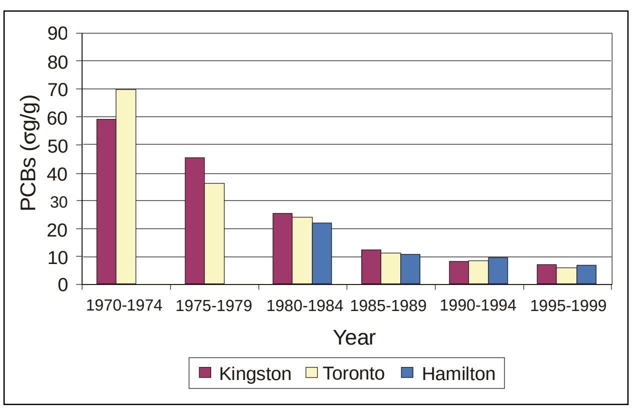


Figure 6. PCB Concentrations in herring gull eggs, 1970-1999.
Source: Bishop et al. ,1992, Pettit et al., 1994, Pekarik et al., 1998 and D.V. Weseloh

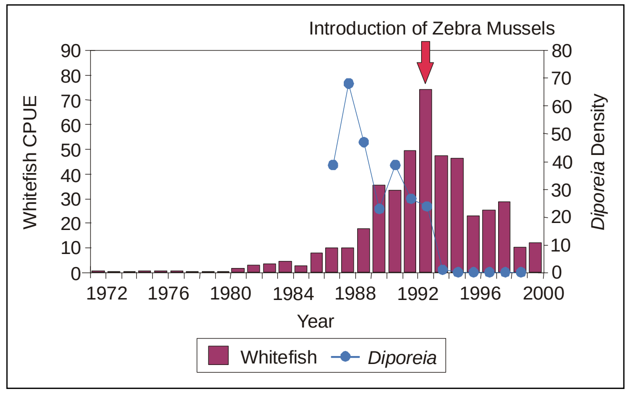


Figure 7. Whitefish and scud (*Diporeia)* abundance before and after the introduction of zebra mussels in Lake Ontario. CPUE = Catch Per Unit Effort.
Source: Whitefish data courtesy of Jim Hoyle, Ontario Ministry of Natural Resources and *Diporeia* data courtesy of Ron Dermott, Department of Fisheries and Oceans

Land use and population growth are putting enormous stress on the ecosystems of the Lake Ontario watershed. By 2020, it is projected that ten million people will live in the Lake Ontario basin. Most of the growth will be concentrated in the Golden Horseshoe area, where low-density development is replacing farmland and natural habitats. In addition, the rural landscape is changing with fewer and larger farms becoming more common in some portions of the basin. In particular, large feedlot operations concentrate hundreds to thousands of animals (cattle, hogs) in a relatively confined area, resulting in significant waste management issues. The cumulative effect is the removal of natural habitat, and a negative impact on the flow and quality of surface water and groundwater feeding local streams and wetlands. Many parts of New York State's basin, however, have seen significant increases in wetland and forest habitat as abandoned farmland returns to more natural conditions.

It is estimated that about 50% of Lake Ontario's original wetlands have been lost. Along the intensively urbanized coastline, the estimate is even higher at 60 to 90%. Wetland losses are a result of urban development, and human alterations such as dyking, dredging, and other disturbances. Of the remaining 80,000 acres of wetlands, 20% are fully protected in parks and other significant wetland areas are protected by a variety of government regulations and programs. There are numerous activities underway throughout the basin by the government and private partners to further protect and restore habitat.

Future and Emerging Management Issues

While the levels of contaminants found in Lake Ontario are declining, there are still inputs of contaminants to the system. Recent studies indicate that the most significant sources of critical pollutants to Lake Ontario now come from outside the basin through upstream sources and atmospheric deposition.

Another emerging issue is Type E Botulism, recently detected at a few locations along the Lake Ontario shoreline. The role that non-native species, such as zebra mussels, play in the movement of pathogens

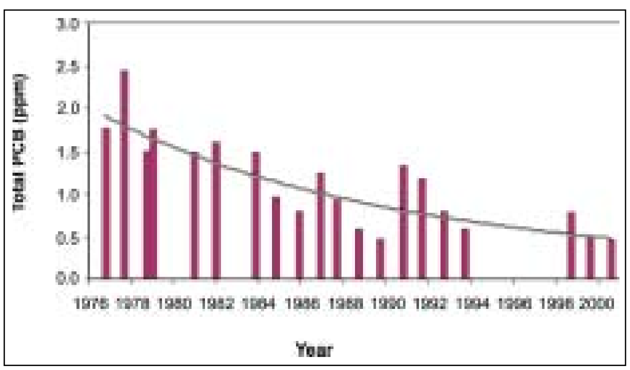


Figure 8. Total PCB levels in coho salmon edible tissue from Credit River, Ontario.
Source: Ontario Ministry of the Environment and Ontario Ministry of Natural Resources

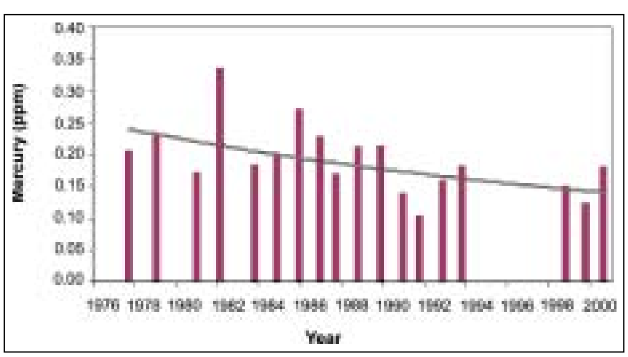


Figure 9. Mercury levels in coho salmon edible tissue from the Credit River, Ontario.
Source: Ontario Ministry of the Environment and Ontario Ministry of Natural Resources

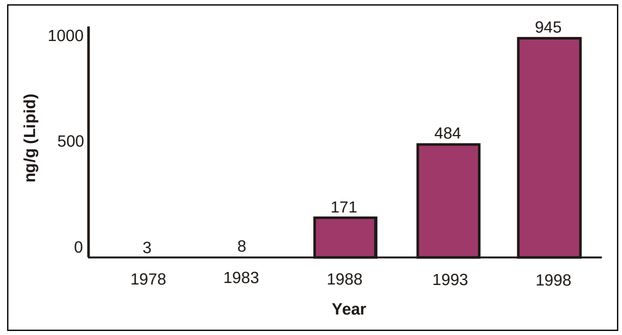


Figure 10. Polybrominated diphenyl ether (PBDE) trends in Lake Ontario lake trout.
Source: Mike Whittle, Department of Fisheries and Oceans

through the system is unknown; however, historic conditions of the Lake will likely change as a result of this movement.

Polybrominated diphenyl ethers (PBDEs) are a class of bioaccumulative chemicals that have been widely used over the last two decades as a flame retardant in textiles, foams, plastics and electrical equipment. Some PBDE compounds are highly mobile in the environment and they are now found in fish, wildlife and human tissues worldwide. Environmental sampling in Lake Ontario has shown that PBDE concentrations in fish and wildlife tissue are increasing. A number of studies are underway to evaluate the potential risk that some PBDE compounds may pose to fish, wildlife and human health.

Lake Ontario fish and wildlife habitat continues to be lost. Losses can be attributed to three principal factors: artificial Lake level management which disturbs natural growth cycles; the modification or destruction of habitats as part of urbanization and other land uses changes; and the introduction of non-native species which alter system functions.

Non-native species introductions continue to be a major issue for Lake Ontario. Some recently introduced non-native species, such as a fish called the round goby and a zooplankton species called the spiny water flea, may take advantage of the unstable conditions in Lake Ontario and expand their range rapidly. As new non-native species continue to be introduced from ballast water from overseas shipping, the potential for continued impacts of non-native species on Lake Ontario is considerable.

The Lake Ontario Lakewide Management Plan continues to work closely with the Great Lakes Fishery Commission's Lake Ontario Committee in identifying priority projects, investigations and the development of appropriate aquatic habitat ecosystem objectives and indicators.

Acknowledgments/Sources of Information

Lake Ontario LaMP 2002 Biennial Report (2002)
Lakewide Management Plan for Lake Ontario, Stage 1: Problem Definition (1998)
Status and Trends of Fish and Wildlife Habitat on the Canadian Side of Lake Ontario (2001)

LaMP presentation at SOLEC 2002 in Cleveland, Ohio. (October 2002)

Lake Ontario Statistics

Elevation [a]	
feet	243
meters	74
Length	
miles	193
kilometers	311
Breadth	
miles	53
kilometers	85
Average Depth [a]	
feet	283
meters	86
Maximum Depth [a]	
feet	802
meters	244
Volume [a]	
cu.mi.	393
km^3	1,640
Water Area	
sq.mi.	7,340
km^2	18,960
Land Drainage Area [b]	
sq.mi.	24,720
km^2	64,030
Total Area	
sq.mi.	32,060
km^2	82,990
Shoreline Length [c]	
miles	712
kilometers	1,146
Retention Time	
Years	6
Population: USA (1990)†	2,704,284
Population: Canada (1991)	5,446,611
Totals	8,150,895
Outlet	St. Lawrence River

[a] measured at low water datum
[b] Lake Ontario includes the Niagara River including islands
[c] including islands
† 1990-1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years

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

Figure 11. Lake Ontario Statistics
Source: The Great Lakes: An Environmental Atlas and Resource Book

Lake Erie

Assessment
The state of the Lake Erie ecosystem is mixed-deteriorating.

This assessment is due to the continuing impacts of non-native species, the reemergence of an area of oxygen depletion in the Central Basin, excessive nutrients in the system, and ongoing habitat degradation. One observed improvement in the system is the recovery of mayfly populations in the Western Basin of Lake Erie.

Summary of the State of Lake Erie
With a population of over 11 million people, the Lake Erie basin is the most densely populated and intensely urbanized watershed of the Great Lakes. It is also the most biologically productive because of the variety of habitats. The Lake Erie basin includes a Carolinian Zone that has been described as Canada's most endangered major ecosystem. The Carolinian Zone sustains at least 18 globally rare vegetation community types; 36 globally rare species; and 108 vulnerable, threatened and endangered species. In addition to the Carolinian Zone, the watershed has habitats that sustain 143 fish species, many of which contribute to a thriving sport and commercial fishery. There are nine Areas

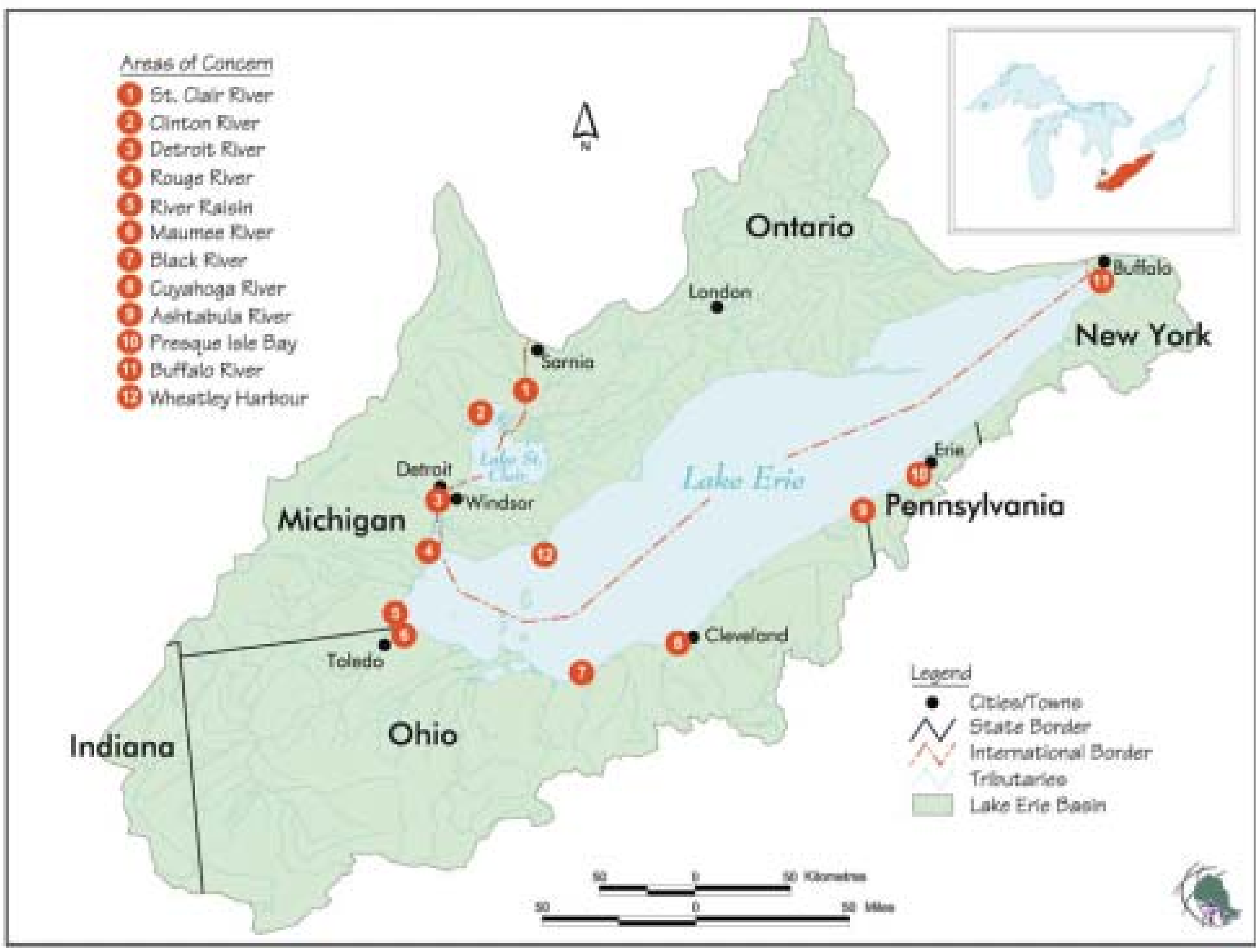


Figure 12. Lake Erie Drainage Basin
Source: Environment Canada

of Concern in the Lake Erie basin (not including the St. Clair River-Lake St. Clair-Detroit River AOCs).

In the Western Basin of Lake Erie, increased populations of mayflies (a bottom-dwelling species) are providing forage for many fish species. Trout-perch, another bottom dwelling species that was in decline in the 1950s, seems to be making a comeback. These changes suggest that the bottom community may be starting to recover.

Although significant reductions in nutrient loadings have been achieved, phosphorus concentrations in Lake Erie appear to be increasing again and may be linked to a zone of oxygen depletion in the Central Basin.

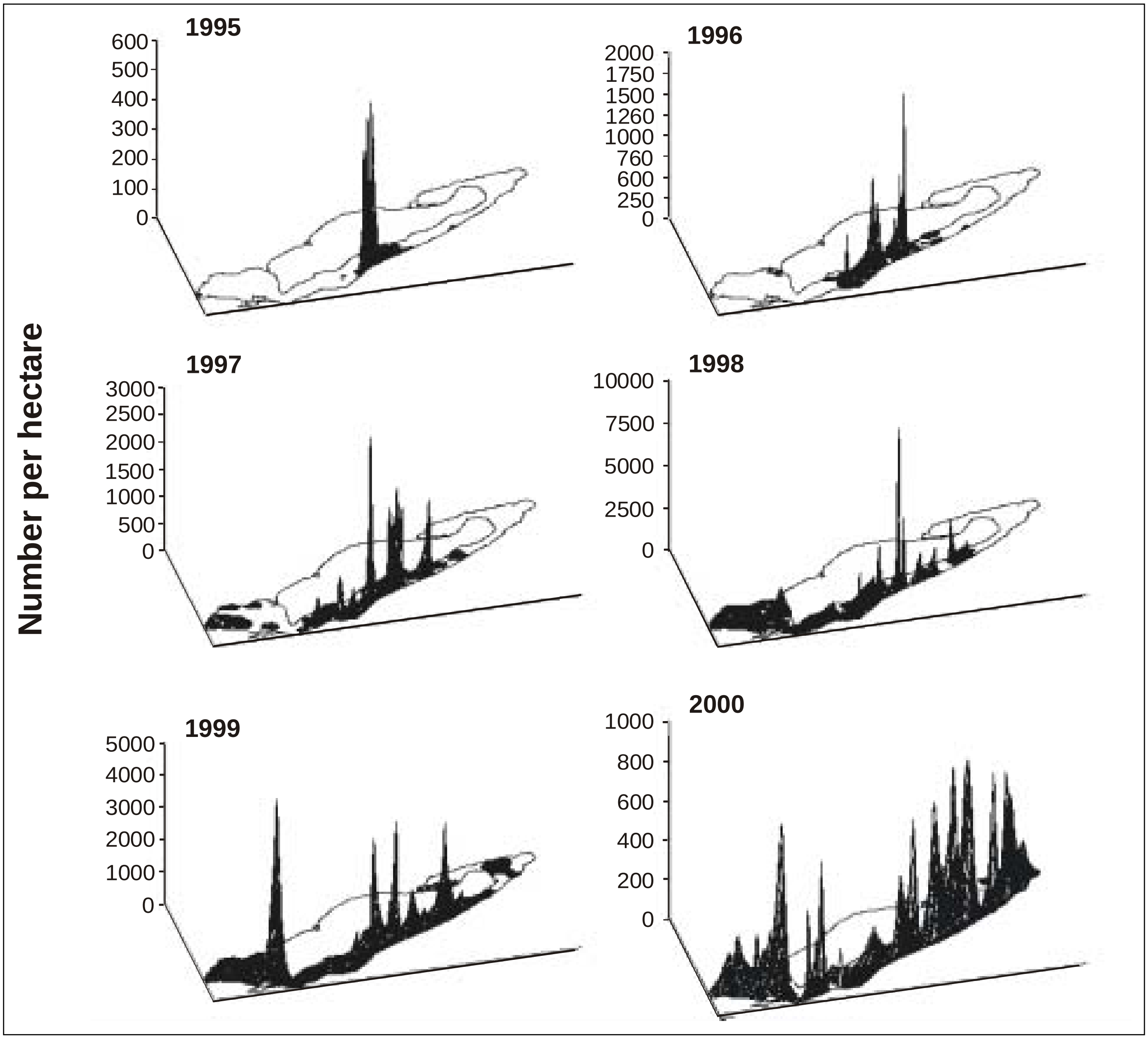


Figure 13. Round Goby distribution and abundance from interagency bottom trawls in Lake Erie, 1996-2001. Data are from Ontario Ministry of Natural Resources, Ohio Department of Natural Resources, Pennsylvania Fish and Boat Commission, and New York State Department of Environmental Conservation

Source: Michigan Department of Natural Resources

Pressures on the System

The greatest threats to biological integrity in Lake Erie are non-native species, changing nutrient dynamics, and land use alterations that affect the quantity and quality of habitats.

Lake Erie is particularly vulnerable to the introduction and establishment of aquatic non-native species because of its basin shape, chemistry, productivity, and a large human population. Currently, at least 144 aquatic non-native species have been recorded in the Lake Erie basin, including 34 fish species. The presence of these species has resulted in changes in the behavior and productivity of native species and in permanent alterations to food webs. Two non-native zooplankton species, *Cercopagis pengoi* and *Daphnia lumholtzi*, are now established in the Western Basin near the Detroit River inflow. Because *Cercopagis* is larger than native zooplankton, it will likely affect both phytoplankton and zooplankton populations, and it might even compete with young-of-the-year fish for prey.

Aquatic non-native species are also affecting contaminant movement, and potentially the health of fish, wildlife and humans. Round gobies, for example, have created a new pathway for contaminant and energy transfer. In the past decade, round gobies have spread throughout Lake Erie and are now one of the most abundant fish species. Round gobies live on rocky substrates and feed on a variety of organisms ranging from plankton to zebra mussels and other benthic invertebrates. They have become a major prey item for many bottom dwelling fish predators, including smallmouth bass, yellow perch, walleye, and freshwater drum. The round goby is quickly establishing its niche in the Lake Erie ecosystem, but the extent that this species is altering the food web and facilitating the movement of contaminants is just beginning to be understood.

The round goby is suspected of aiding the spread of Type E Botulism in the ecosystem, although its exact role is not clear. The disease is caused by a bacterium called *Clostridium botulinum*. Birds such as ducks, gulls, mergansers and loons are paralyzed or die after exposure to a toxin produced by this bacterium. A single event during August and September of 2001, along the Ontario and New York shoreline of Lake Erie, resulted in deaths of loons, mergansers, round gobies, carp, catfish, mudpuppies, freshwater drum and sturgeon. Botulism episodes that have occurred over the past four years have killed thousands of fish and birds.

Changes in nutrient concentrations and cycling in the food web are also significantly stressing Lake Erie. Blooms of the toxic blue-green algal species *Microcystis aeruginosa*, have been linked to the feeding habits of the zebra mussel. Blooms were formerly common in the nutrient-rich Western Basin of Lake Erie before a phosphorus abatement program was initiated in the early 1970s. It is hypothesized that today, zebra mussels induce a shift in algal abundance by ingesting all algae except blue-green species such as *Microcystis aeruginosa*.

Land use conversion is reducing the availability of good quality habitat for native plants and animals and is altering nutrient dynamics. Recent assessments of 15 Lake Erie habitat types and more than 300 species for evidence of impairment showed that all 15 habitats, including sand beaches and dunes, aquatic habitats, wetlands, and islands, are impaired on both sides of the border because of historic or present land use alterations.

The Lake Erie water snake, for example, is a semi-aquatic reptile dependent entirely on specialized western Lake Erie island habitat. It has disappeared from four islands it originally inhabited and has significantly declined in population on other islands. The decline is due to its habitat being severely altered by development, wetland infilling, quarry mining and marina construction, as well as other human activities, including an extermination program on one island. On a positive note, the Lake Erie water snake returned to Green Island, Ohio in 2002.

The large double-crested Cormorant population represents a success story in terms of ecosystem rehabilitation, but this large population remains an issue in Lake Erie. Cormorants physically displace other colonial waterbirds, kill trees and vegetation with their feces, and affect the ecological balance of a site. Of particular concern are the island habitats in Lake Erie. A national cormorant management plan for the U.S. was developed to enhance the flexibility of natural resource agencies to deal with impacts caused by the birds, as well as to ensure healthy and viable bird populations.

Future and Emerging Management Issues

In the summer of 2002, a consortium of universities and agencies from both Canada and the U.S. began an intensive study to investigate the changing and complex nutrient dynamics of the Lake. The scientists are measuring biological and chemical processes in order to improve our understanding of the changes in Lake Erie. Stewardship programs throughout the basin are targeting non-point sources for remediation and promotion of natural habitat restoration projects. Regulatory tools have been introduced to improve agricultural management practices. Many of these stewardship projects integrate aquatic and terrestrial habitat conservation practices and water quality improvement on private lands.

Land use alterations continue to result in habitat loss. It is critical that stewardship efforts are sustained over time. Improved habitat protection and restoration will increase the chances for survival of species impacted by stressors in the Lake.

Releases of species from aquaria, water gardens, aquaculture, as well as baitfish, are also important means for non-native species introductions to Lake Erie. In 2000, a Bighead carp was sighted in the Western Basin of Lake Erie. This filter feeder, if established, would compete with native fishes for plankton.

Acknowledgments/Sources of Information

LaMP presentation at SOLEC 2002 in Cleveland, Ohio (U.S. EPA Region 5). (October 2002).

Degraded Wildlife Populations and Loss of Wildlife Habitat Report, 2001.

Lake Erie Statistics

Elevation [a]	
feet	569
meters	173
Length	
miles	241
kilometers	388
Breadth	
miles	57
kilometers	92
Average Depth [a]	
feet	62
meters	19
Maximum Depth [a]	
feet	210
meters	64
Volume [a]	
cu.mi.	116
km^3	484
Water Area	
sq.mi.	9,910
km^2	25,700
Land Drainage Area [b]	
sq.mi.	30,140
km^2	78,000
Total Area	
sq.mi.	40,050
km^2	103,700
Shoreline Length [c]	
miles	871
kilometers	1,402
Retention Time	
Years	2.6
Population: USA (1990)†	10,017,530
Population: Canada (1991)	1,664,639
Totals	11,682,169
Outlet	Niagara River Welland Canal

[a] measured at low water datum
[b] Lake Erie includes the St. Clair - Detroit system including islands
[c] including islands
† 1990-1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years

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

Figure 14. Lake Erie Statistics
Source: The Great Lakes: An Environmental Atlas and Resource Book

St. Clair River-Lake St. Clair-Detroit River Ecosystem

Assessment

The state of the St. Clair River-Lake St. Clair-Detroit River ecosystem is mixed.

Stressors to natural ecosystems persist, including the impacts of land use, shoreline alteration, and non-native species. On the other hand, there has been a decrease in contaminant levels in water, and an increase in habitat protection activities.

Summary of the State of the St. Clair River-Lake St. Clair-Detroit River Ecosystem

The St. Clair River-Lake St. Clair-Detroit River ecosystem is one of the most highly industrialized areas in the Great Lakes basin. The cities of Port Huron and Detroit, Michigan, and Sarnia and Windsor, Ontario, are major petrochemical and manufacturing centers. Between these cities, the shoreline consists of a mix of small communities, cottages and recreational beaches. Inland, land use is primarily agricultural. There are four Areas of Concern in the St. Clair-Detroit River ecosystem.

Figure 15. St. Clair River-Lake St. Clair-Detroit River Ecosystem
Source: Environment Canada

Wetland areas exist in pockets throughout the region. The largest is in the Walpole Island First Nation Territory at the mouth of the St. Clair River. Walpole Island also has remnant tall grass prairie and oak savanna habitats. A smaller wetland survives in Michigan at the north end of Lake St. Clair.

Sport fishing in Lake St. Clair accounts for nearly half the total Great Lakes sport fishing industry. More than 1.5 million fish are taken annually from the Lake. Overall, there was an increase on return for angler effort in 2002 when compared to the 1970s and 1980s. In 2002, 17% of anglers fished for walleye, catching 14,000 fish. In the late 1970s and 1980s, the average catch of walleye was 85,000 fish annually. In contrast in 2002, the fishery for yellow perch increased significantly and represented 31% of angler effort. The fishery in 2002 was similar to the fishery observed in the 1940s.

In the Detroit River, specifically the Trenton Channel, benthic communities are limited by degraded sediment quality as indicated by the high number of pollution tolerant worms and midges. Although progress toward reducing contaminant loading has been achieved in the system, some historic contaminants such as mercury, arsenic, dioxins, polynuclear aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs), continue to cycle through the sediments and the food web. Mercury still exists in sediments in the St. Clair River, and PCBs are widely distributed throughout the sediments of the Detroit River.

Nutrient loadings from combined sewer overflows, other municipal effluent sources, and rural land use are also issues of concern in the St. Clair River-Lake St. Clair-Detroit River ecosystem.

Pressures on the System

Non-native species, contaminants, quality of habitat, and land use alterations continue to challenge the

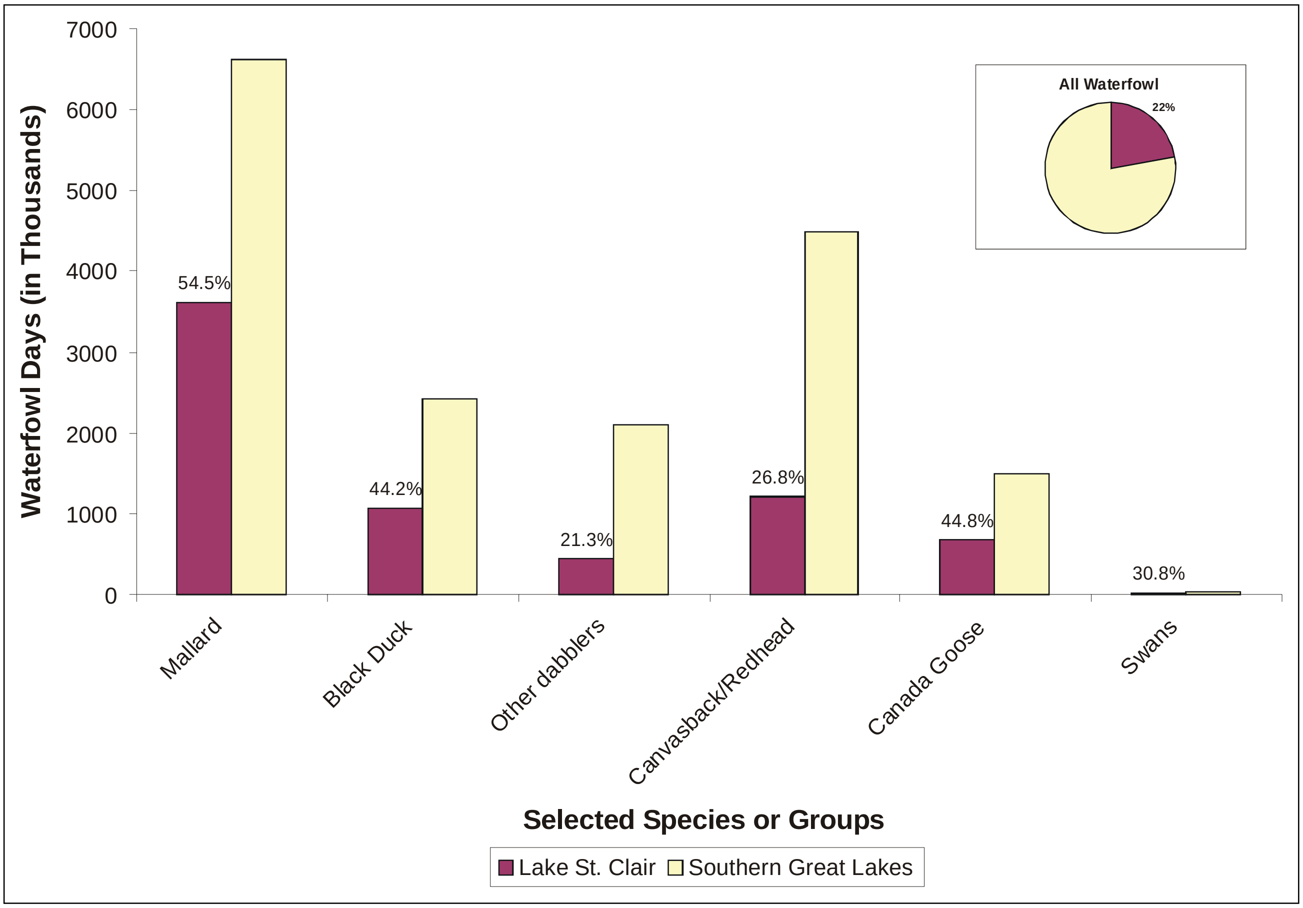


Figure 16. Fall waterfowl days for Lake St. Clair compared to those recorded along the full Canadian shore of the southern Great Lakes.
Source: Canadian Wildlife Service

biological integrity of this ecosystem.
Historically, Lake St. Clair and the Detroit River supported extensive beds of rooted aquatic plants in nearshore areas. These areas provided habitat for abundant populations of native fish such as bluegill, pumpkinseed sunfish, and muskellunge. As habitat was destroyed and degraded during "European" settlement, nearshore fish communities were severely altered. Rooted aquatic vegetation (macrophyte) populations have improved dramatically in density, distribution and species composition since the mid-1980s. Attributed to a 67% increase in water transparency, the changes in the rooted aquatic vegetation communities have led to some improvements in the fish and waterfowl communities.

Native mussel populations provide further evidence of the negative impact on the system by non-native species. Native freshwater mussel species were extirpated from the offshore waters of Lake St. Clair by 1994, when only five of the original eighteen species were found. Similar declines have been observed in the connecting channels and many nearshore habitats. The average number of mussel species found in these areas before the zebra mussel invasion was eighteen. After the invasion, 60% of surveyed sites had three or fewer native species left, and 40% of survey sites had no native mussels at all. The overall abundance of native mussels has declined by 90-95%. Surveys conducted between 1998 and 2001 found 22 remnant populations of native mussel species in nearshore waters off the St. Clair delta and eastern shore of Lake St. Clair. The population numbers and distributions, however, had been considerably reduced.

Dredging and shoreline hardening to facilitate shipping or recreational boating and to protect against flooding, including dyking associated with residential areas, cottages, marinas and agriculture, have significantly altered the hydrology of the St. Clair River-Lake St. Clair-Detroit River system. The modified hydrology changes the movement of sediment within the system, and it can irreversibly alter the location, extent, and diversity of habitats.

While contaminant levels in fish and wildlife have been reduced from their peaks in the 1970s, elevated levels of mercury and PCBs in fish continue to cause restrictions in the consumption of fish caught in Lake St. Clair, the St. Clair River and the Detroit River. These contaminants are also of concern in some wildlife communities.

Future and Emerging Management Issues
Protection of refugia for native mussel species is needed to prevent extirpation from nearshore and connecting channel habitats.

Changes in the original St. Clair River-Lake St. Clair-Detroit River ecosystem to accommodate agricultural, municipal, industrial, commercial, recreational and shipping activities, and the introductions of non-native invasive species, have resulted in altered hydrology; increased chemical, sediment and nutrient loadings; and reductions in habitat quality and native species distribution and abundance. These changes have caused major impairments in the local habitats and are affecting the sustainability of the different components within the ecosystem.

The implementation of activities to eliminate chemical inputs, manage sediment and nutrient inputs, reduce the effects of invasive non-native species, prevent the introduction of new non-native species, and manage for a more natural hydrology, will improve the quality and quantity of habitats in the St. Clair River-Lake St. Clair-Detroit River ecosystem.

Acknowledgments/Sources of Information
LaMP presentation at SOLEC 2002 in Cleveland, Ohio (U.S. EPA, Region 5). (October 2002)

Lake St. Clair Statistics	
Elevation	
feet	569
meters	173
Length	
miles	26
kilometers	42
Mean Breadth	
miles	24
kilometers	39
Mean Depth	
feet	11
meters	3.4
Mean Annual Discharge	
$ft.^3/s$	183,000 [a]
m^3/s	5182 [a]
Maximum Depth (natural)	
feet	21
meters	6.5
Watershed Area	
sq.mi.	460
km^2	1191
Land Drainage Area	
sq.mi.	6,100 [b]
km^2	15,799 [b]
Water Surface Area	
sq.mi.	400 [c]
km^2	1036 [c]
Shoreline Length	
miles	62
kilometers	100

[a] Inflow into Lake St. Clair
[b] Land areas include the total drainage area to the outlet of the upstream lake
[c] Water surface area does not include area of connecting channels

Source: Lake St. Clair: It's Current State and Future Prospects, Lake St. Clair Network, United States Geological Survey

Figure 17. Lake St. Clair Statistics
Source: Lake St. Clair: Its Current State and Future Prospects, Lake St. Clair Network, U.S. Geological Survey

Lake Huron

Assessment

The state of the Lake Huron ecosystem is mixed.

This rating is based upon the overall improvement in the Lake in terms of specific fish communities, contaminant loadings, and the status of the Areas of Concern. However "hotspots" of contamination, the status of a sustainable fishery, sea lamprey predation, and other non-native species are still major stresses to the ecosystem. Rapid changes in biodiversity and ecosystem functioning are of major concern.

Summary of the State of Lake Huron

Lake Huron is the third largest by volume and has the largest drainage area of the Great Lakes. Lake Huron has not experienced the same decline in water quality as some of the other Great Lakes, mainly due to the relatively low population density and industrialization within the watershed. However, it is within easy commuting distance of large population centers, and it has become a recreational destination for millions of cottagers, tourists and anglers. Cottage development and other land uses are beginning to stress this Lake's formerly large and undisturbed shoreline.

Lake Huron has over 30,000 islands, contributing to its distinction of having the longest shoreline of any lake in the world. The islands and nearshore areas

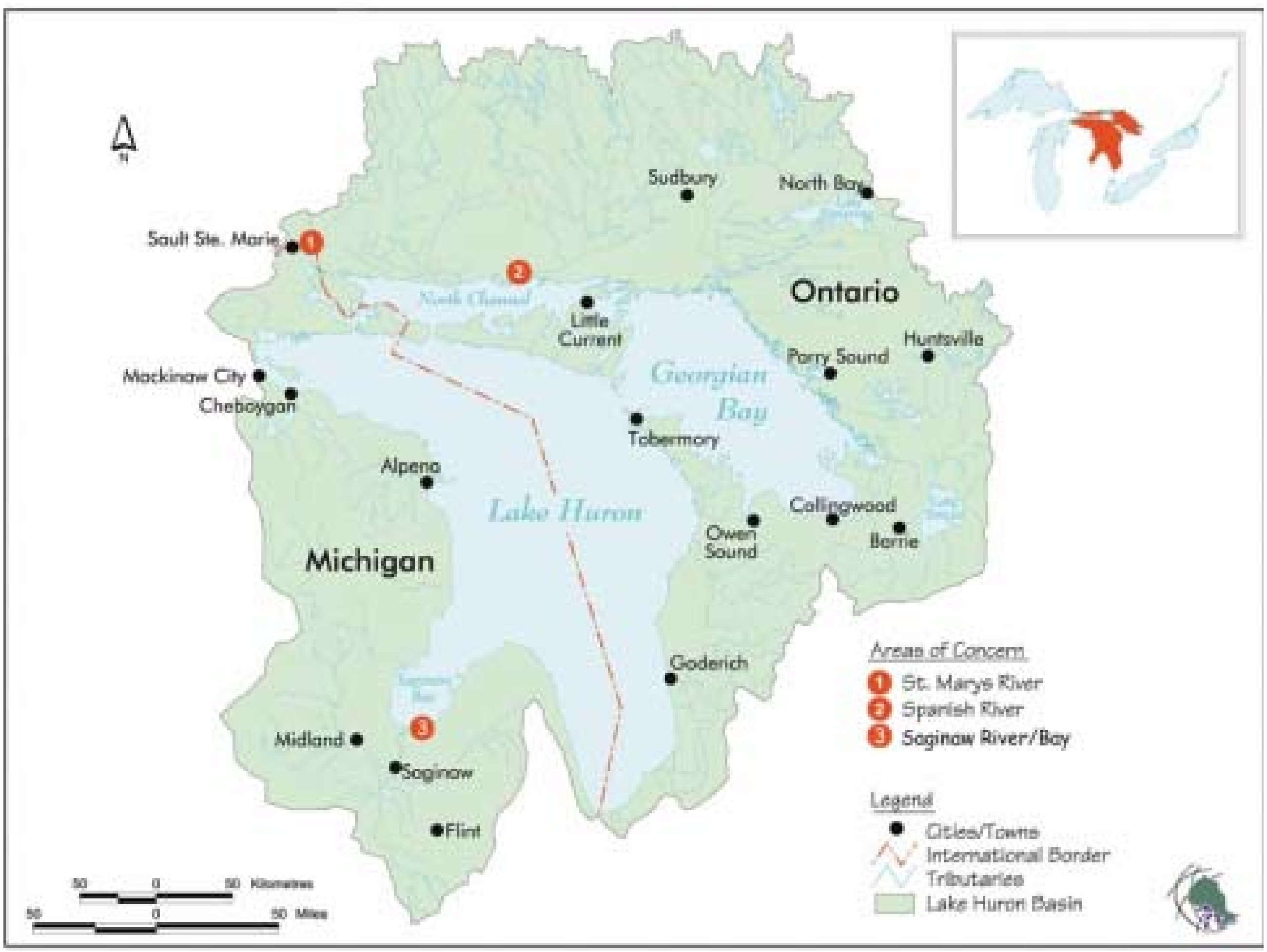


Figure 18. Lake Huron Drainage Basin.
Source: Environment Canada

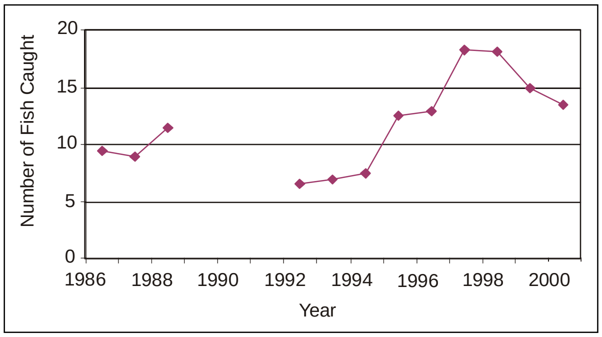


Figure 19. Number of salmon and trout caught per 100 hours of angler effort.
Source: Michigan Department of Natural Resources

still support a high diversity of aquatic and riparian species, yet non-native species continue to pose a threat to native plant and animal populations.

The most densely populated areas of the basin are the most degraded. Within the watershed there are two Areas of Concern (AOCs), Saginaw Bay, Michigan, and Spanish Harbour, Ontario. The causes of impairment within the AOCs are being addressed, and habitat, fish and wildlife populations, and environmental quality are recovering. In fact, Canada has recognized Spanish Harbour as an "Area in Recovery" where all remedial actions have been implemented and improvements are occurring. Severn Sound was delisted as an AOC in 2002 and the Collingwood Harbour AOC was delisted in 1994. St. Clair River is a binational AOC.

The health of fish communities is of particular concern in the Lake Huron basin because of their economic, recreational, and ecological importance. Current stressors on fish communities include continued habitat degradation, loss of food sources due to non-native species, and contamination. In the last few years, however, natural reproduction of native lake trout has once again been documented at several locations. Overall, the health of fish communities in Lake Huron has improved since the 1960s, when fish health was at its poorest.

Although much of the Lake Huron shoreline remains relatively undisturbed, in some areas physical alterations are taking place, thus impacting fish habitats. Resource extraction, water level variation and localized urban activities are leading to permanent habitat loss. Water level fluctuation patterns are also altering the nearshore habitat.

Aquatic habitats in the main basin of Lake Huron are in relatively good health. Many of the tributaries in the system, however, are still severely stressed by both development and point and non-point source pollution. These stressors are resulting in changes to tributary fish community composition. In addition, relatively high trout and salmon catch rates and a declining preyfish population may lead to an unsustainable fishery for some species.

In Lake Huron, connectivity of wetland habitat is as important to ecosystem health as total wetland area because a scattering of wetlands compromises the utility and value of the habitat. Structural barriers between stream reaches are reducing connectivity and blocking important fish habitat. Dams and spillways are fragmenting stream systems, thereby preventing fish from accessing upstream spawning habitats.

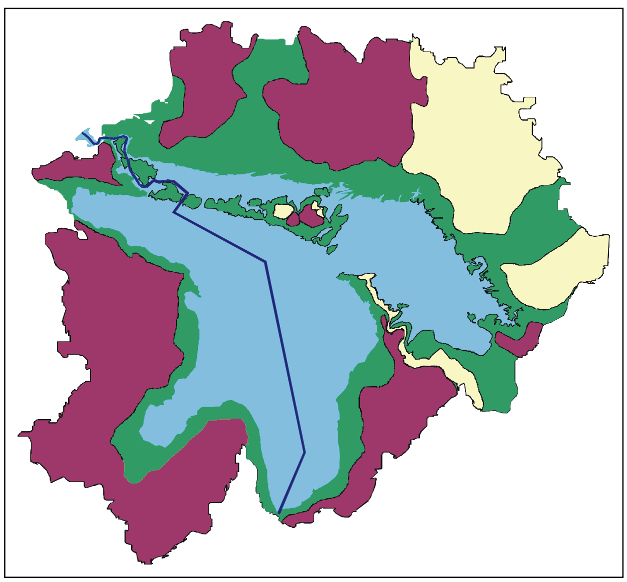


Figure 20. Portions of the Lake Huron watershed inaccessible due to natural barriers (yellow) and human-made barriers (burgundy). Green areas represent open access (no barriers).
Source: David Reid, Ontario Ministry of Natural Resources and Mark MacKay, Michigan Department of Natural Resources

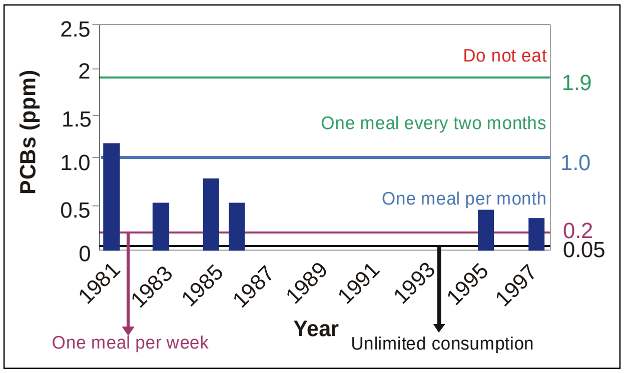


Figure 21. PCBs in Lake Huron coho salmon compared to consumption advisories.
Source: Sandy Hellman, U.S. Environmental Protection Agency-Great Lakes National Program Office

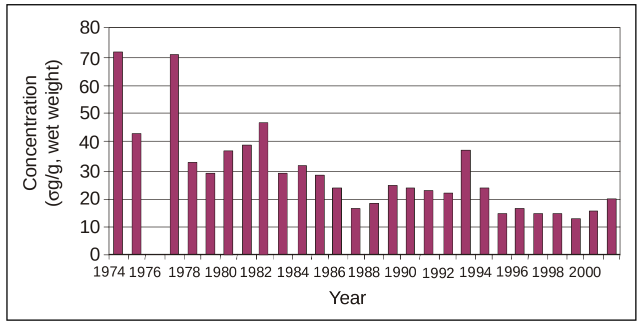


Figure 22. Total PCBs in herring gull eggs, Lake Huron. The 1974-1979 values based on two sites, Chantry and Double Islands; 1980-present values include Saginaw Bay site.
Source: D.V. Weseloh, Environment Canada

Pressures on the System
In the early 1990s, there was wide recognition that considerable ecosystem changes were occurring in Lake Huron as a result of the introduction of non-native species, such as zebra mussels. The loss of important fish foods such as the invertebrate scud, for example, may be related to the invasion of zebra mussels. The mechanisms for the interaction between zebra mussels and scud are uncertain, but may include direct competition for food. As a result, the loss of prey species requires fish communities to respond by seeking other food sources in order to avoid a population decline. Currently, more than 70% of the preyfish population consists of rainbow smelt and alewives, both non-native species.

Zooplankton populations also play an important role in the ecosystem integrity of the basin. Research is underway to track zooplankton populations and develop an indicator to help determine future population trends.

Fish consumption advisories are one of the priority issues in Lake Huron. Contaminants of concern, for which there are localized fish consumption advisories in different areas of Lake Huron, are mercury, dioxins, toxaphene, PCBs, and chlordane. Contaminant sources include historical sediment contamination, air deposition, and non-point source pollution. On a positive note, levels of some contaminants, namely dichlorodiphenyl-trichloroethane (DDT) and PCBs, have declined, improving fish vitality. Studies have documented that the level of contaminants in coho and chinook salmon are on a downward trend. The lake trout monitoring programs of both countries do not show a direct correlation with contaminants in edible fish tissue because analyses are based on the contaminant load in the whole fish. However, recent research indicates decreased concentrations of contaminants in lake trout.

Herring gull eggs are used as an important indicator to determine wildlife contaminant trends. Contaminant levels in herring gull eggs are improving in Lake Huron, but there are "hot spots" in the basin, such as Saginaw Bay, where concentrations are still relatively high.

Total phosphorus is an important indicator of chemical integrity and a driver for eutrophication effects on biota. Phosphorus levels have been meeting Lake Huron Binational Partnership goals for the main basin of Lake Huron. However, concentrations are elevated in areas such as Saginaw Bay, localized areas of Georgian Bay, and the North Channel.

Future and Emerging Management Issues
The future functioning of the Lake Huron fishery is dependent on a better understanding of the impacts and controlling of non-native species. For example, non-native species such as zebra and quagga mussels and the spiny water flea, may divert much of the primary and secondary production to pathways that are unavailable to top predators. Another example is that alewife predation by salmonine predators could indirectly result in early

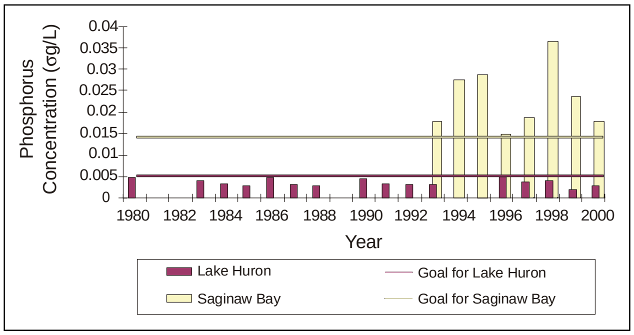


Figure 23. Phosphorus concentrations in Lake Huron and Saginaw Bay.
Source: Environment Canada and U.S. Environmental Protection Agency-Great Lakes National Program Office

mortality syndrome. This is the result of high levels of the enzyme thiaminase in alewife (and to a lesser extent in smelt), which breaks down thiamine in predators and leaves their eggs low in this essential vitamin. Managers are challenged to understand the changes brought about by non-native species and to undertake actions that will control their impacts.

Fish habitat fragmentation is a significant issue in the Lake Huron basin. Physical barriers such as dams restrict or prevent sediment movement and fish migration. The lack of sediment transported downstream can impact the quality of habitat at the river mouths. For lake sturgeon, walleye, chinook salmon and other river spawning fish, stream fragmentation reduces natural reproduction and increases dependence on fish stocking. The

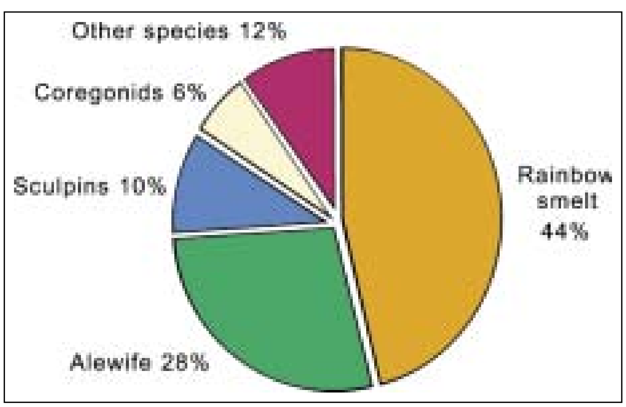


Figure 24. Composition of preyfish in Lake Huron, 1999. More than 70% of preyfish are non-native species (alewife and smelt).
Source: U.S. Geological Survey

tributaries of Lake Huron hold a great, untapped biological potential in terms of restoration of spawning areas for native fish.

Six sites of natural reproduction of lake trout, including two remnant populations, have been documented on Lake Huron. The Parry Sound lake trout population in Georgian Bay, one of the two remnant stocks in the Lake, has been deemed rehabilitated. Despite these limited successes with lake trout rehabilitation, the non-native sea lamprey, in combination with commercial and sportfishing overharvests, continue to impede further reproductive success. Lake Huron managers are currently attempting to address exploitation concerns to provide lake trout with the best chance of rehabilitation lake-wide. Additionally, there is uncertainty about the future of whitefish due to declining scud populations, although the whitefish population is currently maintaining itself at historic high levels.

The Lake Huron environmental management, monitoring, and research community is working closely with the Great Lakes Fishery Commission's Lake Huron Technical Committee to develop environmental objectives relating to fisheries management. This relationship will benefit environmental and fisheries managers by providing increased coordination of ongoing efforts.

Acknowledgments/Sources of Information

James Schardt, U.S. Environmental Protection Agency-Great Lakes National Program Office and Janette Anderson, Environment Canada.

Presentation at SOLEC 2002 in Cleveland, Ohio by Jim Bredin, Michigan Office of the Great Lakes. (October 2002)

Fisheries presentation at SOLEC 2002 in Cleveland, Ohio by David Reid, Ontario Ministry of Natural Resources. (October 2002)

Lake Huron Statistics	
Elevation [a]	
feet	577
meters	176
Length	
miles	206
kilometers	332
Breadth	
miles	183
kilometers	245
Average Depth [a]	
feet	195
meters	59
Maximum Depth [a]	
feet	750
meters	229
Volume [a]	
cu.mi.	850
km^3	3,540
Water Area	
sq.mi.	23,000
km^2	59,600
Land Drainage Area [b]	
sq.mi.	51,700
km^2	134,100
Total Area	
sq.mi.	74,700
km^2	193,700
Shoreline Length [c]	
miles	3,827
kilometers	6,157
Retention Time	
Years	22
Population: USA (1990)†	1,502,687
Population: Canada (1991)	1,191,467
Totals	2,694,154
Outlet	St. Clair River

[a] Measured at low water datum
[b] Land drainage area for Lake Huron includes St. Mary's River
[c] Including islands
† 1990-1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years

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

Figure 25. Lake Huron Statistics
Source: The Great Lakes: An Environmental Atlas and Resource Book

Lake Michigan

Assessment
The state of the Lake Michigan ecosystem remains mixed.

The mixed assessment is due to the continued loss of wetland areas, limited protection of ecologically sensitive areas, and reduction in scud (*Diporeia*) populations. Community partnerships and the efforts to control habitat alteration and non-native species represent the progress that has been made to restore this system.

Summary of the State of Lake Michigan
Lake Michigan is the second largest of the Great Lakes by volume, has the world's largest area of freshwater sand dunes, and contains 40% of the U.S. Great Lakes coastal wetlands. Recreational and industrial activities have had strong impact on both the natural dynamics of the dunes and on dune and wetland habitats.

According to the Lake Michigan Lakewide Management Plan, wetland loss in the Lake Michigan basin states is disproportionately greater than the U.S. average. The status of the Lake bottom is poorly understood. New technologies are mapping the bottom of Lake Michigan and have uncovered ancient lake trout reefs. These reefs are

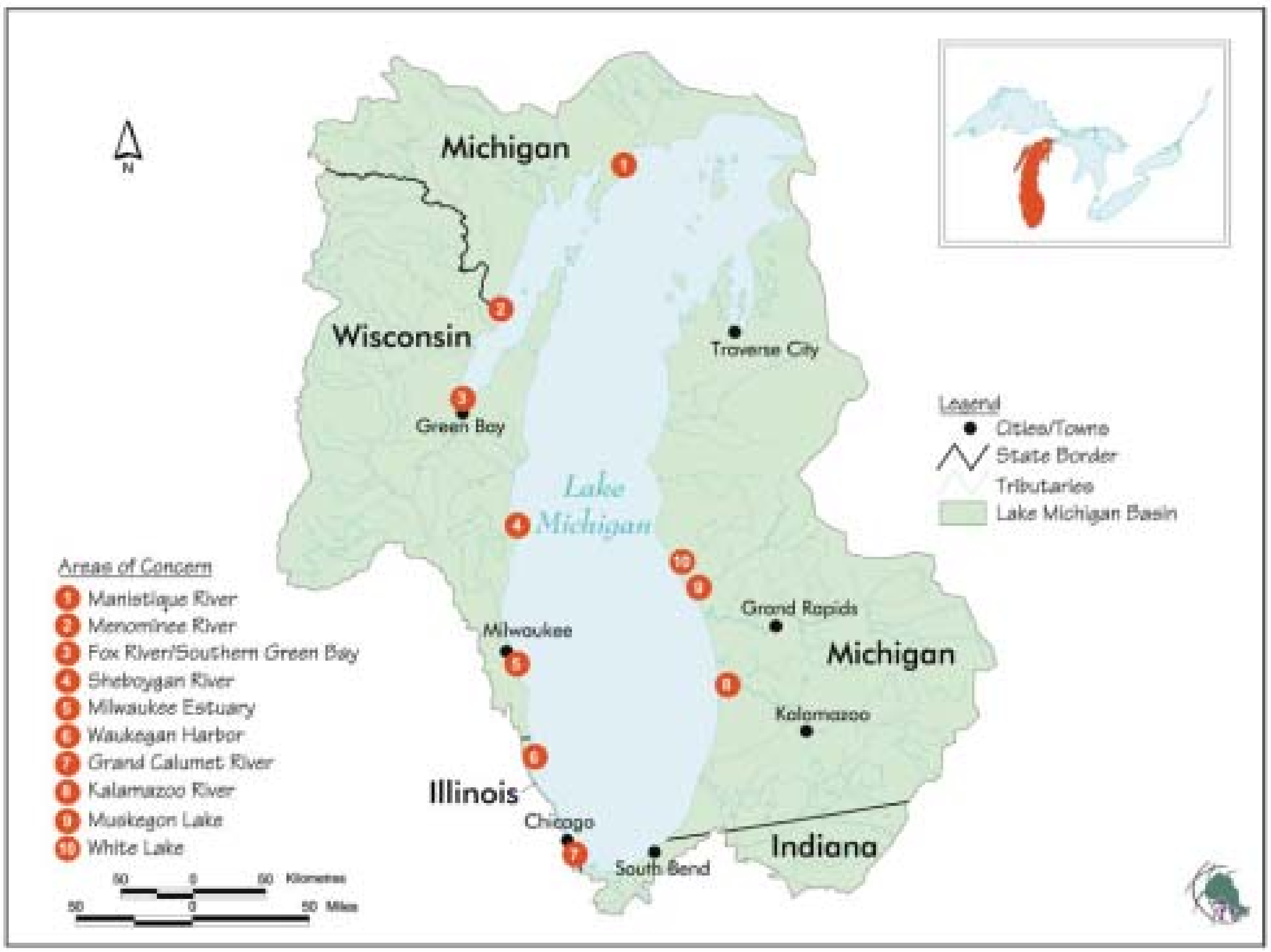


Figure 26. Lake Michigan Drainage Basin
Source: Environment Canada

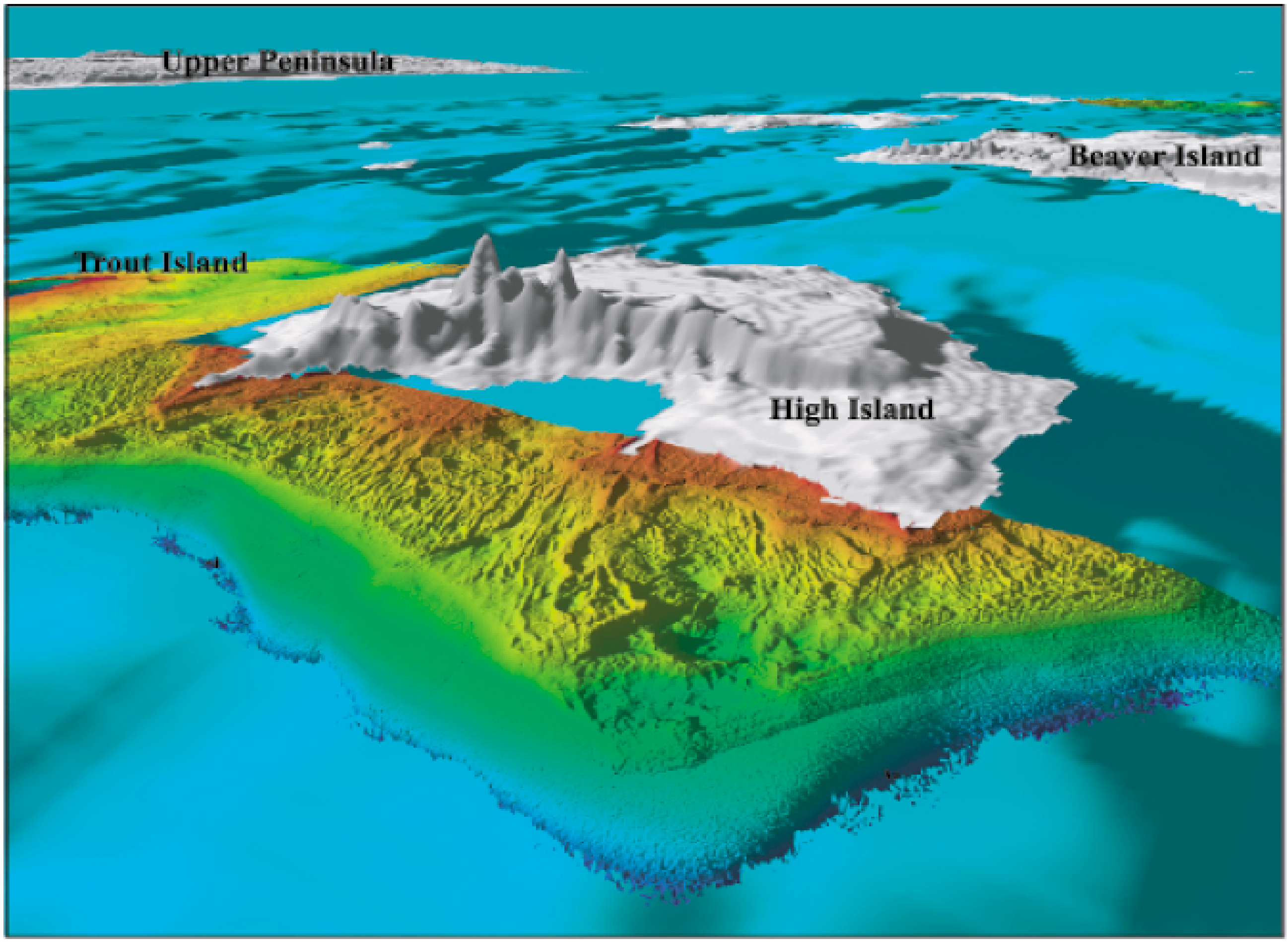


Figure 27. Imagery of the bottom of Lake Michigan.
Source: U.S. Geological Survey and Marine Geology Program, Kristen Lee and Peter Barners

vital to numerous spawning species, as well as the many life stages of many aquatic species.

Invasive non-native species continue to be a concern for Lake Michigan. In 2002, the U.S. Fish and Wildlife Service found the non-native fish species, the ruffe, in Lake Michigan for the first time. Other non-native species, including zebra mussels, are continuing to impact Lake Michigan's aquatic ecosystems. In the spring of 2002, an electric barrier on the Chicago Sanitary and Ship Canal was activated to slow the spread of the non-native goby and to prevent Asian carp from entering Lake Michigan. This system is being further refined to improve its effectiveness.

Persistent toxic contaminants continue to be an important issue in Lake Michigan. Work to produce the Lake Michigan Mass Balance Study is in its final modeling phase. Screening-level models for atrazine, mercury, and PCBs have been completed. Additional, more comprehensive modeling results, will be released in the near future.

Four rare species have shown a marked recovery in the Lake Michigan watershed. Gray wolf, bald eagle, Kirtland's warbler, and Piping plover have all benefited from efforts to protect and restore habitat.

Pressures on the System

The Lake Michigan aquatic food web is showing signs of serious stress. At the base of the food chain is the invertebrate scud *(Diporeia)*. Scud, due to its high fat content, is a staple of the food chain. Recent studies have shown a constant decline in scud

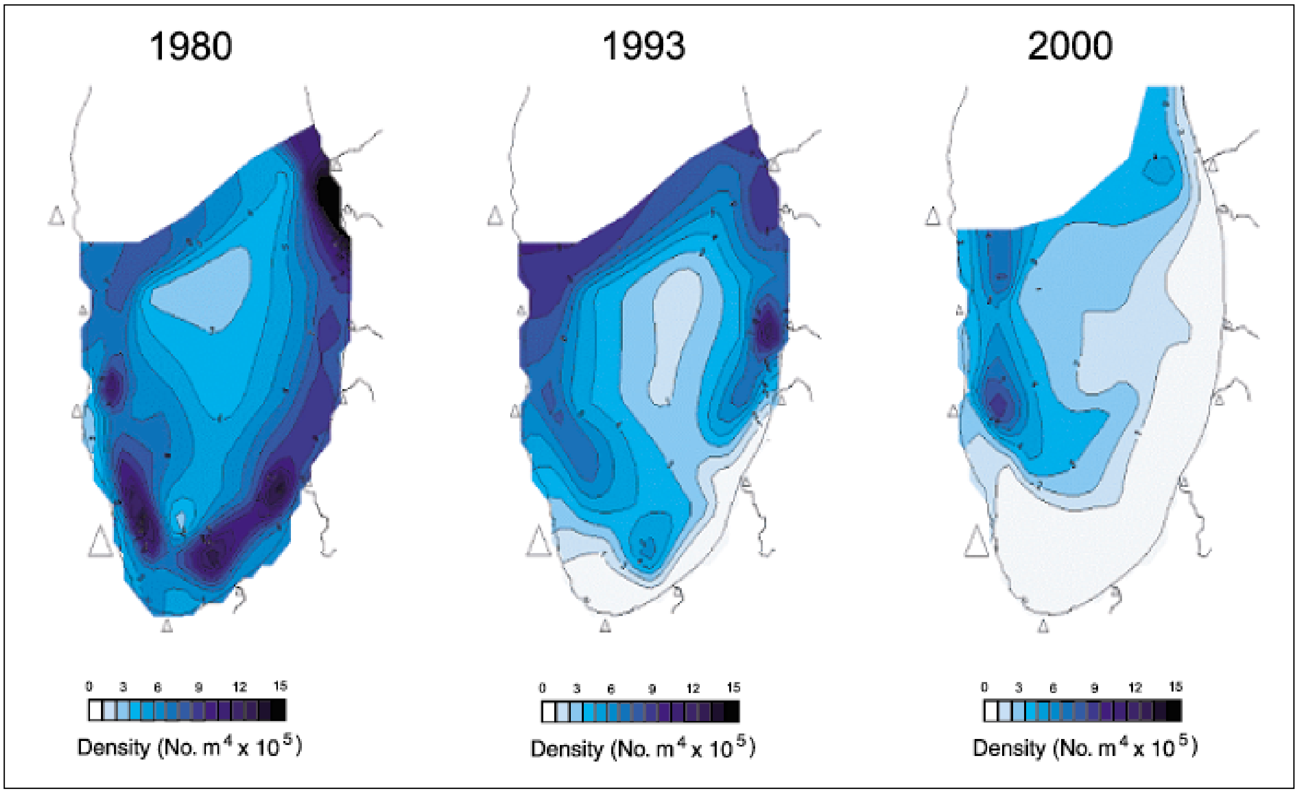


Figure 28. Densities of scud (*Diporeia)* in southern Lake Michigan.
Source: Tom Nalepa, National Oceanic and Atmospheric Administration

density in southern Lake Michigan. The decline is thought to be due to zebra mussel competition with native species for food. The result is reduced food to sustain the natural functioning of the aquatic food chain.

Beaches are closed to swimming when elevated levels of pathogens, primarily *E. coli*, are detected. Sources of contamination are related to poor land use and agricultural practices, poor sewage treatment, and concentrations of wildlife. The National Health Protection Beach survey shows that out of 170 Lake Michigan beaches responding, 97 closed at least once during the 2001 season, and 23 of those closed more than 10 times. The most common cause of Lake Michigan beach closures was contamination related to storm water runoff (148 occurrences), which represents 28% of total closures. Other causes were related to wildlife, combined sewer overflow, and boat discharges. In approximately 15% of the closures, the exact cause of the elevated levels of pathogens was unknown. On several occasions, a combination of causes contributed to a beach closing.

The most recent summary on the fishery of Lake Michigan from the Great Lakes Fishery Commission shows that fish harvests, particularly commercial harvests, have decreased. Findings also indicate that

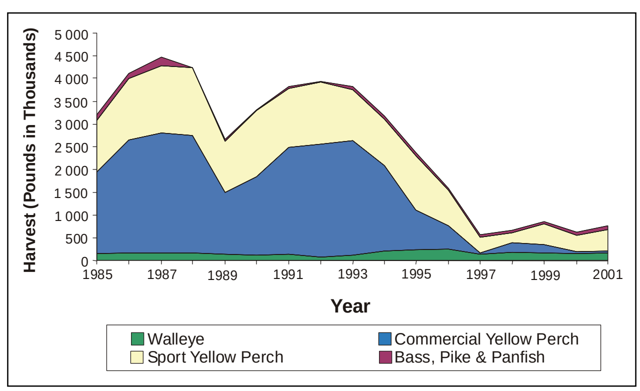


Figure 29. Inshore fishery harvest on Lake Michigan.
Source: Margaret Dochoda, Great Lakes Fishery Commission

the Lake Michigan sport fish harvest now exceeds the commercial fish harvest. Trends indicate that, except for lake whitefish, the commercial harvest is not meeting expectations. This may be caused by a number of interacting factors such as non-native species, warmer winters with less ice cover, and changing wind patterns affecting the availability of food for juvenile fish.

Chicago Wilderness, a consortium of organizations, has produced the "Biodiversity Recovery Plan", which documents the state of the southern Lake Michigan ecosystems and biodiversity, and which recommends necessary actions identified to protect and restore remnant natural areas. Implementation has already begun with the Northeastern Illinois Planning Commission's "Protecting Nature in your Community: A Guidebook for Preserving and Enhancing Biodiversity". The guidebook has lakewide application for local governments.

Future and Emerging Management Issues
Action has been taken at a state level, notably Wisconsin, to protect some categories of wetlands currently left unprotected. The Great Lakes Coastal Wetlands Consortium has developed a common coastal wetland classification system and is working on a long-term monitoring program.

Another issue for the Lake Michigan community is the relationship of the Lake basin with the Upper Mississippi River system. A diversion channel in Chicago links Lake Michigan to the Mississippi River. This channel is an access point to and from the Great Lakes for non-native species. Efforts are underway to improve an electric barrier system at this connection point to prevent incursion into and out of Lake Michigan from the Mississippi River System of non-native species such as the Asian carp.

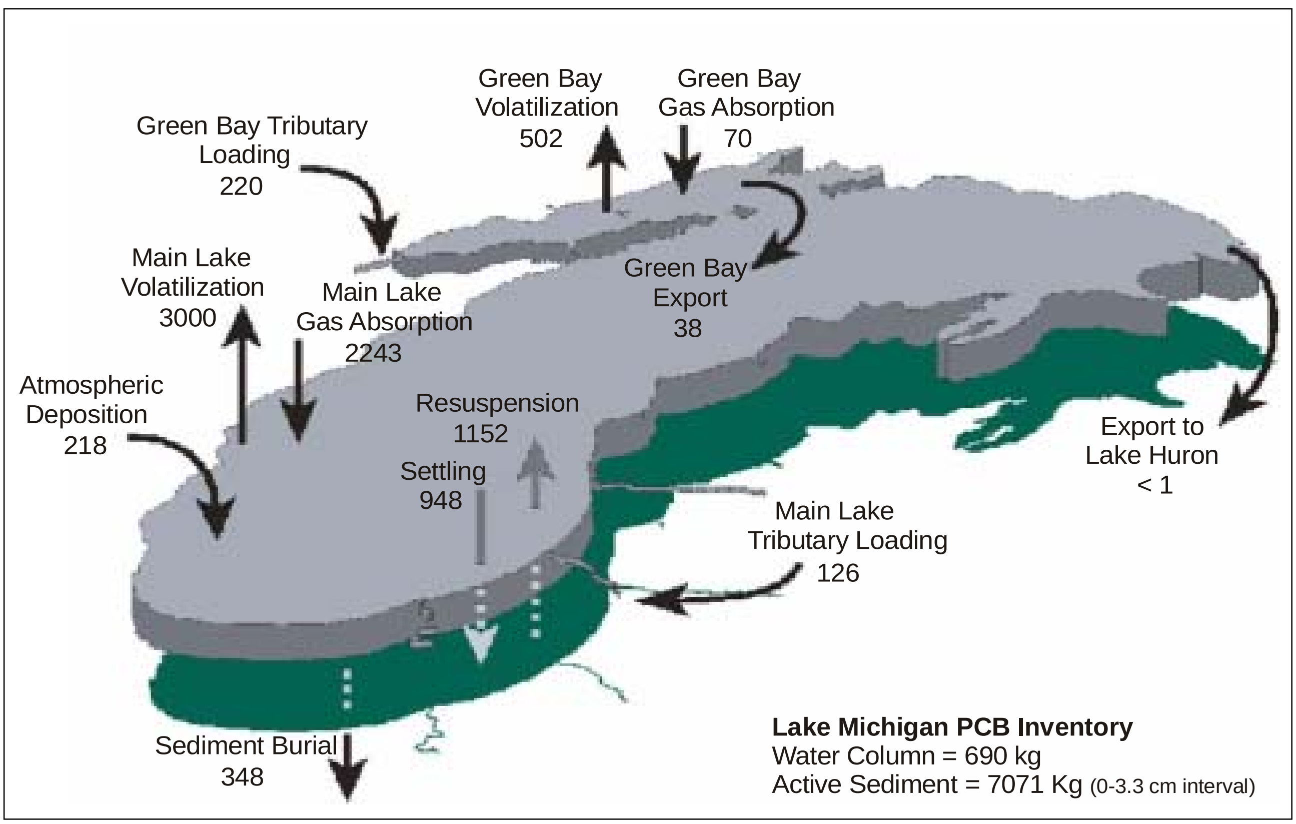


Figure 30. Lake Michigan [PCB] mass balance.
Source: Glenn Warren, U.S. Environmental Protection Agency-Great Lakes National Program Office

Acknowledgments/Sources of Information

Alan Arbogast, Michigan State University; Burr Fisher, U.S. Fish and Wildlife Service; Craig Czarnecki, U.S. Fish and Wildlife Service; David Clapp, Michigan Department of Natural Resources; Judy Beck, U.S. Environmental Protection Agency; Mark Mackay, Michigan Department of Natural Resources; Margaret Dochoda, Great Lakes Fishery Commission; Martha Avilés-Quintero, U.S. Environmental Protection Agency; Mary White, U.S. Environmental Protection Agency; Tom Gorenflo, CORA; Tom Nalepa, National Oceanic Administration Association.

Presentation at SOLEC 2002 in Cleveland, Ohio by Bob Kavetsky, U.S. Fish and Wildlife Service. (October 2002)

Lake Michigan Statistics

Elevation [a]	
feet	577
meters	176
Length	
miles	307
kilometers	494
Breadth	
miles	118
kilometers	190
Average Depth [a]	
feet	279
meters	85
Maximum Depth [a]	
feet	925
meters	282
Volume [a]	
cu.mi.	1,180
km^3	4,920
Water Area	
sq.mi.	22,300
km^2	57,800
Land Drainage Area	
sq.mi.	45,600
km^2	118,000
Total Area	
sq.mi.	67,900
km^2	175,800
Shoreline Length [b]	
miles	1,638
kilometers	2,633
Retention Time	
Years	99
Population: USA (1990) †	10,057,026
Totals	10,057,026
Outlet	Strait of Mackinac

[a] Measured at low water datum
[b] Including islands
† 1990-1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years

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

Figure 31. Lake Michigan Statistics
Source: The Great Lakes: An Environmental Atlas and Resource Book

Lake Superior

Assessment

The state of the Lake Superior ecosystem remains mixed.

Non-native species continue to be a problem; some trends in contaminant loadings are showing declines while others remain constant; and fisheries recovery indicators are mixed. Emerging issues, such as potential water exports and new chemical contaminants, are further stresses on the system.

Summary of the State of Lake Superior

Lake Superior is the largest freshwater lake in the world by area and third largest by volume. The total watershed area is 88,031 mi^2 (228,000 km^2) including Lake Nipigon and two major diversions. Six percent of the water supply to Lake Superior comes from the Ogoki and Long Lac diversions in Canada. These two hydroelectric diversions are significant to the water levels of all the Great Lakes.

The Lake Superior basin is sparsely populated, relative to the other Lakes. Data from Statistics Canada show an overall population density of 1 person per square kilometer (includes land and water) that was unchanged through the 1990s. By comparison, the population density for the U.S. part of the basin is 9 persons/km^2. Despite the low population density, human activities still impact the

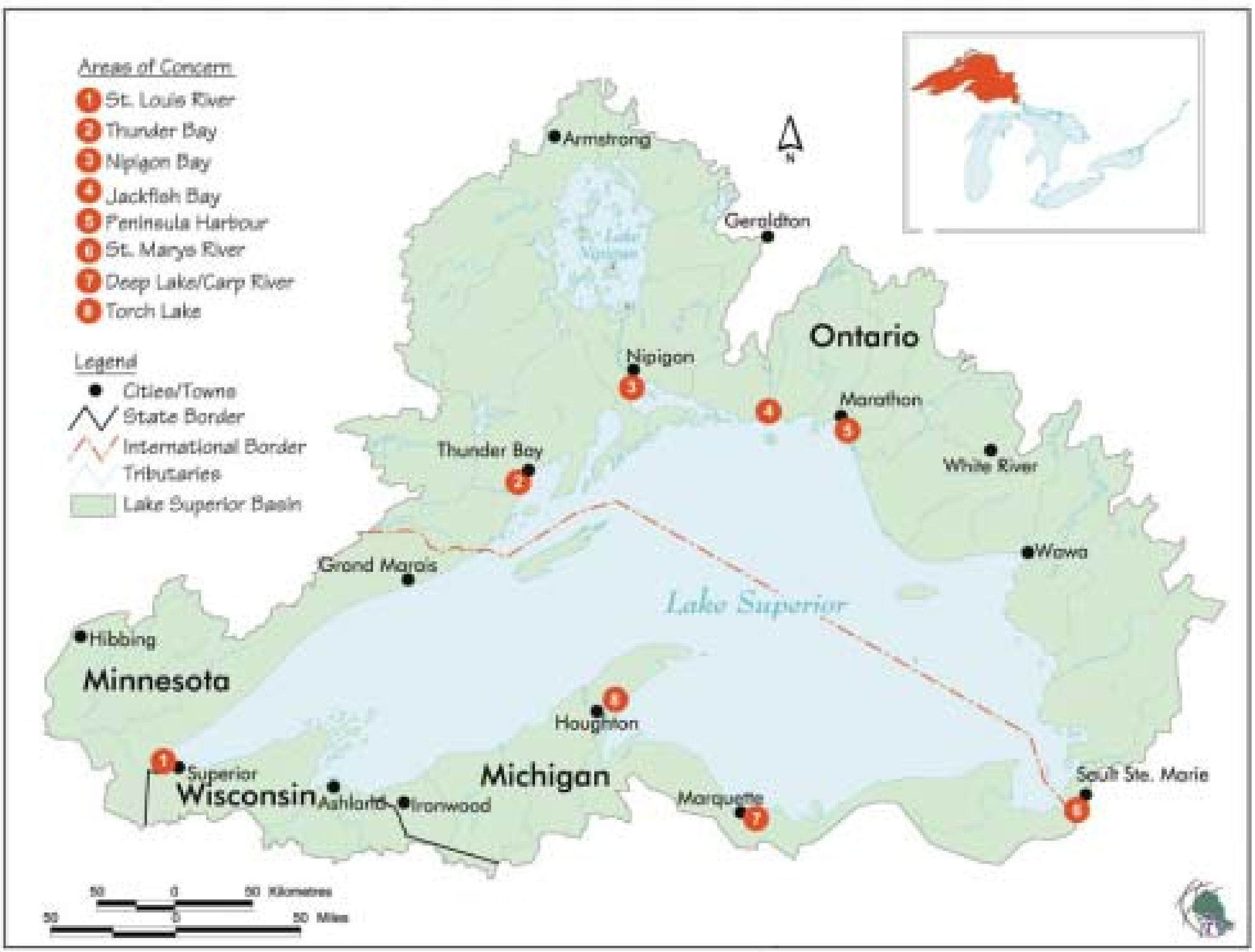


Figure 32. Lake Superior Drainage Basin
Source: Environment Canada

system. There are eight Areas of Concern in the Lake Superior basin, including the binational St. Marys River AOC.

The watershed contains many globally rare vegetation types, including arctic alpine communities, sand dunes and pine barrens. Fourteen species found in the Lake Superior watershed are listed by Canada and 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.

Much of the Lake Superior shoreline is still forested. The U.S. shoreline consists primarily of hardwoods while the Canadian shoreline is a coniferous/ hardwood mixed forest. The original red and white pine forests have been cut in the U.S., but Ontario still retains 3,800 hectares of old growth red and white pines.

Average concentrations of phosphorus in the open waters of Lake Superior are at or below the expected level of 5 micrograms per liter based on the maximum allowable annual loadings of phosphorus listed in the Great Lakes Water Quality Agreement. This concentration has shown no marked increase or decrease in the Lake over time.

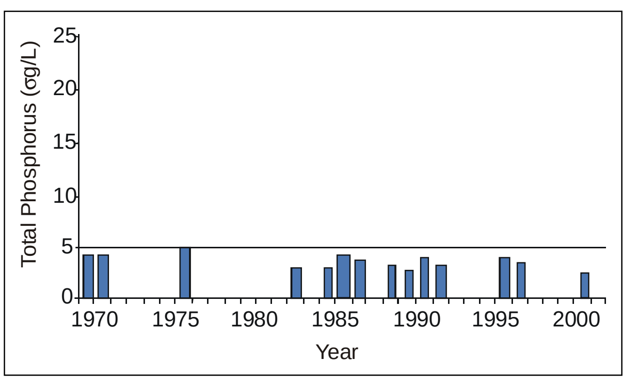


Figure 33. Average phosphorus concentrations in Lake Superior. The horizontal line represents the expected level of phosphorus (5 micrograms per liter) based on phosphorus loads in the Great Lakes Water Quality Agreement.
Source: Environment Canada and U.S. Environmental Protection Agency

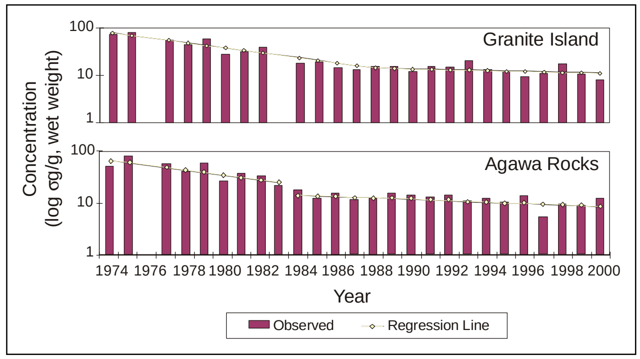


Figure 34. PCBs in herring gull eggs, Lake Superior, 1974-2000.
Source: D.V. Weseloh, Environment Canada

Other contaminants such as PCBs, are showing a decline over a 25-year period, as measured in herring gull eggs. In fact, a year-by-year analysis of the concentrations of seven contaminants (PCBs, hexachlorobenzene (HCB), dichlorodiphenyl-dichloroethylene (DDE), heptachlorepoxide (HE), 2,3,7,8-dioxin, dieldrin and mirex) in herring gulls at 15 annually monitored Great Lakes sites showed a 78% decline. Granite Island (Lake Superior-Black Bay) showed the greatest number of repeatedly declining concentrations. During the 1970s and 1980s, mercury declined but the current trend is not clear.

The Lake Superior commercial fishery has undergone a shift. Lake whitefish is now the dominant species harvested throughout the Lake. Significant decreases have been observed in lake herring, walleye, and yellow perch catches. Overall, the size of the Lake's commercial fishery industry is declining because of poor market conditions and regulatory action on the part of management agencies.

The numbers of wild lake trout are high in specific management zones, but overall the numbers of lean native lake trout are lower than historic values. The growth rate of this species, moreover, continues to decline, a trend that began in the 1970s. Also of note is that sea lampreys kill more lake trout than the sport and commercial fisheries combined.

Overall, the future of Lake Superior fish communities is likely to improve. Currently, brook trout, lake sturgeon and walleye populations are

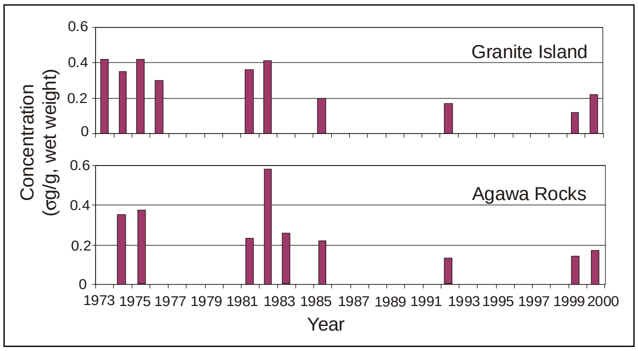


Figure 35. Mercury in herring gull eggs, Lake Superior, 1973-2000.
Source: D.V. Weseloh, Environment Canada

beginning to rebound. There is a measurable increase in lake trout abundance, and the whitefish stocks are also stabilizing. However, habitat degradation will continue to stress the fishery and non-native species will always exert pressure on the native fish communities.

Pressures on the System
Non-native species in Lake Superior continue to influence the functioning of the ecosystem. In 2000, Minnesota Sea Grant reported observations of 28 non-native species in Lake Superior: 17 fish, 5 aquatic invertebrates, and 6 aquatic plants. Most of these were introduced after 1960. Eight species were introduced intentionally. Lake Superior has the highest percentage of non-native (20%) to native species of all the Great Lakes.

Ship ballast is the primary source of unintentionally introduced non-native species in Lake Superior. The St. Louis River estuary seems to be an entry point for many non-natives, because many non-native species are first detected at this site. Some of the non-native species, such as the sea lamprey and zebra mussel, are found throughout the Lake, while others such as the roundnose goby, tubenose goby, ruffe and the threespine stickleback, are currently only found in limited areas in the western sections of the Lake. Non-native plant species of concern include purple loosestrife, Eurasian water milfoil, leafy spurge, garlic mustard, buckthorn, and honeysuckle.

Anthropogenic alteration of terrestrial habitats is another stress on the Lake Superior basin. Pressures

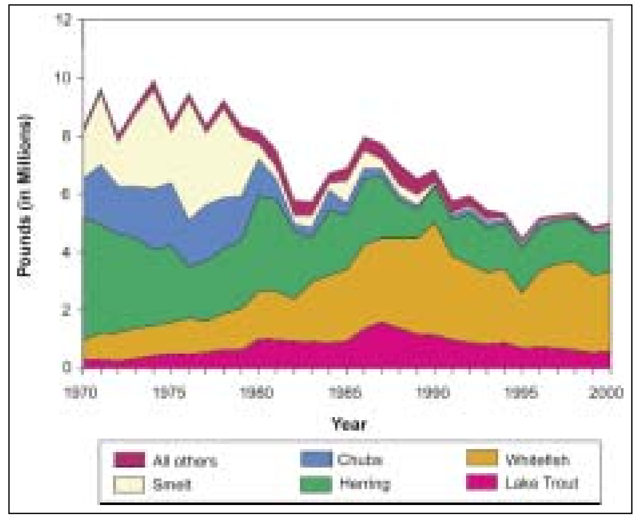


Figure 36. Commercial fishery harvest, 1970-2000.
Source: Mark P. Ebener, Chippewa/Ottawa Resource Authority

from forestry practices and associated road building, as well as from residential and recreational development, are having an impact on the health of Lake Superior's forests. Twenty-five percent of the basin is considered fragmented.

Chemical contaminants are still a concern in Lake Superior. At the species level, impacts can include acute and chronic effects in the food web. For example, effects on fish reproduction have been

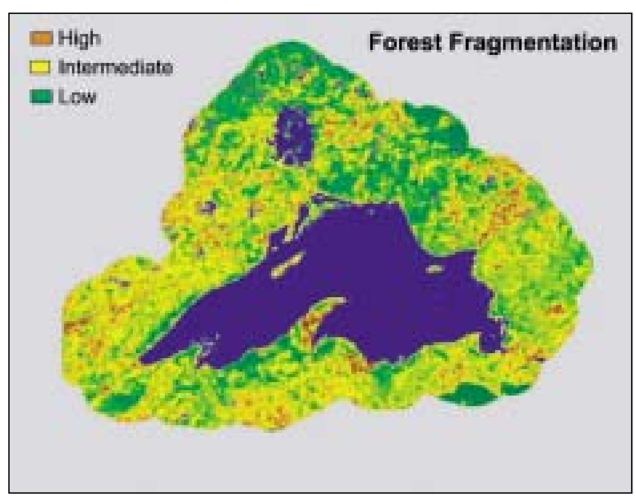


Figure 37. Forest fragmentation in the Lake Superior basin.
Source: University of Minnesota

observed in the effluent receiving waters of some pulp and paper mills, and toxicity testing of both industrial effluent and contaminated sediment has shown effects on aquatic organisms. However, with the implementation of well-treated effluent and pulping liquor spill control measures, these effects have been eliminated or minimized.

Fish consumption advisories illustrate the presence of chemical contaminants in fish and demonstrate the need to reduce contaminant levels in birds, fish, waterfowl, and wildlife. Exposure to contaminants may contribute to increased probabilities of cancer and other physiological effects (e.g., developmental problems such as learning disabilities, skin rashes, chronic disease) in humans.

Future and Emerging Management Issues
In Lake Superior, the associated impacts from the introduction of non-native species on the environment are not well understood. It is anticipated that non-native species will continue to enter the Lake basin in the future.

There are concerns regarding certain chemicals which may be entering the Lake Superior basin. These products, including polybrominated diphenyl ethers (PBDE-flame retardants), pharmaceuticals, and others such as those used in personal care products, are regulated by consumer and health protection agencies. Their potential for adversely affecting the Lake Superior ecosystem needs further study.

The Lake Superior Binational Program is working towards the designation of Lake Superior as a demonstration area, where no point source discharge of any toxic substance would be permitted. A number of source indicators are being used to track progress towards zero discharge. One source indicator is household trash burning. In 1990, thousands of small, inefficient incinerators were a major source of dioxin emissions in the basin. Air emission controls required by governments in the 1990s, in large part, have controlled this dioxin source. However, burn barrels or backyard garbage burning, produces dioxin that enters the environment and can be deposited on agricultural crops, posing human health risks through food consumption. As air pollution control on commercial incinerators improves, emissions from burn barrels are expected to become the dominant source of dioxin in the basin. The Binational Program and the Binational Toxics Strategy have projects underway to determine the best approach to reduce burn barrel emissions.

Broader issues such as global warming have implications for the health of the Lake Superior ecosystem. Changes associated with climate change could affect habitat composition and structure. Climate change could alter habitat by increasing water temperatures, and by lowering water levels that would result in the exposure of previously buried contaminants in sediments to the air and to land-based organisms. The potential for large-scale water export is also a concern in the Lake Superior basin.

Acknowledgments/Sources of Information
Ronald Rossman, Janet R. Keough, U.S. Environmental Protection Agency; Deb Swackhammer, University of Minnesota; Carri Lohse-Hanson, Judy Crane, Patti King, Minnesota Pollution Control Agency; Melanie Neilson, Scott Painter, Chip Weseloh, Darrell Piekarz, Environment Canada; Tom Crow, North Central Forest Experimentation Station; Bill Meades, Natural Resources Canada; Jan Shultz, U.S. Forestry Service; Carl Richards, Minnesota Sea Grant College Program; Kory Groetsch, Great Lakes Indian Fish and Wildlife Commission; Mark P. Dryer & Gary Czypinski, U.S. Fish and Wildlife Service, Ashland Fishery Resources Office; Douglas A. Jensen, Minnesota Sea Grant Program.

Presentation at SOLEC 2002 in Cleveland, Ohio by John Marsden, Environment Canada. (October 2002)

Fisheries presentation at SOLEC 2002 in Cleveland, Ohio by Ken Cullis, Ontario Ministry of Natural Resources. (October 2002)

Lake Superior Statistics	
Elevation [a]	
feet	600
meters	183
Length	
miles	350
kilometers	563
Breadth	
miles	160
kilometers	257
Average Depth [a]	
feet	483
meters	147
Maximum Depth [a]	
feet	1,332
meters	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
kilometers	4,385
Retention Time	
Years	191
Population: USA (1990)†	425,548
Population: Canada (1991)	181,573
Totals	607,121
Outlet	St. Marys River

[a] Measured at low water datum
[b] Including islands
† 1990-1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years

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

Figure 38. Lake Superior Statistics
Source: The Great Lakes: An Environmental Atlas and Resource Book

Section 4
Assessment Based on Indicators

This section of the *State of the Great Lakes 2003* report provides an assessment of the Great Lakes basin ecosystem based on 43 of approximately 80 basinwide indicators. The 43 indicators were selected because basinwide data or data available for a portion of the basin were readily available. Staff from more than 50 governmental and non-governmental entities contributed to the analysis, interpretation and assessment of data for particular indicators.

The indicator reports are grouped into three categories: state, pressure, and societal response indicators. State indicators assess the state or condition of the ecosystem. Pressure indicators assess the pressures that may affect the condition of the ecosystem. Societal response indicators are indicators that assess the societal responses to the state or pressures.

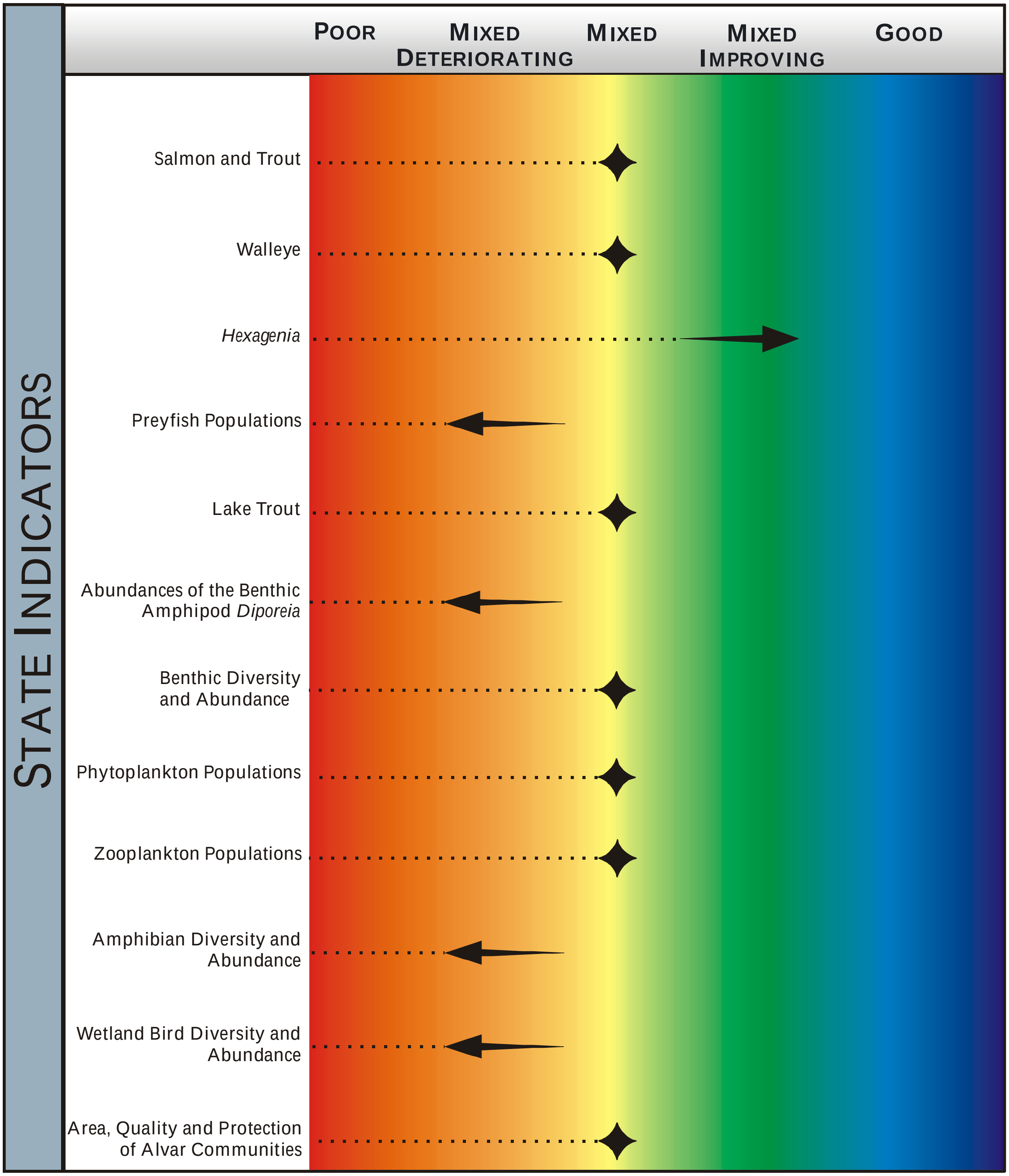
Within each of the three categories, the indicators are further split into two groups. The first group consists of indicator reports whose data are recent, available across the whole of the Great Lakes basin, and whose methodologies or data collection and analyses are consistent year-to-year (at least within the same Lake basin). The second group consists of indicator reports that are not up-to-date, data that are not available across the whole of the Great Lakes basin, or whose methodologies or data collection and analyses are not consistent year-to-year.

The same five ranking categories that were applied to the assessments of Lakes and rivers in the previous section (Good, Mixed Improving, Mixed, Mixed Deteriorating, and Poor), were used to characterize each indicator assessment.

In addition to the assessment, each indicator report includes the purpose of the indicator, the state of the ecosystem, and future pressures. Comprehensive indicator reports prepared for SOLEC 2002 are found in the full technical report, *Implementing Indicators 2003 A Technical Report.* Streaming video of the presentations about the indicators from SOLEC 2002 are available at: http://www.epa.gov/glnpo.solec.2002/plenaries.html. A full description of the entire suite of Great Lakes indicators can be found in the *Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 4*, at http://www.binational.net.

4.1 State Indicator Reports-Part 1

State Indicators-Assessments at a Glance



SUMMARY OF STATE INDICATORS-PART 1

The overall assessment for the State indicators is incomplete. Part One of this Assessment presents the indicators for which we have the most comprehensive and current basin-wide information. Data presented in Part Two of this report represent indicators for which information is not available year to year or are not basin-wide across jurisdictions. Within the Great Lakes indicator suite, 38 have yet to be reported, or require further development. In a few cases, indicator reports have been included that were prepared for SOLEC 2000, but that were not updated for SOLEC 2002. The information about those indicators is believed to be still valid, and therefore appropriate to be considered in the assessment of the Great Lakes. In other cases, the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs are also needed. Several indicators are under development. More research or testing may be needed before these indicators can be assessed.

Indicator Name	Assessment in 2000	Assessment in 2002
Salmon and Trout	No Report	Mixed
Walleye	Good	Mixed
Hexagenia	Mixed, improving	Mixed, improving
Preyfish Populations	Mixed	Mixed, deteriorating
Lake Trout	Mixed	Mixed
Abundance of Benthic Amphipod *Diporeia*	Mixed	Mixed, deteriorating
Benthic Diversity and Abundance	No Report	Mixed
Phytoplankton Populations	Not Assessed	Mixed
Zooplankton Populations	Not Assessed	Mixed
Amphibian Diversity and Abundance	Mixed, deteriorating	Mixed, deteriorating
Wetland-Dependent Bird Diversity and Abundance	Mixed, deteriorating	Mixed, deteriorating
Area, Quality and Protection of Alvar Communities	Mixed	Mixed

Green represents an improvement of the indicator assessment from 2000.
Red represents deterioration of the indicator assessment from 2000.
Black represents no change in the indicator assessment from 2000, or where no previous assessment exists.

Salmon and Trout

Indicator #8

Assessment: Mixed

Purpose

This indicator shows trends in populations of introduced trout and salmon species in the Great Lakes basin. These non-native species have become a prominent element in the Great Lakes ecosystem and are an important component in Great Lakes fisheries management.

State of the Ecosystem

Non-native trout and salmon species are stocked in the Great Lakes ecosystem for two purposes: 1) to exert a biological control over alewife and rainbow smelt populations (both non-native species) and 2) to develop a new recreational fishery after near extirpation of the native lake trout by the invasive, predatory sea lamprey. A dramatic increase in stocking of non-native trout and salmon occurred in the 1960s and 1970s. This is now augmented by natural reproduction. It is estimated from stocking data that about 745 million non-native trout and salmon have been stocked in the Great Lakes basin between 1966 and 1998.

Lake Michigan is the most heavily stocked Lake, while Lake Erie has the lowest rates of stocking. Since the late 1980s, the number of non-native trout and salmon stocked in the Great Lakes has been

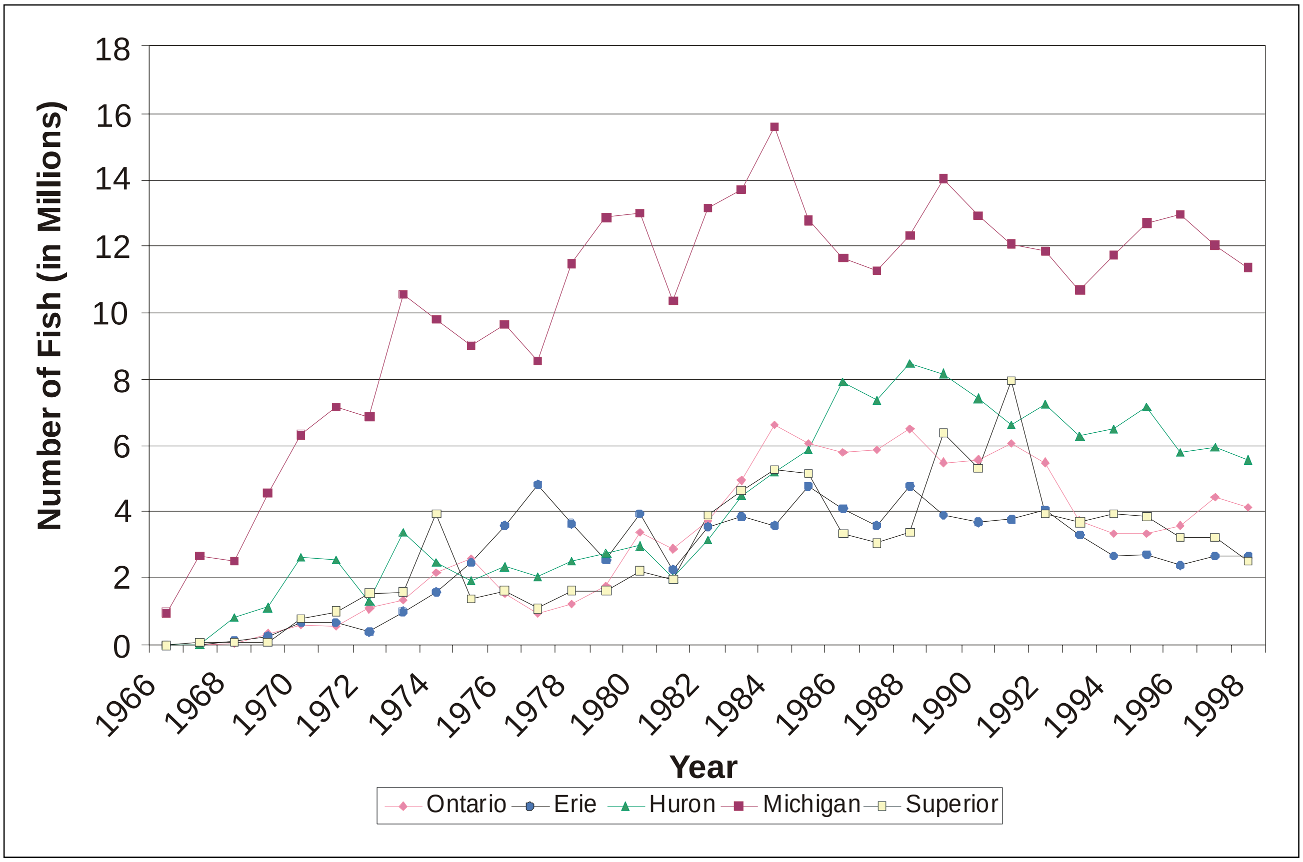


Figure 39. Total number of non-native trout and salmon stocked in the Great Lakes, 1966-1998.
Source: Crawford, S.S., 2001

leveling off or slightly declining. This trend can be explained by stocking limits implemented in 1993 by fish managers.

Future Pressures
Chinook salmon will probably continue to be the most abundantly stocked salmon species in the basin, since they are inexpensive to rear, feed heavily on alewife, and are highly valued by recreational fishers. They are, however, extremely vulnerable to low alewife abundance. While suppressing alewife populations, managers must seek to avoid extreme "boom and bust" predator and prey populations, a condition not conducive to biological integrity.

Acknowledgments
Author: Melissa Greenwood, Environment Canada Intern, Downsview.
Stocking Data: Adapted from Crawford (2001). Primary source from the Great Lakes Fishery Commission fish stocking database (1966-1998) received from Mark Holey, U.S. Fish and Wildlife Service, March 2000.

Walleye
Indicator #9
Note: This indicator has been split from the "Walleye and Hexagenia" indicator

Assessment: Mixed

Purpose
Walleye health is a useful indicator of ecosystem health, particularly in moderately productive (mesotrophic) areas of the Great Lakes. Trends in walleye fishery yields generally reflect changes in walleye health. As a top predator, walleye can strongly influence overall fish community composition and affect the stability and resiliency of Great Lakes aquatic communities.

State of the Ecosystem
Improved mesotrophic habitats (i.e., western Lake Erie, Bay of Quinte, Saginaw Bay, and Green Bay) in

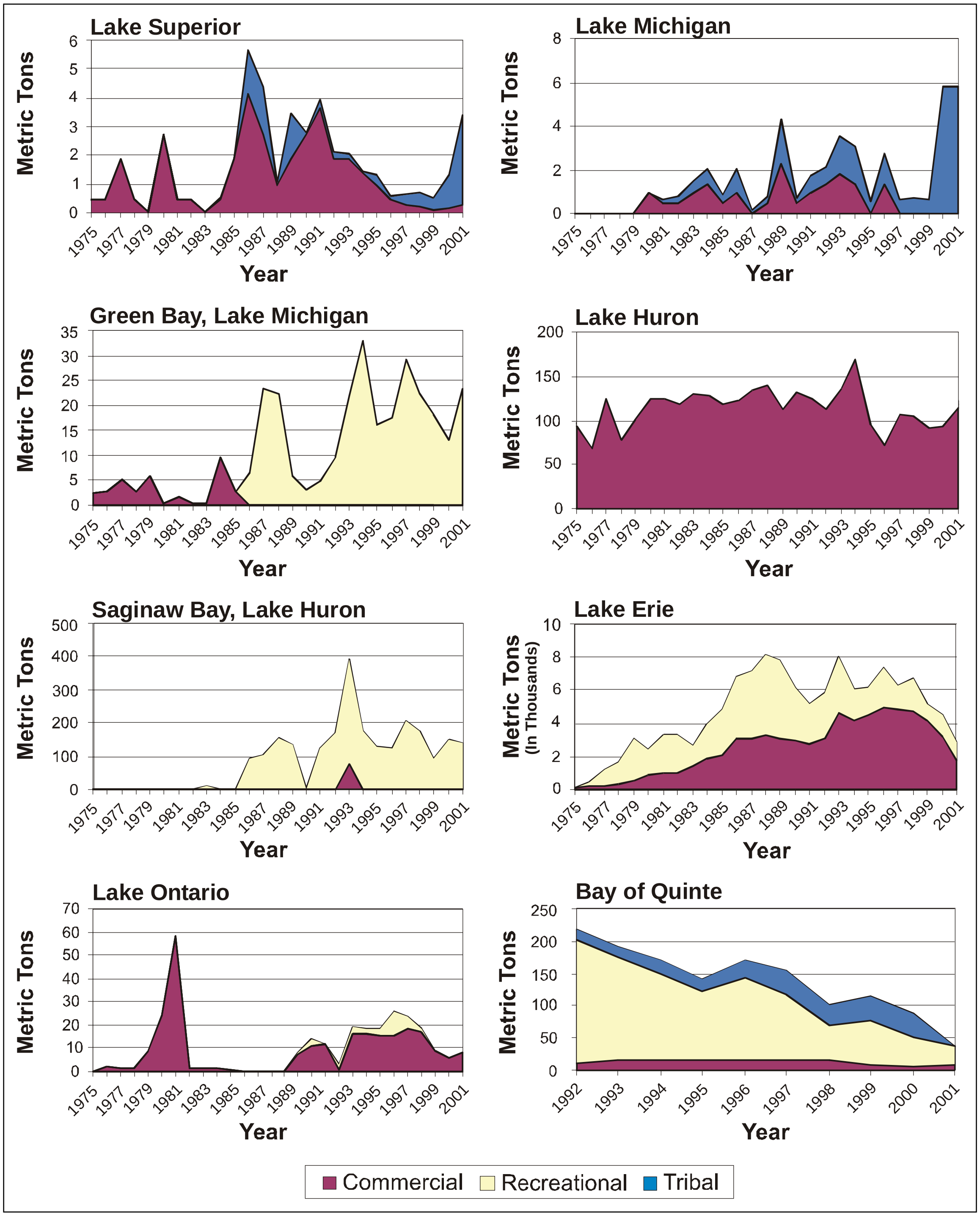


Figure 40. Recreational, commercial and tribal harvest of Walleye from the Great Lakes. Fish Community Goals and Objectives; Lake Huron: 700 metric tons; Lake Michigan: 100-200 metric tons; Lake Erie: sustainable harvest in all basins.

Source: Fishery harvest data were obtained from Tom Stewart and Jim Hoyle (Lake Ontario-OMNR), Tom Eckhart and Steve Lapan (Lakes Ontario-NYDEC), Karen Wright (Upper Lake tribal data-COTFMA), Dave Fielder (Lake Huron-MDNR), Lloyd Mohr (Lake Huron-OMNR), Terry Lychwyck (Green Bay-WDNR), Bruce Morrison (Lake Erie-OMNR), Ken Cullis and Jeff Black (Lake Superior-OMNR), various annual OMNR and ODNR Lake Erie fisheries reports, and the GLFC commercial fishery database

the 1980s, along with interagency fishery management programs that increased adult survival, led to a dramatic recovery of walleye in many areas of the Great Lakes, especially in Lake Erie. Declines after the mid-1990s were likely related to shifts in environmental states (i.e., from mesotrophic to more oligotrophic conditions, which are less favorable to walleye), less frequent production of strong hatches, changing fisheries, and, perhaps in the case of Lake Erie, a population naturally coming into balance with its prey base. The effects of non-native species on the food web or on walleye behavior (increased water clarity can limit daytime feeding) may also have been a contributing factor. Despite recent declines in walleye yields, environmental conditions remain improved relative to the1970s.

Future Pressures

Natural, self-sustaining walleye populations require adequate spawning and nursery habitats. Degradation or loss of these habitats is the primary concern for the future health of walleye populations and can result from both human causes and natural environmental variability. Global warming and its subsequent effects on temperature and precipitation in the Great Lakes basin may influence walleye habitat and, therefore, become an increasingly important determinant of walleye health. Non-native species, such as zebra and quagga mussels, ruffe, and round gobies continue to disrupt the efficiency of energy transfer through the food web, potentially affecting growth and survival of walleye and other fishes.

Acknowledgments

Author: Roger Knight, Ohio Department of Natural Resources, OH. Fishery harvest data were obtained from Tom Stewart and Jim Hoyle, Lake Ontario-OMNR; Tom Eckhart and Steve Lapan, Lake Ontario-NYDEC; Karen Wright, Upper Lakes tribal data-COTFMA; Dave Fielder, Lake Huron-MDNR; Lloyd Mohr, Lake Huron-OMNR; Terry Lychwyck, Green Bay-WDNR; Bruce Morrison Lake Erie-OMNR; Ken Cullis and Jeff Black, Lake Superior-OMNR; various annual OMNR and ODNR Lake Erie fisheries reports, and the GLFC commercial fishery data base. Fishery data should not be used for purposes outside of this document without first contacting the agencies that collected them.

Hexagenia (mayfly)

Indicator #9a

Note: This indicator has been split from the "Walleye and *Hexagenia*" indicator

Assessment: Mixed, improving

Purpose

The distribution, abundance, biomass, and annual production of the burrowing mayfly (*Hexagenia*) in mesotrophic Great Lakes habitats is measured directly and used as an indicator. Mayflies are intolerant of pollution and are thus a good reflection of water and lakebed sediment quality in mesotrophic Great Lakes habitats, where it was historically the dominant, large, benthic invertebrate and an important item in the diets of many fish.

State of the Ecosystem

Surveys conducted in 2001 revealed full or nearly full recovery of the population in western Lake Erie and evidence of the beginnings of recovery of mayflies in Green Bay. Mayflies are again found in the Bay of Quinte, Lake Ontario, and in most of Lake St. Clair and portions of the upper Great Lakes connecting channels. However, mayflies were eliminated in polluted portions of the St. Marys and Detroit Rivers by the mid-1980s, and recovery has not yet been reported for some of these areas, nor have mayflies recovered in Saginaw Bay.

The recovery of *Hexagenia* in western Lake Erie is a signal event, which shows clearly that properly

Figure 41. Areas of recovery and non-recovery of mayflies (*Hexagenia)* in the Great Lakes.
Source: Edsall,T.A., M.T., Gorman, O.T., and Schaeffer, J.S., 2002

implemented pollution controls can bring about the recovery of a major Great Lakes mesotrophic ecosystem.

Future Pressures
Historic pollutants in lakebed sediments appear to be a problem in some areas. Paved surface runoff, spills of pollutants, and combined sewer overflows also pose problems in some urban and industrial areas. Phosphorus loadings still exceed guideline levels in some portions of the Great Lakes, especially Lake Erie, and loadings may increase as the human population in the Great Lakes basin grows.

Acknowledgments
Author: Thomas Edsall, U.S. Geological Survey, Biological Resources Division, Ann Arbor, MI.

Preyfish Populations

Indicator #17

Assessment: Mixed, deteriorating

Purpose
This indicator directly measures the abundance and diversity of preyfish populations, especially in relation to the stability of predator species necessary to maintain the biological integrity of each Lake. In order to restore an ecologically balanced fish community, a diversity of prey species must be maintained at population levels matched to primary production and predator demands.

State of the Ecosystem
Fish communities that we classify as preyfish comprise species that prey on invertebrates such as crustacean zooplankton and larger invertebrates such as scud (*Diporeia*) and *Mysis*, as well as other fish, for their entire life history.

Assessment for Lake Ontario: Mixed, deteriorating: The non-native alewives, and to a lesser degree rainbow smelt, dominate the preyfish population. Alewives declined to a low population level in 2002. Rainbow smelt were at record low levels in 2000-2002, and a lack of large individuals indicated heavy predation pressure. Slimy sculpin populations declined coincident with the collapse of scud and show no signs of returning to former levels of abundance. No deepwater sculpins were caught in 2000-2001.

Assessment for Lake Erie: Mixed, deteriorating: The preyfish communities in all three basins of Lake Erie have shown declining trends. In the Eastern Basin, rainbow smelt abundance has declined over the past two decades. The Western and Central Basins have also shown declines in abundance of young-of-the-year white perch (spiny-rayed preyfish) and rainbow smelt (soft-rayed preyfish), respectively. Gizzard shad and alewife abundances have been quite variable across the survey period.

Assessment for Lake Michigan: Mixed, deteriorating: Bloater biomass has declined steadily since 1990 due to a lack of recruitment and slow growth. In recent years, alewife biomass has remained at consistently lower levels than during the 1970-1980s, driven in large part by predation pressure. Rainbow smelt have declined and remain at low levels, also possibly due to predation. Sculpins, however, continue to contribute a significant portion of the preyfish biomass.

Assessment for Lake Huron: Mixed, deteriorating: The decline in bloater abundance over the past decade or so has resulted in an increased proportion of alewives in the preyfish community. Alewife regained their position as the dominant preyfish species in Lake Huron, largely as a result of a series of strong year classes since 1998. Whitefish also continue to decline from peak levels in the mid-1990s.

Assessment for Lake Superior: Mixed, deteriorating: Over the past 10-15 years, total biomass of preyfish populations has declined. Since the early 1980s, dynamics in the total biomass of preyfish has been driven largely by variation in recruitment of young lake herring. The rise and fall of total preyfish biomass over the period from 1984-2001 reflects the recovery of wild lake trout stocks and resumption of commercial harvest of lake herring in Lake Superior. Other species, notably sculpins, burbot, and stickleback have also declined in abundance since the recovery of wild lake trout populations.

Future Pressures
The influences of predation by salmon and trout on preyfish populations appear to be common across

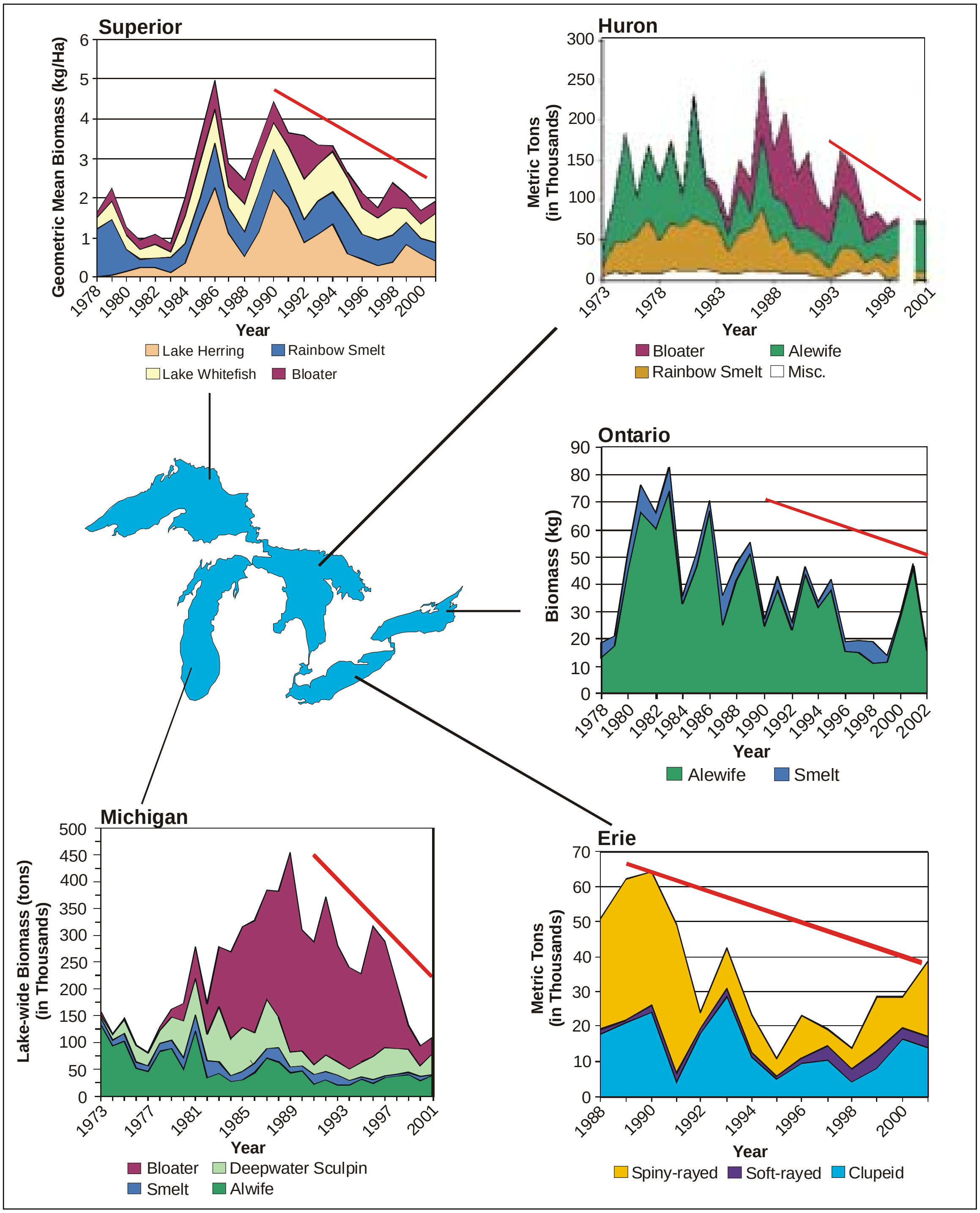


Figure 42. Preyfish population trends in the Great Lakes. The red lines indicate the general trend in overall preyfish populations in each Lake. The measurement reported varies from Lake to Lake, as shown on the vertical scale, and comparisons between Lakes may be misleading. Overall, trends over time provide information on relative abundances.

Source: U.S. Geological Survey Great Lakes Science Center, except Lake Erie, which is from surveys conducted by the Ohio Division of Wildlife and the Ontario Ministry of Natural Resources

all Lakes. Additional pressures from zebra and quagga mussels populations are apparent in Lakes Ontario, Erie, and Michigan. "Bottom-up" effects on the preyfishes have already been observed in Lake Ontario following the zebra and quagga mussel-linked collapse of scud (*Diporeia*), and they are likely to become apparent in Lakes Michigan and Huron as these non-native mussels expand their range and scud populations decline.

Acknowledgments

Authors: Owen T. Gorman, U.S. Geological Survey Great Lakes Science Center, Lake Superior Biological Station, Ashland, WI. Contributors: Robert O'Gorman and Randy W. Owens, U.S. Geological Survey Great Lakes Science Center, Lake Ontario Biological Station, Oswego NY; Jean Adams, Charles Madenjian and Jeff Schaeffer, USGS Great Lakes Science Center, Ann Arbor, MI.; Mike Bur U.S. Geological Survey Great Lakes Science Center, Lake Erie Biological Station, Sandusky, OH; and Jeffrey Tyson, Ohio Division of Wildlife Sandusky Fish Research Unit, Sandusky, OH.

Lake Trout

Indicator #93

Note: This indicator has been split from the "Lake Trout and Scud" indicator

Assessment: Mixed

Purpose

This indicator tracks the status and trends in lake trout populations, and it will be used to infer the basic structure of the cold water predator community and the general health of the ecosystem. Lake trout were historically the principal predator in the coldwater communities of the Great Lakes. Self-sustaining, naturally reproducing populations

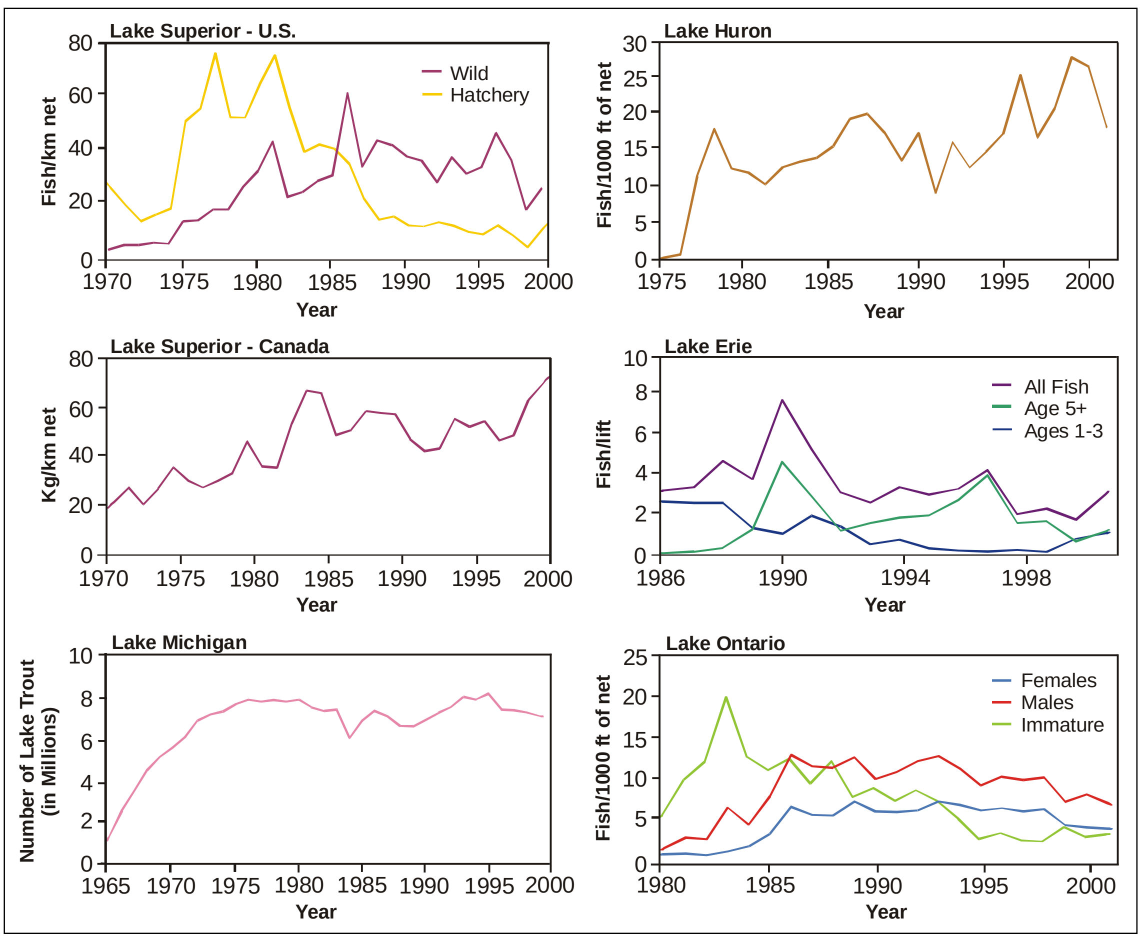


Figure 43. Relative or absolute abundance of lake trout in the Great Lakes. The measurement reported varies from Lake to Lake, as shown on the vertical scale, and comparisons between Lakes may be misleading. Overall trends over time provide information on relative abundances.

Source: U.S. Fish and Wildlife Service

that support target yields to fisheries is the goal of the lake trout restoration program.

State of Ecosystem

Natural reproduction from large parental stocks of wild fish is occurring throughout Lake Superior, and populations occur both onshore and offshore. Stocking in Lake Superior has been largely discontinued. Sustained natural reproduction, albeit at low levels, has also been occurring in Lake Ontario since the early 1990s, and in isolated areas of Lake Huron, but it has been largely absent elsewhere in the Great Lakes. Parental stock sizes of hatchery-reared fish are relatively high in Lake Ontario, southern Lake Huron, and in a few areas of Lake Michigan, but sea lamprey predation, human fishing pressure, and low stocking densities have limited population expansion elsewhere.

Future Pressures

Sea lamprey continue to limit population recovery, particularly in northern Lake Huron. Fishing pressures also continue to limit recovery. High biomass of alewives and predators on lake trout spawning reefs are thought to inhibit restoration through egg and fry predation, although the magnitude of this pressure is unclear. A diet dominated by alewives may be limiting fry survival (early mortality syndrome) through thiamine deficiencies. The loss of scud and dramatic reductions in the abundance of slimy sculpins is reducing prey for young lake trout and may be affecting survival.

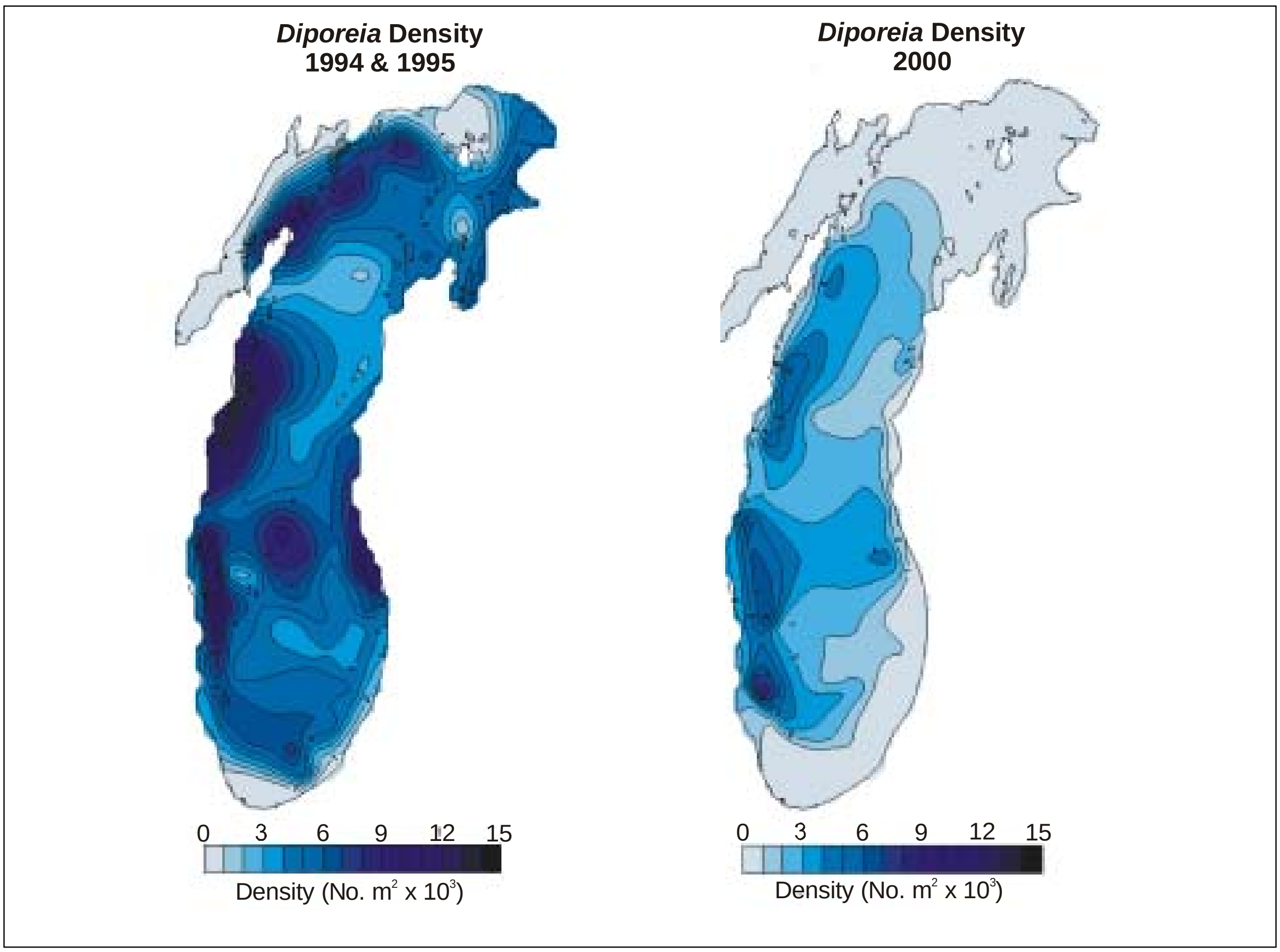


Figure 44. Density (numbers/m^2 x 10^3) of scud (*Diporeia*) in Lake Michigan in 1994-1995 and in 2000. Over the entire Lake, populations declined 68% over this time period.

Source: Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration

Acknowledgments
Authors: Charles R. Bronte, U.S. Fish and Wildlife Service, Green Bay, WI; James Markham, New York Department of Environmental Conservation; Brian Lantry, U.S. Geological Survey, Oswego, NY; Aaron Woldt, U.S. Fish and Wildlife Service, Alpena, MI; and James Bence, Michigan State University, East Lansing, MI.

Abundances of the Benthic Amphipod *Diporeia* (Scud)

Indicator #93a
Note: This indicator has been split from the "Lake Trout and Scud" indicators and has a new title

Assessment: Mixed, deteriorating

Purpose
This indicator assesses the abundance of the bottom dwelling invertebrate *Diporeia* (scud). This glacial-marine relict is the most abundant benthic organism in cold, offshore regions (depths greater than 30 meters) of each of the Lakes. Scud feeds on algal material that has freshly settled to the bottom from the water column (i.e. mostly diatoms), and in turn, they are fed upon by many forage fish species. The forage fish species then serve as prey for larger fish such as trout and salmon.

State of the Ecosystem
Populations of scud are currently in a state of dramatic decline in portions of Lakes Michigan, Ontario, Huron, and eastern Lake Erie. Populations appear to be stable in Lake Superior. In all the Lakes except Superior, abundances have decreased in both nearshore and offshore areas over the past 12 years, and large areas are now completely devoid of this organism. Areas where scud are known to be rare or absent include the southern, southeastern and northern portions of Lake Michigan at depths less than 70 meters, almost all of Lake Ontario at depths less than 70 meters, the entire southern end of Lake Huron, and the Eastern Basin of Lake Erie. In other areas of these Lakes, scud are still present, but abundances are lower than those reported in the 1970s and 1980s. In all the Lakes, population declines coincide with the introduction and rapid spread of zebra and quagga mussels.

Future Pressures
As populations of zebra and quagga mussels continue to expand, declines in scud may become more extensive. In the open waters of Lake Michigan, zebra mussels are most abundant at depths of 30-50 meters, and scud are now absent from areas as deep as 70 meters. Since quagga mussels have recently been reported in Lake Michigan and quagga mussels tend to occur deeper than zebra mussels, the decline or complete loss of scud will likely extend to depths greater than 70 meters.

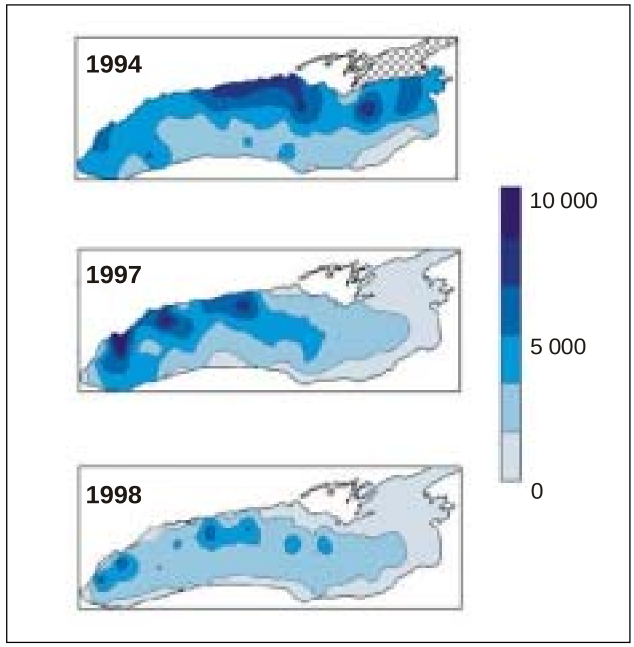


Figure 45. Density (numbers/m^2 x 10^3) of scud (*Diporeia*) in Lake Ontario in 1994, 1997, and 1998. The cross-hatched area in 1994 indicates no samples taken.
Source: S.J. Lozano, Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration

Acknowledgments
Author: T. F. Nalepa, Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration, Ann Arbor, MI.
Contribution of Diporeia abundances in Lake Ontario from S. J. Lozano, Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration, Ann Arbor, MI.

Benthic Diversity and Abundance-Aquatic Oligochaete Communities

Indicator #104

Assessment: Mixed

Purpose

This indicator assesses species diversity and abundance of aquatic oligochaete (a type of worm) communities in order to determine the trophic status and relative health of benthic communities in the Great Lakes. A measure of biological response to organic enrichment of sediments is based on Milbrink's 1983 Modified Environmental Index.

State of the Ecosystem

Use of Milbrink's index values to characterize aquatic oligochaete communities provided one of the earliest measures of habitat quality improvements (e.g., western Lake Erie). This index appears to be a reasonable measure of productivity in waters of all the Great Lakes. Most index values from sites in the Upper Lakes are relatively low and fall into the oligotrophic category, whereas index values from sites in known areas of higher productivity (e.g., nearshore southeastern Lake Michigan; Saginaw Bay, Lake Huron) exhibit higher index values. Sites in Lake Erie, which exhibit the highest index values, generally fall in the mesotrophic to eutrophic range, while in Lake Ontario nearshore sites are classified as mesotrophic, and offshore sites are oligotrophic.

Future Pressures

This benthic index has been routinely applied to the open waters of all the Great Lakes for only a few years. Pollution prevention programs and natural processes will continue to improve water and substrate quality. Improvements in the measured index, however, could be suppressed by impacts of zebra and quagga mussels or by other unknown entities.

Acknowledgments

Authors: Don W. Schloesser, U.S. Geological Survey, Ann Arbor, MI; Richard P. Barbiero, Dyncorp I & ET, Inc., Chicago, IL, and Mary Beth Giancarlo, U.S. Environmental Protection Agency Intern-Great Lakes National Program Office, Chicago, IL.

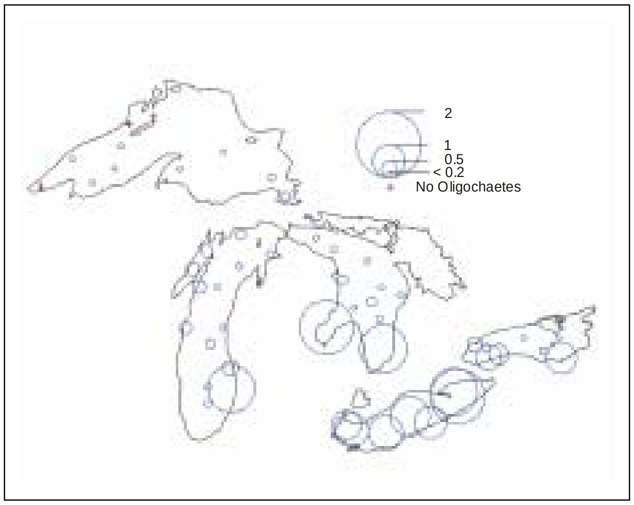


Figure 46. Milbrink's Modified Environmental Index applied to benthic oligochaete communities in the Great Lakes. Data are from 1999, U.S. Environmental Protection Agency-Great Lakes National Program Office Biological Open Water Surveillance Program of the Laurentian Great Lakes 1999, January 2002.

Source: Barbiero, Richard P. and Marc Tuchman, 2002

Phytoplankton Populations

Indicator #109

Assessment: Mixed

Note: This assessment is based on historical conditions and expert opinion. Specific objectives or criteria have not been determined.

Purpose

This indicator involves the direct measurement of phytoplankton species composition and biomass in the Great Lakes, and indirectly assesses the impact of nutrient/contaminant enrichment and invasive non-native predators on the microbial food web of the Great Lakes.

State of the Ecosystem

Records for Lake Erie indicate that substantial reductions in summer phytoplankton populations occurred in the early 1990s in the Western Basin. The timing of this decline suggests the possible impact of zebra mussels. In Lake Michigan, a significant increase in the size of summer phytoplankton (diatom) populations occurred during the 1990s, most likely due to the effects of phosphorus

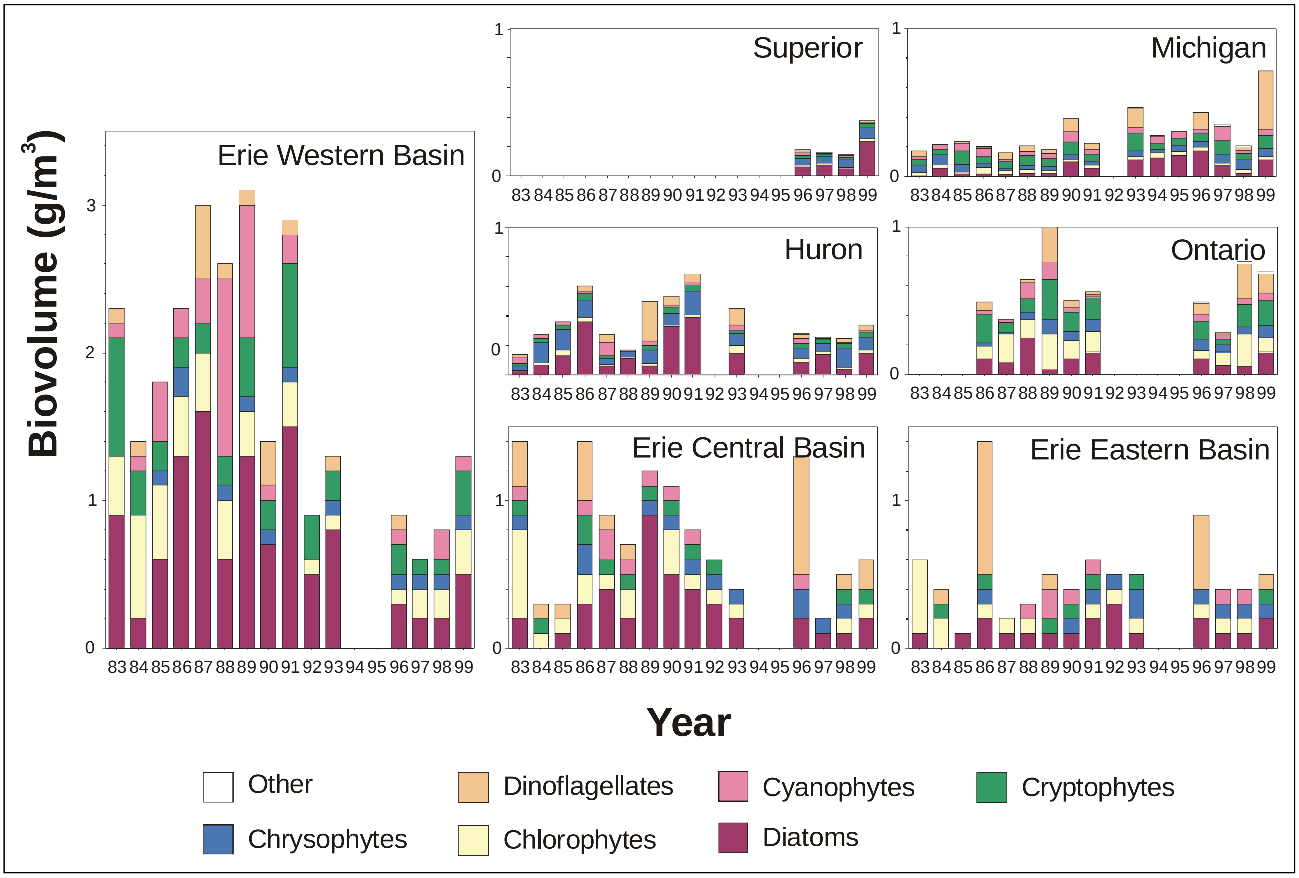


Figure 47. Trends in phytoplankton biovolume (g/m³) and community composition in the Great Lakes 1983-1999. Samples were collected from offshore, surface waters during August.
Source: U.S. Environmental Protection Agency-Great Lakes National Program Office

reductions on the silica mass balance in this Lake. This suggests that diatom populations might be a sensitive indicator of declining nutrient levels (oligotrophication) in Lake Michigan. No trends are apparent in summer phytoplankton populations in Lakes Huron or Ontario, while only three years of data exist for Lake Superior.

Future Pressures

The two most important potential future pressures on the phytoplankton community are changes in nutrient loadings and continued introductions and expansions of non-native species. Increases in phosphorus concentrations might result in increases in phytoplankton biomass and in shifts in phytoplankton community composition away from diatoms and towards other taxa. Continued expansion of zebra mussel populations might be expected to result in reductions in overall phytoplankton biomass, and perhaps also in a shift in species composition.

Acknowledgments

Authors: Richard P. Barbiero, DynCorp, A CSC company, Alexandria, VA, and Marc L. Tuchman, U.S. Environmental Protection Agency-Great Lakes National Program Office, Chicago, IL.

Zooplankton Populations

Indicator #116

Note: This indicator report is from 2000. Assessment has been reevaluated in 2003. Specific objectives or criteria for assessment have not been determined.

Assessment: Mixed

Purpose

This indicator directly measures changes in community composition, mean individual size and biomass of zooplankton populations in the Great Lakes basin, and indirectly measures zooplankton production as well as changes in food web dynamics due to changes in vertebrate or invertebrate predation.

State of the Ecosystem

The ratio of biomass of (calanoid copepods)/(cladocerans + cyclopoid copepods) tends to increase with decreasing nutrient enrichment. Therefore high ratios are desirable. The average value for the oligotrophic Lake Superior was at least four times as high as that for any other Lake, while Lakes Michigan and Huron and the Eastern Basin of Lake Erie were also high. The Western Basin of Lake Erie and Lake Ontario were identically low, while the Central Basin of Lake Erie had an intermediate value.

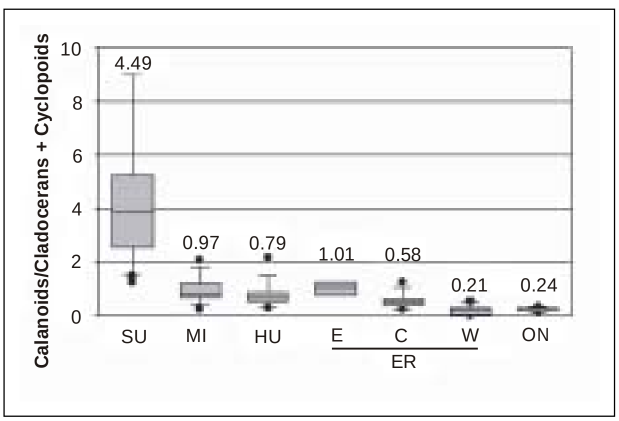


Figure 48. Ratio of biomass of calanoid copepods to that of cladocerans and cyclopoid copepods for the five Great Lakes. Lake Erie (ER) is divided into Western, Central and Eastern basins. (Data collected with 153 µm mesh net tows to a depth of 100 meters of the bottom of the water column, whichever was shallower. Numbers indicate arithmetic averages.

Source: U.S. Environmental Protection Agency-Great Lakes National Program Office, 1998

Future Pressures

The most immediate potential threat to the zooplankton communities of the Great Lakes is posed by non-native species. A non-native predatory cladoceran, spiny waterflea (*Bythotrephes cedarstroemii*), has already been in the Lakes for over ten years, and is suspected to have had a major impact on zooplankton community structure. A second non-native predatory cladoceran, *Cercopagis pengoi*, was first noted in Lake Ontario in 1998, and is expected to spread to the other Lakes.

Acknowledgments

Authors: Richard P. Barbiero, DynCorp, A CSC company, Alexandria, VA, Marc L. Tuchman, U.S. Environmental Protection Agency-Great Lakes National Program Office, Chicago IL, and Ora Johannsson, Fisheries and Oceans Canada.

Amphibian Diversity and Relative Abundance

Indicator #4504

Assessment: Mixed, deteriorating

Purpose

This indicator assesses species composition and relative abundance of calling frogs and toads in Great Lakes marshes. This information helps to infer wetland habitat health. Because frogs and toads are relatively sedentary, have semi-permeable skin, and breed within and adjacent to aquatic systems, they are likely to be more sensitive to, and indicative of, local sources of wetland contamination and degradation than are most other wetland-dependent vertebrates.

State of the Ecosystem

Since 1995, Marsh Monitoring Program (MMP) volunteers have surveyed 474 routes across the Great Lakes basin and collected amphibian occurrence data. Trends in amphibian occurrence were assessed for eight species commonly detected on MMP routes. Statistically significant declines in trends were detected for American Toad, Chorus Frog, and Green Frog.

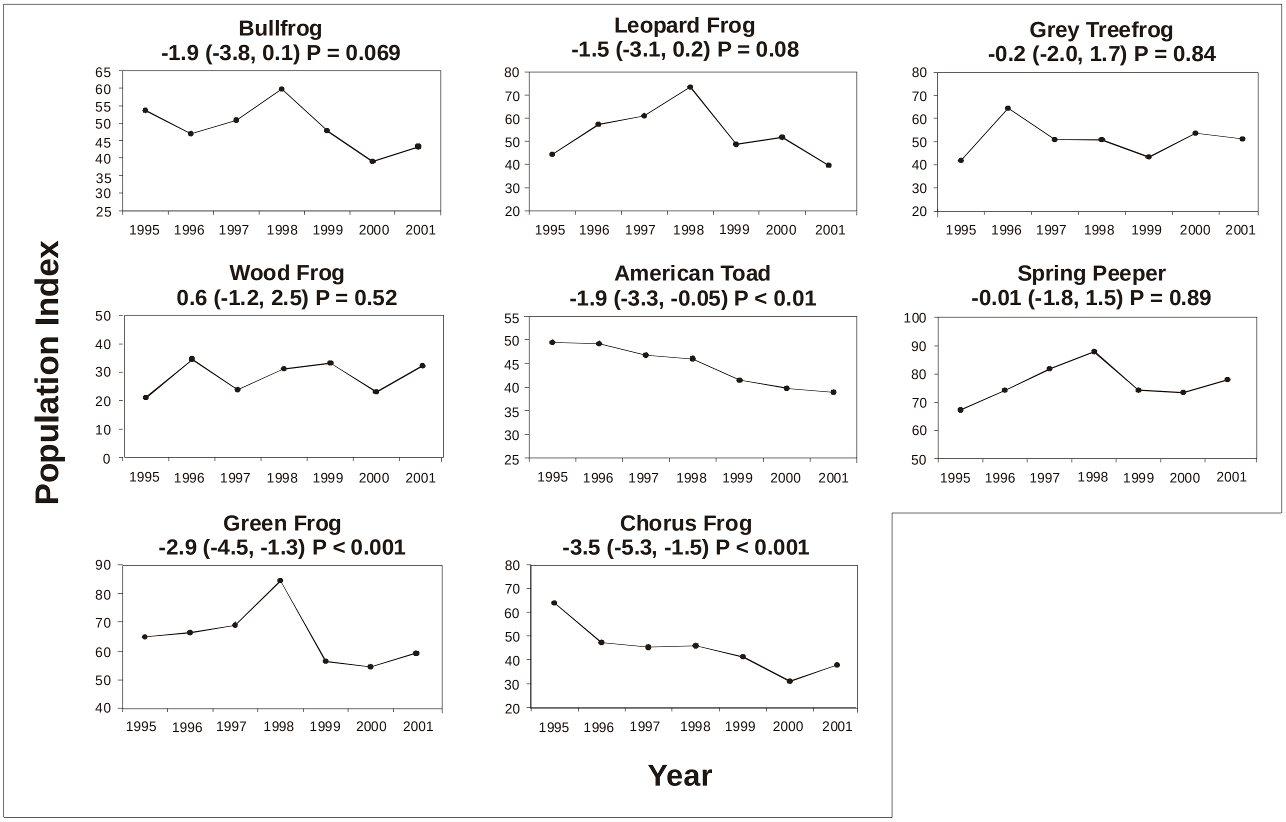


Figure 49. Annual proportion of stations on Marsh Monitoring Program routes at which eight species of amphibians were commonly detected. Data are from 1995-2001.
Source: Marsh Monitoring Program

Comparisons were made between trends in mean annual water levels of the Great Lakes and trends in amphibian annual station occurrence indices. Some species' trends (Bullfrog, Green Frog, Spring Peeper) appeared to correlate with average lake levels to some degree, whereas others' trends (American Toad, Chorus Frog) showed no apparent correlation and instead declined steadily.

Future Pressures
Habitat loss and deterioration remain the predominant threat to Great Lakes amphibian populations. Many coastal and inland Great Lakes wetlands are at the lowest elevations in watersheds that support very intensive industrial, agricultural and residential development.

Acknowledgments
Author: Steve Timmermans, Bird Studies Canada.
The Marsh Monitoring Program is delivered by Bird Studies Canada in partnership with Environment Canada's Canadian Wildlife Service and the U.S. Environmental Protection Agency-Great Lakes National Program Office. The contributions of all Marsh Monitoring Program volunteers are gratefully acknowledged.

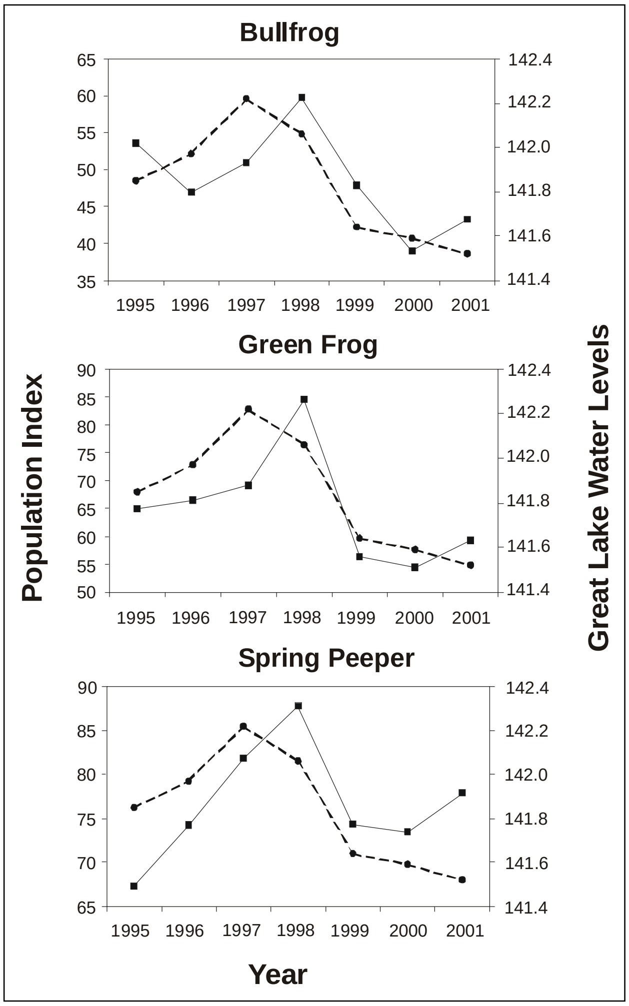


Figure 50. Comparison of mean annual water levels of the Great Lakes (dashed line) and trends in amphibian annual relative occurrence (solid line). These frog populations track average Lake levels to some degree.
Source: Marsh Monitoring Program

Wetland-Dependent Bird Diversity and Relative Abundance

Indicator #4507

Assessment: Mixed, deteriorating

Purpose

Assessments of wetland-dependent bird diversity and abundance in the Great Lakes basin are used to evaluate the health and function of coastal and inland wetlands. Breeding birds are valuable components of Great Lakes wetlands and rely on physical, chemical and biological health of their habitats. Information about abundance, distribution and diversity of marsh birds provides needed measures of their population trends and their habitat associations.

State of the Ecosystem

Populations of several wetland-dependent birds are believed to be at risk due to continuing loss and degradation of their habitats. From 1995 through 2002, 53 species of birds that use marshes (wetlands dominated by non-woody emergent plants) for feeding, nesting or both were recorded by Marsh Monitoring Program (MMP) volunteers at 434 routes throughout the Great Lakes basin. Of those species with significant basin-wide declines, Black Tern, undifferentiated American Coot/Common Moorhen, Marsh Wren, Pied-billed Grebe, Sora, and Virginia Rail are particularly dependent on availability of healthy wetlands. Statistically significant basin-wide increases were observed for Common Yellowthroat, Mallard, and Willow Flycatcher.

The trends for some species (e.g., American Bittern, Marsh Wren, Sora, and Virginia Rail) appeared to correlate with average lake levels quite closely, whereas other species (e.g., Black Tern, Pied-billed Grebe) showed no apparent correlation with lake levels at the basin-wide level. Differences in habitats, regional population densities, timing of survey visits, annual weather variability, and other additional factors likely interplay with water levels to explain variation in species-specific bird populations.

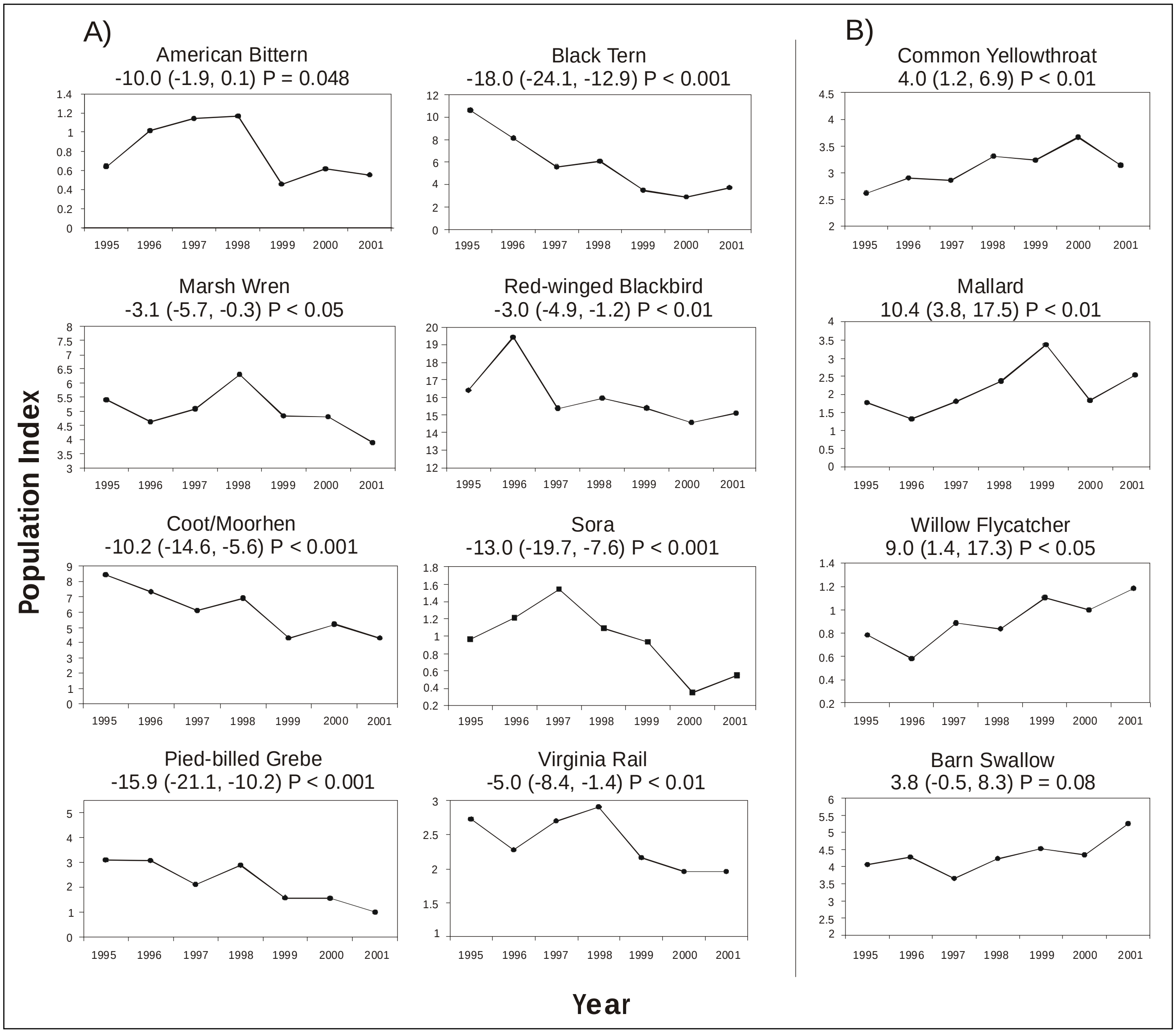


Figure 51. Annual population trends of declining (A) and increasing (B) marsh nesting and aerial foraging bird species detected at Marsh Monitoring Program routes, 1995-2001.
Source: Marsh Monitoring Program

Future Pressures

Future pressures on wetland-dependent birds will likely include continuing loss and degradation of important breeding habitats as a result of wetland loss, water levels stabilization, sedimentation, contamination, excessive nutrient inputs, and invasion of non-native plants and animals.

Acknowledgments

Author: Steve Timmermans, Bird Studies Canada
The Marsh Monitoring Program is delivered by Bird Studies Canada in partnership with Environment Canada's Canadian Wildlife Service and the U.S. Environmental Protection Agency-Great Lakes National Program Office. The contributions of all Marsh Monitoring Program volunteers are gratefully acknowledged.

Area, Quality and Protection of Alvar Communities

Indicator #8129 (alvar)
Note: This indicator report is from 2000.

Assessment: Mixed

Purpose
This indicator assesses the status of one of the 12 special lakeshore communities identified within the nearshore terrestrial area. Alvar communities are naturally open habitats occurring on flat limestone bedrock. Over 2/3 of known alvar occurrences within the Great Lakes basin are close to the shoreline.

State of the Ecosystem
More than 90% of the original extent of alvar habitats has been destroyed or substantially degraded. Emphasis is focused on protecting the remaining 10%. Approximately 64% of the remaining alvar area exists within Ontario, 16% in New York State, 15% in Michigan, and smaller areas in Ohio, Wisconsin and Quebec.

Less than 20% of the nearshore alvar acreage is currently fully protected, while over 60% is at high risk. Michigan has 66% of its nearshore alvar acreage in the Fully Protected category, while Ontario has only 7%. In part, this is a reflection of the much larger total shoreline acreage in Ontario.

Each alvar community occurrence has been assigned an "EO (Element Occurrence) rank" to reflect its relative quality and condition. (EO ranks summarize the quality and condition of each individual alvar community at a site, based on

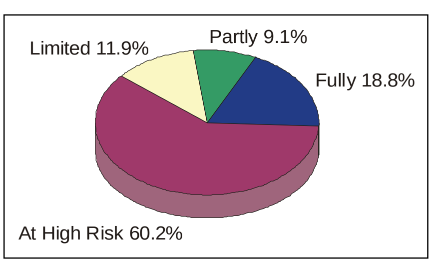


Figure 52. Protection Status 2000. Nearshore alvar acreage.
Source: Ron Reid, Bobolink Enterprises

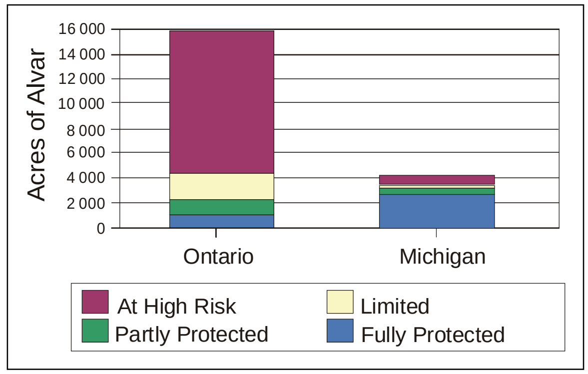


Figure 53. Comparison of acreage protected. Nearshore alvars: Ontario and Michigan.
Source: Ron Reid, Bobolink Enterprises.

standardized criteria for size, site condition, and landscape content.) A and B-ranks are considered viable, while C-ranks are marginal and D- ranks are poor. Protection efforts to secure alvars have clearly focused on the best quality sites. Recently, 10 securement projects have resulted in protection of at least 5,289 acres of alvars across the Great Lakes basin.

Future Pressures
Continuing pressures on alvars include habitat fragmentation and loss; trails; off-road vehicles; resource extraction uses such as quarrying or logging; adjacent land uses such as residential subdivisions; grazing or deer browsing; plant collecting for bonsai or other hobbies; and invasion by non-native plants.

Acknowledgments
Authors: Ron Reid, Bobolink Enterprises, Washago, ON, and Heather Potter, The Nature Conservancy, Chicago, IL.
wetlands, but it is vital in maintaining wetland diversity.

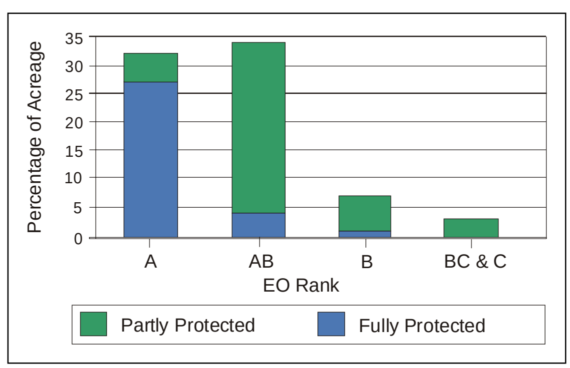


Figure 54. Protection of high quality alvars.
Source: Ron Reid, Bobolink Enterprises

4.2 State Indicator Reports-Part 2

Summary of State Indicators-Part 2

The overall assessment for the State indicators is incomplete. Part One of this Assessment presents the indicators for which we have the most comprehensive and current basin-wide information. Data presented in Part Two of this report represent indicators for which information is not available year to year or are not basin-wide across jurisdictions. Within the Great Lakes indicator suite, 38 have yet to be reported, or require further development. In a few cases, indicator reports have been included that were prepared for SOLEC 2000, but that were not updated for SOLEC 2002. The information about those indicators is believed to be still valid, and therefore appropriate to be considered in the assessment of the Great Lakes. In other cases, the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs are also needed. Several indicators are under development. More research or testing may be needed before these indicators can be assessed.

Indicator Name	Assessment in 2000	Assessment in 2002
Native Freshwater Mussels	Mixed, deteriorating	Not Assessed
Urban Density	Unable to Assess	Mixed, deteriorating (for Lake Superior basin)
Economic Prosperity	Mixed	Mixed (for Lake Superior basin)
Area, Quality and Protection of Great Lakes Islands	No Report	Not Assessed

Green represents an improvement of the indicator assessment from 2000.
Red represents deterioration of the indicator assessment from 2000.
Black represents no change in the indicator assessment from 2000, or where no previous assessment exists.

Native Freshwater Mussels

Indicator #68
Note: Title has been changed from Native Unionid Mussels

Assessment: Not Assessed
Data are not system-wide

Purpose
The purpose of this indicator is to report on the location and status of freshwater mussel (unionid) populations and their habitats throughout the Great Lakes system, with emphasis on endangered and threatened species. The long-term goal for the management of native mussels is for populations to be stable and self-sustaining wherever possible throughout their historical range in the Great Lakes, including the connecting channels and tributaries.

State of the Ecosystem
The introduction of the zebra mussel to the Great Lakes in the late 1980s has destroyed unionid communities throughout the system. Unionids were virtually extirpated from the offshore waters of western Lake Erie by 1990 and Lake St. Clair by 1994, with similar declines in the connecting channels and many nearshore habitats. There were on average, 18 unionid species found in these areas before the zebra mussel invasion. After the invasion, 60% of surveyed sites had 3 or fewer native species left alive, 40% of sites had no native species left, and the abundance of native mussels had declined by 90-95%.

Significant communities were, however, recently discovered in several nearshore areas where zebra mussel infestation rates are low. All of the refuge sites discovered to date have two things in common: they are very shallow (less than 1-2 meters deep), and they have a high degree of connectivity to the

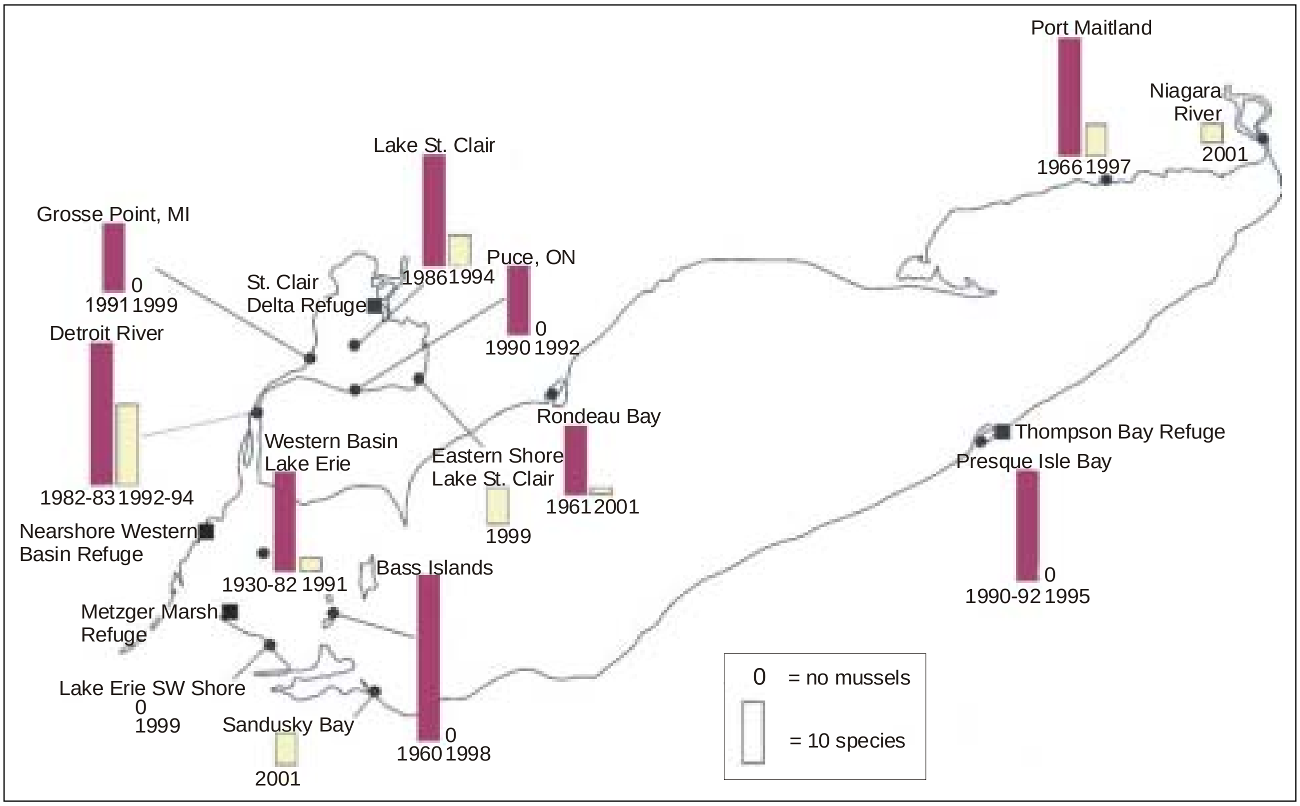


Figure 55. Numbers of freshwater mussel species found before and after the zebra mussel invasion at 13 sites in Lake Erie, Lake St. Clair, and the Niagara and Detroit Rivers (no "before" data available for 4 sites), and the locations of the four known refuge sites (Thompson Bay, Metzger Marsh, Nearshore Western Basin, and St. Clair Delta).
Source: Metcalfe-Smith, J.L., D.T. Zanatta, E.C. Masteller, H.L. Dunn, S.J. Nichols, P.J. Marangelo, and D.W. Schloesser, 2002.

Lake that ensures access to host fishes. These features appear to combine with other factors to discourage the settlement and survival of zebra mussels.

Future Pressures

Zebra mussel expansion is the main threat facing unionids in the Great Lakes drainage basin. Other non-native species may also impact unionid survival through the reduction or redistribution of native fishes. Non-native fish species such as the Eurasian ruffe and round goby can completely displace native fish, thus causing the functional extirpation of local unionid populations.

Acknowledgments

Authors: Janice L. Smith, Aquatic Ecosystem Impacts Research Branch, National Water Research Institute, Burlington, ON, and S. Jerrine Nichols, U.S. Geological Survey, Biological Resources Division, Ann Arbor, MI.

Urban Density

Indicator #7000

Assessment: Mixed, deteriorating (for Lake Superior basin)

Data are not system-wide

Purpose

This indicator assesses the human population density in the Great Lakes basin, and it infers the degree of inefficient land use and urban sprawl.

State of the Ecosystem

The average population density for the 16 U.S. counties entirely or predominantly in the Lake Superior basin was 20.1 persons/mi^2 (7.76 persons/km^2) in 1990 and 20.4 persons/mi^2 (7.88 persons/km^2) in 2000, compared to 70.3 persons/mi^2 (27.1

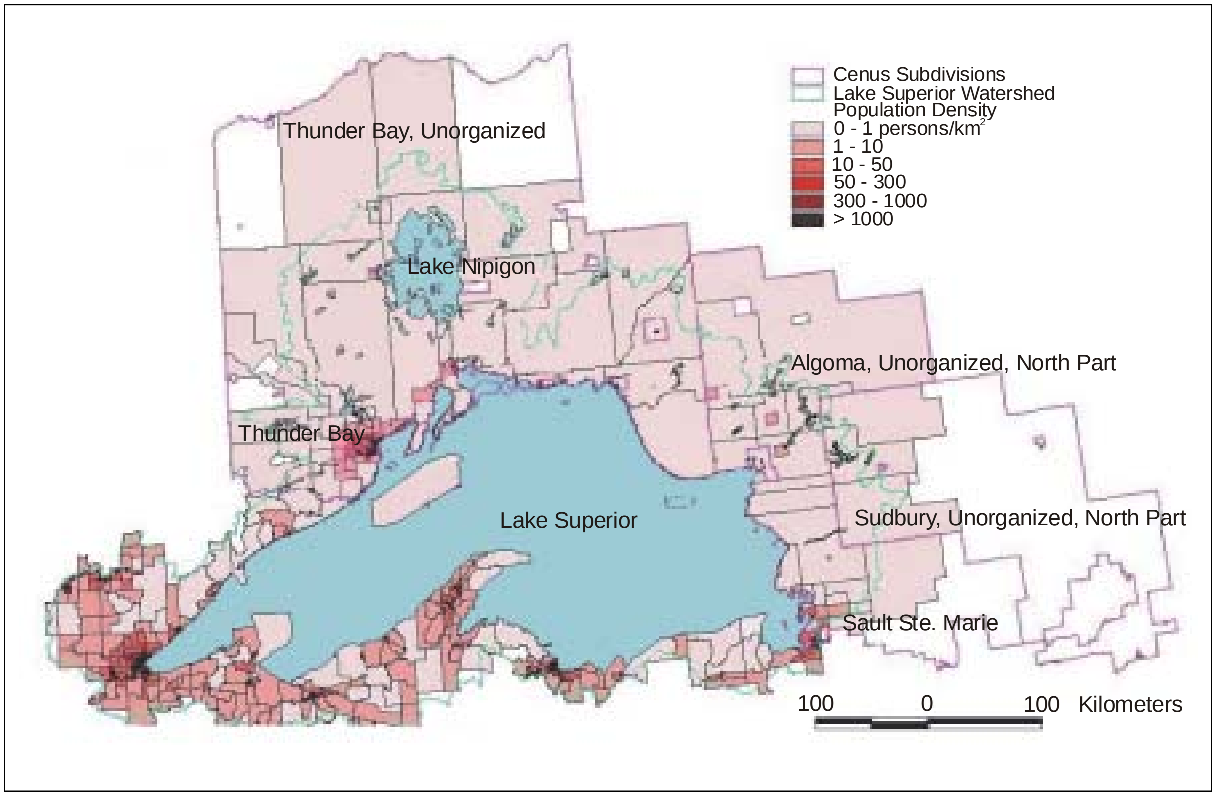


Figure 56. Population density in the U.S. and Canadian Lake Superior basin, 1990-1991.
Source: U.S. Census TIGER 1990 census block group and Statistics Canada 1991 census enumeration area demographics; U.S. Geological Survey and Natural Resources Canada watershed boundaries

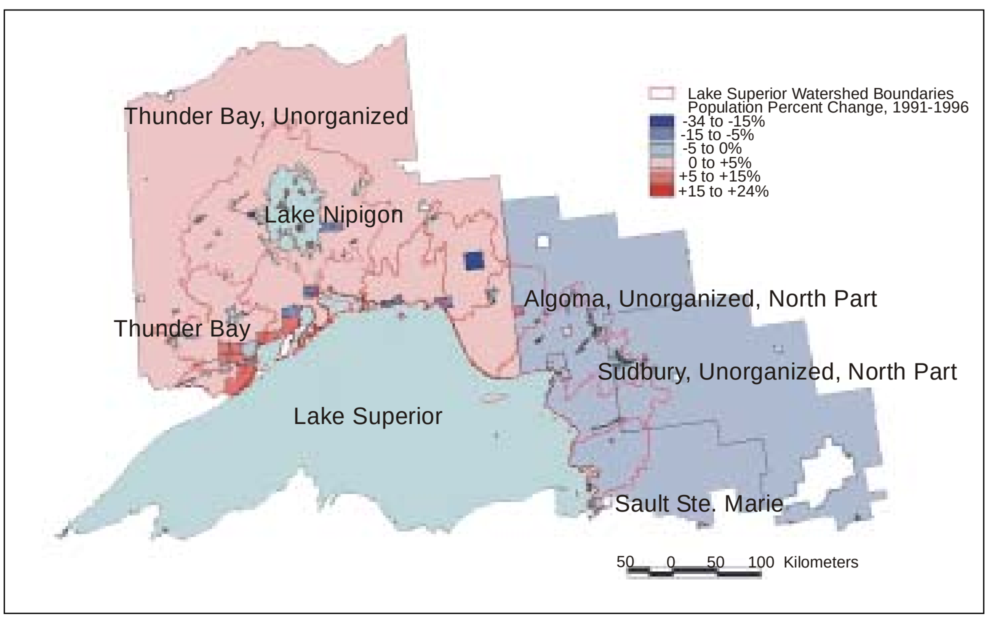


Figure 57. Percent change in population in the Ontario portion of the Lake Superior basin from 1991-1996.
Source: Statistics Canada 1996 Census subdivision profiles for Ontario and Natural Resources Canada watershed boundaries

persons/km²) in 1990 and 79.6 persons/mi² (30.7 persons/km²) in 2000 for the U.S. as a whole. For the 31 participating Ontario census subdivisions that are entirely or predominantly within the Lake Superior basin, average overall population density in 1991 and 1996 was 2.19 persons/km² and 2.17 persons/km², respectively. The greatest population growth, in some cases 10 to 15%, generally occurred in townships adjacent to the City of Thunder Bay, which itself was essentially unchanged (-0.2%).

Future Pressures
Urban sprawl is increasingly becoming a problem in rural parts of the Great Lakes basin near urban centers, placing a strain on infrastructure and consuming habitat in areas that tend to have healthier environments overall than those that remain in urban areas. This trend is expected to continue. This will exacerbate other problems, such as increased consumption of fossil fuels, longer commute times from residential to work areas, and fragmentation of habitat.

Acknowledgments
Authors: Kristine Bradof, GEM Center for Science and Environmental Outreach, Michigan Technological University, MI, and James G. Cantrill, Communication and Performance Studies, Northern Michigan University, MI.

Economic Prosperity

Indicator #7043

Assessment: Mixed (for Lake Superior basin)
Data are not system-wide

Purpose
This indicator assesses the unemployment rates within the Great Lakes basin, and, when used in association with other societal indicators, infers the capacity for society in the Great Lakes region to make decisions that will benefit the Great Lakes ecosystem.

State of the Ecosystem
From 1975 through 2000, the civilian unemployment rate in the 16 U.S. Lake Superior basin counties averaged about 2.0 points above the U.S. average, and above the averages for their respective states, except occasionally for Michigan. Unemployment rates in individual counties ranged considerably, for

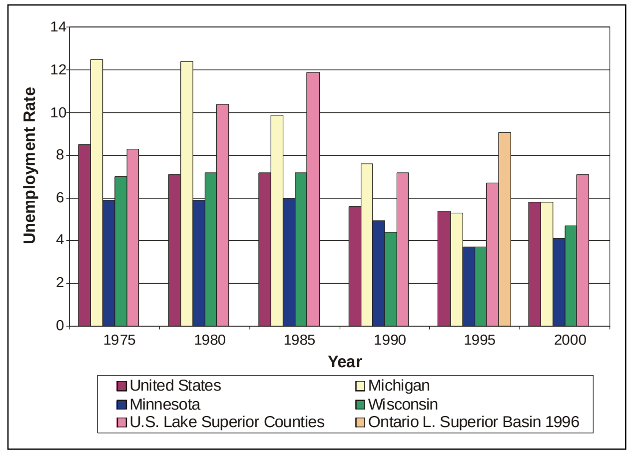


Figure 58. Unemployment rate in Michigan, Wisconsin, and the U.S. and Ontario Lake Superior basin, 1975-2000.
Source: U.S. Census Bureau and Statistics Canada

example from 8.6% to 26.8% in 1985. In the 29 Ontario census subdivisions mostly within the Lake Superior watershed, the 1996 unemployment rate for the population 25 years and older was 9.1%. Of areas with population greater than 200 in the labor force, the range was from 2.3% to 31%. Clearly, the goal of full employment (less than 5% unemployment) was not met in either the Canadian or the U.S. portions of the Lake Superior basin during the years examined. Poverty rates for individuals and children in the U.S. Lake Superior basin in 1979, 1989, and 1999 ranged from 10.4% to 17.1%, while 12.8% of families in the Ontario Lake Superior basin had incomes below the poverty level in 1996.

Acknowledgments
Authors: Kristine Bradof, GEM Center for Science and Environmental Outreach, Michigan Technological University, MI, and James G. Cantrill, Communication and Performance Studies Northern Michigan University, MI.

Area, Quality, and Protection of Great Lakes Islands

Indicator #8129 (islands)

Assessment: Not Assessed

Indicator is under development. Data are not available

Purpose

This indicator assesses the status of one of the 12 special lakeshore communities identified within the nearshore terrestrial area. The Great Lakes contain the world's largest freshwater island system, which are globally significant in terms of their biological diversity.

State of the Ecosystem

By their very nature, islands are vulnerable and sensitive to change. As water levels rise and fall, islands are exposed to the forces of erosion and accretion. Islands are exposed to weather events due to their 360-degree exposure to the elements across the open water. Marine islands may have been isolated for perhaps thousands of years from the mainland. Islands in the past rarely gained new species, and their resident species often evolved into endemics that may be different than mainland varieties. This means that islands are especially vulnerable to, among other things, the introduction of non-native species.

Some islands are among the last remaining wildlands on Earth. Islands could be considered as a

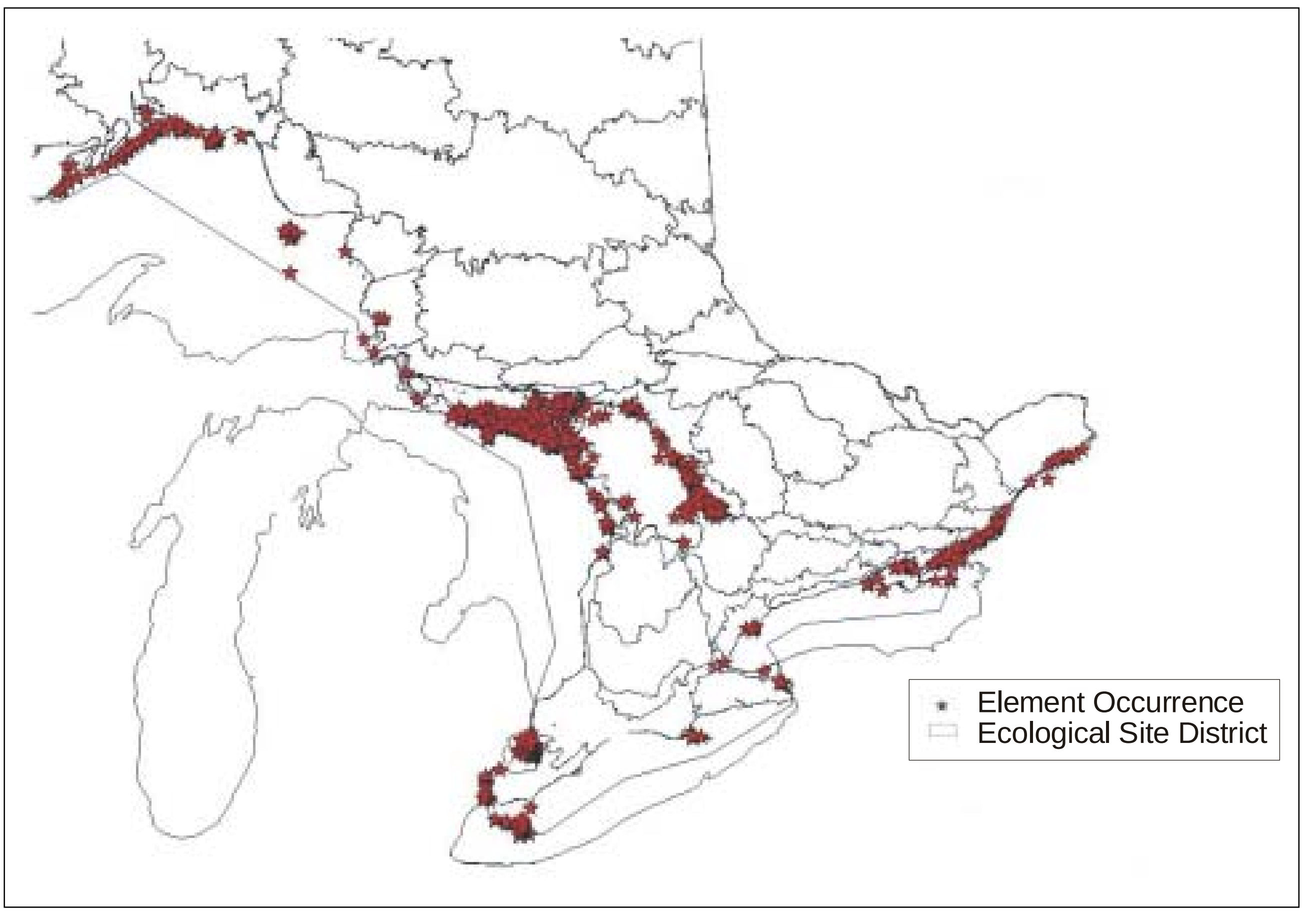


Figure 59. Distribution of Ontario's provincially rare species and vegetation communities on islands in the Great Lakes.
Source: Ontario Natural Heritage Information Centre, March 2003

single irreplaceable resource and protected as a whole if the high value of this natural heritage is to be maintained. For example, Michigan's Great Lakes islands contain one-tenth of the state's threatened, endangered, or rare species while representing only one-hundredth of the land area. All of Michigan's threatened, endangered, or rare coastal species occur at least in part on its islands. The natural features of particular importance are the colonial waterbirds, neartic-neotropical migrant songbirds, endemic plants, endangered species, fish spawning and nursery use of associated shoals and reefs and other aquatic habitat, marshes, alvars, coastal barrier systems, sheltered embayments, nearshore bedrock mosaic, and sand dunes.

Future Pressures

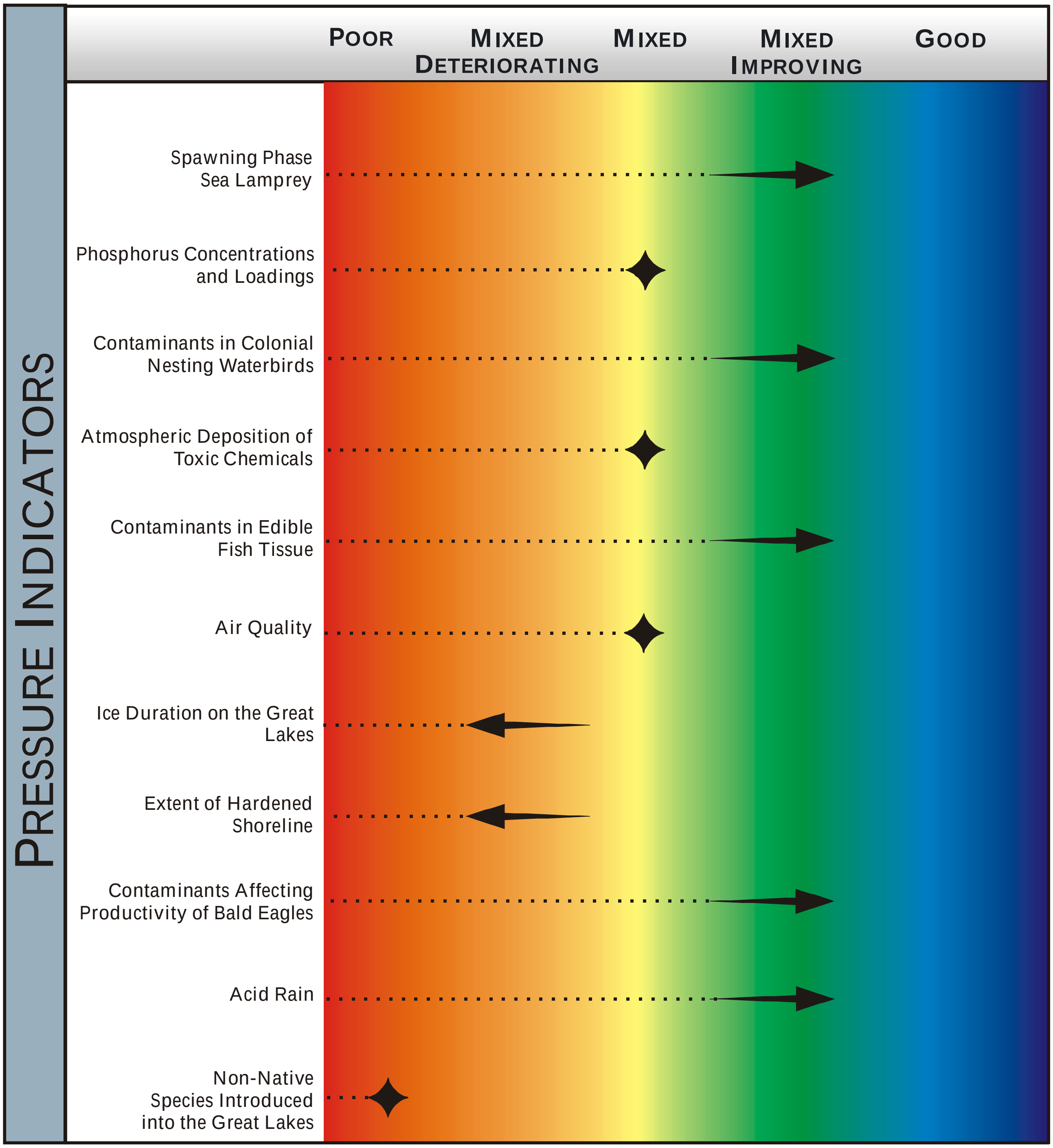
Islands are more sensitive to human influence than the mainland. Island stressors include: development, non-native species, shoreline modification, marina development, agriculture and forestry practices, recreational use, navigation and shipping practices, wastewater discharge, mining practices, drainage or diversion systems, overpopulation of certain species such as deer and cormorants, industrial discharge, development of roads or utilities, and disruption of natural disturbance regimes.

Acknowledgments

Author: Richard H. Greenwood, U.S. Fish and Wildlife Service, Great Lakes Basin Ecosystem Team Leader and Liaison to U.S. Environmental Protection Agency-Great Lakes National Program Office, Chicago, IL. Contributors: Karen Vigmostad, Director, U.S.-Canada Great Lakes Islands Project, East Lansing, MI; Dr. Judith Soule, Director, Michigan Natural Features Inventory; and Susan Crispin, The Nature Conservancy.

4.3 Pressure Indicator Reports-Part 1

Pressure Indicators-Assessments at a Glance



SUMMARY OF PRESSURE INDICATORS-PART 1

The overall assessment for the Pressure indicators is incomplete. Part One of this Assessment presents the indicators for which we have the most comprehensive and current basin-wide information. Data presented in Part Two of this report represent indicators for which information is not available year to year or are not basin-wide across jurisdictions. Within the Great Lakes indicator suite, 38 have yet to be reported, or require further development. In a few cases, indicator reports have been included that were prepared for SOLEC 2000, but that were not updated for SOLEC 2002. The information about those indicators is believed to be still valid, and therefore appropriate to be considered in the assessment of the Great Lakes. In other cases, the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs are also needed. Several indicators are under development. More research or testing may be needed before these indicators can be assessed.

Indicator Name	Assessment in 2000	Assessement in 2002
Spawning-Phase Sea Lamprey	Mixed	Mixed, improving
Phosphorus Concentrations and Loadings	Mixed	Mixed
Contaminants in Colonial Nesting Waterbirds	Good	Mixed, improving
Atmospheric Deposition and Toxic Chemicals	Mixed, improving	Mixed
Contaminants in Edible Fish Tissue	Mixed, improving	Mixed, improving
Air Quality	Mixed	Mixed
Ice Duration on the Great Lakes	No Report	Mixed, deteriorating (with respect to climate change)
Extent of Hardened Shoreline	Mixed, deteriorating	Mixed, deteriorating
Contaminants Affecting Productivity of Bald Eagles	Mixed, improving	Mixed, improving
Acid Rain	Mixed	Mixed, improving
Non-native Species introduced into the Great Lakes	Poor	Poor

Green represents an improvement of the indicator assessment from 2000.
Red represents deterioration of the indicator assessment from 2000.
Black represents no change in the indicator assessment from 2000, or where no previous assessment exists.

Spawning-Phase Sea Lamprey

Indicator #18

Assessment: Mixed, improving

Purpose

This indicator estimates the abundance of sea lampreys in the Great Lakes. These invaders have a direct impact on the structure of the fish community and health of the aquatic ecosystem.

State of the Ecosystem

The first complete round of stream treatments with the lampricide TFM, as early as 1960 in Lake Superior, successfully suppressed sea lampreys to less than 10% of their pre-control abundance in all of the Great Lakes.

Lake Superior: During the past 20 years, populations have fluctuated but remain at levels less than 10% of peak abundance. Survival objectives for lake trout continue to be met, but recent increases in sea lamprey abundance pose a real threat. Abundance estimates for sea lamprey for 2001 and 2002 show a continuation of the pattern of increase. Wounding and mortality estimates on lake trout have also increased in recent years. Stream treatments were increased during 2001 in response to the observed trends and the results of these actions will not be observed until 2003.

Lake Michigan: Populations have shown a slow, but continuing increasing trend. Increases in wounding rates on lake trout suggest an increasing threat. This continuing trend suggests sources of sea lampreys in Lake Michigan itself rather than from Lake Huron as previously believed. Stream treatments were increased in 2001 and 2002, including treatment of previously untreated lake and ponded areas.

Lake Huron: During the early 1980s, sea lamprey populations increased in Lake Huron, particularly in the north. Through the 1990s, Lake Huron contained more sea lamprey than all the other Lakes combined. Lake trout restoration activities in the northern portion of the Lake during 1995 were abandoned because so few lake trout were surviving attacks by sea lamprey to survive to maturity. An integrated control strategy, which included targeted application of a new formulation

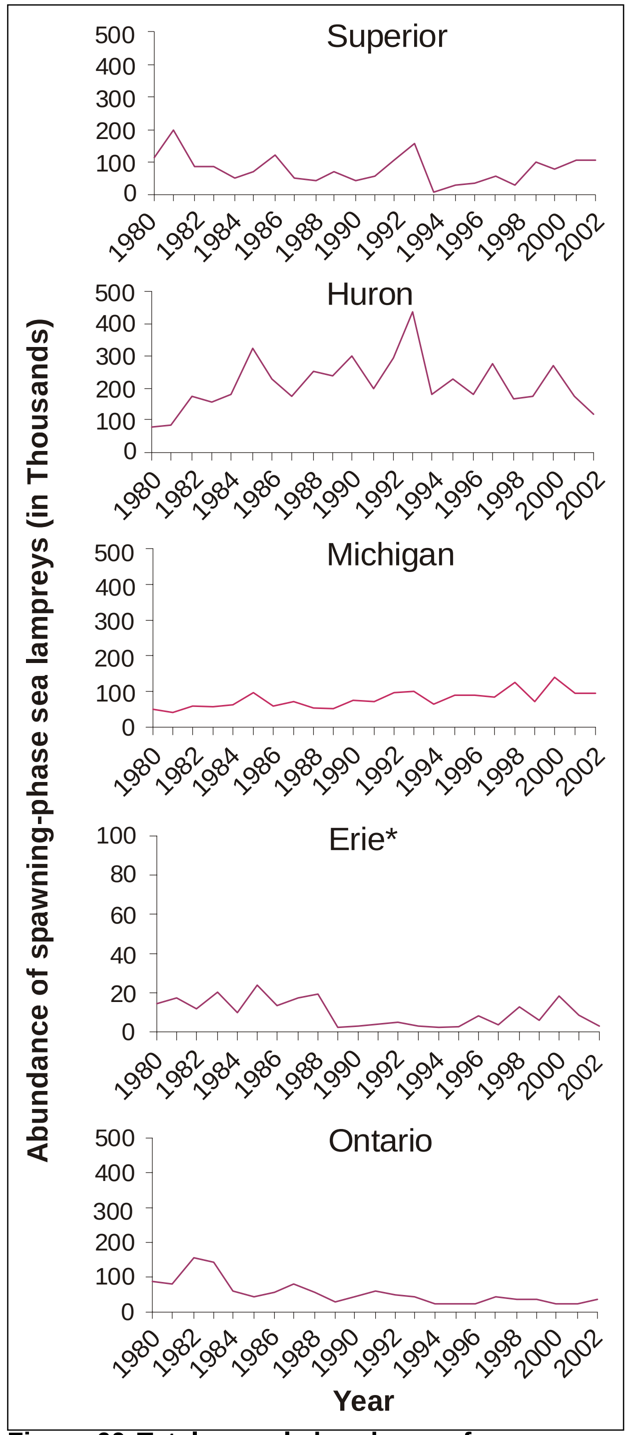


Figure 60. Total annual abundance of sea lamprey estimated during the spawning migration. *Note the scale for Lake Erie is 1/5th the scale size of the other Lakes.

Source: Gavin Christie and Jeffrey Slade, Great Lakes Fishery Commission, Rodney McDonald, Department of Fisheries and Oceans Canada, and Katherine Mullett, U.S. Fish and Wildlife Service

of bottom-release lampricide in the St. Marys River, enhanced trapping of spawning animals, and sterile-male release, was initiated in 1997. As predicted, the sea lamprey populations were observed to decline during 2001 and 2002 suggesting the strategy was successful. However, the population shows considerable variation and the full effect of the control program will not be observed for 2-4 years.

Lake Erie: Sea lamprey abundance increased since the mid-1990s to levels that threaten lake trout restoration goals. An assessment during 1998 indicated that the sources of this increase were several streams in which treatments had been deferred due to low water flows or concerns for non-target organisms. These critical streams were treated during 1999 and 2000. The declines observed in 2001 and 2002 in sea lamprey abundance and lake trout wounding may be a preliminary indication of success.

Lake Ontario: Abundance of spawning-phase sea lampreys has continued to decline to low levels through the 1990s. The abundance of sea lampreys has remained stable during 2000-2001.

Future Pressures

The potential for sea lampreys to colonize new locations has increased with improved water quality and the removal of dams. Short lapses in control can result in rapid increases of abundance. As fish communities recover from the effects of lamprey predation or overfishing, there is evidence that the survival of parasitic sea lamprey might increase due to increased prey availability. Better survival means that the remaining sea lampreys will cause more harm to the Great Lakes fish communities.

Acknowledgments

Author: Gavin Christie, Great Lakes Fishery Commission, Ann Arbor, MI., Jeffery Slade and Kasia Mullet, U.S. Fish and Wildlife Service, Ludington and Marquette, MI., and Rodney McDonald, Dept. Fisheries and Oceans Canada, Sault Ste. Marie, Ontario.

Phosphorus Concentrations and Loadings

Indicator #111

Assessment: Mixed

Note: This assessment is based on attainment of the Great Lakes Water Quality Agreement targets.

Purpose

This indicator assesses total phosphorus levels in the Great Lakes, and is used to support the evaluation of trophic status and food web dynamics in the Great Lakes.

State of the Ecosystem

Strong efforts begun in the 1970s to reduce phosphorus loadings have been successful in maintaining or reducing nutrient concentrations in the Lakes, although high concentrations still occur locally in some embayments and harbors. Phosphorus loads have decreased in part due to changes in agricultural practices (e.g., conservation tillage and integrated crop management), promotion of phosphorus-free detergents, and improvements made to sewage treatment plants and sewer systems.

Average concentrations in the open waters of Lakes Superior, Michigan, Huron, and Ontario are at or below expected levels. Concentrations in the three basins of Lake Erie fluctuate from year to year and frequently exceed target concentrations. In Lakes Ontario and Huron, some offshore and nearshore areas and embayments experience elevated levels that can promote nuisance algae growths such as the attached green alga, *Cladophora*.

Future Pressures

Even if current phosphorus controls are maintained, additional loadings of phosphorus can be expected. Increasing numbers of people living in the Great Lakes basin will exert increasing demands on existing sewage treatment facilities, likely contributing to increases in phosphorus loads.

Acknowledgments

Author: Scott Painter, Environment Canada, Burlington, ON.

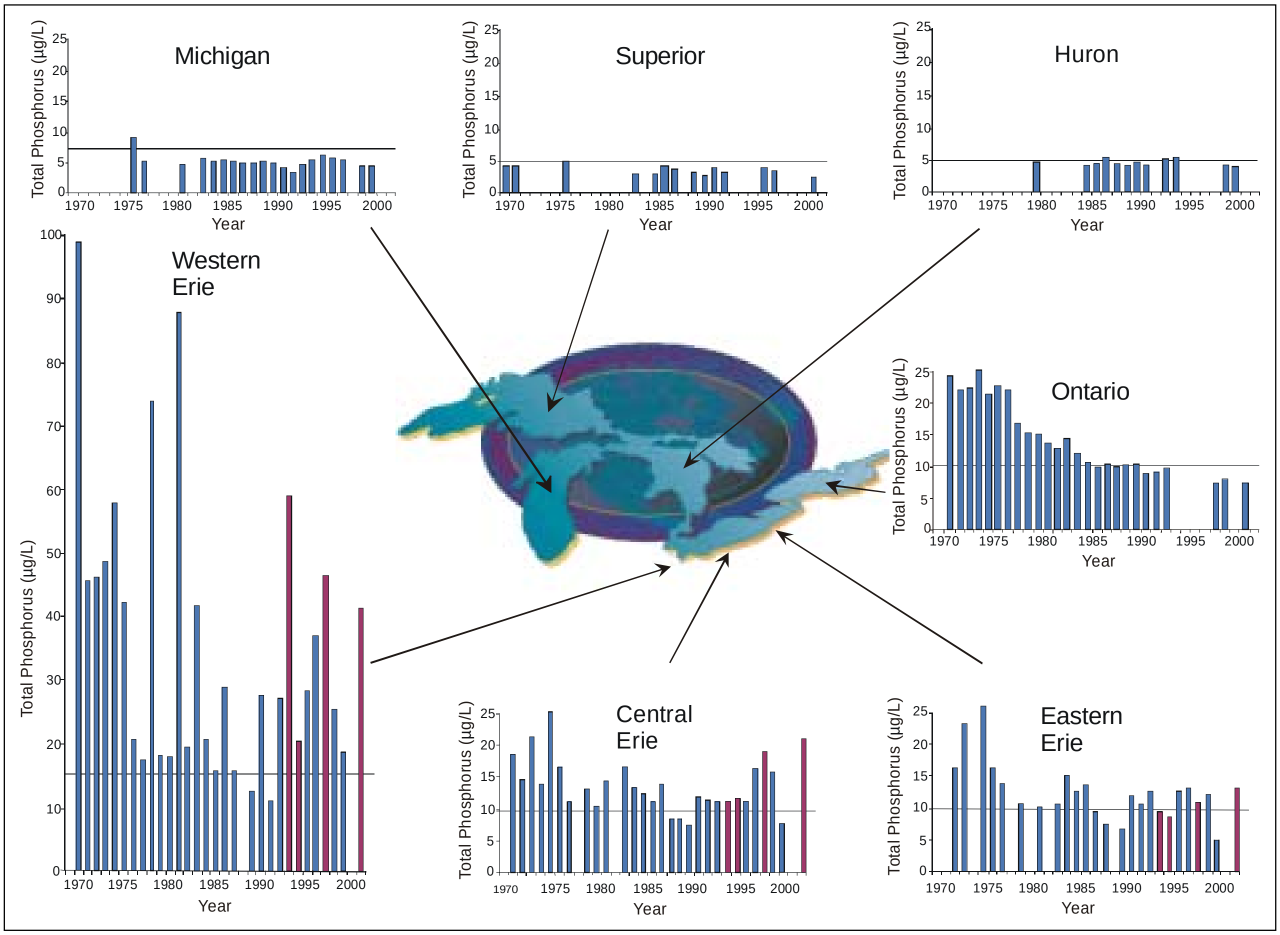


Figure 61. Total phosphorus trends in the Great Lakes 1971-2002 (Spring, Open Lake, Surface). Blank indicates no sampling. Horizontal line on each graphic represents the phosphorus guideline as listed in the Great Lakes Water Quality Agreement for each Lake. Burgundy bar graphs represent Environment Canada data. Blue bar graphs represent U.S. Environmental Protection Agency data.
Source: Environmental Conservation Branch, Environment Canada and U.S. Environmental Protection Agency

Contaminants in Colonial Nesting Waterbirds

Indicator #115

Assessment: Mixed, improving

Purpose

This indicator assesses the current chemical concentrations and trends, as well as ecological and physiological endpoints, in representative colonial waterbirds (gulls, terns, cormorants and/or herons). These features will be used to infer and measure the impact of contaminants on the health (i.e., the physiology and breeding characteristics) of the waterbird populations.

State of the Ecosystem

Testing for spatial patterns has identified contaminant "hot spots". The database shows that most contaminants in gull eggs have declined a minimum of 50% and many have declined more than 90% since the program began in 1974. In 2002, analysis of seven contaminants in Herring Gull eggs from fifteen sites showed that, in more than 72% of cases, contaminants levels were decreasing as fast or faster than they had been in the past.

Spatially, in 2001, gull eggs from Lake Ontario and the St. Lawrence River continued to have the highest levels of mirex. The highest dioxin (2,3,7,8-TCDD) levels were found at Saginaw Bay (Lake

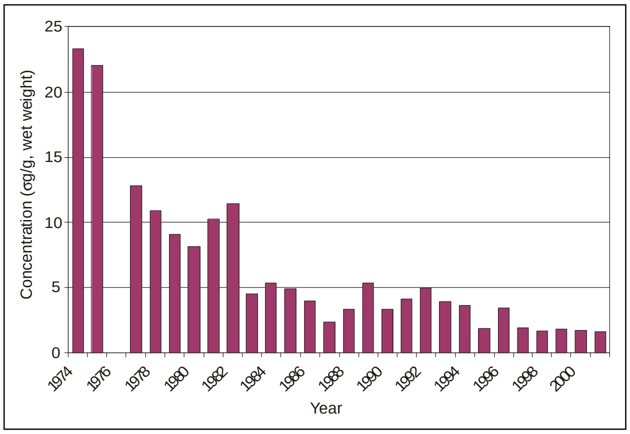


Figure 62. Temporal trends in DDE in herring gull eggs from Toronto Harbour, 1974-2002.
Source: Bishop et al., 1992; Pettit et al., 1994; Pekarik et al., 1998 and Jermyn et al., 2003

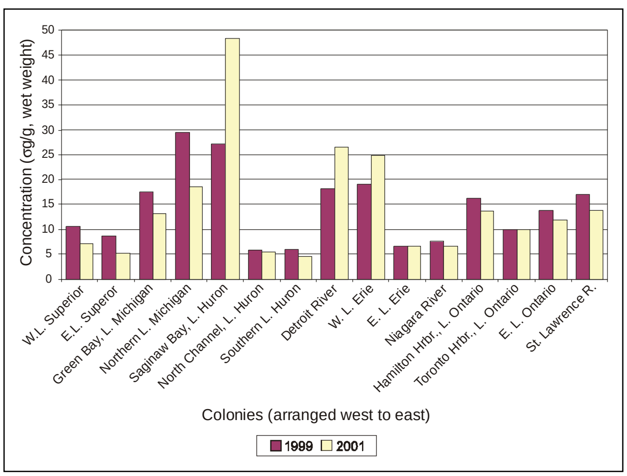


Figure 63. Changes in spatial patterns of PCB 1:1 levels in herring gull eggs from the Annual Monitor Colonies, 1999 and 2001.
Source: Jermyn et al., 2003

Huron) followed by the St. Lawrence-Lake Ontario-Niagara River corridor. Sites on Lake Michigan had the highest levels of dieldrin and heptachlor epoxide. Eggs from Saginaw Bay and Lake Michigan had the highest levels of dichlorodiphenyl-dichloroethylene (DDE). Hexachlorobenzene (HCB) was found in the highest amounts at Saginaw Bay and the Niagara River. Eggs from Saginaw Bay and the Detroit River-western Lake Erie area had the highest levels of PCBs.

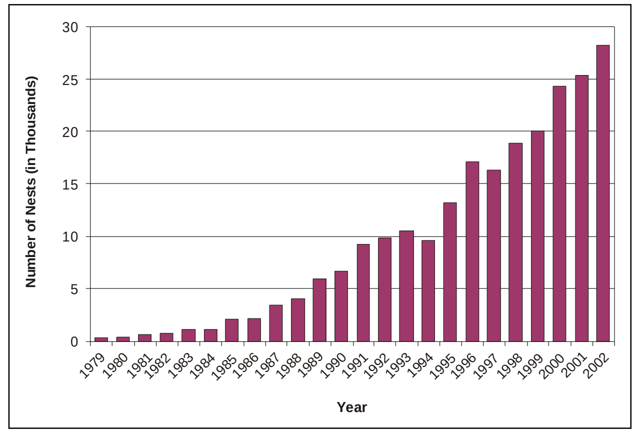


Figure 64. Nest Numbers (number of breeding pairs) of Double-crested Cormorants on Lake Ontario, 1979-2002.
Source: Price and D.V. Weseloh, 1986; Havelka and D.V. Weseloh, 2003

Populations of most species have increased over the past 25-30 years. Double-crested Cormorants, whose population levels have increased more than 400-fold, have been shown to still exhibit some eggshell thinning.

Future Pressures

Future pressures for this indicator include all sources of contaminants that reach the Great Lakes, such as resuspension of sediments, as in western Lake Erie, and atmospheric inputs, such as PCBs in Lake Superior, as well as other sources, such as underground seepage from landfill sites.

Acknowledgments

Authors: D.V. Chip Weseloh and Tania Havelka, Canadian Wildlife Service, Environment Canada, Downsview, ON.
Thanks to past and present staff at CWS-Ontario Region (Burlington and Downsview), as well as staff at the CWS National Wildlife Research Centre (Ottawa, ON) and wildlife biologists Ray Faber, Keith Grasman, Ralph Morris, Jim Quinn and Brian Ratcliff for egg collections, preparation, analysis and data management over the 28 years of this project.

Atmospheric Deposition of Toxic Chemicals

Indicator #117

Assessment: Mixed

Purpose

This indicator assesses annual average loadings of priority toxic chemicals from the atmosphere to the Great Lakes and temporal trends in contaminant concentrations.

State of the Ecosystem

The binational U.S.-Canada Integrated Atmospheric Deposition Network (IADN) consists of five master sampling sites, one near each of the Great Lakes, and several satellite stations.

Concentrations of gas-phase total PCBs (polychlorinated biphenyls) have generally decreased over time at the rural master stations. However, PCB concentrations at a satellite site in downtown Chicago are an order of magnitude higher than at the master stations.

Gas-phase α-hexachlorocyclohexane (HCH) concentrations are decreasing at all sites. Generally, this downward trend applies to other banned or restricted pesticides measured by IADN. Concentrations of organochlorine pesticides in precipitation have also decreased over time.

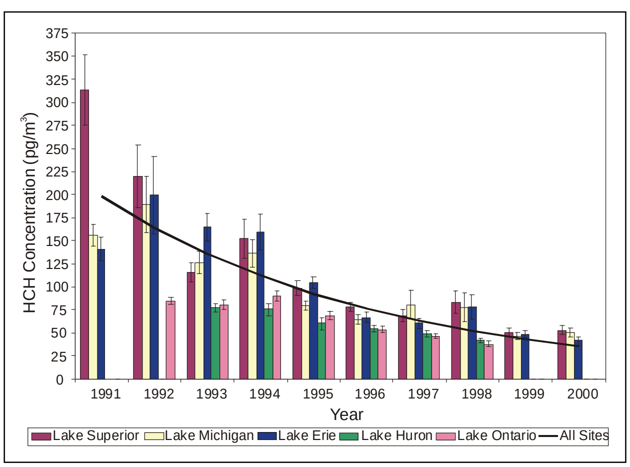


Figure 65. Gas phase α-HCH (hexachlorocyclohexane) concentrations for all five Great Lakes.

Source: Buehler, S.S. and Hites, R.A., 2002

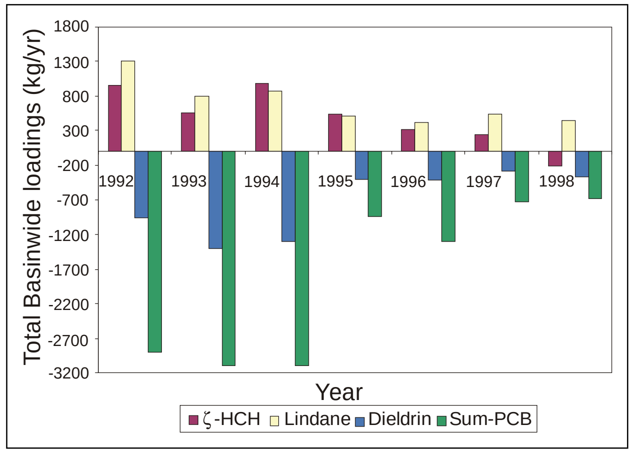


Figure 66. Annual total basinwide loadings for α-HCH, lindane, dieldrin and total PCBs.

Source: Adapted from Buehler et al., 2001

Loadings calculations reveal that inputs of measured in-use pesticides (lindane and endosulfan) are generally twice that of the banned pesticide with the highest inputs. Banned pesticides are volatilizing out of the Lakes in amounts almost 10 times more than the in-use pesticides.

Benzo[*a*]pyrene (BaP), a PAH (polycyclic aromatic hydrocarbon), is produced by the incomplete combustion of almost any fuel, and is carcinogenic. The concentrations of BaP are relatively high at Lakes Erie and Ontario, sites near major population centers, and the concentrations are relatively unchanged over time at all sites.

Basin-wide loadings are summed over all five Lakes. A bar pointing downward indicates that the net loading is negative, and the compound is volatilizing into the atmosphere. The values of the loadings are generally getting smaller, which indicates that the lake water and the air above it are getting closer to being in equilibrium.

In general, loadings of metals showed a decrease during the 1990s, but showed an increase in 1997 and 1998 for lead and cadmium, mainly due to an increase in wet deposition. Dry deposition of metals has been consistent over time.

Future Pressures

Pressure on the Lakes from atmospheric deposition of toxic chemicals is likely to continue. The concentrations of chemicals no longer in use, such as most of the organochlorine pesticides, may decrease to undetectable levels.

Residual sources of PCBs remain in the environment, and atmospheric deposition will still be significant in the future. PAHs and metals continue to be emitted, and concentrations of these substances may not decrease or may decrease very slowly. Currently released substances, including mercury, other in-use pesticides, and dioxins and furans, will also be present in the future. Atmospheric deposition of chemicals of emerging concern, such as brominated flame retardants, could also become a future stressor on the Great Lakes.

Acknowledgments

Author: Melissa Hulting, U.S. Environmental Protection Agency on behalf of the IADN Steering Committee.

Contaminants in Edible Fish Tissue

Indicator # 4083

Assessment: Mixed, improving

Purpose

This indicator assesses the concentration of persistent bioaccumulative toxic (PBT) chemicals in Great Lakes fish, and it is used to infer the potential exposure of humans to PBT chemicals through consumption of Great Lakes fish caught via sport and subsistence fishing. This will be accomplished using fish contaminant data and a standardized fish advisory protocol. The approach is illustrated using the Great Lakes protocol for PCBs as the standardized fish advisory benchmark.

State of the Ecosystem

Since the 1970s, there have been declines in many persistent bioaccumulative toxic chemicals in the Great Lakes basin. However, PBT chemicals, because of their ability to bioaccumulate and persist in the environment, continue to be a significant concern.

Fish consumption advisory programs are well established in the Great Lakes. States, tribes, and the Province of Ontario have extensive fish contaminant monitoring programs, and issue advice to their residents about how much fish and which fish are

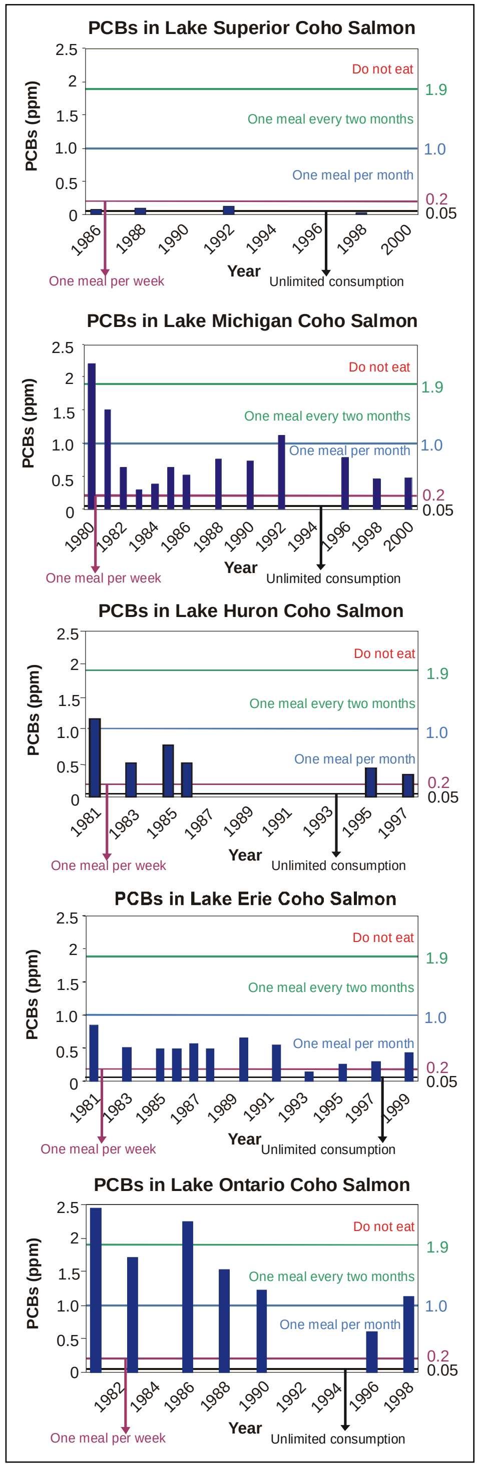


Figure 67. Results of a uniform fish advisory protocol applied to historical data (PCBs, coho salmon) in the Great Lakes.

Source: Sandy Hellman, U.S. Environmental Protection Agency-Great Lakes National Program Office

safe to eat. Advice from these agencies to limit consumption of fish results from levels of PCBs, mercury, chlordane, dioxin, and toxaphene in the fish tissues.

The accompanying figures illustrate the results of applying a uniform fish advisory protocol to historical data for PCBs in coho salmon fillets. The resulting advisories do not necessarily reflect actual advisories issued in each Lake basin.

Future Pressures
Organochlorine contaminants in fish in the Great Lakes are generally decreasing. As these contaminants decline, mercury will become a more prominent contaminant of concern regarding the edibility of fish. Contaminants, such as certain brominated flame retardants, are increasing in the environment and could be a concern in the future.

Acknowledgments
Authors: Sandy Hellman, U.S. Environmental Protection Agency-Great Lakes National Program Office, Chicago, IL, and Patricia McCann, Minnesota Department of Health.

Air Quality
Indicator #4176

Assessment: Mixed

Purpose
This indicator assesses air quality in the Great Lakes ecosystem, and it infers the potential impact of air quality on human health in the Great Lakes basin.

State of the Ecosystem
There has been significant progress in reducing air pollution in the Great Lakes basin. For most substances of interest, both emissions and ambient concentrations have decreased over the last ten years or more. However, progress has not been uniform and differences in weather from one year to the next complicate analysis of ambient trends. Ozone can be particularly elevated during hot summers. Drought conditions result in more fugitive dust emissions from roads and fields, increasing the ambient levels of particulate matter.

For this report, the pollutants can be divided into urban (or local) and regional pollutants. References to the U.S. or Canada refer to the respective portions of the Great Lakes basin. Latest published air quality data are for 2000. Urban pollutants include carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), lead, total reduced sulfur (TRS) and particulate matter (PM). In the U.S., CO ambient levels have decreased approximately 41% from 1991 to 2000, and 61% from 1981 to 2000. Emissions have declined by 4.1% in Ontario between 1991 and 2000.

Average ambient NO_2 concentrations in Ontario and the U.S. have declined during the period from 1991 to 2000, but remain unchanged in the Lake Michigan area. From 1991 to 2000, ambient concentrations of SO_2 in the U.S. decreased 37%. Canadian ambient levels have remained relatively constant since 1994. Canadian emissions decreased 45% overall from 1980 to 2000, but since 1995 have remained relatively constant. U.S. and Canada lead concentrations decreased 93% from 1981 to 2000 and 50% from 1991 to 2000. Ambient concentrations of TRS are significantly lower than in the early 1990s with a decrease of 33.3% during the period of 1991 to 2000.

Ambient concentrations of PM10 (diameter 10 microns or less) in the U.S. have decreased 19% from 1991 to 2000. Canadian objectives have focused on Total Suspended Particulate matter (TSP). Both PM10 and TSP affect locations relatively close to pollutant sources. Ontario PM10 emissions decreased from 1988 to 1992, but have shown no significant trend since that time.

Regional pollutants include ozone, PM2.5 (diameter 2.5 microns or less), and air toxics. Ozone is a problem pollutant over broad areas of the Great Lakes region, except for the Lake Superior basin. Consistently high levels are found in provincial parks near Lakes Huron and Erie, and western Michigan is impacted by transport across Lake Michigan from Chicago. Volatile Organic Compounds (VOCs) emissions have decreased 16% and NO_x emissions have increased three percent from 1991 to 2000. Human made VOC emissions have decreased about 17% since 1991. NO_x emissions have remained fairly constant since 1995 with a slight increase in overall emissions since 1990. PM2.5 is a health concern because it can penetrate deeply into the lungs, in contrast to larger particles. As PM2.5 monitoring has only begun quite recently, there are not enough data to show a national long-term trend in urban concentrations. In Ontario, 93% of the sites experienced exceedences. As of August 2002, Ontario had also introduced PM2.5 into their Air Quality Index and Smog Advisory Programs. In the U.S., there are not enough years of data from the recently established reference-method network to determine trends, but it appears that there may be many areas that do not attain the new U.S. standard.

The term "Air Toxics" includes a large number of pollutants that have potential to harm human health or cause adverse environmental and ecological effects. Some of these are of local importance, near to sources, while others may be transported over long distances. Monitoring is difficult and expensive, and it is usually limited in scope. Usually such toxic air pollutants are present only at trace levels. In both Canada and the U.S., efforts focus on minimizing emissions and setting standards. Once fully implemented, these standards will cut emissions of toxic air pollutants by nearly 1.5 million tons per year from the 1990 levels.

Future Pressures
Continued population growth and associated urban sprawl are threatening to counterbalance emission reduction efforts. The changing climate may affect the frequency of weather conditions conducive to high ambient concentrations of many pollutants. There is also increasing evidence of changes to the atmosphere as a whole. Continuing health research is focusing on a larger number of toxic chemicals, and it is producing evidence that existing standards should be lowered.

Acknowledgments
Authors: Bryan Tugwood, Environment Canada, Meteorological Services of Canada, Downsview, ON; Todd Nettesheim, U.S. Environmental Protection Agency-Great Lakes National Program Office, Chicago, IL; and Michael Rizzo, U.S. Environmental Protection Agency, Air and Radiation Division, Chicago, IL.

Ice Duration on the Great Lakes
Indicator #4858

Assessment: Mixed, deteriorating (with respect to climate change)

Purpose
This indicator assesses the ice duration, and thereby the temperature and accompanying physical changes to each Lake over time, in order to infer the potential impact of climate change.

State of the Ecosystem
Observations of the Great Lakes data showed no conclusive trends with respect to the date of freeze-up or break-up. It was not possible to observe an entire Lake during the winter season (at least before satellite imagery), and therefore only regional observations were made (inner bays and ports). However, there were enough data collected from ice charts to state that a decrease in the maximum ice cover has occurred over the last thirty years.

The trend on each of the five Lakes shows that during this 30 year period, the maximum amount of ice forming each year has been decreasing. This can be correlated to the average ice cover per season observed for the same period. Between the 1970s and 1990s there was a 10% decline in the maximum ice cover on each Lake, as much as 18% in some cases, with the greatest decline occurring during the1990s.

Future Pressures
It appears that ice formation of the Great Lakes will likely continue to decrease in total cover, based on current predictions of global atmospheric warming.

Lake	1970-1979	1980-1989	1990-1999	Change from 1970s to 1990s
Erie	94.5	90.8	77.3	-17.2
Huron	71.3	71.7	61.3	-10.0
Michigan	50.2	45.6	32.4	-17.8
Ontario	39.8	29.7	28.1	-11.7
Superior	74.5	73.9	62.0	-12.6

Figure 68. Mean ice coverage, in percent, during the corresponding decade.
Source: National Oceanic and Atmospheric Administration

Milder winters will have a drastic effect on ice cover of the Lakes that will affect many aquatic and terrestrial ecosystems that rely on Lake ice for protection and food acquisition. Effects from general development, human habitation, hydroelectric development and wastewater input will also affect ice duration on the Great Lakes.

Acknowledgments
Author: Gregg Ferris, Environment Canada Intern, Downsview, ON.

Extent of Hardened Shoreline

Indicator #8131
Note: This indicator report is from 2000

Assessment: Mixed, deteriorating

Purpose
This indicator assesses the extent of hardened shoreline through construction of sheet piling, rip rap, or other erosion control structures.

State of the Ecosystem
Shoreline hardening not only directly destroys natural features, but also disrupts more subtle biological communities that depend upon the transport of shoreline sediment by lake currents. Hardening also destroys inshore habitat for fish, birds and other biota.

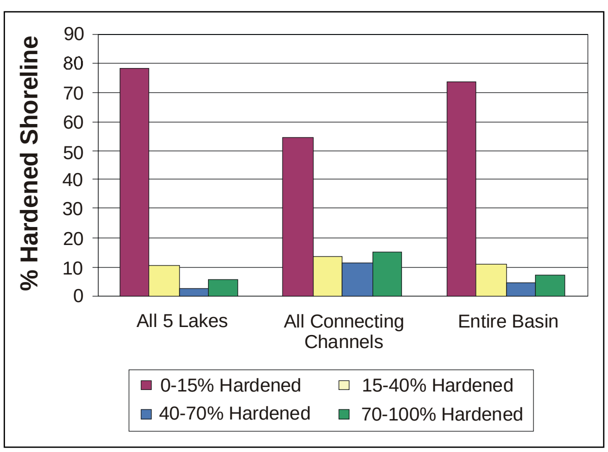


Figure 69. Shoreline hardening in the Great Lakes compiled from 1979 data for the state of Michigan and 1987-1989 data for the rest of the basin.
Source: Environment Canada and National Oceanic Atmospheric Administration

The St. Clair, Detroit, and Niagara Rivers have a higher percentage of their shorelines hardened than anywhere else in the basin. Of the Lakes themselves, Lake Erie has the highest percentage of its shoreline hardened, and Lakes Huron and Superior have the lowest.

Shoreline changes along 13.7 miles (22 kilometers) of the Canadian side of the St. Clair River were assessed from 1991-1999. An additional 3.4 miles (5.5 kilometers) of the shoreline had become hardened during this time. This rate of hardening is not representative of the overall basin as the St. Clair River is a narrow shipping channel with high volumes of Great Lakes shipping traffic. Many property owners are also hardening the shoreline to reduce the impacts of erosion.

Future Pressures
Shoreline hardening can be considered a permanent feature. Pressure will continue to harden additional stretches of shoreline, especially during periods of high Lake levels. The hardening of shoreline will starve the down-current areas of sediment to replenish that which eroded away, causing further erosion and a further incentive for additional hardening. Other ecological costs include further degradation and loss of coastal wetlands and sand dunes.

Acknowledgments
Authors: John Schneider, U.S. Environmental Protection Agency-Great Lakes National Program Office, Chicago, IL; Duane Heaton, U.S. Environmental Protection Agency-Great Lakes National Program Office, Chicago, IL, and Harold Leadlay, Environment Canada, Environmental Emergencies Section, Downsview, ON.

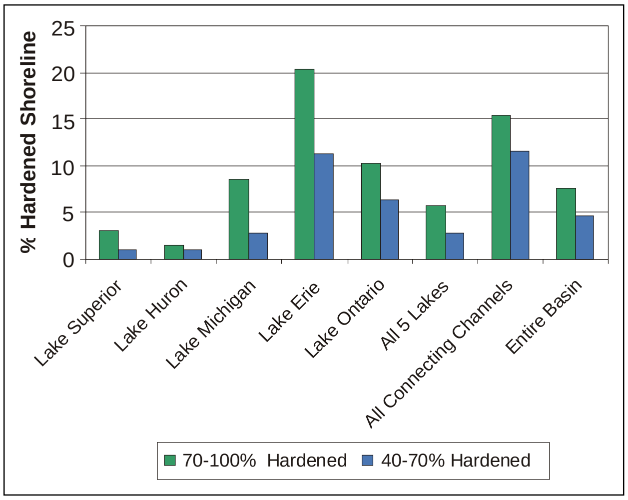


Figure 70. Shoreline hardening by Lake compiled from 1979 data for the state of Michigan and 1987-1989 data for the rest of the basin.
Source: Environment Canada and National Oceanic Atmospheric Administration

Contaminants Affecting Productivity of Bald Eagles

Indicator #8135

Assessment: Mixed, improving

Purpose
This indicator assesses the number of fledged young, the number of developmental deformities and the concentrations of persistent organic pollutants and heavy metals in bald eagle eggs, blood, and feathers. The data will be used to infer the potential for harm to other wildlife and human health through the consumption of contaminated fish.

State of the Ecosystem
Concentrations of organochlorine chemicals are decreasing or stable, but still above No Observable Adverse Effect Concentrations (NOAECs) for the primary organic contaminants, DDE and PCBs. Bald eagles are now distributed extensively along much of the shoreline of the Great Lakes, but there are still several reaches of Great Lakes shoreline where the bald eagle has not recovered.

The number of active bald eagle territories has risen in the Great Lakes basin. The recovery of reproductive output at the population level has followed similar patterns in each basin, but the timing has differed between the various Lakes. Established territories in most areas are now producing one or more young per territory, indicating that the population is healthy and capable of increasing.

Future Pressures
High levels of persistent contaminants in bald eagles continue to be a concern. Eagles are relatively rare and contaminant effects on individuals can be important to the well being of local populations. In addition, relatively large areas of habitat are necessary to support eagles, and continued development pressures along the shorelines of the Great Lakes constitute a concern. The interactions of contaminant pressures and habitat limitations are unknown at present.

Acknowledgments
Authors: Ken Stromborg and David Best, U.S. Fish and Wildlife Service, and Pamela Martin, Canadian Wildlife Service. Contributions by: Ted Armstrong, Ontario Ministry of Natural Resources; Lowell Tesky, Wisconsin Department of Natural Resources; Cheryl Dykstra, Cleves, OH; Peter Nye, New York Department of Environmental Conservation; William Bowerman, Clemson University. John Netto, U.S. Fish and Wildlife Service assisted with computer support.

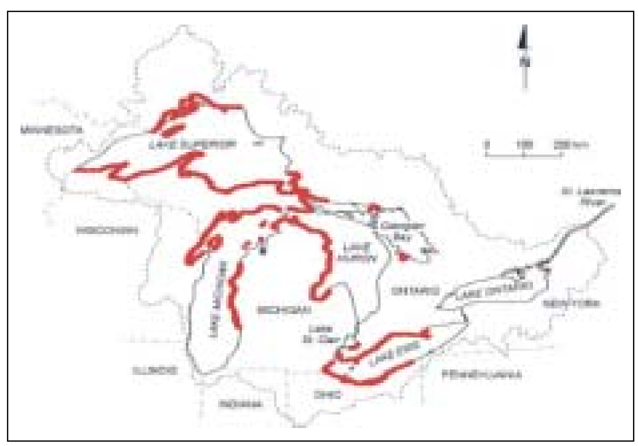


Figure 71. Approximate nesting locations of bald eagles along the Great Lakes shorelines, 2000.
Source: W. Bowerman, Clemson University, Lake Superior LaMPs, and for Lake Ontario, Peter Nye, and N.Y. Department of Environmental Conservation

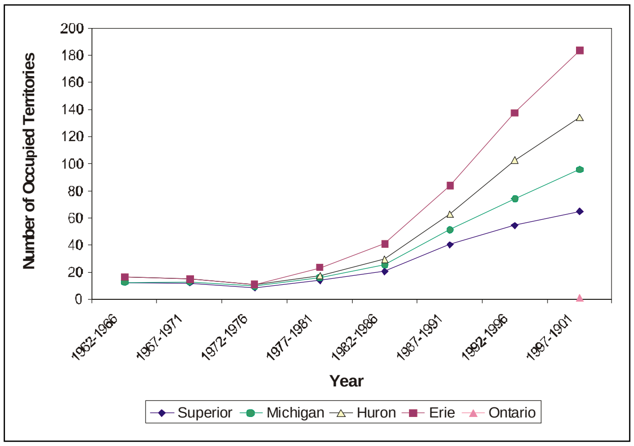


Figure 72. Average number of occupied territories per year by Lake.
Source: Dave Best, U.S. Fish and Wildlife Service; Pamela Martin, Canadian Wildlife Service; and Michael Meyer, Wisconsin Department of Natural Resources

Acid Rain

Indicator #9000

Assessment: Mixed, improving

Purpose
This indicator assesses the sulphate levels in precipitation and critical loadings of sulphate to the Great Lakes basin. This indicator can be used to infer the effectiveness of policies to reduce sulphur and nitrogen oxide emissions to the atmosphere.

State of the Ecosystem
Much of the acidic deposition in North America falls in the Great Lakes basin and surrounding areas. However, the five Great Lakes are so large that acidic deposition has little effect on them directly. Impacts are mainly felt on vegetation and inland lakes in acid-sensitive areas, such as the Canadian Shield. Acid deposition is still a significant problem in those areas.

The most common releases of SO_2 in Canada are from industrial processes such as non-ferrous mining and metal smelting. In the United States, electrical utilities constitute the largest emissions source. The primary source of NO_x emissions in both countries is the combustion of fuels in motor vehicles, with electric utilities and industrial sources also contributing.

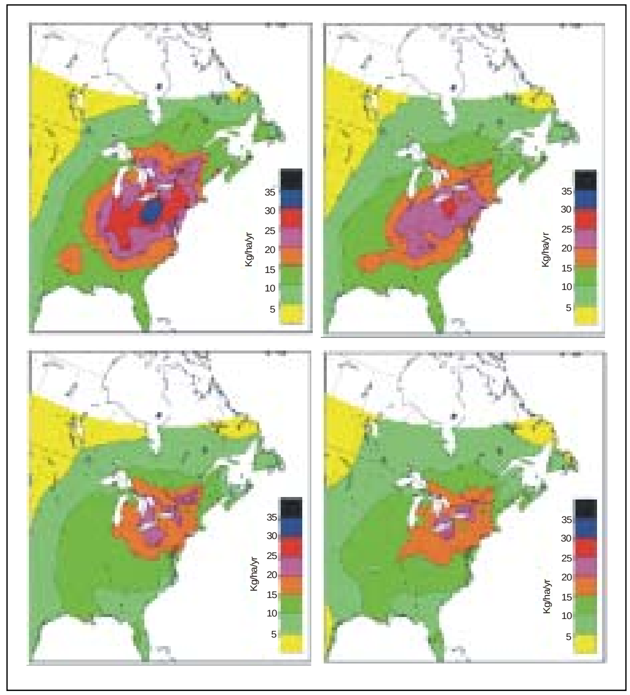


Figure 73. Patterns of wet non-sea salt SO_4 and wet NO_3 deposition for two five-year periods during the 1990s. (top left: SO_4 for 1990-1994; top right: SO_4 for 1996-2000; bottom left: NO_3 for 1990-1994; bottom right: NO_3 for 1996-2000).
Source: Canada-U.S. Air Quality Agreement 2002 Progress Report

In 2000, total SO_2 emissions in Canada were 2.5 million tons, which was about 20% below the national cap of 3.2 million tons. Emissions in 2000 also represented a 45% reduction from 1980 emission levels. In 2001, all participating sources of the U.S. Environmental Protection Agency's Acid Rain Program achieved a total reduction in SO_2 emissions of about 32% from 1990 levels, and 35% from 1980 levels. Overall, a 38% reduction in SO_2 emissions is projected in Canada and the United States from 1980 to 2010. In the United States, the reduction is mainly due to controls on electric utilities, while in Canada, the reduction is mainly due to controls on both the non-ferrous mining/ smelting sector and electric utilites that occur as part of the Canada-Wide Acid Rain Strategy program. Despite these efforts, rain is still too acidic throughout most of the Great Lakes region, and if SO_2 emissions remain relatively constant after the year 2000, as predicted, it is unlikely that sulfate deposition will change in the coming decade.

By 2000, Canadian NO_x emissions were reduced by more than 100,000 tons below the forecast level of 970,000 tons at power plants, major combustion sources, and smelting operations. Canada is also developing other programs to further reduce NO_x emissions. In the U.S., reductions in NO_x emissions have already surpassed the 2 million ton reduction for stationary and mobile sources mandated by the Clean Air Act Amendments of 1990. Trends have been predicted for NO_x emission levels in Canada and the United States through 2010. By 2010, U.S. levels are expected to have decreased by approximately 21% from 2000 levels. Canadian NO_x emissions have increased slightly since 1990, but are expected to decrease to 1980 levels by 2010. These small reductions are attributed to mobile sources.

Wet sulfate deposition in the eastern part of Canada and the U.S. has decreased after the implementation of the U.S. Clean Air Act Amendment emission reductions of SO_2 in 1995. Wet nitrate deposition changed little in the 1990s in response to minimal change in nitrogen oxide emissions throughout the decade.

Future Pressures

Pressures will continue to grow as the population within and outside the basin increases, causing increased demands on electrical utilities, resources and an increased number of motor vehicles.

Acknowledgments

Authors: Dean S. Jeffries, National Water Research Institute, Environment Canada, Burlington, ON; Robert Vet, Meteorological Service of Canada, Environment Canada, Downsview, ON; and Todd Nettesheim, U.S. Environmental Protection Agency-Great Lakes National Program Office, Chicago, IL.

Non-Native Species Introduced into the Great Lakes

Indicator #9002

Assessment: Poor

Purpose

This indicator reports introductions of aquatic organisms not naturally occurring in the Great Lakes, and it is used to assess the status of biotic communities in the basin. This indicator will expand to include terrestrial organisms in the future.

State of the Ecosystem

Since the 1830s, there have been 78 non-native aquatic animal (fauna) species introduced into the Great Lakes. Main entry mechanisms are associated with the ship vector, migration through canals, and accidental releases. In terms of aquatic plant species (flora), in almost the same timeframe there have been 84 species introduced into the Great Lakes ecosystem, primarily in association with shipping and cultivation.

Even with ballast exchange programs recently implemented in Canada and the United States, new non-native species associated with shipping activities have been reported and identified. It is essential that entry mechanisms be closely monitored and effective safeguards introduced and adjusted as necessary.

Future Pressures

Introductions of non-native species will continue due to increases in global trade; new diversions of water into the Great Lakes; aquaculture industries, such as fish farming, live food, and garden ponds; changes in water quality and temperature; and the previous introduction of non-native species from outside the basin.

Acknowledgments

Authors: Edward L. Mills, Department of Natural Resources, Cornell University, Bridgeport, NY, and Margaret Dochoda, Great Lakes Fishery Commission, Ann Arbor, MI.

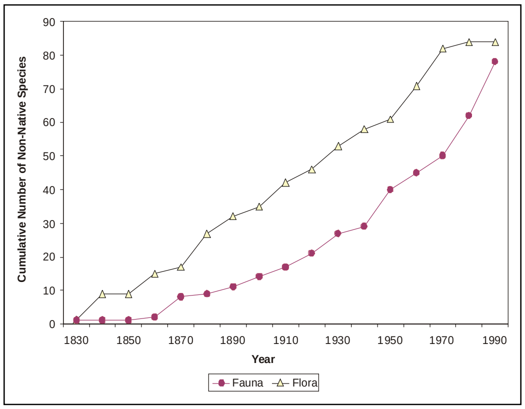


Figure 74. Cumulative number of aquatic non-native species established in the Great Lakes basin since the 1830s.
Source: Mills et al., 1993, Ricciardi, 2001

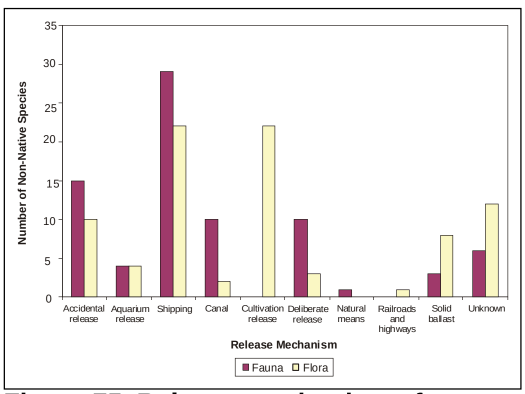


Figure 75. Release mechanisms for aquatic non-native species established in the Great Lakes basin since 1830.
Source: Mills et al., 1993, Ricciardi, 2001

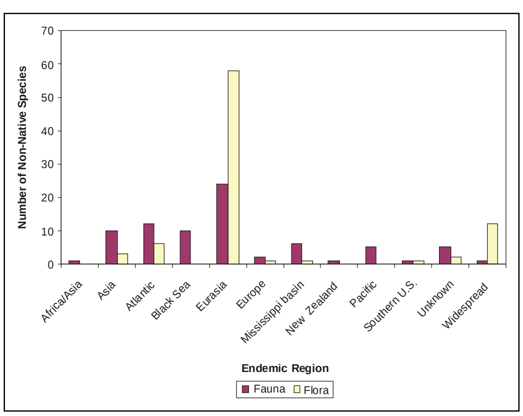


Figure 76. Regions of origin for aquatic non-native species established in the Great Lakes basin.
Source: Mills et al., 1993, Ricciardi, 2001

4.4 Pressure Indicator Reports-Part 2

Summary of Pressure Indicators-Part 2

The overall assessment for the Pressure indicators is incomplete. Part One of this Assessment presents the indicators for which we have the most comprehensive and current basin-wide information. Data presented in Part Two of this report represent indicators for which information is not available year to year or are not basin-wide across jurisdictions. Within the Great Lakes indicator suite, 38 have yet to be reported, or require further development. In a few cases, indicator reports have been included that were prepared for SOLEC 2000, but that were not updated for SOLEC 2002. The information about those indicators is believed to be still valid, and therefore appropriate to be considered in the assessment of the Great Lakes. In other cases, the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs are also needed. Several indicators are under development. More research or testing may be needed before these indicators can be assessed.

Indicator Name	Assessment in 2000	Assessement in 2002
Contaminants in Young-of-the-Year Spottail Shiners	No Report	Mixed, improving
Toxic Chemical Concentrations in Offshore Waters	Mixed	Mixed, improving
Concetnrations of Contaminants in Sediment Cores	No Report	Mixed, improving
E.coli and Fecal Coliform Levels in Nearshore Recreational Waters	Mixed	Mixed
Drinking Water Quality	Good	Good
Contaminants in Snapping Turtle Eggs	Mixed	Mixed
Effect of Water Level Fluctuations	Mixed, deteriorating	Mixed
Mass Transporation	Not Assessed	Mixed
Water Use	Not Assessed	Mixed
Energy Consumption	No Report	Mixed, deteriorating (for Lake Superior basin)
Solid Waste Generation	No Report	Mixed
Population Monitoring and Contaminants Affecting the American Otter	Not Assessed	Mixed

Green represents an improvement of the indicator assessment from 2000.
Red represents deterioration of the indicator assessment from 2000.
Black represents no change in the indicator assessment from 2000, or where no previous assessment exists.

Contaminants in Young-of-the-Year Spottail Shiners

Indicator #114

Assessment: Mixed, improving
Data are not system-wide

Purpose
This indicator assesses the levels of persistent bioaccumulative toxic (PBT) chemicals in young-of-the-year spottail shiners, and it will help to infer local areas of elevated contaminant levels and potential harm to fish-eating wildlife.

State of the Ecosystem
In each of the Great Lakes, PCB is the contaminant most frequently exceeding the International Joint Commission's Aquatic Life Guideline. Total dichlorodiphenyl-trichloroethane (DDT) is often detected, and although the guideline has been exceeded in the past, current concentrations are well below the guideline. Mirex is detected and exceeds the guideline only at Lake Ontario locations. Other PBT chemicals are not frequently detected, and if detected, are at concentrations well below the guidelines.

In Lake Erie, the trends show higher concentrations of polychlorinated biphenyls (PCBs) in the early years with a steady decline over time. After 1987, PCB concentrations have remained near the guideline of 100 ng/g. At Thunder Bay Beach the highest concentration of PCBs was in 1978 (146ng/g). After 1978, PCB concentrations have been less than 100ng/g. Total DDT concentrations at almost all sites in Lake Erie have been well below the guideline of 200 ng/g.

In Lake Huron, Collingwood Harbour had the highest PCB concentrations when sampling commenced in 1987 (206ng/g). Since then, PCB concentrations have either exceeded or fallen just below the guideline of 100 ng/g.

In Lake Superior, contaminant concentrations were generally low in all years and at all locations. The highest PCB concentrations in Lake Superior were found at the Mission River in 1983 (139ng/g). All other analytical results were less than the guideline.

Contaminant concentrations from five locations in Lake Ontario were examined for trend analysis. PCBs, total DDT and mirex are generally higher at these (and other Lake Ontario) locations than elsewhere in the Great Lakes. Overall, PCBs at all locations tended to be higher in the early years, ranging from 3 to 30 times the guideline. Mirex has exceeded the guideline of 5ng/g intermittently at all five locations. Since 1992, mirex has not been detected at any of these locations. Total DDT concentrations approached or exceeded the guideline (200 ng/g) at all five locations in the 1970s and on occasion in the 1980s. The typical concentration of total DDT at all five locations is currently near 50 ng/g.

Future Pressures
Future pressures for this indicator include all sources of contaminants that enter the Great Lakes ecosystem. New and emerging contaminants will also pose a threat to young-of-the-year spottail shiners.

Acknowledgments
Authors: Emily Awad and Alan Hayton, Sport Fish Contaminant Monitoring Program, Ontario Ministry of Environment, Etobicoke, ON.

Toxic Chemical Concentrations in Offshore Waters

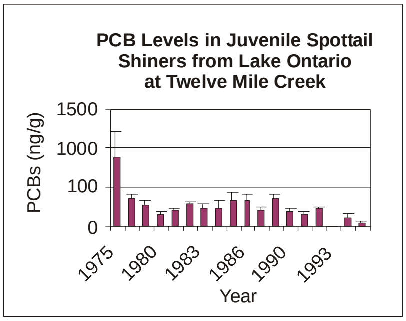
Indicator #118

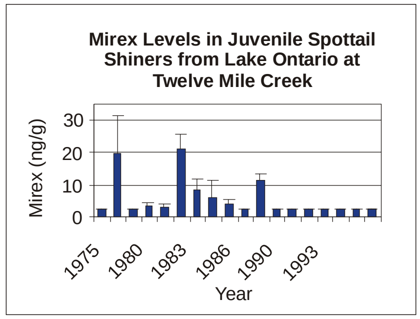
Assessment: Mixed, improving
Data are not system-wide

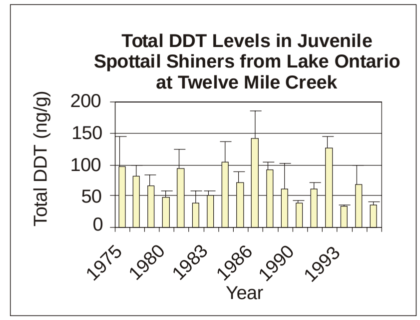
Purpose
This indicator reports the concentration of priority toxic chemicals in offshore waters, and by comparison to criteria for the protection for aquatic life and human health, infers the potential for impacts on the health of the Great Lakes aquatic ecosystem.

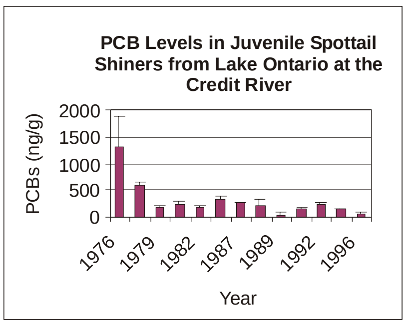
State of the Ecosystem
Many toxic chemicals are present in the Great Lakes. As a result of various ecosystem health assessments, a comparatively small number have been identified as "critical pollutants".

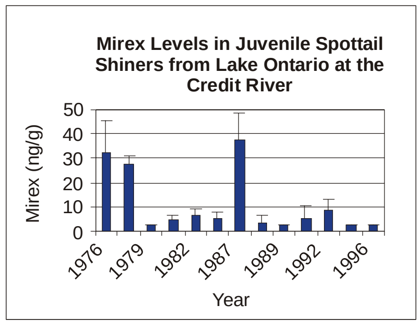
Concentrations of organochlorines are still declining

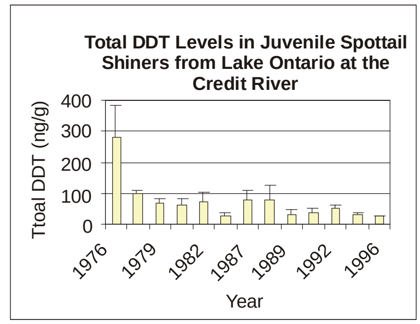


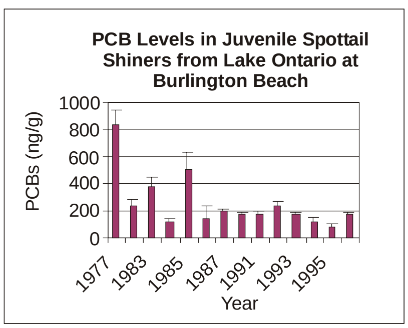


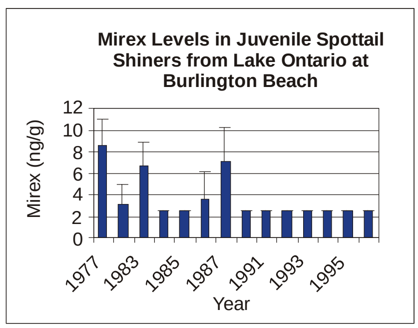


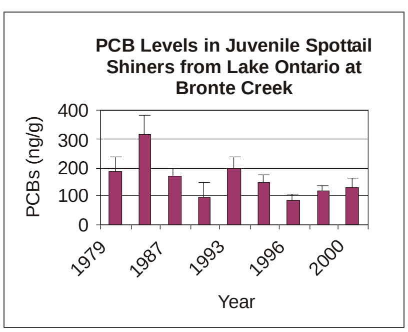












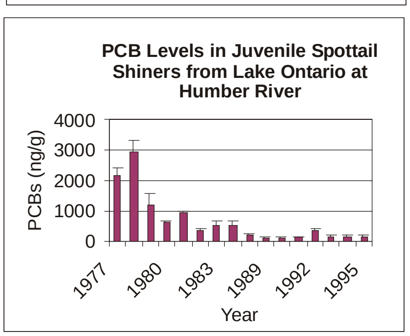


Figure 77. PCB, mirex, and total DDT levels in Juvenille Spottail Shiners from five locations in Lake Ontario. The figures show mean concentrations plus standard deviations of PCBs, total DDT and mirex. When not detected, one half of the detection limit was used to calculate the mean concentration.

Source: Ontario Ministry of the Environment

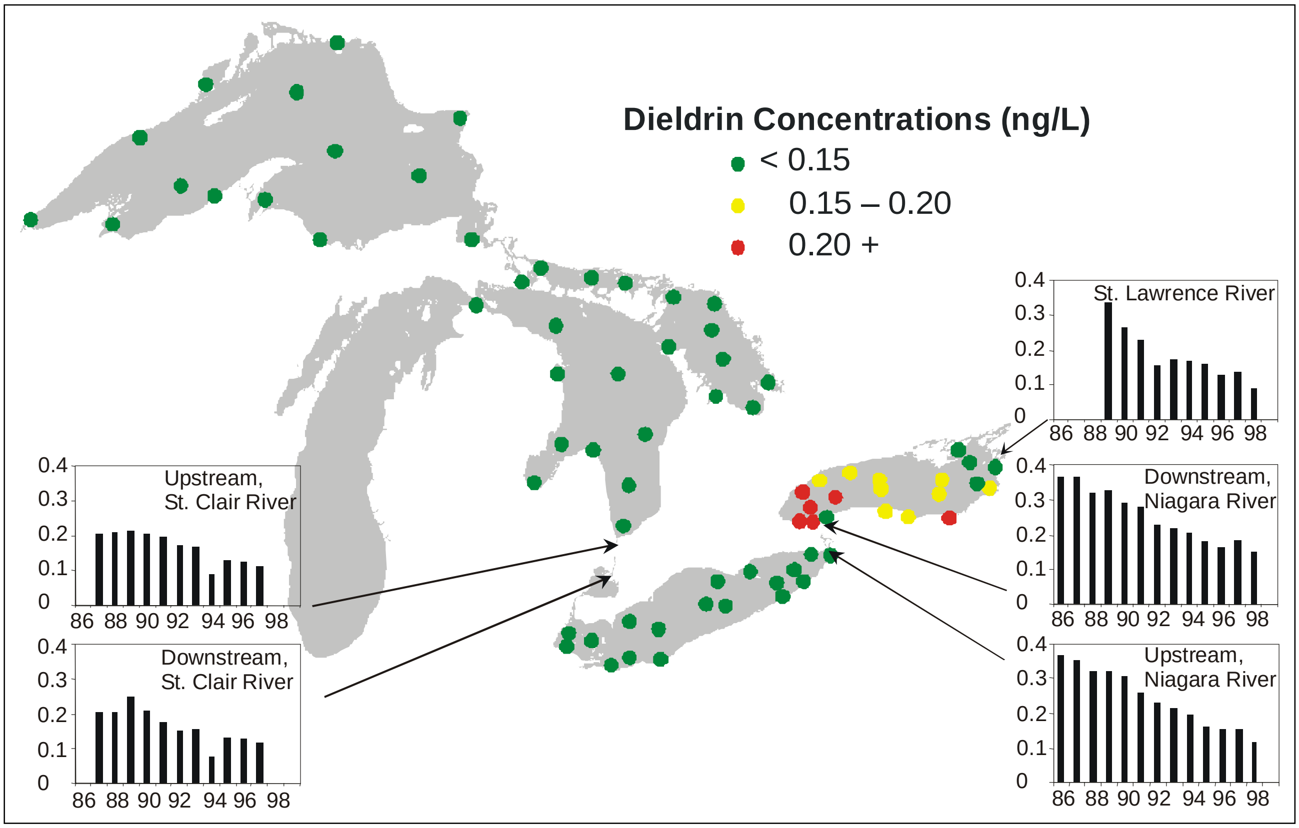


Figure 78. Spatial dieldrin patterns in the Great Lakes (Spring 1997, 1999, or 2000, Surface) and annual mean concentrations for the interconnecting channels from 1986 to 1998. Units = ng/L.
Source: Environmental Conservation Branch, Environment Canada

in the Great Lakes in response to management efforts. An example of an organochlorine with more widespread distribution is dieldrin, which is observed at all open Lake stations and connecting channels sites. Concentrations throughout the Great Lakes have decreased by more than 50% between 1986 and 2000 and are still declining. However, dieldrin exceeds New York State's water quality criterion (0.0006 ng/L) for the protection of human consumers of fish by a factor of 50-300 times.

Hexachlorobenzene (HCB), octachlorostyrene, and mirex are present due to historical, localized sources, and their occurrence in the environment is isolated to specific locations in the Great Lakes basin. Concentrations of all three in the Niagara River have decreased by more than 50% between 1986 and 1998. However, both HCB and mirex continue to exceed New York State's criteria of 0.03 ng/L and 0.001 ng/L respectively, for the protection of human consumers of fish.

Most chlorobenzenes, chlorinated pesticides and PCBs have decreased in concentration. For poly-aromatic hydrocarbons (PAHs), some have decreased, some have not changed and a few have increased.

Future Pressures

Management efforts to control inputs of organochlorines have resulted in decreasing concentrations in the Great Lakes. Historical sources for some, however, still appear to affect ambient concentrations in the environment. Chemicals such as endocrine disrupting chemicals, in-use pesticides, and pharmaceuticals are emerging issues.

Acknowledgments

Author: Scott Painter, Environment Canada, Burlington, ON.

Concentrations of Contaminants in Sediment Cores

Indicator #119

Assessment: Mixed, improving

Data are not system-wide

Purpose

This indicator assesses the concentrations of toxic chemicals in sediments. This indicator will also be used to infer the potential harm to aquatic ecosystems by contaminated sediments, and to infer the progress of various Great Lakes programs toward virtual elimination of toxic chemicals in the Great Lakes.

State of the Ecosystem

A comprehensive sediment contaminant survey of the open waters of the Great Lakes in 1997 was initiated by Environment Canada. Data for 34 chemicals with guidelines were available for Lakes Erie and Ontario. Generally, the Canadian federal probable effect level (PEL) guideline was used when available; otherwise the Ontario lowest effect level (LEL) guideline was used. The sediment quality index (SQI) ranged from fair in Lake Ontario to excellent in eastern Lake Erie. Spatial trends in sediment quality in Lakes Erie and Ontario reflected overall trends for individual contaminant classes such as mercury and polychlorinated biphenyls (PCBs). The spatial representation of sediment quality using the individual site SQI scores as well as the area SQI scores represent the individual spatial patterns in the 34 chemicals.

The U.S. Environmental Protection Agency-GLNPO used the SQI to evaluate data collected as part of the investigation of contaminated sediments in nearshore areas and rivers within the Areas of Concern (AOCs). The SQI was applied to 5 priority AOCs for which sediment data had been collected. SQI scores for these AOCs are based on the results of available chemical analysis for surficial sediment concentrations only. Future sediment data collected at these sites can be compared to these SQI scores to determine trends in sediment contamination.

Environment Canada and U.S. Environmental Protection Agency integrated available data from the open waters of each of the Great Lakes. To date, data on lead, zinc, copper, cadmium, and mercury have been integrated. Open lake sediment data was analyzed to identify trends in sediment contamination at open lake index sites. In most cases, the declines in concentrations from 1971 to 1997 are in the range of 40%-50%, but this value varies from Lake to Lake.

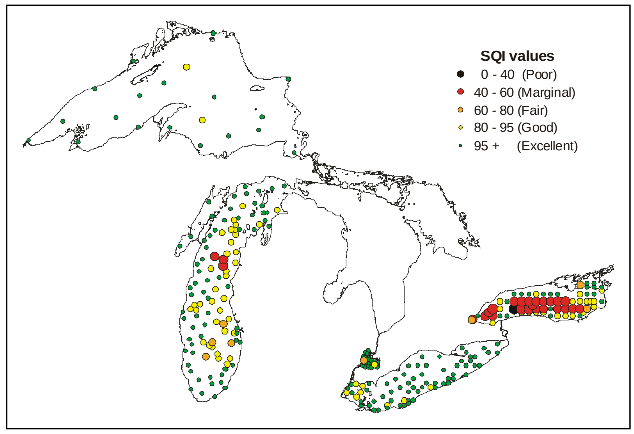


Figure 79. Site Sediment Quality Index (SQI) based on lead, zinc, copper, cadmium and mercury.

Source: Chris Marvin, Environment Canada, National Water Research Institute (1997-2001 data for all Lakes except Michigan); and Ronald Rossman, USEPA (1994-1996 data for Lake Michigan)

Future Pressures

Management efforts to control inputs of historical contaminants have resulted in decreasing contaminant concentrations in the Great Lakes open-water sediments for the standard list of chemicals. However, additional chemicals such as polybrominated diphenyl ethers (PDBEs), polychlorinated naphthalenes (PCNs), polychlorinated alkanes (PCAs), endocrine disrupting chemicals, in-use pesticides, and pharmaceuticals represent emerging issues and potential future stressors to the ecosystem.

Acknowledgments

Authors: Scott Painter and Chris Marvin, Environment Canada, Burlington, ON, and Scott Cieniawski, U.S. Environmental Protection Agency, Chicago, IL.

E.coli and Fecal Coliform Levels in Nearshore Recreational Waters

Indicator #4081

Assessment: Mixed

Data are not system-wide and multiple sources are not consistent

Purpose

This indicator assesses *E. coli* and fecal coliform levels in nearshore recreational waters, which act as surrogate indicators for other pathogen types, in order to infer potential harm to human health through body contact with nearshore recreational waters.

State of the Ecosystem

For both the U.S. and Canada, as the frequency of monitoring and reporting increases, more advisories and closings are also observed. Both countries experienced a doubling of beaches that had advisories or closings for more than 10% of the season in 2000. Further analysis of the data may show seasonal and local trends in recreational waters. If episodes of poor recreational water quality can be associated with specific events, then

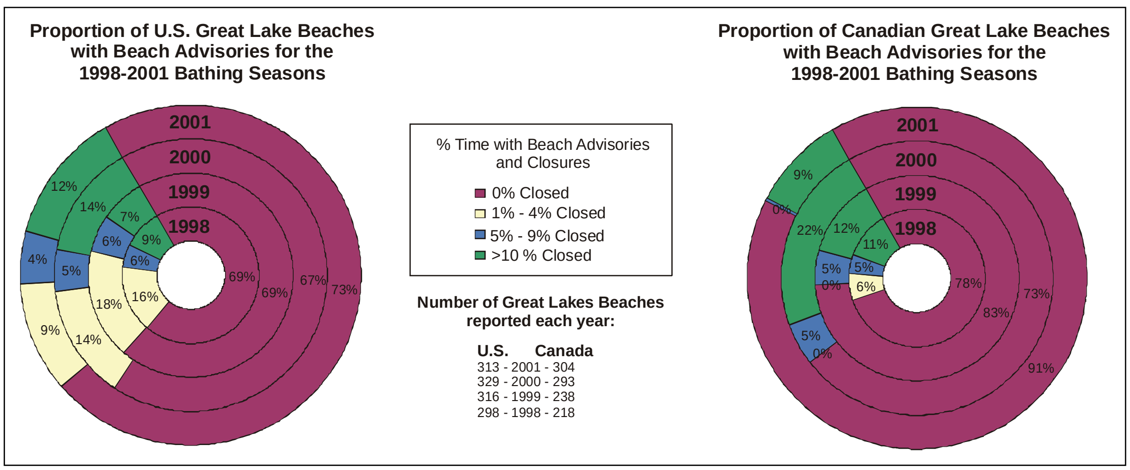


Figure 80. Proportion of U.S. and Canadian Great Lakes beaches with beach advisories and closures for 1998 to 2001 bathing seasons.

Source: Adapted from U.S. EPA Beach Watch Program, National Health Protection Survey of Beaches for Swimming, 1998 – 2001, and Canadian data obtained from Ontario Health Units along the Great Lakes

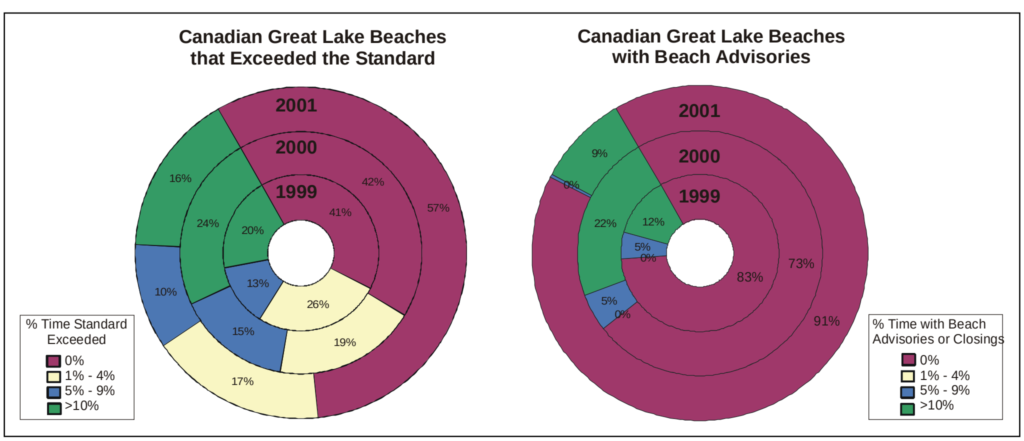


Figure 81. Status of Canadian Great Lakes beaches reported in terms of Beach Advisories versus Provincial Standard Exceedances (for the 1999 to 2001 bathing seasons).

Source: Data obtained from Ontario Health Units along the Great Lakes

forecasting for episodes of poor water quality may become more accurate. In the Great Lakes basin, unless new contaminant sources are removed or introduced, beaches tend to respond with similar bacteria levels after events with similar precipitation and meteorological conditions.

The method of issuing beach advisories is sometimes imperfect. When bacterial counts are above the standard, this information is not known until one or two days later when the lab results arrive. This process may leave a potentially contaminated beach open, risking swimmers' health, and may result in an advisory being issued when the problem has likely passed. Methods are needed to identify risk before exposure takes place. An examination of historical geometric means may provide a less subjective way of determining the health risk category of beaches.

Conditions required to post Canadian beaches have become more standardized as a result of the 1998 Beach Management Protocol, but the conditions required to remove the postings remain variable. In the U.S., all coastal states will adopt, by April 2004, *E. coli* indicators for fresh water as a condition of the BEACH Act grant.

Future Pressures

Additional point and non-point source pollution at coastal areas due to population growth and increased land use may result in additional beach closings and advisories. Inability to develop a rapid test protocol for *E.coli* is lending support to advanced models to predict when to post beaches.

Acknowledgments

Authors: Christina Clark, Environment Canada Intern, Downsview, ON; David Rockwell and Martha Avilés-Quintero, U.S. Environmental Protection Agency Intern-Great Lakes National Program Office, Chicago, IL, and Holiday Wirick, U.S. Environmental Protection Agency-Regional 5 Water Division.

Drinking Water Quality

Indicator #4175

Assessment: Good

Data from multiple sources are not consistent

Purpose

This indicator assesses the chemical and microbial contaminant levels in drinking water. It also assesses the potential for human exposure to drinking water contaminants and the effectiveness of policies and technologies to ensure safe drinking water.

State of the Ecosystem

There are many facets of drinking water. This report focuses on raw, treated and some distributed samples of water from lake, river, and groundwater sources.

This indicator assessment is based on ten parameters. The chemical parameters are: atrazine, nitrate and nitrite. The microbiological parameters are: total coliform, *Escherischia coli (E.coli)*, *Giardia*, and *Cryptosporidium*. Turbidity and total organic carbon/dissolved organic carbon (TOC/DOC) can be used to indicate other potential health problems such as microbial pathogens, or the presence of organic matter in the water.

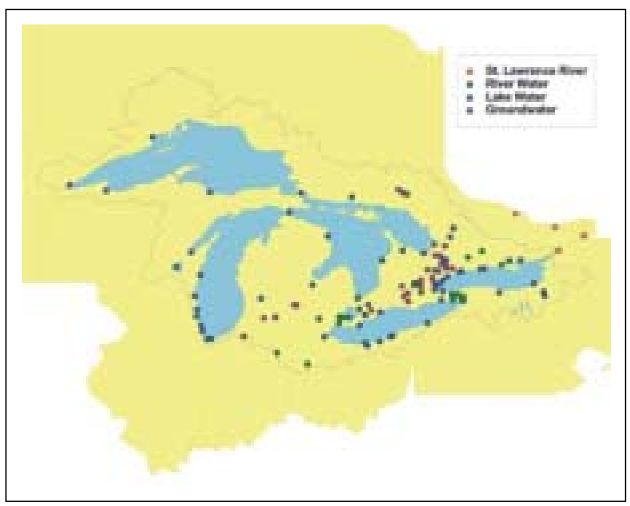


Figure 82. Locations of the public water systems (PWS) and the source from which the water is drawn.

Source: Mike Makdisi, U.S. Environmental Protection Agency Intern

The risk for human exposure to chemical contaminants is minimal, based on atrazine data from 104 Public Water Systems (PWSs), and nitrate and nitrite data from 56 PWSs. Average and maximum levels for all three chemicals rarely exceeded the limits in treated drinking water, and most facilities' source water had levels so low that treatment was not needed to ensure compliance with the set standards.

Based on data provided by 48 Water Treatment Plants (WTPs), the trend for total coliform and *E. coli* from 1999-2001 shows that higher coliform counts are found in the Great Lakes surface waters and rivers, with the highest counts occurring during the spring, summer and early fall.

Total coliform by itself is not necessarily harmful, but may indicate the presence of harmful bacteria such as *E. coli*. The standard in both countries for *E. coli* is zero. In both countries, low exceedence rates for total coliform in treated water, compared to the higher rates of coliform and *E. coli* found in source waters, is indicative of the effective disinfection processes used at WTPs within the Great Lakes basin.

For *Giardia* and *Cryptosporidium*, there are no proposed numerical guidelines at the moment for Ontario. *Giardia* or *Cryptosporidium* are rarely found in treated water, and no reports of *Giardia* or *Cryptosporidium* were found in the few reported samples that were tested from distributed water.

Turbidity levels for source water from the Great Lakes from 1999-2001 are declining, and treatment of source waters further reduces turbidity levels in drinking water.

Based on 98 PWSs, TOC/DOC levels are usually higher in inland lakes and rivers, regardless of the season, with occasional elevated levels, scattered throughout the year, found in the Great Lakes and their connecting channels. Trends also indicate that WTPs across the basin have relatively low TOC/DOC levels after treatment.

Taste and odor are very important to the consumer, but are also very difficult to measure quantitatively. From 1999 to 2001, higher levels of Geosmin and 2-MIB (chemicals indicative of taste and odor, which are also associated with algae blooms) were associated with warmer waters. These elevated levels appeared in samples taken from the Great Lakes surface water, even though these samples had few taste and odor problems identified. In contrast to Great Lakes surface water, elevated levels of Geosmin and 2-MIB were found during other times of the year in river water, and once in groundwater. Overall, based primarily on samples before distribution, there were infrequent problems with taste and odor in drinking water from the Great Lakes basin.

Future Pressures

Future pressures on drinking water quality in the Great Lakes basin will include runoff from land use and agricultural practices, point source pollution, newly introduced chemicals, non-native species, increases in algal presence and water temperatures, byproducts of drinking water disinfection processes, and problems associated with aging distribution systems.

Acknowledgments

Authors: Mike Makdisi, U.S. Environmental Protection Agency Intern-GLNPO, and Angelica Guillarte, Environment Canada Intern, Downsview, ON.

Much thanks goes to Tom Murphy, Miguel Del Toral, Kimberly Harris, and Sahba Rouhani from the U.S. Environmental Protection Agency, and Fred Schultz from the Chicago Water Department for their input. Additional thanks go to all the operators and managers from the water treatment plants that helped to gather and submit data.

Contaminants in Snapping Turtle Eggs

Indicator #4506

Assessment: Mixed

Data are not system-wide

Purpose

This indicator measures the concentrations of persistent contaminants in the eggs of common snapping turtles living in wetlands of the Great Lakes basin in order to provide an indirect measure of foodweb contamination and its effects on wetland wildlife.

State of the Ecosystem

Contaminants in snapping turtle eggs show changes over time and space. Snapping turtle eggs collected at two Lake Ontario sites (Cootes Paradise and Lynde Creek) had the highest concentrations of polychlorinated dioxins and number of furans. Eggs from Cranberry Marsh (Lake Ontario) and two Lake Erie sites (Long Point and Rondeau Provincial Park) had similar levels of polychlorinated biphenyls (PCBs) and organochlorines. Eggs from Akwesasne (St. Lawrence River) contained the highest level of PCBs. Levels of PCBs and dichlorodiphenyl-dichloroethylene (DDE) increased significantly from 1984 to 1990-1991 in eggs from Cootes Paradise and Lynde Creek, but levels of dioxins and furans decreased significantly at Cootes Paradise during this time. Eggs with the highest contaminant levels also showed the poorest developmental success. Rates of abnormal development of snapping turtle eggs from 1986-1991 were highest at all four Lake Ontario sites compared to other sites studied.

Lake	Site	1984	1989-1991	1998-1999	2001-2002[1]
Reference site	Algonquin Park	0.187	0.018	0.020	0.016
Lake St. Clair	St. Clair N.W.A.[2]	1.095	-	-	0.074
Detroit River	Turkey Creek	-	-	-	1.134
Erie	Wheatley area	-	-	-	0.491
Erie	Rondeau Provincial Park	1.093	0.617	-	-
Ontario	Cootes Paradise	1.315	3.575	2.956	1.306
Ontario	Lynde Creek	-	1.430	-	-
St. Lawrence River	Akwesasne	0.869	3.946	6.373[3]	-

Figure 83. Total PCB concentrations in Snapping Turtle eggs from selected sites and years. Contaminants are ppm on a wet weight basis.

[1]K. Fernie, unpublished data; [2]St. Clair National Wildlife Area; [3]Mean concentrations for Raquette and St. Regis sites in Akwesasne.

Source: Canadian Wildlife Service contaminants database

Lake	Site	1984	1989-1991	1998-1999	2001-2002[1]
Reference site	Algonquin Park	0.027	0.002	0.002	0.013
Lake St. Clair	St. Clair N.W.A.[2]	0.115	-	-	0.058
Erie	Rondeau Provincial Park	0.040	0.037	-	-
Ontario	Cootes Paradise	0.200	0.389	0.135	0.088
Ontario	Lynde Creek	-	0.232	-	-
St. Lawrence River	Akwesasne	0.010	0.068	0.020 [3]	-

Figure 84. DDE concentrations in snapping turtle eggs from selected sites and years. Concentrations are ppm on a wet weight basis.

[1]K. Fernie, unpublished data; [2]St. Clair National Wildlife Area; [3]Mean concentrations for Raquette and St. Regis sites in Akwesasne.

Source: Canadian Wildlife Service contaminants database

Over a two-year period, the clutch size was smallest at the St. Clair River Area of Concern (AOC) and largest near Wheatley Harbour. Despite having the largest clutches, hatching success was very poor near the Wheatley Harbour AOC. The growth of young turtles from near the Wheatley Harbour AOC was suppressed and changes in growth were also seen in juveniles from the St.Clair and Detroit River AOCs. Fifteen percent of adult male turtles from one AOC showed effects of being exposed to estrogenic-mimicking contaminants.

Future Pressures

Future pressures for this indicator include all sources of contaminants that reach the Great Lakes wetlands.

Acknowledgments

Author: Kim Fernie, Canadian Wildlife Service, Environment Canada, Burlington, ON. Thanks to other past and present staff at CWS-Ontario Region (Burlington and Downsview), as well as staff at the CWS National Wildlife Research Centre (Hull, QC), the wildlife biologists not associated with the CWS, and private landowners.

Effect of Water Level Fluctuations

Indicator #4861

Assessment: Mixed

Data are available for water level fluctuations for all Lakes. A comparison of wetland vegetation along regulated Lake Ontario to vegetation along unregulated Lakes Michigan and Huron provides insight into the impacts of water level regulation.

Purpose

The purpose of this indicator is to assess the water level trends that may significantly affect components of wetland and nearshore terrestrial ecosystems, and to infer the effect of water level regulation on emergent wetland extent.

State of the Ecosystem

Quasi-periodic water level fluctuations occur on average of about 160 years with sub-fluctuations of approximately 33 years. Because Lake Superior is at the upper end of the watershed, the fluctuations there have less amplitude than in the other Lakes. Lake Ontario showed these quasi-periodic fluctuations but the amplitude has been eliminated since the Lake level began to be regulated in 1959.

Seasonal water level fluctuations result in higher summer water levels and lower winter levels. Additionally, the often unstable summer water levels ensure a varied hydrology for the diverse plant species inhabiting coastal wetlands. Without the seasonal variation, the wetland zone would be much narrower and less diverse.

During periods of high water levels, there is a die-off of vegetation that cannot tolerate long periods of high water. At the same time, there is an expansion of aquatic communities into the newly inundated area. During periods of low water, woody plants and emergents expand again to reclaim their former area as aquatic communities establish themselves further outward into the Lake. The long-term high-low fluctuation puts natural stress on coastal wetlands, but it is vital in maintaining wetland diversity.

Future Pressures

At the moment there are no plans for large scale water withdrawals, and agencies within the Great Lakes basin are working on a process to regulate new withdrawals. Nevertheless, withdrawals or diversions of water from the Lakes still represent a potential pressure on the ecosystem. Additional regulation of high and low water levels will also impact water levels. Global warming also has the potential to greatly alter the water levels in the Lakes.

The long-term high-low fluctuation puts natural stress on coastal wetlands, but is vital in maintaining wetland diversity. It is the mid-zone of coastal wetlands that harbors the greatest biodiveristy. Under more stable water levels, coastal wetlands occupy narrower zones along the Lakes and are considerably less diverse, as the more dominant species, such as cattials, take over to the detriment of those less able to compete under a stable water regime. This is characteristic of many of the coastal wetlands of Lake Ontario, where water levels are regulated.

Acknowledgments

Author: Duane Heaton, U.S. Environmental Protection Agency-Great Lakes National Program Office, Chicago, IL.
Contributions from Douglas A. Wilcox, U.S. Geological Survey; Todd A. Thompson, Indiana Geological Survey and Steve J. Baedke, James Madison University

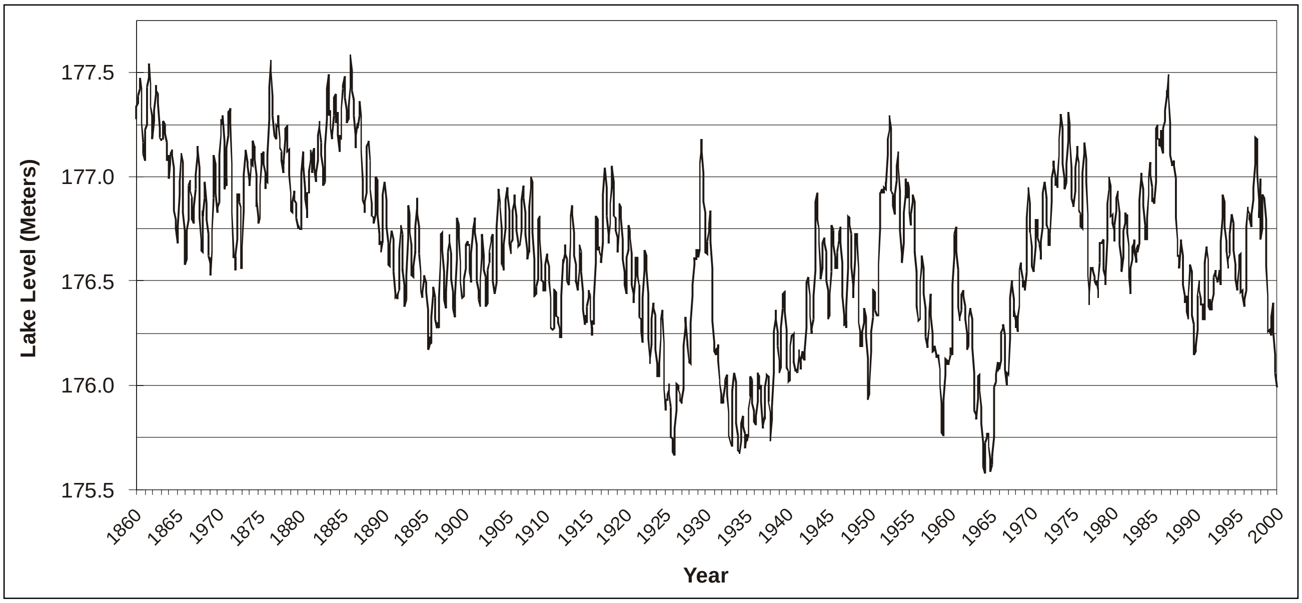


Figure 85. Actual water levels for Lakes Huron and Michigan. IGLD-International Great Lakes Datum. Zero for IGLD is Rimouski, Quebec, at the mouth of the St. Lawrence River. Water level elevations in the Great Lakes/St. Lawrence River system are measured with reference to this site.
Source: National Oceanic and Atmospheric Administration

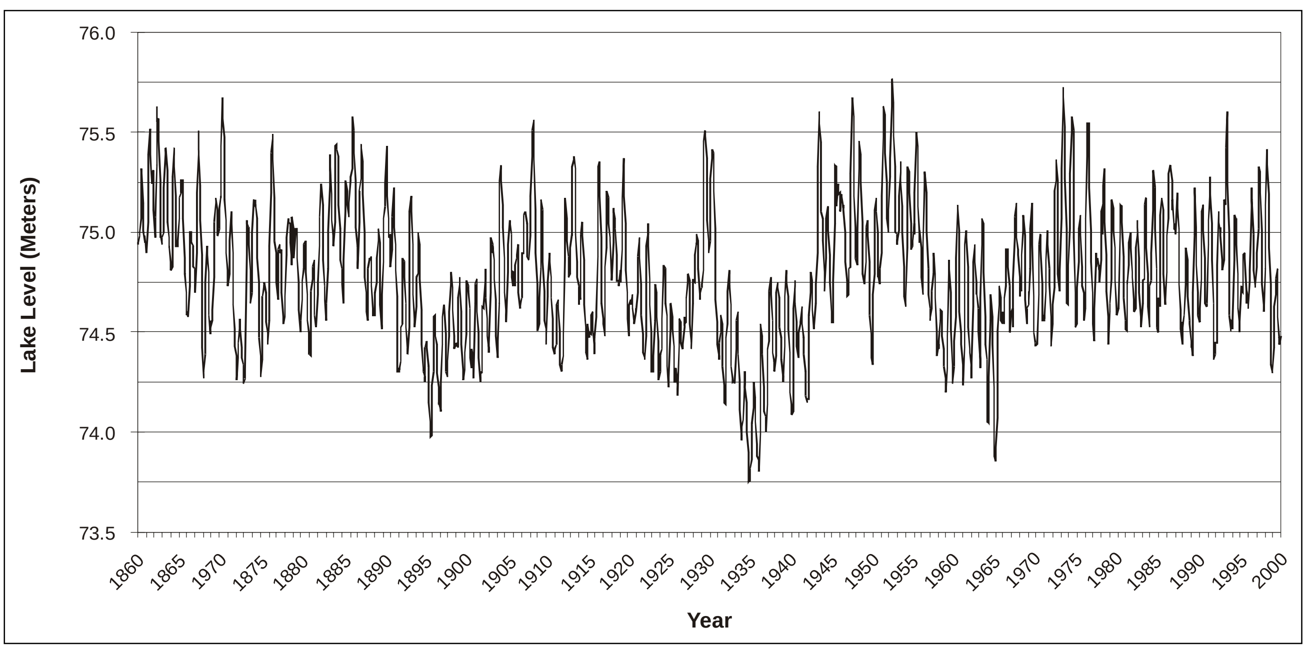


Figure 86. Actual water levels for Lake Ontario. IGLD-International Great Lakes Datum. Zero for IGLD is Rimouski, Quebec, at the mouth of the St. Lawrence River. Water level elevations in the Great Lakes/St. Lawrence River system are measured with reference to this site.
Source: National Oceanic and Atmospheric Administration

Mass Transportation

Indicator #7012

Assessment: Mixed

Data from multile sources are not consistent

Purpose

The purpose of this indicator is to assess the percentage of commuters using public transportation, and to infer the stress to the Great Lakes ecosystem caused by high resource utilization and pollution from the use of private motor vehicles.

State of the Ecosystem

Public transit ridership data for the years 1993-2000 were collected from 38 transit authorities in Ontario, and data for the years 1996-2000 were collected from 15 transit agencies in the United States within the Great Lakes basin.

The trend in Canadian cities is an increase in public transit ridership in many established urban areas, particularly in southern Ontario, and the converse for rural areas in northern Ontario. The increase in public transit ridership from 1993-2000 is evident in the established urban areas of the cities of Toronto and Hamilton and in developing suburban areas. In addition, there is an increase in ridership for transit agencies serving inter-regional areas, i.e., transit agencies linking to other agencies. The increasing trend in Canadian public transit ridership supports a direct relationship between public transportation and the degree of urban density.

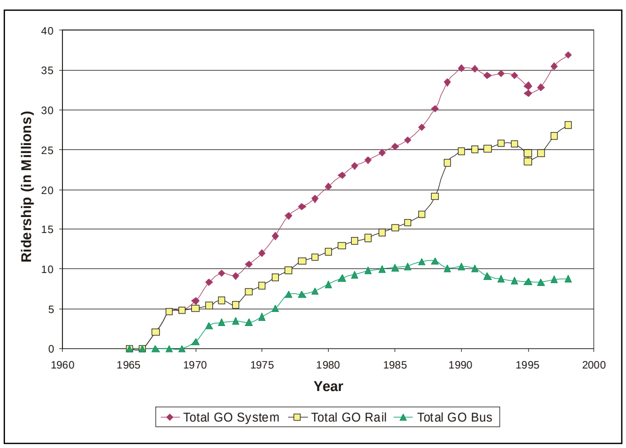


Figure 87. GO Transit System's ridership trends, 1965-1998, including total two-way rides, weekday plus weekend, trips without passengers transferring from a bus-train or train-bus connection. Data are only from 1965-1998 because the reporting system for trips without transfers has been abandoned by the transit system.
Source: GO Transit System, Toronto, Ontario

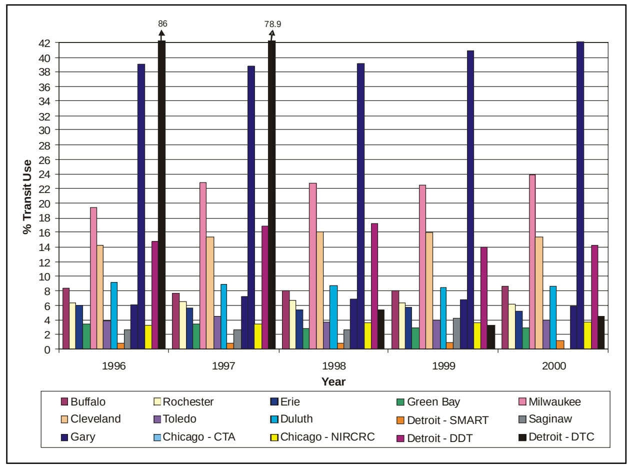


Figure 88. Percentage of transit use for 15 U.S. Transit Agencies in the Great Lakes basin from 1996-2000. The dramatic decrease in Detroit-DTC's % of transit use in 1998 is due to a service area increase of approximately 15.5 times the area reported in 1997. CTA = Chicago Transit Authority, NIRCRC = Northeast Illinois Regional Commuter Railroad Corporation, DTC = Detroit Transit Authority.
Source: National Transit Database

Public transit ridership numbers in U.S. cities and surrounding suburbs remained relatively constant from 1996-2000. The majority of transit agencies have not seen more than a 2% change in ridership numbers, and less than 10% of the service area population use public transportation. The four agencies that showed the highest transit use percentages are located in the four largest cities. Of these agencies, the Chicago Transit Authority, which serves the City of Chicago and surrounding suburbs, had the largest percent of transit use. Percentage of transit use is high where the concentration of people is the highest.

Future Pressures
The increasing rate of industrial development and land use segregation in suburban areas will make public transportation use more difficult. The convenience afforded by private motor vehicles seems to outweigh the benefits of public transit use, depending on how well linkages are established between and within transit systems.

Acknowledgments
Authors: Angelica Guillarte, Environment Canada Intern, Downsview, ON, and Mary Beth Giancarlo, U.S. Environmental Protection Agency Intern-Great Lakes National Program Office, Chicago, IL.

Water Use

Indicator #7056

Assessment: Mixed
Data from mulitple sources are not consistent

Purpose
This indicator measures the per capita water use in the Great Lakes basin and indirectly measures the demand for water resources within the basin and the amount of wastewater generated.

State of the Ecosystem
Per capita consumption (consumptive use) for Canada and the U.S. appears to be equal. Hydroelectric water use continues to be the largest use of all the categories at approximately 95% for each reported year. However, hydroelectric water use is considered to be an "instream" use and does not add to consumptive use.

From a sectoral analysis of municipal water use on the Canadian side of the Great Lakes basin, residential water use accounted for almost 50% of the total municipal water use in 1999. During the time from 1983-1999, the commercial sector showed an increase in water use of 54.8%, residential water use increased by 58.7% and industrial water use increased by 42.4%. The rise in residential water use can be attributed to an increase in municipal populations, an increase in economic activity and recent warmer summer temperatures.

The average per capita water use over all sectors and municipalities has actually decreased by 15% from 1983-1999 in Canadian municipalities of

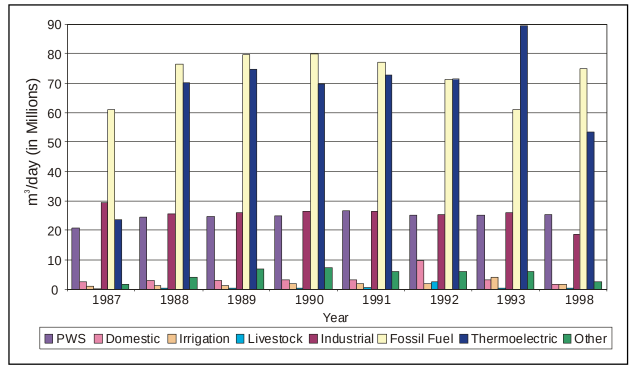


Figure 89. Great Lakes water, other surface water, and groundwater use by category in the Great Lakes basin from 1987 to 1993, and 1998 (without Hydroelectricity). The Province of Ontario did not submit water use data for 1987. PWS = Public Water Supply.
Source: Great Lakes Commission, Annual Report of the Great Lakes Regional Water Use database repository. Adapted for SOLEC by U.S. Environmental Protection Agency-Great Lakes National Program Office

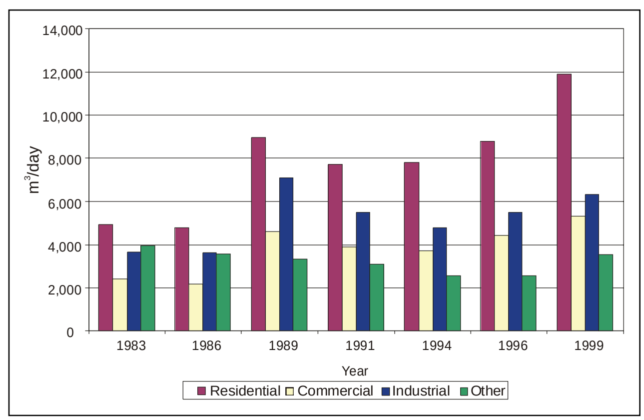


Figure 90. Daily average municipal water use by sector on the Canadian side of the Great Lakes basin, 1983-1999.
Source: Municipal Water Use Database (MUD). Adapted for SOLEC by Environment Canada

populations greater than 1000. This decrease in per capita water use could be attributed to new technological advances in water saving devices, metering, and user pay systems. Per capita water use in the United States has increased by approximately 10% from 1985-1995 even though the population served decreased in 1995. This increase in per capita water use could be attributed to an increase in public use or losses and possible water

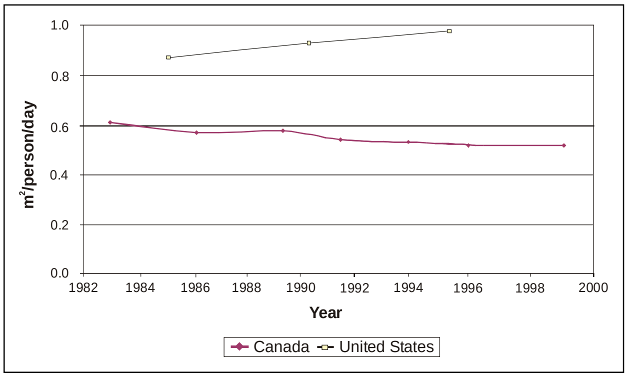


Figure 91. Average municipal per capita water use on the Canadian, 1983-1999, and U.S., 1985-1995, sides of the Great Lakes basin.
Source: Municipal Water Use Database (MUD), adapted for SOLEC by Environment Canada, and the U.S. Geological Survey

transfer between states or regions. New York State, when compared to other states, uses the largest volume of water, which is due to high amounts of hydroelectric water use.

Thermoelectric generation (fossil fuel and nuclear) comprises over 50% of the total water (surface and groundwater) used in the U.S. side of the Great Lakes basin. Industrial and public water supply make up approximately 40% of the water use, and less than 10% of the water used is from self-supplied domestic, irrigation, livestock, and other categories.

Future Pressures

As population and economic activity increase in the Great Lakes basin, it is expected that an increased demand for water will also continue. Water use and demand in the Great Lakes will increase especially for thermoelectric power, agriculture, and residential uses. Growing communities in the U.S., near the basin border, may look to the Great Lakes as a source of water in the future.

Acknowledgments

Authors: Melissa Greenwood, Environment Canada Intern, Downsview, ON, and Mary Beth Giancarlo, U.S. Environmental Protection Agency Intern-Great Lakes National Program Office, Chicago IL.

Energy Consumption

Indicator #7057

Assessment: Mixed, deteriorating (U.S. section of Lake Superior only)
Data are not system-wide

Purpose

This indicator assesses the amount of energy consumed in the Great Lakes basin per capita. This indicator will also be used to infer the demand for resource use, the creation of waste and pollution, and stress on the ecosystem.

State of the Ecosystem

Data extracted from the Energy Information Administration (EIA) 1998 "Retail Electricity Sales" tables for the 29 utilities operating in the Lake Superior basin can be used to calculate the following total electricity use per sector: 3,105,032 Megawatts-hour (MWh) commercial, 13,395,707 MWh industrial, and 4,044,659 MWh residential. Note that consumers may include households and businesses and is not equivalent to per capita energy use. Per capita total energy consumption from all sources (coal, natural gas, petroleum, electricity and other) is the desired measure for this indicator, but it can be calculated only at the state level from EIA energy use tables. Overall, energy use per consumer is higher for the Lake Superior

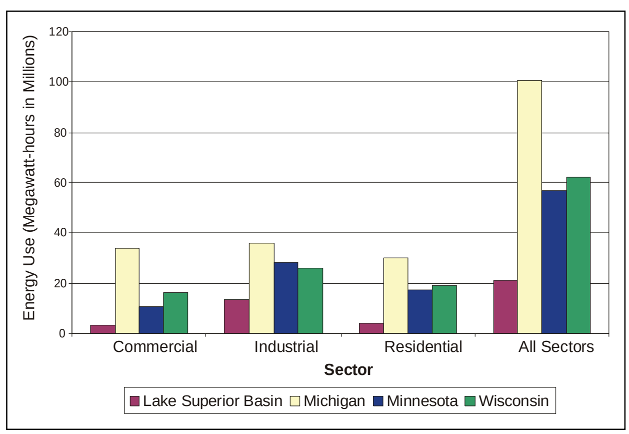


Figure 92. Total electric energy use (MWh) in the U.S. Lake Superior basin by sector, 1998. Data are from Energy Information Administration.
Source: GEM Center for Science and Environmental Outreach, Michigan Technological University

basin than for portions of Michigan, Minnesota, or Wisconsin that are not in the basin, mainly because industrial energy use is much higher. Commercial energy use per consumer is lower in the basin than in any of the three states, as is residential energy use, except for Michigan, which is slightly less than that for the basin.

The Energy Information Administration gathers data on total energy consumption by sector and over time. Electric energy consumption in Michigan rose 21.8% between 1988 and 1998, mainly due to increases in the commercial and residential sectors since 1992.

Future Pressures

Canada's Energy Outlook 1996-2020 notes that "a significant amount of excess generating capacity exists in all regions of Canada" because demand has not reached the level predicted when new power plants were built in the 1970s and 1980s. Demand is projected to grow at an average annual rate of 1.3% in Ontario and 1.0% in Canada overall between 1995 and 2020, compared to 2.6% annually from 1980 to 1995. From 2010-2020, Ontario will add 3,650 megawatts of new gas-fired and 3,300 megawatts of clean coal-fired capacity. Several hydroelectric plants will be redeveloped, but none appears to be in the Lake Superior basin. Renewable resources are projected to quadruple between 1995 and 2020, but will contribute only 3% of total power generation.

Acknowledgments

Authors: Kristine Bradof, GEM Center for Science and Environmental Outreach, Michigan Technological University, MI, and James G. Cantrill, Communication and Performance Studies
Northern Michigan University, MI.

Solid Waste Generation

Indicator ID #7060

Assessment: Mixed

Data are not system-wide and from multiple sources are not consistent

Purpose

This indicator assesses the amount of solid waste generated per capita in the Great Lakes basin. This indicator can also be used to infer inefficiencies in human economic activity and the potential adverse impacts to human and ecosystem health.

State of the Ecosystem

Canada and the United States are working towards improvements in waste management by developing efficient strategies to reduce, prevent, reuse and recycle waste.

Per capita solid waste generation (SWG) declined approximately 45% from 1991 to 2001 in Ontario. The decline in per capita solid waste generation in the early 1990s can be attributed to the increased access to municipal curbside recycling and backyard and centralized composting programs in most Ontario municipalities. The amount of municipal solid waste generation disposed per capita increased from 1994 to 2000 in Minnesota. The data suggest that these trends are not significant despite

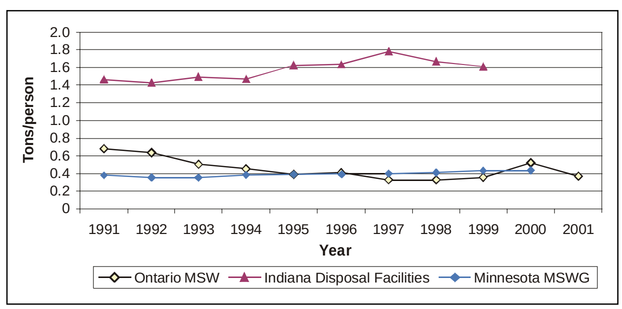


Figure 93. Average per capita solid waste generation and disposal (tons/person) from selected municipalities in Ontario, Indiana and Minnesota, 1991-2001. MSW = Municipal Solid Waste; MSWG = Municipal Solid Waste Generation.

Source: IDEM-Indiana Department of Environmental Management, 2000; MOEA-Minnesota Office of Environmental Assistance, 2000, Ontario data obtained from Statistics Canada, Environmental Account and Statistics Division, and Demography Division

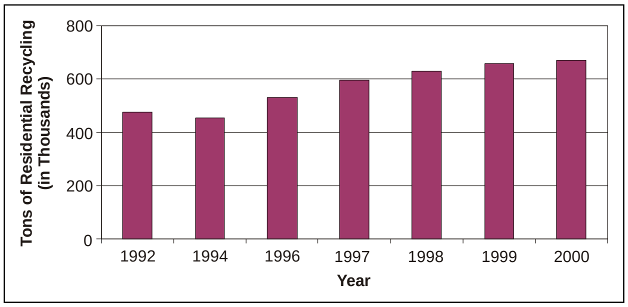


Figure 94. Residential recycling tonnage in Ontario, 1992-2000.
Source: WDO-Ontario Waste Diversion Organization, 2000

growth in population over the same time period. In Indiana, a 21% increase in the per capita quantity of non-hazardous waste disposed was evident between 1992 and 1998, but from 1998 to 2000, there was a 9% decrease in the amount disposed. In New York, the solid waste generation per capita average from 1990 to 1998 increased by 20%. The reusable tons in New York State increased to approximately 30% of the waste disposed. The calculated average per capita municipal waste landfilled in Wisconsin in 2001 was 1.85 tons. The counties with the larger average values are those located closer to the Lake Michigan.

Reuse and recycling are opportunities to reduce solid waste levels. Recycling and waste diversion in Ontario indicate that both the tonnage of municipal solid waste diverted from disposal and the number of households with access to recycling have increased in recent years. There has been a 41% increase in the amount of residential recycling from 1992-2000 in Ontario, accounting for the reduced per capita solid waste generation displayed in recent years in Ontario municipalities.

It is estimated that more residential solid waste is being generated each year, but a greater proportion is being recovered for recycling and reuse.

Future Pressures

The generation and management of solid waste have important environmental, economic and social impacts. The costs associated with the disposal of such wastes will continue to be a problem. The space or location for the development of new landfill sites to dispose of wastes will continue to cause debate as current landfills are reaching their capacities. Alternate ways to dispose of wastes generated is and will be a contentious issue. A thriving economy will put pressure on the amount of waste generated as more products and materials are fabricated during an economic boom. The generation of municipal solid waste contributes to soil, water, and air pollution that will continue to be a stress on ecosystem health.

Acknowledgments

Authors: Martha I. Avilés-Quintero, U.S. Environmental Protection Agency Intern-Great Lakes National Program Office, Chicago, IL, and Melissa Greenwood, Environment Canada Intern, Downsview, ON.

Population Monitoring and Contaminants Affecting the American Otter

Indicator #8147

Assessment: Mixed

Data are not system-wide and from multiple sources are not consistent

Purpose

This indicator measures the contaminant concentrations found in American otter populations within the Great Lakes basin. This indicator also indirectly measures the health of Great Lakes habitat, progress in Great Lakes ecosystem management, and concentrations of contaminants present in the Great Lakes.

State of the Ecosystem

Data indicate primary areas of population suppression still exist in southern Lake Huron watersheds, lower Lake Michigan and most Lake Erie watersheds. Recent data provided by the New York State Department of Environmental Conservation and the Ontario Ministry of Natural Resources suggest that otters are making a slow recovery in western Lake Ontario. Most coastal shoreline areas have more suppressed populations than interior zones. Areas of otter population suppression are directly related to human population centers and to the resulting habitat loss and elevated contaminant concentrations associated with human activity.

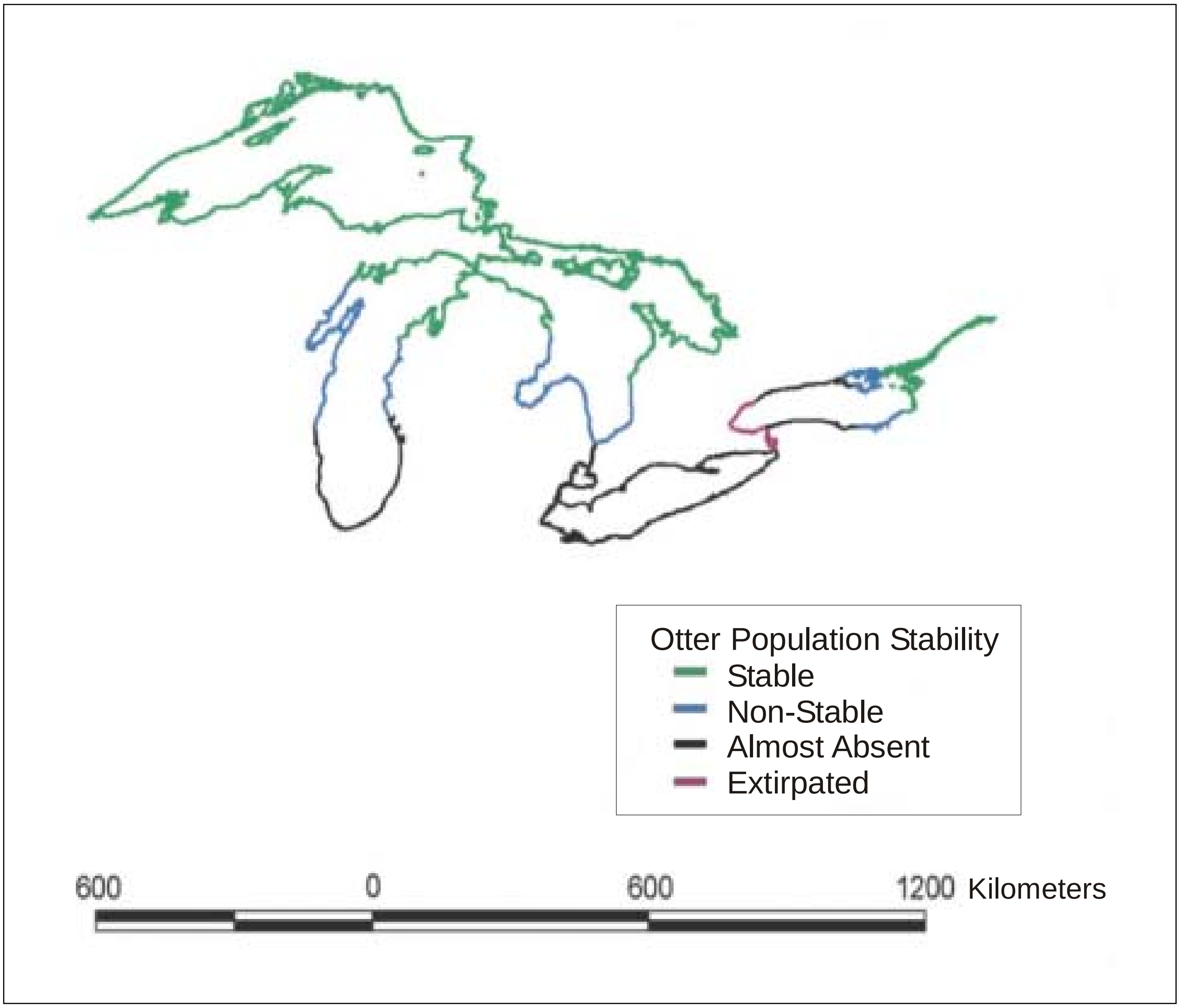


Figure 95. Great Lakes shoreline population stability estimates for the American Otter.
Source: Thomas C.J. Doolittle, Bad River Band of Lake Superior Tribe of Chippewa Indians

Future Pressures

American otters are a direct link to organic and heavy metal concentrations in the food chain. The otter is a more sedentary species and subsequently accumulates contaminants from smaller areas. Contaminants are a potential and existing problem for many otter populations throughout the Great Lakes basin. Contaminants in otters may cause a decrease in population levels, morphological abnormalities and a decline in fecundity. Changes in the species population and range are also representative of human habitat alterations.

Acknowledgments

Author: Thomas C.J. Doolittle, Bad River Band of Lake Superior Tribe of Chippewa Indians, Odanah, WI.

4.5 Response Indicator Reports

Summary of Response Indicators

The overall assessment for the Response indicators is incomplete. Data presented in this section of the report represent indicators for which information is not available year to year or are not basin-wide across jurisdictions. Within the Great Lakes indicator suite, 38 have yet to be reported, or require further development. In a few cases, indicator reports have been included that were prepared for SOLEC 2000, but that were not updated for SOLEC 2002. The information about those indicators is believed to be still valid, and therefore appropriate to be considered in the assessment of the Great Lakes. In other cases, the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs are also needed. Several indicators are under development. More research or testing may be needed before these indicators can be assessed.

Indicator Name	Assessment in 2000	Assessment in 2002
Citizen/Community Place - Based Stewardship Activities	No Report	Mixed, improving
Brownfield Redevelopment	Mixed, improving	Mixed, improving
Sustainable Agricultural Practices	Mixed	Not Assessed
Green Planning Process	No Report	Not Assessed

Green represents an improvement of the indicator assessment from 2000.
Red represents deterioration of the indicator assessment from 2000.
Black represents no change in the indicator assessment from 2000, or where no previous assessment exists.

Citizen/Community Place-Based Stewardship Activities

Indicator #3513

Assessment: Mixed, improving
Data are not system-wide and from multiple sources are not consistent

Purpose
This indicator assesses the number, vitality and effectiveness of citizen and community stewardship activities. Community activities that focus on local landscapes/ecosystems provide a fertile context for the growth of the stewardship ethic and the establishment of a "sense of place".

State of the Ecosystem
Land trusts and conservancies are a particularly relevant subset of all community-based groups that engage in activities to promote sustainability within the Great Lakes basin because of their direct focus on land and habitat protection. Data from the Land Trust Alliance's (LTA) National Land Trust Censuses show that the number of land trusts operating at least partly within the Great Lakes basin increased from 3 in 1930 to 116 in 2000, with half of the increase occurring since 1990. The total area protected by land trusts in the basin more than doubled between 1990 and 2000, rising from 177,077 to 397,784 acres. Nationally, protected land increased from 1,908,547 acres to 6,479,672 acres, according to LTA. The Nature Conservancy alone had protected an additional 111,725 acres in the Great Lakes basin.

In a survey of Canadian land trusts in 2000, 24 of 30 Ontario land trusts reported that they protected 8,569 acres. The survey excludes the Nature Conservancy of Canada, which protected an additional 82,700 acres in Ontario. Conservation Ontario, an alliance of 38 Conservation Authorities (CAs), 32 of which are in the Great Lakes basin, reports that as of 2000, CAs owned and managed 352 conservation areas totaling 340,000 acres

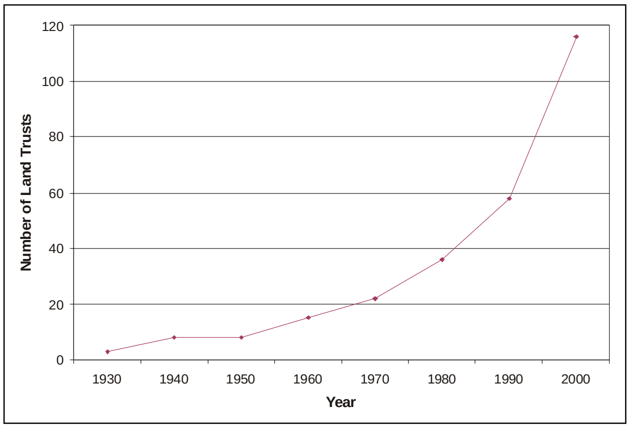


Figure 96. Number of land trusts operating in the U.S. Great Lakes basin, 1930-2000.
Source: Land Trust Alliance

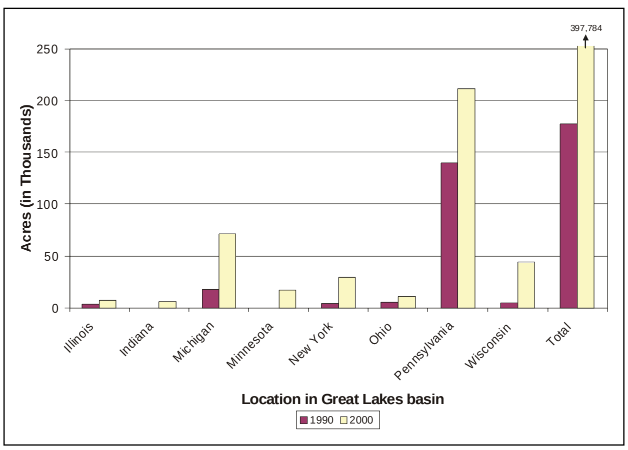


Figure 97. Acres protected by land trusts in the U.S. Great Lakes basin.
Source: Land Trust Alliance

(138,000 hectares). Although CAs are community watershed-based partnerships, they often work cooperatively with private land trusts.

Future Pressures
Continued development of land will be the primary pressure for this indicator, and it will make land trusts increasingly important for permanently protecting natural habitat and "open space". Community organizations such as watershed councils and conservation groups will encourage more sustainable management of public and private lands and direct public attention to those areas of critical habitat that need to be safeguarded to prevent permanent loss.

Acknowledgments
Authors: Kristine Bradof, GEM Center for Science and Environmental Outreach, Michigan Technological University; and James Cantrill, Professor of Communication and Performance Studies at Northern Michigan University. This report was prepared in consultation with Laurie Payne, Lura Consulting, ON

Brownfield Redevelopment
Indicator #7006

Assessment: Mixed, improving
Data are not system-wide and from multiple sources are not consistent

Purpose
This indicator assesses the area of redeveloped brownfields, and evaluates over time the rate at which society remediates degraded or abandoned sites.

State of the Ecosystem
All Great Lakes states, Ontario and Quebec have programs to promote remediation of brownfield sites. Available information on the actual area of remediated brownfields reveals that as of August 2002, Illinois, Minnesota, New York, Ohio, Pennsylvania, and Quebec had remediated a total of 32,103 acres, of which approximately 4,600 acres were remediated between 2000-2002. Also, among the eight Great Lakes states and Quebec approximately 24,000 brownfields sites have participated in cleanup programs since the mid-1990s, although the degree of "remediation" varies

Figure 98. Brownfield site in Detroit, Michigan, 1998.
Source: Victoria Pebbles, Great Lakes Commission

considerably among sites. Remediation includes the utilization of exposure controls (i.e. engineering controls such as capping a site with clean soil or restricting groundwater use) that are designed to limit the spread of, or human exposure to, contaminants left in place. Such controls are major factors in advancing brownfields redevelopment, a criterion for eligibility under many brownfields cleanup programs. Data indicate that the majority of cleanups in the Great Lakes basin are occurring in older urbanized areas, many of which are located on the shoreline of the Great Lakes as well as inland.

Future Pressures

Poor land use planning, laws and policies that encourage new development to occur on undeveloped land, as opposed to urban brownfields, is a significant and ongoing pressure that can be expected to continue. Programs to monitor, verify and enforce effectiveness of exposure controls are in their infancy, and exposure presents an ongoing pressure. Also, because some Great Lakes states allow brownfields redevelopment to proceed without first cleaning up unusable, contaminated groundwater, some surface water quality may continue to be at risk from brownfields contamination despite a pronounced status of "clean".

Acknowledgments

Authors: Victoria Pebbles, with assistance from Becky Lameka and Kevin Yam, Great Lakes Commission, Ann Arbor, MI.

Sustainable Agricultural Practices

Indicator #7028

Assessment: Not Assessed

Data from multiple sources are not consistent

Purpose

This indicator assesses the number of Environmental and Conservation Farm Plans, and it is used to infer environmentally friendly practices in place.

State of the Ecosystem

Agriculture accounts for 35% of the land area of the Great Lakes basin and dominates the southern portion of the basin. In the past there were higher

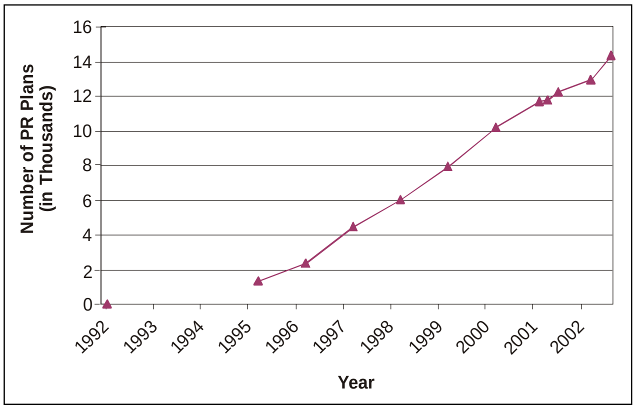


Figure 99. Ontario Environmental Farm Plans (EFP) Peer-reviewed (PR) Plans, 1995-August 2002. The linear trend line indicates a steady increase in the number of Peer Reviewed Plans per year. EFP RP plans identify on-farm environmental risks and develop action to remediate risks.

Source: Ontario Soil and Crop Improvement Association and Ontario Ministry of Agriculture and Food, 2002

amounts of conventional tillage, a lack of crop rotation, and land management practices that were not environmentally responsible. These practices resulted in soil erosion and poor water quality.

Recently, increased cooperation with the farm community in the basin regarding Great Lakes water quality management programs has resulted in a 38% reduction in U.S. erosion rates over the last several decades. The overall reduced risk of water mediated soil erosion on Canadian Great Lakes cropland also shows a positive trend, resulting primarily from shifts toward conservation tillage and more environmentally responsible cropping and land management practices. The adoption of more environmentally responsible practices has helped to replenish carbon in the soils back to 60% of levels seen at the turn-of-the-20th Century. More cooperative work is needed, especially for intensive row crop or horticultural crop production and for areas of vulnerable topography or soil.

The Ontario Ministry of Agriculture and Food (OMAF) and the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) provide conservation and planning advice, technical assistance, and incentives to farm clients and rural landowners, resulting in plans to conserve natural resources while achieving business objectives. Other programs encouraging action plans and the use of responsible technologies include the Ontario Environmental Farm Plan (EFP), in cooperation with the Ontario Farm Environmental Coalition (OFEC). The Ontario Nutrient Management Act, passed in June 2002 will provide regulations for new and expanding large livestock operations to address key water and environmental protection objectives. The USDA's Environmental Quality Incentives Program provides technical, educational, and financial assistance to landowners that install conservation systems, and the Conservation Reserve Program allows landowners to convert environmentally sensitive acreage to vegetation cover. An Ontario program (Greencover) with similar objectives to the U.S. Quality Incentives program, is currently under development.

Future Pressures

Increasing farm size and concentration of livestock will change the face of agriculture in the basin. Development pressure from the urban areas may increase the conflict between rural and urban landowners, including higher taxes, traffic congestion, flooding, and pollution. Also, the urbanization of productive farmland may lead to a potential difficulty or inability to deal with future social, economic, food security and environmental problems.

Acknowledgements

Authors: Ruth Shaffer and Roger Nanney, U.S. Department of Agriculture, NRCS; Peter Roberts and Jean Rudichuk, Ontario Ministry of Agriculture and Food, Guelph, Ontario.

Green Planning Process

Indicator #7053

Assessment: Not Assessed

Data are not consistent, not long-term, and not system-wide

Purpose

This indicator assesses the number of municipalities with environmental and resource conservation management plans in place, and it is used to infer the extent to which municipalities utilize environmental standards to guide their management decisions with respect to land planning, resource conservation, and natural area preservation.

State of the Ecosystem

An American Planning Association (APA) survey, known as *Planning for Smart Growth: 2002 State of the States*, confirms that state planning reforms and "smart growth" measures were priority state concerns between 1999 and 2001. The APA divides states into four categories reflecting the status of smart growth planning reforms. Of the Great Lakes states, Wisconsin and Pennsylvania are credited with implementing moderate to substantial statewide comprehensive planning reforms. New York is the only Great Lakes state that is strengthening local planning requirements or improving regional or local planning reforms already adopted. Illinois, Michigan, and Minnesota are actively pursuing their first major statewide smart growth planning reforms. Ohio and Indiana have not yet begun to pursue significant statewide planning reforms.

The Province of Ontario is conducting a five-year review of the 1996 Provincial Policy Statement (PPS) on land use planning to "determine whether Ontario's land use planning policies are consistent with Smart Growth: the government's strategy for promoting and managing growth in ways that sustain a strong economy; build strong communities; and promote a healthy environment". The PPS's three major policy areas are (1) managing change and promoting efficient, cost-effective development and land-use patterns that stimulate economic growth and protect the environment and public health, (2) protecting resources for their economic use and/or environmental benefits, and (3) reducing the potential for public cost or risk to Ontario's residents by directing development away from areas where there is a risk to public health or safety, or of property damage.

A positive trend in recent years is planning based on regional-scale natural features, such as the Niagara Escarpment and Oak Ridges Moraine in Ontario. The 1985 Niagara Escarpment Plan (NEP) was the first large-scale environmental land use plan in Ontario, and it could be a model for future environmentally sensitive land-use planning.

The Oak Ridges Moraine Conservation Act, passed in December 2001, and the subsequent Oak Ridges Moraine Conservation Plan are also ecologically based measures "established by the Ontario Government to provide guidance and direction for the 190,000 hectares of land and water within the Moraine" north of Toronto.

Conservation Authorities (CAs), community-based environmental protection and resource planning agencies that function within watershed boundaries, are another example of planning and resource management based on ecosystem features. The 38 Ontario CAs today, manage watersheds that are home to 90% of the provincial population.

The following are some examples of data obtained from municipalities in parts of the U.S. Great Lakes basin. Crawford County, Pennsylvania, has a professional planning office and planning commission but no countywide zoning. Its 2000 comprehensive plan reflects Pennsylvania's new "Growing Greener" policy. The plan addresses a variety of green features, such as developing greenways and concentrating development near existing services and in clusters to preserve open space. In the rural western Upper Peninsula of Michigan, the Western U.P. Planning and Development Regional Commission recently surveyed the 72 local units of government in its 6-county region regarding basic planning and zoning information. Of the 64 municipalities that responded, only 29 have planning commissions, 20 have land use or comprehensive plans, and 44 have zoning (49 counting the townships covered by the Keweenaw County ordinance).

Future Pressures

Though new and expanded planning both in rural and urban areas is encouraging, progress will likely be limited by too little emphasis on implementation of agreed-upon planning goals, lax enforcement, too few human and financial resources, and too great a willingness to make exemptions in the name of development.

Acknowledgments

Authors: Kristine Bradof, GEM Center for Science and Environmental Outreach, Michigan Technological University; and James Cantrill, Professor of Communication and Performance Studies at Northern

Section 5
Looking Forward

The development of Great Lakes indicators began in 1997, the result of the recognition by participants in the 1994 and 1996 State of the Lakes Ecosystem Conferences (SOLEC) that a unified suite of regularly monitored indicators was needed to properly characterize the status of the ecosystem. The participants also understood the significance of the information derived from the indicators. Great Lakes managers' decision making tools and opportunities are greatly enhanced by scientific, accurate and timely information based on monitoring chemical, physical, and biological parameters of the ecosystem. SOLEC 2002 and this *State of the Great Lakes 2003* report move the Great Lakes community one step further toward a deeper and more comprehensive grasp of both the suite of indicators needed to monitor adequately and the management responses that can be derived from the subsequent findings.

The work of the Great Lakes community to enhance the suite of indicators continues. More than 150 subject experts were involved in updating and assessing the indicators for SOLEC 2002. As of the conference, there were 80 accepted indicators in the suite, 43 have been reported on, and approximately 45 additional indicators have been proposed and are awaiting review.

Adjusting the suite of indicators to be able to report succinctly on the status of ecosystem components is challenging. Whole subject areas have yet to be included in the suite of indicators. Human health indicators, for example, are complex, and concerted efforts by many agencies and organizations will be required to correctly portray all concerns. Upland ecosystems are beginning to be included in indicator discussions, primarily because the indicator work began with open water and nearshore ecosystems, and efforts to include inland indicators have been part of the evolution of the indicator suite.

Numerous agencies, organizations, sectors, and individuals are involved in developing the suite of indicators. It is correct and necessary to involve as many people as possible in the varied tasks associated with indicator development, monitoring, analysis, and reporting. However, agreement on what indicators to monitor, how to monitor them, and the resulting data interpretation require coordinated and continuous communication by binational, multi-jurisdictional groups at local, lake basin, and basinwide scales. Effective coordination of priorities among multiple organizations is difficult at best.

There are, however, positive steps being taken by the Great Lakes community involved in the development of a suite of indicators:

Č The current indicator suite will be peer reviewed by experts outside the Great Lakes basin prior to SOLEC 2004. Experts will be asked to determine how the process followed since 1997 can be improved upon and what improvements can be made to the suite based on user needs and other factors.

Č A second component of the Peer Review will be a management review of the indicators and their effectiveness in influencing management decisions including monitoring programs. The review will consider recent reports such as the US government's GAO report on indicators.

Č The biological integrity indicators proposed at SOLEC 2002 will be reviewed and vetted as part of the peer review and the state of biological integrity reported on at SOLEC 2004.

- Č The groundwater, agriculture, forestry and climate indicators proposed at SOLEC 2002 will be reviewed as part of the peer review and incorporated into the entire suite.

- Č A review of the scientific literature will help define "physical integrity" and the indicators needed to measure its health. Because the number of indicators in the suite is growing, indices will be developed to assist in indicator assessment and interpretation.

- Č Indicator assessments are at present subjective due to the lack of indicator endpoints. End points will be developed through the Lakewide Management Plan (LaMP) programs and by specific subject matter experts.

- Č Inland ecosystem indicators for rivers and streams, upland ecosystems, and inland ponds, wetlands and lakes will be incorporated into the suite over time.

- Č Efforts will be made to consider Traditional Ecological Knowledge in the reporting of ecosystem health.

As the experts begin to gather and sort and analyze the indicator data that will contribute to SOLEC 2004, the Great Lakes community is aware of emerging as well as recurring environmental issues to contend with over the next decades. The global demand for accessible fresh water, the recognition that quality of life requires a healthy ecosystem, and the needs of two countries for competitive markets based on Great Lakes resources, will all impact what the indicators tell us. The status of the chemical, physical, and biological integrity of the waters of the Great Lakes ecosystem is dependent on a binational response grounded in science, cooperation, and tenacious adherence to the goal of a sustainable ecosystem.

Section 6
Acknowledgments

The **State of the Great Lakes 2003** preparation team included:

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U.S. Environmental Protection Agency
- Great Lakes National Program Office
- Region 5

U.S. Fish and Wildlife Service
- Green Bay Fishery Resources Office

U.S. Geological Survey
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- Great Lakes Science Center
  - Lake Ontario Biological Station
  - Lake Erie Biological Station
  - Lake Superior Biological Station

Provincial and State
Indiana Geological Survey
Michigan Department of Natural Resources
Minnesota Department of Health
New York Department of Environmental Conservation
Ontario Ministry of Environment
Ontario Ministry of Natural Resources
Ontario Ministry of Agriculture and Food
Ohio Division of Wildlife
Ohio Department of Natural Resources
Pennsylvania Department of Environmental Protection
Wisconsin Department of Natural Resources

Municipal
City of Chicago

Aboriginal
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Chippewa Ottawa Treaty Fishery Management Authority
Mohawk Council of Akwesasne

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Cornell University, NY
Indiana University, IN
James Madison University, VA
Michigan State University, MI
Michigan Technological University, MI
Northern Michigan University, MI

Coalitions
Lake Superior Binational Program
U.S.- Canada Great Lakes Islands Project

Commissions
Great Lakes Commission
Great Lakes Fishery Commission
International Joint Commission

Environmental Non-Government Organizations
Bird Studies Canada
Michigan Natural Features Inventory
The Nature Conservancy

Industry
Council of Great Lakes Industries

Private Organizations
Bobolink Enterprises
DynCorp, A CSC company
Environmental Careers Organization

Private Citizens